LIFECYCLE FORECASTING IMPROVEMENT

CAUSATIVE RESEARCH AND ITEM INTRODUCTION PHASE

REPORT DL920T1

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Executive Summary

In FY2010, the Department of Defense developed its *Comprehensive Inventory Management Improvement Plan* as a management tool to oversee and guide efforts to improve DoD inventory management. Although the Plan is organized to respond to Section 328 of the *National Defense Authorization Act* (NDAA) *for FY2010*,[1] it addresses a broad range of efforts to better size the DoD inventory and to continue effective and efficient materiel support to the forces defending our country.

Prior to developing the Plan, the Office of the Secretary of Defense (OSD) initiated a program to improve demand forecasting for secondary items throughout their lifecycles. As the first action in that program, OSD tasked LMI to conduct this demand forecasting project. Because improved forecasting should reduce inventory excesses and shortfalls and, thereby, provide for more effective and efficient materiel support, the program and this project subsequently became part of the overall improvement plan.

The project itself had two objectives. The first was to use inventory stratification data to categorize items with excesses and shortfalls and quantify the role that demand forecasting plays in causing excesses and shortfalls. The second was to review the procedures the military services and the Defense Logistics Agency (DLA) use to forecast demand for new items being introduced into the DoD supply system—the first stage of an item's lifecycle. In addition to satisfying the two objectives, LMI was to report on forecast performance metrics.

This project directly aligns with the Section 328 requirement that DoD include in its plan "a comprehensive review of demand forecasting procedures to identify and correct any systematic weaknesses in such procedures, including the development of metrics to identify bias toward over-forecasting and adjust forecasting methods accordingly."

[1] Section 328 required the Secretary of Defense to "…submit a comprehensive plan for improving the inventory management systems of the military services and the Defense Logistics Agency."

FINDINGS AND PLAN ACTIONS

Table ES-1 relates the findings in this report to the actions they support within the overall inventory improvement plan.

Table ES-1. Findings and Plan Actions

Focus area	Finding	Supported plan action
Causative analysis of item stratification data		
Excess inventory and item lifecycle	Initial demand forecasts for new items are not a significant cause of excess inventory.	Review forecasting procedures for established items.
Excess inventory and item usage	Excess inventories predominantly comprise reparable items, most of which were used at least once.	Measure the accuracy of potential reutilization stock (PRS) reviews. How much has the department benefited from items being sent to disposal?
Excesses and shortfalls and demand forecasting	Forecastability is more of an issue with both excess and shortfall items than forecast accuracy.	Assess alternatives for setting levels for low demand items.
Other drivers of excesses and shortfalls	Demand forecasting is not the only driver of excesses and shortfalls.	Reduce excesses by examining areas other than forecasting.
Review of forecasting procedures for new items entering the DoD supply system		
Forecastability	The military services tend to initially over-forecast future demands because demands for most of the items they manage are intermittent, making them very difficult to forecast even with the best statistical models.	Assess alternatives for setting levels for low demand items.
Inventory levels for new consumable items	Because of historically poor buy-back rates, DLA does not procure supply support request forecasts from the military services until preliminary requisitions are received, which initially and predictably leads to backorders.	Review alternatives for sharing the financial risk of procuring supply support requests.
Inventory stratification and performance measurement	The DoD capability to utilize inventory stratifications as a tool for evaluating DoD inventories and forecasts is rapidly declining.	Update DoD stratification policy and processes to clarify terminology and standardize its systemic application across the department.

OPPORTUNITIES FOR IMPROVEMENT

Statistical Approach

Item introduction forecasts are based on engineering estimates that are updated with historical demand over a 2-year demand development period. The current update procedures can be improved by using an approach that revises forecasts by weighting the number of demands and operating hours at the system level.

Collaboration

DoD can minimize the effect of inaccurate demand forecasts by prioritizing forecast reviews based on the value of the demand forecast.

Also, DLA does not procure supply support requests (SSRs) forecasts until initial requisitions are received, which initially and predictably leads to backorders. DLA cites the military services' historically poor buy-back rates and lack of a financial stake in the forecasts as reasons for delaying procurement. DoD should revise supply and financial policy to specify how SSRs should be processed and funded.

Performance Measurement

The military services do not measure demand forecast accuracy for item introduction forecasts. The percent error metric is the most appropriate metric to measure forecast accuracy for new item introductions because it measures both the amount of error and the direction (i.e., under- or over-forecast).

Demand Management

Instead of relying on increasing inventory to mitigate supply chain risks, DoD should implement a supply chain management best practice that uses a defined end-to-end risk management approach that includes risk identification, analysis, mitigation planning and implementation, and risk tracking.

FINAL OBSERVATION

Changes in operations will cause forecasts to change, which, in turn, will cause inventory requirements levels to change. Thus, inventory procured to support a given operating tempo may become excess because the operating tempo declines over time. In light of this reality, we can conclude that inventory excesses and shortfalls cannot be avoided, even with perfect knowledge of the future. Improvements in demand forecasting will only reduce inventory excesses and shortfalls; it will not eliminate them.

Contents

Figures

Tables

Chapter 1
Introduction

This report documents

- an analysis of stratification data for items with excesses and shortfalls, and
- a review of the current processes used by the military services to forecast demands for new item introductions.

BACKGROUND

Because private and public suppliers maintain inventory to fill future customer demand, demand forecasting is the keystone of inventory management. Accurate forecasts result in effective and efficient inventories, whereas inaccurate forecasts often cause inventory excesses and shortfalls.

In June 2009, the Office of the Secretary of Defense initiated a program to improve demand forecasting throughout the lifecycle of secondary items managed by the military services and Defense Logistics Agency (DLA). Appendix A describes that program.

Subsequent to the commencement of this program, the *FY2010 National Defense Authorization Act*, Section 328, was enacted. Section 328 requires the Secretary of Defense to

> … submit to the congressional defense committees a comprehensive plan for improving the inventory management systems of the military services and the Defense Logistics Agency.

A required element of the overall plan is

> a comprehensive review of demand forecasting procedures to identify and correct any systematic weaknesses in such procedures, including the development of metrics to identify bias toward over-forecasting and adjust forecasting methods accordingly.

The Department of Defense has included this item introduction forecasting review as an initial milestone in the required plan for demand forecasting. The findings and recommendations of this review support other milestones in the overall DoD *Comprehensive Inventory Management Improvement Plan*.

CAUSATIVE RESEARCH AND ANALYSIS

LMI's causative research and analysis answers a number of questions relative to inventory excesses and shortfalls. In what follows, we list the questions, what we found, and how it relates to the actions in the sub-plans in the overall DoD inventory management improvement plan. Chapter 2 discusses our causative research and analysis in detail.

Excess Inventory and Item Lifecycle

Question: Are initial demand forecasts for new items a significant cause of excess inventory?

We found that initial demand forecasts for new items are not a significant cause of excess inventory. Most excess inventories tend to occur for items that have been in the inventory for many years. The majority of the items with excess have been in the system for more than 10 years, and many have been in the system for more than 20 years.

If systemic problems in demand forecasting are a leading cause of excesses but initial forecasts are not, then the DoD demand forecasting program should focus on demand forecasts for established items. Accordingly, Action A-1 of the sub-plan for demand forecasting[1] has a milestone for reviewing demand forecasting procedures when an item is in the sustainment phase of its lifecycle.

Excess Inventory and Item Usage

Question: How much use has the Department of Defense had from excess inventory it sends to disposal?

We found that excess inventories predominantly comprise reparable items, most of which were used at least once. Depending on the military service, reparable items constitute 90–97 percent of the excess inventory, and 56–80 percent of the excess is unserviceable items. For a reparable item to be unserviceable, it must have been used at least once since it entered the DoD supply system and now is in need of repair before it can be used again.

To monitor the timeliness and accuracy of excess reviews, the sub-plan for potential reutilization stock (PRS)[2] calls for the development of new metrics. Periodic reviews dispose of items no longer required for continued use. Since unserviceable reparables are the most costly to retain, these items should be identified for disposal first. New metrics should focus on how much inventory is sent to disposal that is unserviceable reparable stock versus serviceable reparable stock.

[1] *Department of Defense Comprehensive Inventory Management Plan*, Chapter 2, "Sub-Plan A: Demand Forecasting."

[2] *Department of Defense Comprehensive Inventory Management Plan*, Appendix 9, "Sub-Plan H: Disposition of PRS."

Excesses and Shortfalls and Demand Forecasting

Question: To what extent is inaccurate demand forecasting a primary cause for DoD excess inventory?

Two issues involving the creation of excesses revolve around demand forecasting. The first is the ability to produce an accurate forecast that limits inventory excesses and shortfalls. The second, which is more germane to the Department of Defense, is the ability to produce any credible forecast for items that have low, sporadic demand or limited "forecastability." We found forecastability is more of an issue with both excess and shortfall items than forecast accuracy.

Action A-4 of the sub-plan for demand forecasting looks at alternatives for setting inventory levels for items with low sporadic demand. One such alternative, Peak Policy, doesn't rely on a point estimate of future demand; it sets levels based on the demand peaks in extended demand histories for low demand items.

Other Drivers of Excesses and Shortfalls

Question: What additional factors drive inventory excesses and shortfalls?

We found demand forecasting is not the only driver of excesses and shortfalls. Excesses can be the result of reductions in readiness objectives and safety levels or unserviceable returns that exceed current demand rates. Shortfalls can be the result of increases in lead times, repair cycle times, and safety levels or changes in operational availability targets.

In addition to the sub-plan for demand forecasting, the DoD inventory improvement plan has seven other sub-plans aimed at making improvements in other areas:

- Total asset visibility and multi-echelon modeling
- On-order excesses
- Economic retention
- Contingency retention
- Storage and direct vendor delivery
- Items with no demand
- Disposition of PRS.

Review of Demand Forecasting Procedures Used During Item Introduction

We analyzed how initial forecasts are used to set inventory levels. To do so, we conducted an extensive case study on demand forecasting for a new weapon system. The improvements we recommend are based on what we uncovered during that case study analysis.

Validity of Initial Forecasts for New Item Introductions

We started our review focusing on the demand forecasting processes involved in new item introductions and the validity of initial forecasts. We found the following:

- Based on an analysis of the forecast error for Army, Navy, and Air Force, initial forecasts tend to over-forecast future demands because demands for most of the items the military services manage are intermittent, making them very difficult to forecast, even with the best statistical models.
- Initial forecasts are inherently less reliable than sustainment forecasts because they are based largely on engineering estimates.
- The current supply support request (SSR) process for supporting the military services' item introduction forecasts for new consumable items provides poor support.

Chapter 3 discusses forecasting policies and processes for new item introductions and our analysis of demand and forecast data for new items.

Forecasting Impact on Inventory

We next looked at how demand forecasts are used to set inventory requirements levels. We found the following:

- Inventory overages and shortages are not solely due to inaccurate demand forecasts. Rather, inventory levels are largely determined based on a combination of forecasts of demand, resupply times, and operating hours. An error in any one of these will likely result in an inventory imbalance.
- Even under the best conditions, demand forecasting methods will inevitably produce overages and shortages for reparable items because of the randomness of demand from year to year.
- The advent of readiness-based sparing (RBS) modeling that considers on-hand inventory further blurs the distinction of what constitutes an inventory excess. When computing the optimum mix of inventory to achieve a weapon system readiness goal, RBS models can apply the excesses of one item to offset the need to procure others.

Chapter 4 discusses the role of forecasting in setting requirements levels and the risks that cause over- and under-forecasts.

Case Study

To quantify the relationship initial demand forecasts and other inventory requirement-setting factors have with inventory overages, we conducted a series of experiments with actual data for a weapon system. The results confirmed our findings in Chapter 4.

Moreover, the case study demonstrated that, under the best of conditions, demand forecasting methods will inherently produce overages. The best forecasting methods would yield only a 1 percent overage; whereas, methods that overreact to the latest demands could produce overages as high as 9 percent.

Chapter 5 discusses the details of our case study analysis.

RECOMMENDED ITEM INTRODUCTION FORECASTING IMPROVEMENT STRATEGIES

The following summarizes forecasting improvement strategies stemming from our review to improve accuracy and reduce the potential for inventory excesses and shortfalls. Details on these improvement strategies can be found in Chapter 6.

Statistical Approaches

Item introduction forecasts based primarily on engineering estimates can be improved by incorporating historical demand when available. The current DoD practice of revising forecasts by time-weighting engineering estimates and historic demand at the item level tends to over-forecast demands for items with no demands and under-forecast items with many demands. More accurate forecasts can be obtained by using a Bayesian approach, which revises forecasts by weighting the number of demands and operating hours at the system level.

Collaboration

DOLLAR VALUE GROUPS

DoD can minimize the effect of inaccurate demand forecasts by prioritizing forecast reviews based on the value of the demand forecast. Greater collaboration and more frequent forecasts produce less forecast error for the higher value groups than demand forecasts that receive less scrutiny and are forecast less frequently.

SUPPLY SUPPORT REQUESTS

Currently, DLA does not procure SSR forecasts until initial requisitions are received, which initially and predictably leads to backorders. DLA cites the military services' historically poor buy-back rates and lack of a financial stake in the forecasts as reasons for delaying procurement. Alternative approaches are to allow the military services to manage new maintenance-significant consumable items for the first year before transferring item management to DLA or require that the military services fund procurement of some portion of the SSR forecasts.

Measurement

METRICS

The military services do not measure demand forecast accuracy for item introduction forecasts. Many of the metrics used to assess forecast accuracy for sustainment are not useful for item introductions when little demand data is available. The percent error metric is the most appropriate metric to measure forecast accuracy for new item introductions because it measures both the amount of error and the direction (i.e., under- or over-forecast).

STRATIFICATION CAPABILITIES

DoD's capability to utilize inventory stratifications as a tool for evaluating its inventories and forecasts is rapidly declining. The DoD components are implementing enterprise resource plans (ERPs), and inventory stratifications need to be incorporated into the ERPs at the item level for the purpose of evaluating inventory management. DoD inventories managed by contractors are currently excluded from stratification despite the increasing reliance on contractors to manage DoD inventories.

Demand Management

DoD has adopted a supply chain management approach but relies primarily on increasing inventory to mitigate supply chain risks. A relevant supply chain management best practice involves a defined end-to-end risk management approach that includes risk identification, analysis, mitigation planning and implementation, and risk tracking.

SUMMARY

Accurate forecasting of materiel demand is an essential element of properly sizing future inventory. Inaccurate forecasting leads to imperfect level setting of stock, which may result in either excess inventory or shortfalls in filling customer demand. Our review addresses demand forecasting issues relevant to the item introduction phase of lifecycle materiel management, and we recommend actions that support the objectives of the DoD *Comprehensive Inventory Management Improvement Plan*.

Chapter 2
Causative Research and Analysis

From 2007 to 2009, the Government Accountability Office (GAO) conducted a series of inventory audits[1] on items managed by the military services to determine the extent to which on-hand and on-order secondary inventories support current requirements. GAO found the military services had billions of dollars worth of spare parts in excess of current requirements, while still experiencing some inventory shortfalls. At the conclusion of these audits, GAO submitted a report to Congress on high risk areas.[2] That report stated how a major cause for excess inventory was weakness in demand forecasting.

In an effort to better understand the causes for having inventory in excess or in shortfall to current requirements, Deputy Assistant Secretary of Defense for Supply Chain Integration (DASD[SCI]) requested LMI follow up on the GAO findings. Specifically, we were to assess the sample excess and shortfall items in the GAO inventory audits and categorize the causes of the identified excesses and shortfalls. GAO's sampling method did not use life phase as a distinguishing factor; therefore, items assessed in this chapter cut across all life phases.

APPROACH

We built on the analysis completed by GAO in the inventory audits and leveraged the same sample of excess and shortfall items. GAO's analysis drew on data from four fiscal years of DoD's central secondary item stratification reports,[3] which are from September 30 of each year. The crux of GAO's analysis was based on the opening position table from these reports.

Our broader analysis leveraged stratification reports from eight fiscal years and included both the opening position and the retention position tables. To maintain consistency with GAO's analysis, we were able to obtain stratification records for seven of eight fiscal years (September 30 files for 2002–2008) from GAO. We obtained the additional September 30, 2009, data directly from the military services. We used attribute data from auxiliary sources, such as the Federal Logistics Information System, to further characterize these items.

[1] Appendix B summarizes the findings from the audits.

[2] GAO, *DoD's High-Risk Areas, Actions Needed to Reduce Vulnerabilities and Improve Business Outcomes*, GAO-09-460T, March 12, 2009.

[3] GAO's inventory analysis for the Army and Navy used September 30 files for 2004–2007; the Air Force analysis used September 30 files for 2002–2005.

ANALYSIS OF EXCESS

In each military service inventory audit, GAO identified a representative sample of items that had inventory in excess of current requirements. GAO used these items to survey the military services about reasons for maintaining excess inventory and to draw general conclusions about the entire population of managed items. We analyzed this same sample of excess items, which included 153 Army-managed items, 384 Navy-managed items, and 230 Air Force-managed items.

This section outlines our findings from this review. Since GAO had selected a random probability sample, the results of our analysis should be representative of the total item population for each military service.

Stratification of Inventory

In Section 328, Congress defined excess inventory as inventory in excess of the approved acquisition objective (AAO) and not needed for economic or contingency retention. Although this definition matches the DoD definition for potential reutilization stock (PRS), it differs from the definition GAO used as the basis of its findings.

Because DoD considers PRS as potential excess subject to disposal, our analysis focused on PRS; however, to understand how the sample items identified by GAO as excess related to current DoD inventory stratifications, we categorized on-hand and on-contract inventory value for these items by AAO, economic retention stock, contingency retention stock, and PRS. Figure 2-1 shows this breakout using the base year[4] stratification data for each military service.[5] For the GAO sample items, we found 4 percent of the Army inventory, 18 percent of the Navy inventory, and 8 percent of the Air Force inventory to be PRS. These numbers closely relate the percentage of DoD inventory value that is PRS, which was an average of 15 percent from FY2005 to FY2009.[6]

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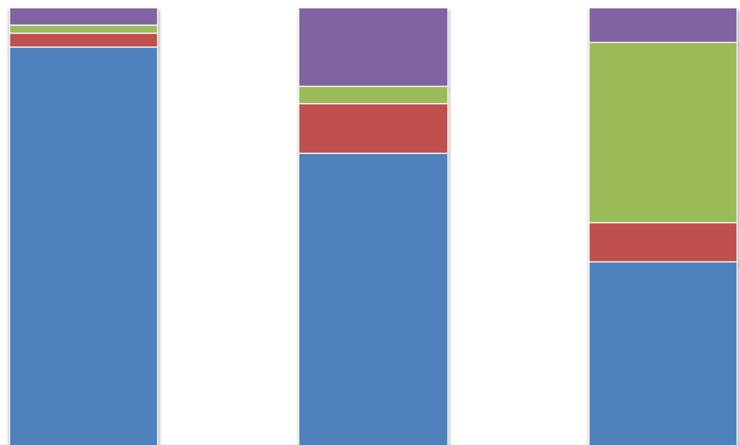
[4] We use base year to describe the data point used by GAO when identifying the service-managed sample items. GAO used September 30, 2007, data to identify Army and Navy excess and shortfall items and September 30, 2005, data to identify Air Force excess and shortfall items.

[5] Within the Department of Defense, PRS is valued at the expected return of sales from the disposal activity; however, for the purpose of this report, all inventory categories are valued at full stratification value to fully compare relativity to total inventory. Army and Navy stratification data uses standard price and Air Force stratification data uses latest acquisition cost.

[6] Based on DoD Supply System Inventory Report, an annual publication that provides summary statistics on the status of DoD supply system inventories, by dollar value, inventories by DoD component, retention categories, and funding source.

Figure 2-1. Inventory Stratification of GAO Excess Items



	Army	Navy	Air Force
PRS	4%	18%	8%
CRS	2%	4%	41%
ERS	3%	11%	9%
AAO	91%	67%	42%

Note: CRS = contingency retention stock; ERS = economic retention stock.

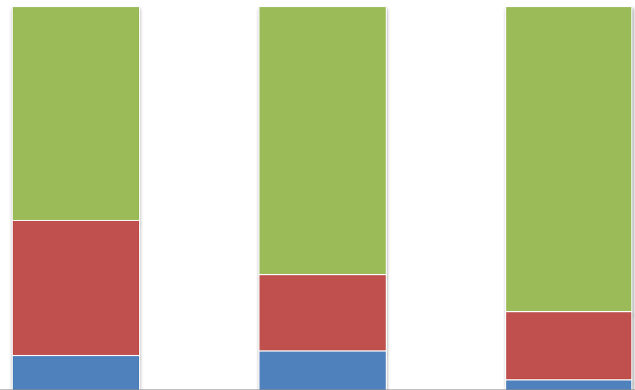
Breakdown of PRS

To better understand what made up this PRS inventory, we looked at the data by inventory type and determined how much was on-order.

INVENTORY TYPE

We further divided PRS inventory value by inventory type and found the majority of this inventory comprises reparable items (see Figure 2-2). Much of the reparable inventory is in unserviceable condition, indicating that it was used, sometimes repeatedly.

Figure 2-2. Percentage of PRS Inventory Value by Type for GAO Excess Items



	Army	Navy	Air Force
Reparable-Unserviceable	56%	70%	80%
Reparable-Serviceable	35%	20%	18%
Consumable	9%	10%	3%

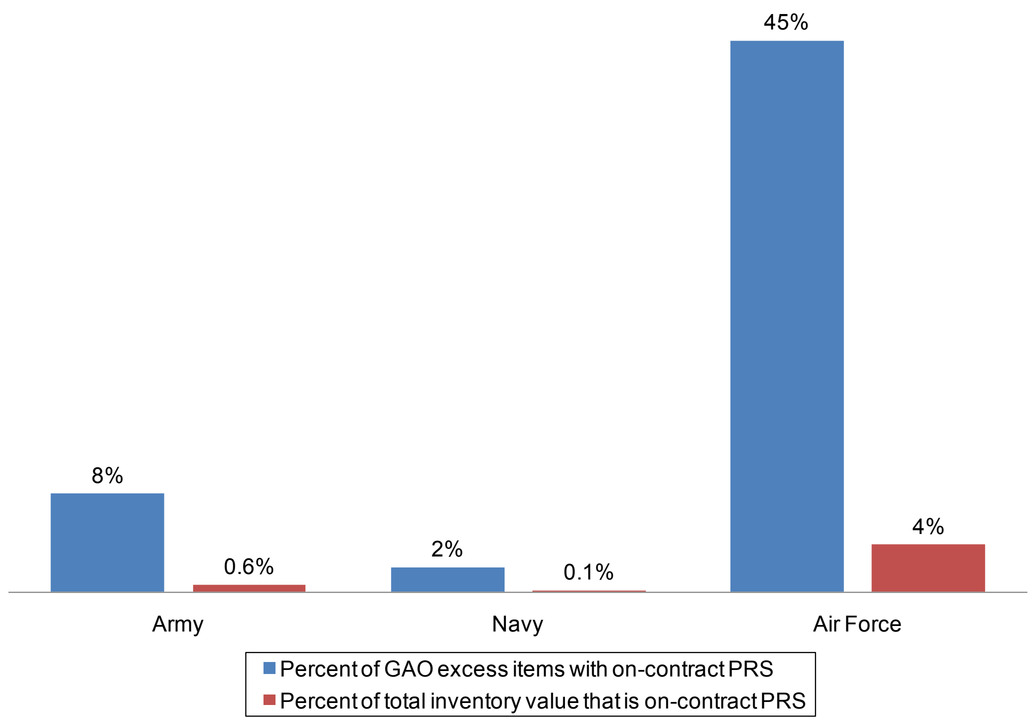
Because reparables are investment items, when they fail, the military services requisition a new one and the unserviceable item may be either repaired or retained in unserviceable condition. As weapon system programs and demand expand and contract over time, requirements increase and decrease. Repair schedules are based on current requirements, but the total number of reparable items in the supply system is based on peak buy requirements. Unserviceable stock is an indication that the items were needed at one time, but perhaps not currently. Because an unserviceable item may be needed in the future, it may not make economic sense to dispose of it.

On-Order

Changes in mission, consumption factors, and other factors affect requirements and can lead to inventory excess. Sometimes, this may cause part or all of the on-order stock to be identified as PRS. When this happens, DoD policy requires timely action to reduce or cancel orders before contract award and to consider terminating contracts for certain items. If the buy is still in the procurement request stage and no award has been made, inventory managers can make quick reductions because no funds are obligated and they are not bound by any agreement with their suppliers. Once a contract is in place, termination may become uneconomical and more difficult.

Reacting to on-order excess is important because this excess is identified before coming into the DoD supply system and while it is still possible to prevent. To quantify the significance of this on-order issue, we considered the portion of GAO-identified excess items that had on-contract PRS, as well as the portion of total inventory value that was on-contract. As Figure 2-3 shows, 8 percent of the Army-managed, 2 percent of the Navy-managed, and 45 percent of the Air Force-managed items identified as excess by GAO had on-contract PRS.

Figure 2-3. Percentage of GAO Excess Items and Total Inventory Value That Is On-Contract PRS



While on-contract PRS represents a relatively small amount of total inventory—0.6 percent of Army inventory, 0.1 percent of inventory Navy, and 4 percent of Air Force inventory—it still represents an opportunity to proactively eliminate unnecessary inventory.

Relationship of Forecast Error to Excess

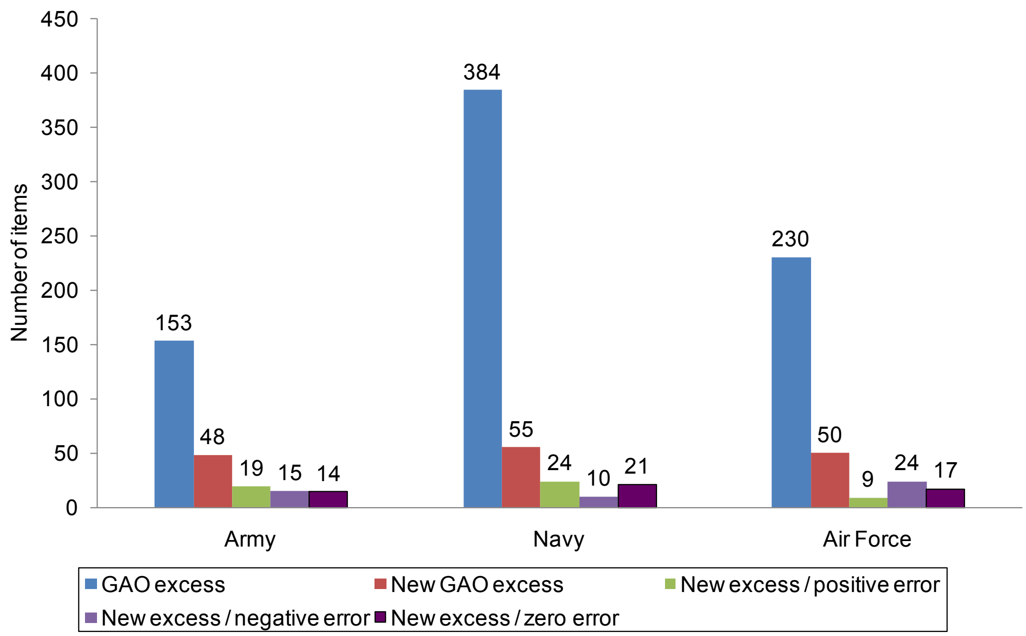
GAO identified inaccurate demand forecasting as a primary cause for the military services' inability to align inventory levels with current demands. When forecasts are too high, inventory managers buy too much too soon; inventory arrives before it is needed and in larger quantities than necessary. GAO suggested that improving demand forecasting procedures will help eliminate this excess inventory situation.

But, there are reasons other than inaccurate forecasting that can lead to inventory excess. Requirements can change, even if forecasts do not. Lead times, repair cycle times, and safety levels can also be reduced, and operational availability targets can change. In addition, large returns, when they exceed demand requirements, can raise the inventory level and lead to excess.

To better understand the correlation between inaccurate demand forecasts and the inability to align inventory levels with current demands, we reviewed forecast error for the items identified as excess by GAO. To identify forecasting as the cause of an excess, an item must not have been in excess in one year and have both positive forecast error and excess condition in the next year. To test this, we looked at the base year stratification data for the items identified as excess by GAO and analyzed the demand forecasts, actual demands, and excess data of each.

Figure 2-4 shows that, of the 767 items identified as excess by GAO, only 153 items entered excess status in the base year (i.e., they were not considered excess the previous year). Of those 153 items, 52 had positive forecast error the previous year, 49 had negative error, and 52 had no error.[7] In other words, most of the items entering excess status in the base year were not over-forecasted the previous year. This finding does not support the general contention that over-forecasting (positive forecast error) is the main cause of excess. While this may be true intuitively, we were not able to identify a strong correlation between forecast error and excess using the data from GAO's inventory audits.

Figure 2-4. Forecast Error and Excess



Forecastability of Excess Items

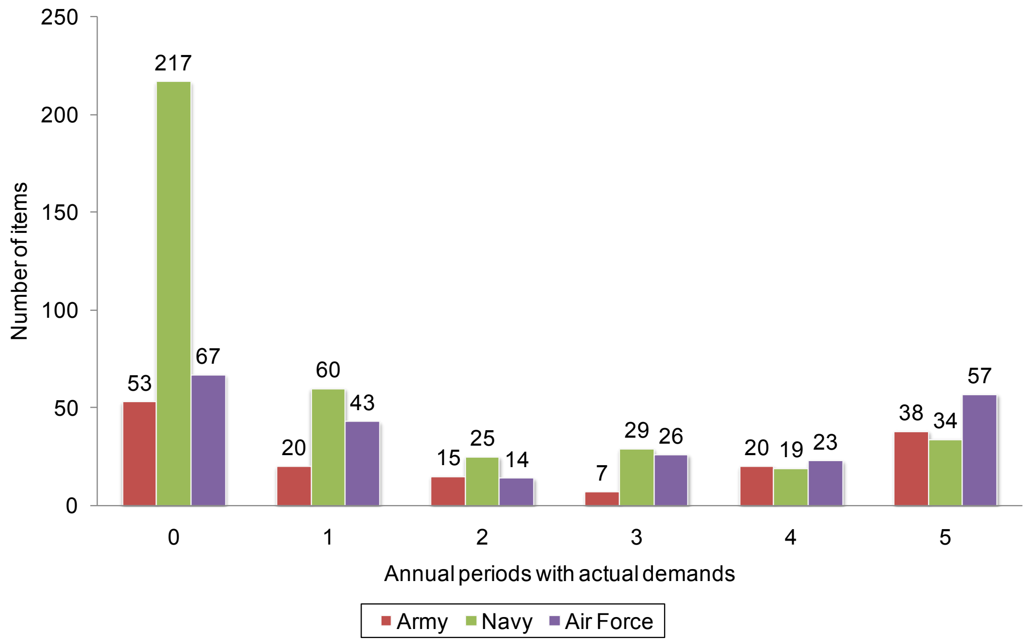
As we took a closer look at the actual demands for the items identified as excess by GAO, we saw that many had sporadic or no demand. Since standard forecasting techniques work best on items with continuous and stable historical demand, the ability to forecast these items is limited.

[7] Virtually all of the zero-error items had zero demands and zero forecasts.

To understand this forecastability issue, we reviewed historical demand for a 5-year period (2 years leading to the base year, the base year, and 2 years after the base year) for the items identified as excess by GAO.

Figure 2-5 shows the number of annual periods with actual demands for these items. Only 38 Army-managed items, 34 Navy-managed items, and 57 Air Force-managed items had actual demands in all 5 years, which makes them more suitable for standard forecasting techniques. The remaining 115 Army-managed items, 350 Navy-managed items, and 173 Air Force-managed items had intermittent demand during these 5 years, which makes them more difficult to forecast using standard techniques.

Figure 2-5. Number of Annual Periods with Actual Demands for GAO Excess Items



While commenting on GAO's inventory audit reports, the military services explained that many of the items with no current demand are used on older weapon systems and can no longer be procured. According to the services, these items may still have future demands, and, therefore, are retained for possible future use. This adds to the complexity of accurately forecasting demand for these items and weighing the need to retain this inventory.

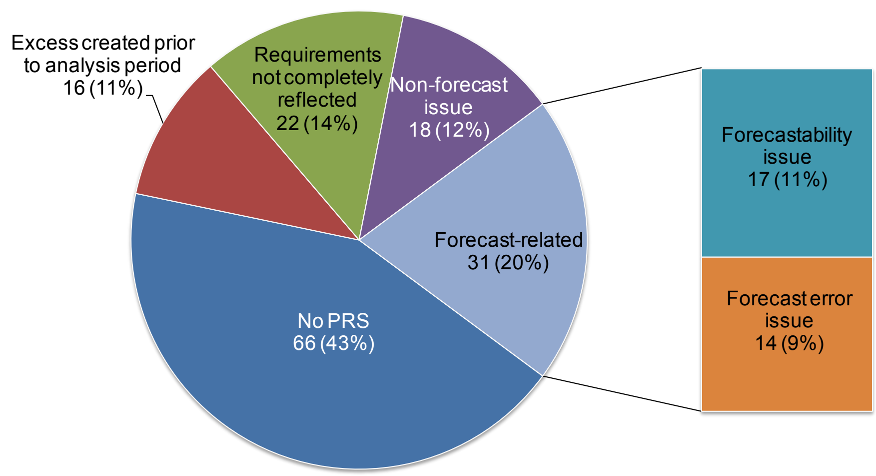
Excess Items by Cause

In each of the military service inventory audits, GAO used survey responses from item managers to estimate the frequency of reasons why excess items were maintained in inventory. To complement this approach, we analyzed 8 years of item-specific stratification data to further characterize causes for excess. We looked at item characteristics, number and frequency of historical observations, and inventory requirements and stock levels over time. We then grouped items by excess cause. Even though we found a large portion of items to have forecast-related issues, we found even more items had either no PRS or excess issues that could not be aligned with forecast-related errors. Our causative findings for each military service are outlined below.

ARMY

The 153 Army-managed items identified as excess by GAO fall into one of the following categories (see Figure 2-6):

Figure 2-6. Causes for Army-Managed GAO Excess Items



- *No PRS.* Sixty-six items (43 percent) did not have PRS; therefore, we did not consider them to be excess.

- *Excess created before the analysis period.* Sixteen items (11 percent) had PRS prior to 2002, which is the first data point in our analysis. Eleven of these items showed no actual demand or forecasted demand during the analyzed 8-year period. Limited data prevented us from attributing a cause for the excesses of these items.

- *Requirements not completely reflected.* Twenty-two items (14 percent) did not completely or accurately reflect requirements. Sixteen of these items were part of the consumable item transfer to another agency, which caused a temporary misalignment between assets and requirements in the stratification reports. The remaining six items are components being assembled into aircraft safety kits. The dependent demand for these subordinate items is only reflected at the kit item level, causing the total requirements in subordinate stratification records to appear understated.

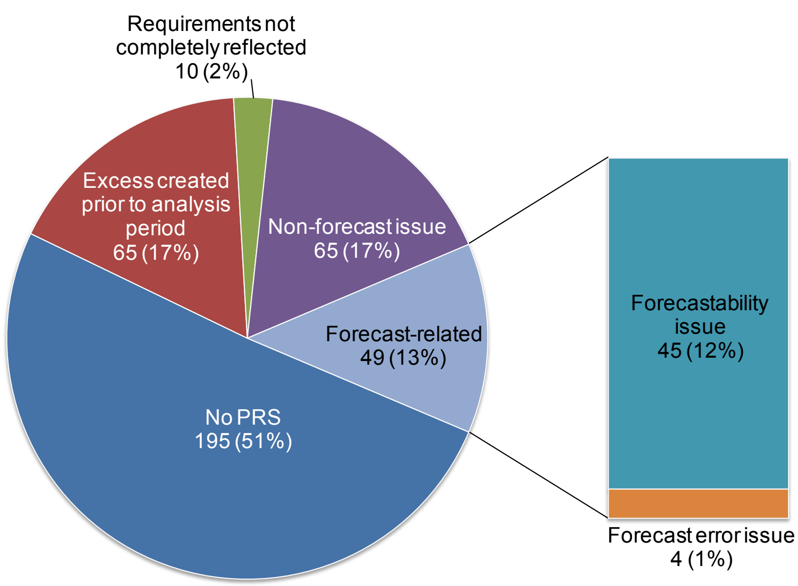
- *Non-forecast issue.* Eighteen items (12 percent) had excesses not attributable to inaccurate forecasts. Three of these items had unserviceable returns that were greater than current demand rates, which led to excess. Eight items had non-demand-based reductions (i.e., contingency retention or numeric stock objective) that have led to excess. The remaining seven items had an increase in serviceable inventory that was not justified by demand quantities, possibly from returns.

- *Forecast-related*. Thirty-one (20 percent) items had excesses attributable to inaccurate forecasts. These items had demand-based (i.e., forecast, economic retention, or lead-time) errors or reductions that led to excess. These items are further divided into two categories: 17 items had limited or no history and were identified as having a *forecastability* issue; 14 items had sufficient actual demands and were identified as having a *forecast error* issue.

NAVY

The 384 Navy-managed items identified as excess by GAO fall into one of the following categories (see Figure 2-7):

Figure 2-7. Causes for Navy-Managed GAO Excess Items



- *No PRS.* 195 items (51 percent) did not have PRS; therefore, we did not consider them to be excess.

- *Excess created before the analysis period.* Sixty-five items (17 percent) had PRS prior to 2002, which is the first data point in our analysis. Fifty-seven of these items showed no actual demand or forecasted demand during the analyzed 8-year period. Limited data prevented us from attributing a cause for the excess of these items.

- *Requirements not completely reflected.* Ten items (2 percent) did not completely or accurately reflect requirements. Eight of these items were part of the consumable item transfer to another agency, which caused a temporary misalignment between assets and requirements in the stratification reports. The remaining two items were subordinate items, and demand was reflected at the head of the family.

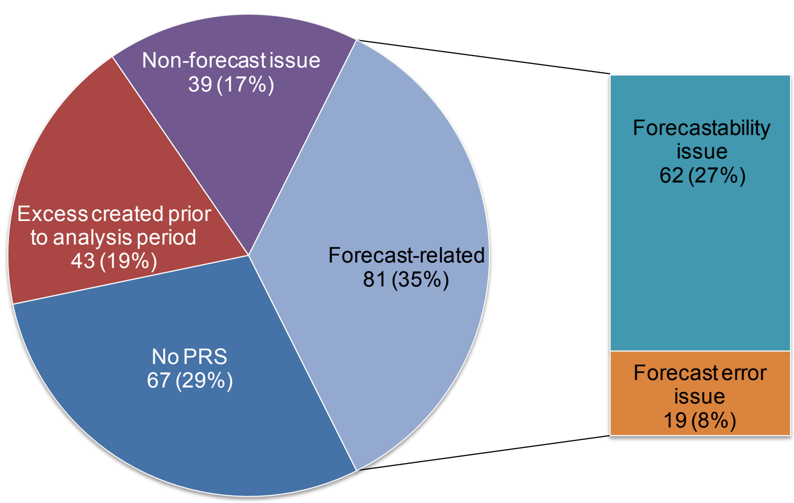
- *Non-forecast issue*. Sixty-five items (17 percent) had excesses not attributable to inaccurate forecasts. Thirty-nine of these items had unserviceable returns that were greater than demand rates, which led to excess. Sixteen of these items have non-demand based reductions (i.e., contingency retention or numeric stock objective) that have led to excess. The remaining 10 items had an increase in serviceable inventory that was not justified by demand quantities, possibly from returns.

- *Forecast-related*. Forty-nine items (13 percent) had excesses attributable to inaccurate forecasts. These items had demand-based (i.e., forecast, economic retention, or lead-time) errors or reductions that led to excess. These items are further divided into two categories: 45 items had limited or no history and were identified as having a *forecastability* issue; 4 items had sufficient actual demands and were identified as having a *forecast error* issue.

Air Force

The 230 Air Force-managed items identified as excess by GAO fall into one of the following categories (see Figure 2-8):

Figure 2-8. Causes for Air Force-Managed GAO Excess Items



- *No PRS.* Sixty-seven items (29 percent) did not have PRS; therefore, we did not consider them to be excess.

- *Excess created before the analysis period.* Forty-three items (19 percent) had PRS prior to 2002, which is the first data point in our analysis. Six of these items showed no actual demand or forecasted demand during the analyzed 8-year period, and another 10 had no forecasted demand. Most of the remaining items appeared to have decreasing demands. Our limited data prevented us from attributing an excess cause to these items.

- *Non-forecast issue*. Thirty-nine items (17 percent) had excesses not attributable to inaccurate forecasts. Fifteen of these items had unserviceable returns that were greater than demand rates, which led to excess. Five items had non-demand based reductions (i.e., numeric stock objective or safety level) that led to excess. One item reflected bad data in the stratification record in the form of unserviceable consumable inventory. Fifteen items reflected an increase in on-order inventory, and three items showed an increase in on-hand inventory that did not appear to be justified by demand quantities, possibly caused by returns or inaccurate data.
- *Forecast-related*. Eighty-one (35 percent) items have excesses attributable to inaccurate forecasts. These items had demand-based (i.e., forecast, economic retention, or lead-time) errors or reductions that led to excess. These items are further divided into two categories: 62 items had limited or no history and were identified as having a *forecastability* issue; 19 items had sufficient actual demands and were identified as having a *forecast error* issue.

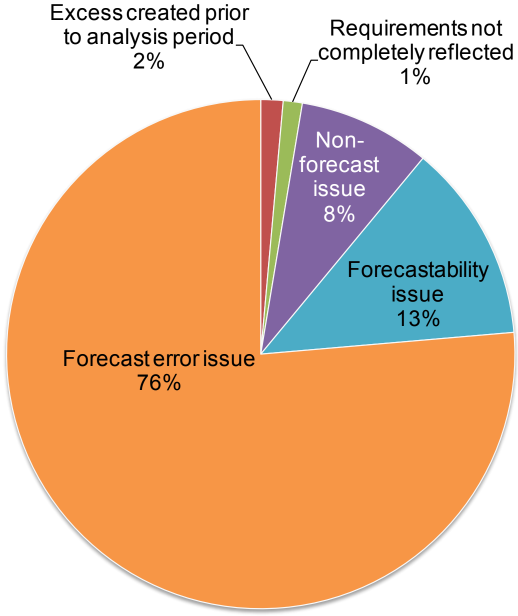
Excess Inventory by Cause

In addition to item counts, we looked at PRS value by cause. The results of these findings are outlined below by military service.

Army

Figure 2-9 represents the PRS inventory value by excess cause for Army-managed items identified as excess by GAO. Seventy-six percent was aligned with forecast error issues, while 13 percent were aligned with forecastability issues and 8 percent were aligned with non-forecast issues. Of the 76 percent aligned with forecast error issues, one item, a gas turbine engine, accounted for most (75 percent) of this inventory. This item was first identified with PRS when economic retention fell to zero from 2006 to 2007. It then transitioned to the Army’s Logistics Modernization Program, eliminating it from stratification data after 2007 and preventing us from tracking it further.

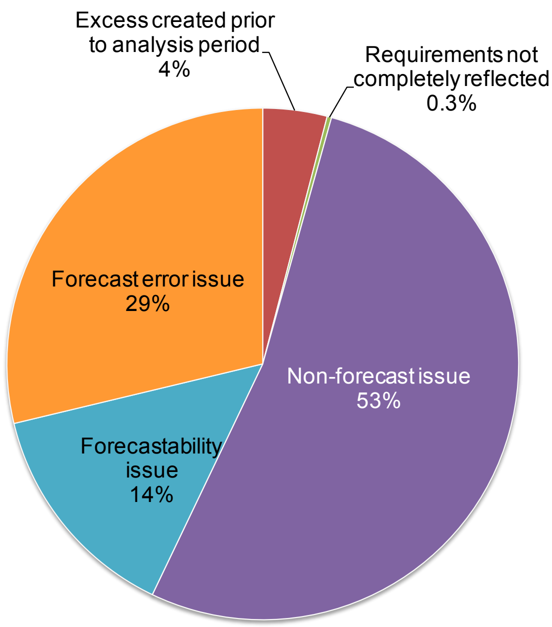
Figure 2-9. Percentage of PRS Inventory Value by Excess Cause for Army-Managed GAO Excess Items



Navy

Figure 2-10 represents the PRS inventory value by excess cause for Navy-managed items identified as excess by GAO. Fifty-three percent of this inventory was aligned with non-forecast issues, while 29 percent aligned with forecast error issues and 14 percent aligned with forecastability issues.

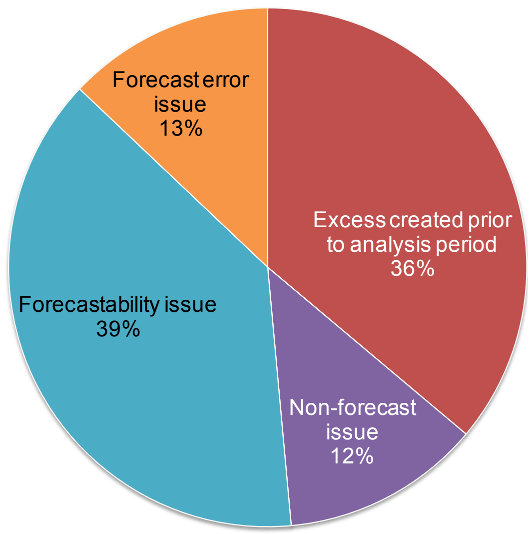
Figure 2-10. Percentage of PRS Inventory Value by Excess Cause for Navy-Managed GAO Excess Items



AIR FORCE

Figure 2-11 represents the PRS inventory value by excess cause for Air Force–managed items identified as excess by GAO. Thirty-nine percent of this inventory was aligned with forecastability issues, while 13 percent aligned with forecast error issues, 12 percent aligned with non-forecast issues, and 36 percent had excess created prior to analysis period.

Figure 2-11. Percentage of PRS Inventory Value by Excess Cause for Air Force-Managed GAO Excess Items



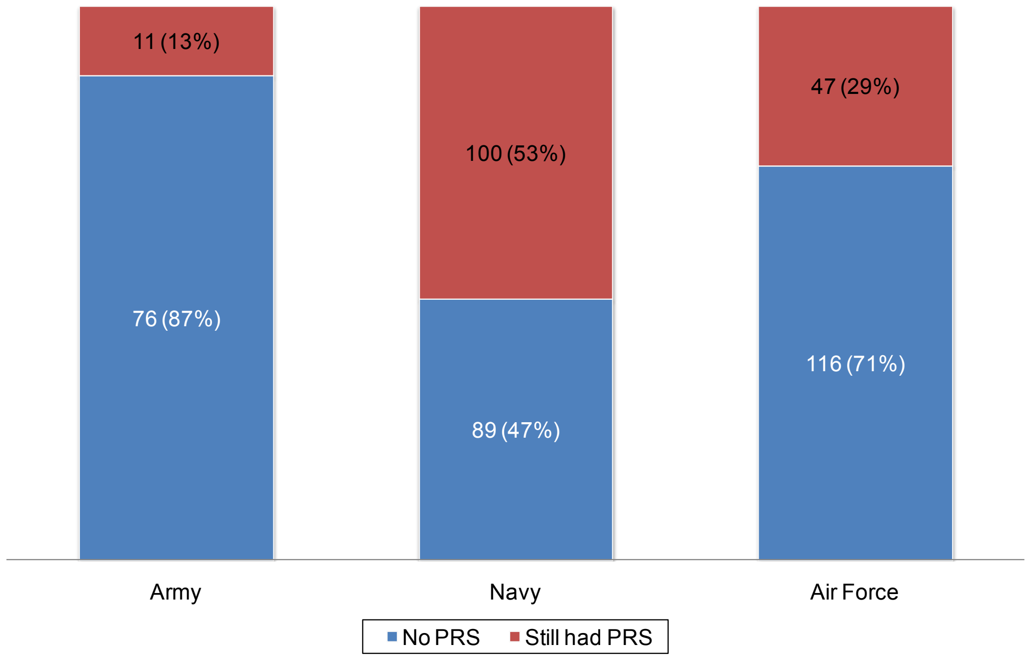
Length of Excess

Once inventory is identified as PRS, it is reviewed by the inventory manger for potential reuse within DoD or transfer as excess to the Defense Reutilization and Marketing Service for possible reutilization by another DoD component; donation to a federal, state, or local governmental agency; or disposal through sale to the public. Requirements can also fluctuate, removing these items from excess or making it necessary to retain this inventory for economic or contingency reasons.

To determine how much of this inventory left or remained in a state of excess, we reviewed whether the GAO-identified excess items with PRS still had PRS 2 years later. Figure 2-12 shows that only 13 percent of Army-managed, 53 percent of Navy-managed, and 29 percent of Air Force-managed items still had excess inventory 2 years after the GAO inventory audits.[8]

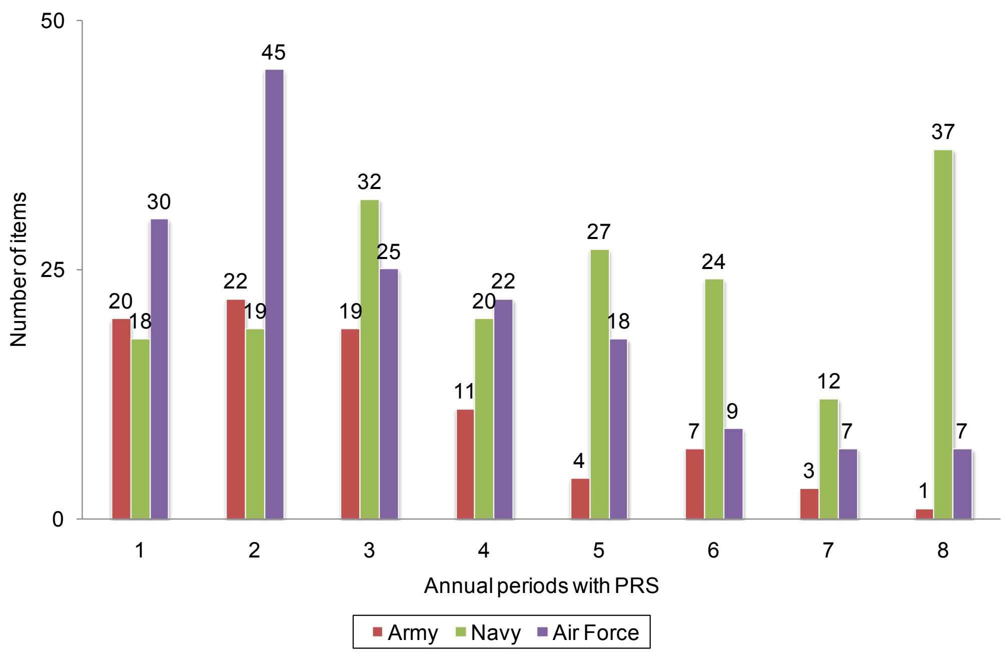
[8] For Army and Navy items, we identified items with PRS in 2009. For Air Force-managed items, we identified items with PRS in 2007.

Figure 2-12. GAO Excess Items with PRS 2 Years Later



To further understand how long an item remained in excess, we looked at the number of consecutive periods with PRS for the items identified as excess by GAO. Figure 2-13 aligns these items with the number of consecutive annual stratification periods in which they had PRS. Most of the Army-managed and Air Force-managed items had 3 or fewer years of PRS; however, most of the Navy-managed items with PRS stayed in an excess state for more than 3 years.

Figure 2-13. Number of Consecutive Periods with PRS for GAO Excess Items

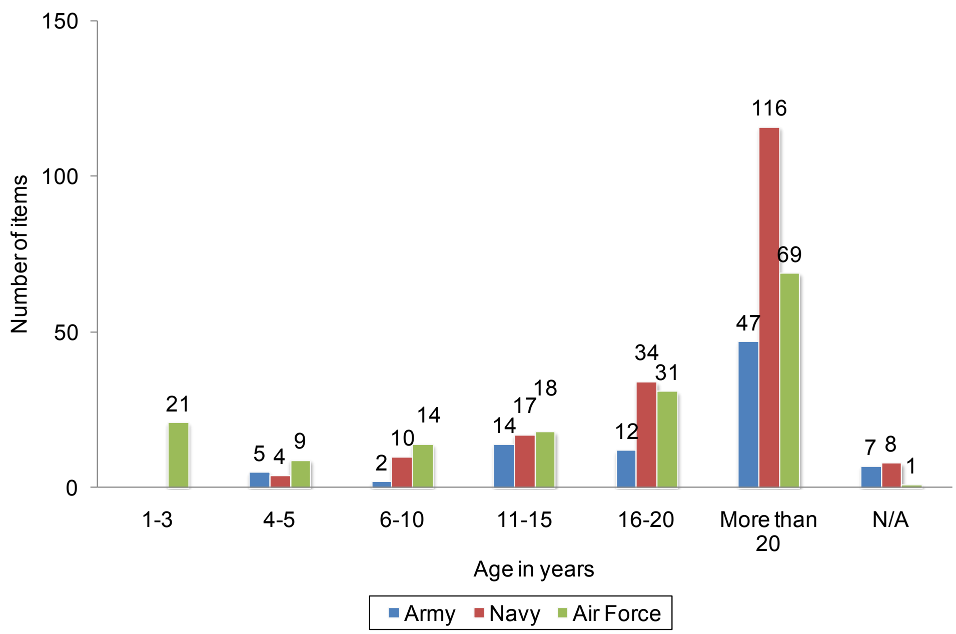


Item Phase

GAO indicated that initial provisioning of spare parts based on engineering estimates can result in the purchase of unneeded stock when these estimates prove to be inaccurate.[9] To understand the relationship between item introduction and excess inventory, we looked at the age of items during GAO's audits using the system entry date from the Federal Logistics Information System. From this, we were able to approximate the life phases for these items.

Figure 2-14 shows the age of all GAO-identified excess items that had PRS. While it is true that inaccurate estimates during item introduction can lead to excess, we found inventory excesses to be more of a problem in older items. In fact, the majority of the items with excess had been in the system for more than 10 years, and many had been in the system for more than 20 years. Only 21 Air Force-managed items had been in the system for less than 3 years; these were most likely in the introduction phase.

Figure 2-14. Age of All GAO Excess Items with PRS



Additional Item Attributes

To further characterize the items that had PRS and were identified as excess by GAO, we looked at inventory type, inventory control point (ICP), and federal supply group (FSG). Our review did not indicate that any of these factors was a leading indicator of whether items would have PRS.

[9] GAO, *Defense Inventory: Management Actions Needed to Improve the Cost Efficiency of the Navy's Spare Parts Inventory*, GAO-09-103, December 2008, p. 5.

Figure 2-15 shows, by inventory type, the number and percentage of items identified as excess by GAO that had PRS.

Figure 2-15. GAO Excess Items with PRS by Inventory Type

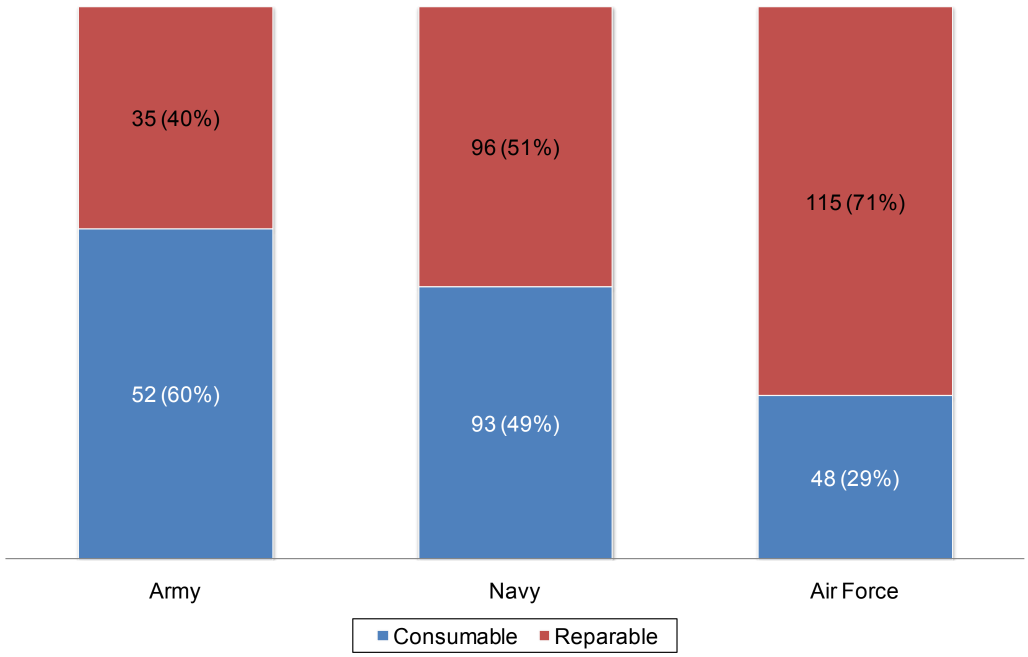


Table 2-1 shows the inventory control point for the items identified as excess by GAO that had PRS.

Table 2-1. Inventory Control Points for GAO Excess Items with PRS

Military service	Inventory control point	Number of items	Percentage of items
Army	Armament and Chemical Acquisition and Logistics Activity (ACALA) (Rock Island)	34	39%
	AMCOM (Missile)	20	23%
	TACOM (Warren)	17	20%
	AMCOM (Aviation)	16	18%
Navy	Philadelphia (Aviation)	118	62%
	Mechanicsburg (Maritime)	71	38%
Air Force	Ogden	66	40%
	Warner Robins	52	32%
	Oklahoma City	43	26%
	San Antonio	2	1%

Table 2-2 shows the top five federal supply groups within each military service for the items identified as excess by GAO that had PRS.

Table 2-2. Top Five Federal Supply Groups for GAO Excess Items with PRS

Military service	FSG	Description	Number of items	Percentage of items
Army	59	Electrical and electronic equipment components	13	15%
	53	Hardware and abrasives	12	14%
	61	Electric wire and power and distribution equipment	8	9%
	51	Hand tools	5	6%
	25	Vehicular equipment components	5	6%
Navy	59	Electrical and electronic equipment components	52	28%
	49	Maintenance and repair shop equipment	13	7%
	58	Communications, detection, and coherent radiation equipment	13	7%
	16	Aircraft components and accessories	12	6%
	51	Hand tools	12	6%
Air Force	59	Electrical and electronic equipment components	36	22%
	16	Aircraft components and accessories	23	14%
	13	Ammunition and explosives	23	14%
	28	Engines, turbines, and components	17	10%
	15	Aircraft and airframe structural components	15	9%

ANALYSIS OF SHORTFALLS

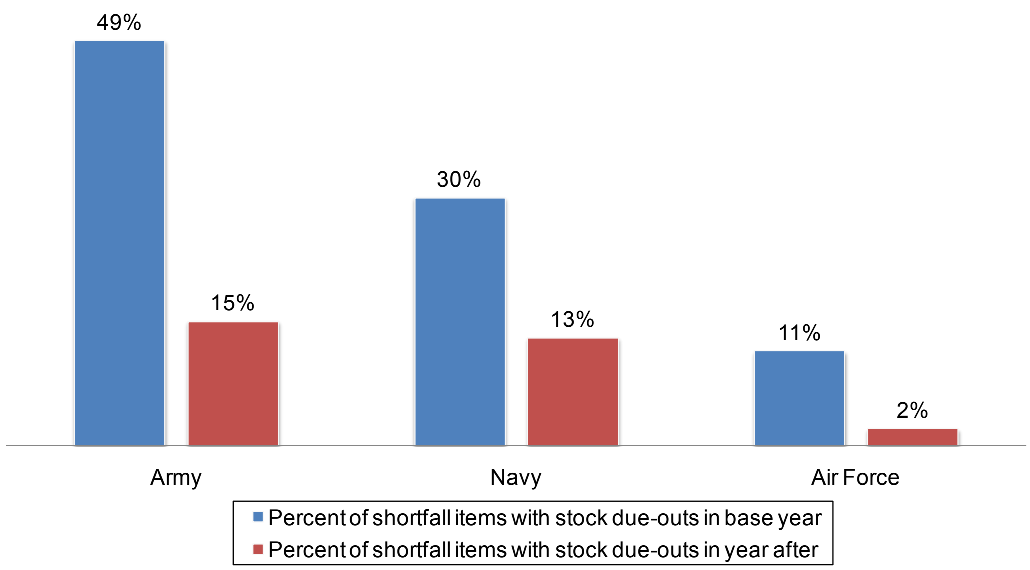
In each military service inventory audit, GAO identified a representative sample of items that had inventory shortfalls. GAO used these items to survey the military services about reasons for inventory shortfalls and to draw general conclusions about the entire population of managed items. We analyzed this same sample of shortfall items, which included 67 Army-managed items, 40 Navy-managed items, and 105 Air Force-managed items. Because GAO had selected a random probability sample, the results of our analysis should be representative of the total item population for that military service.

Stock Due-Outs

GAO's audits identified inventory shortfalls when inventory levels dipped below the reorder point or requirements objective threshold. Even though these measures are used to trigger inventory replenishments within DoD, they do not translate to operational impact. DoD's metrics in this area use stock due-out or backorders to identify when inventory is short of operational requirements.

To understand the operational impact associated with these lower inventory levels, we looked at the items identified as having an inventory shortfall by GAO and found only a portion of them also had stock due-out requirements in the stratification records. Figure 2-16 shows that only 49 percent of the Army-managed items, 30 percent of Navy-managed, and 11 percent of Air Force-managed items with shortfalls had stock due-out requirements in the base year. Even smaller percentages of items had stock due-out requirements in the year after the base year. These findings confirm that, even when inventory levels fall below these thresholds, managers are often able to leverage built-in safety levels and avoid operational impact.

Figure 2-16. Portion of GAO Shortfall Items with Stock Due-Out Requirements in Base Year and 1 Year after Base Year



Relationship of Forecast Error to Shortfalls

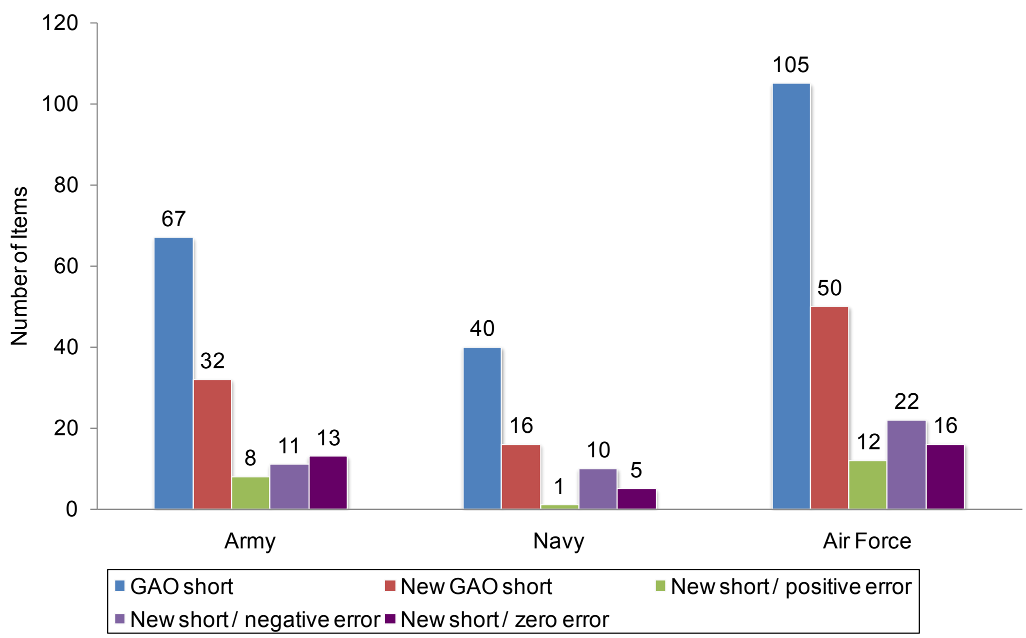
Demand forecasting is not an exact science, and forecasts are rarely 100 percent accurate. Shortages can occur when forecasts are too low (i.e., actual demand exceeds forecast). Inventory managers also sometimes buy too little and too late. In addition, under estimating lead-time demand can deplete inventory levels before the purchased stock arrives.

GAO attributed under-forecasting as the leading cause for shortfall inventories; however, as with excesses, there can be other reasons for inventory shortfalls. Lead times, repair cycle times, and safety levels can increase and operational availability targets can change. Timing of returns and delays with repairs can also lead to inventory shortfalls.

To better understand the correlation between inaccurate demand forecasts and shortfall inventory levels, we reviewed forecast error for items GAO identified as having an inventory shortfall. Just like excesses, to show that forecasting caused the problem, an item would have to have had no shortfall in one year, but both negative forecast error and an inventory shortfall in the next year. To test this, we looked at the base year stratification data for the items identified as shortfalls by GAO and analyzed the demand forecast, actual demand, and shortfall data.

Figure 2-17 shows that, of the 212 items with GAO-identified shortfalls, only 98 items entered shortfall status in the base year (i.e., they were not shortfalls the previous year). Of those 98 items, 43 had negative forecast error. In other words, about 44 percent of the items entering shortfall status in the base year were under-forecasted the previous year. This finding does not support the contention that under-forecasting (negative forecast error) causes inventory shortfalls. In fact, we found virtually no correlation between the magnitude of the negative forecast error and that of the inventory shortfall.

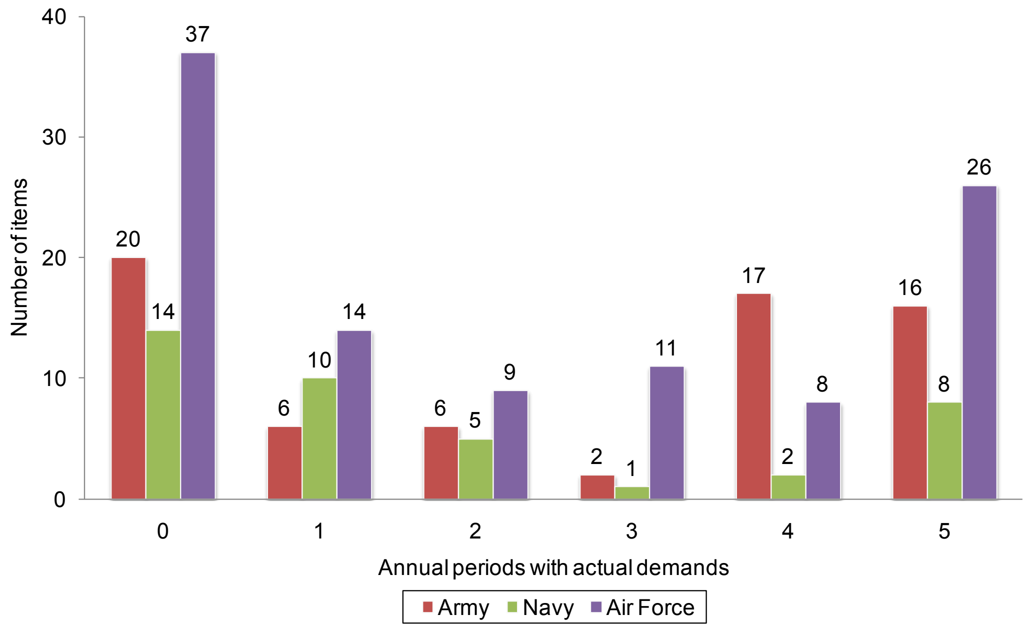
Figure 2-17. Forecast Error and Shortfalls



Forecastability of Shortfall Items

When we looked at the actual demands for the GAO-identified shortfall items, we saw that many items had sporadic or no demand, which affects the ability to forecast these items using standard forecasting techniques. Considering historical demand for a 5-year period (2 years leading up to the base year, the base year, and 2 years after the base year), Figure 2-18 shows the annual periods that contained actual demands for these items. Only 16 Army-managed items, 8 Navy-managed items, and 26 Air Force-managed items observed actual demands in all 5 years, which makes them more suitable for standard forecasting techniques. The remaining 51 Army-managed items, 32 Navy-managed items, and 79 Air Force-managed items had intermittent demand during these 5 years, which makes them more difficult to forecast using standard techniques.

Figure 2-18. Number of Annual Periods with Actual Demands for GAO Shortfall Items



Shortfall Items by Cause

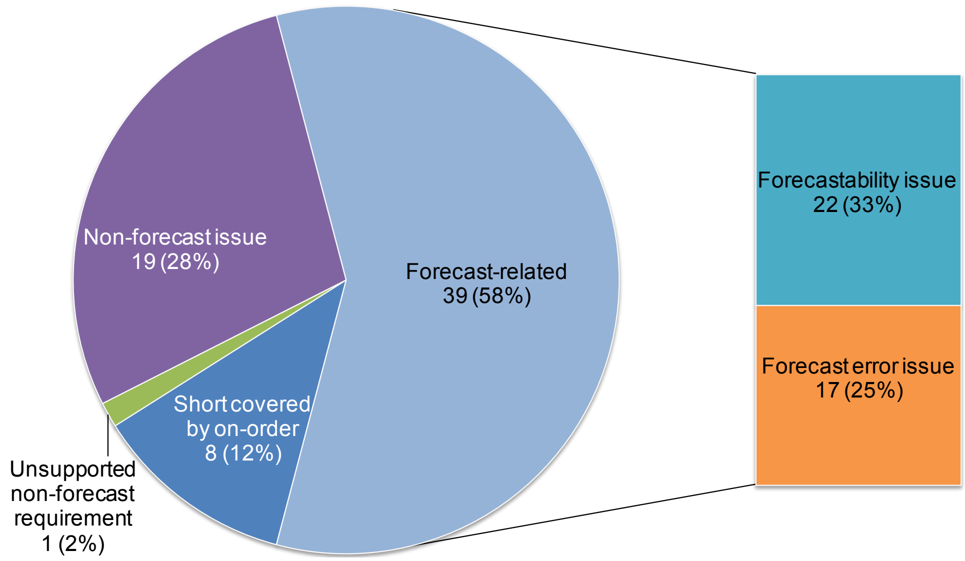
In each of the military service inventory audits, GAO used survey responses from item managers to estimate the frequency of reasons for having inventory shortfalls. To complement this approach, we analyzed 8 years of item-specific stratification data to further characterize causes for shortfalls. We looked at item characteristics, number and frequency of historical observations, and inventory requirements and stock levels over time. We then grouped these items by shortfall cause.

Even though we found a large portion of these items to had forecast-related causes, we did not find this for the majority of the items across all military services. In fact, we found larger portions of Navy and Air Force-managed items with non-forecast requirements that were either ignored or unsatisfied due to availability issues or other reasons. Our causative findings for each military service are outlined below.

ARMY

The 67 Army-managed GAO-identified shortfall items fall into one of the following categories (see Figure 2-19):

Figure 2-19. Causes for Army-Managed GAO-Identified Shortfalls

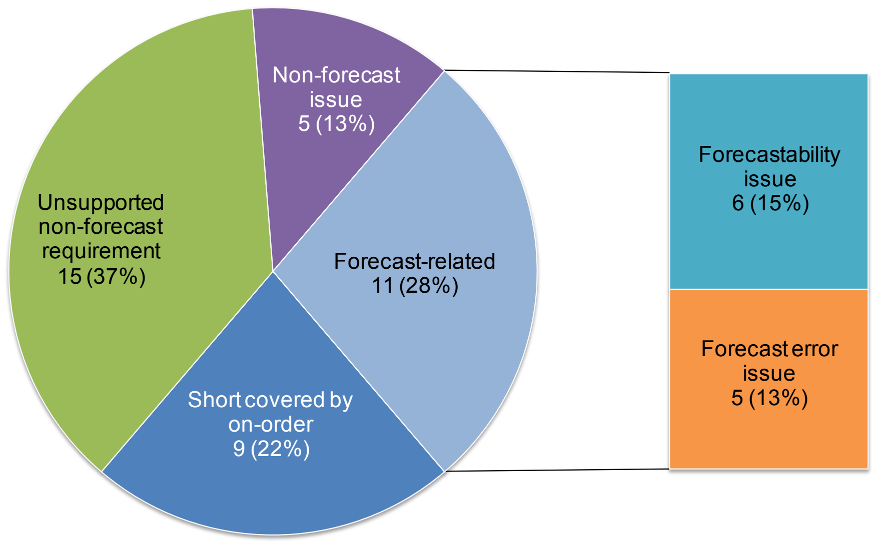


- *Shortage covered by on-order*. Eight items (12 percent) did not have stock due-out requirements and had all requirements covered by inventory that was on-order.
- *Unsupported non-forecast requirements*. One item (2 percent) had a numeric stock objective requirement that was not fully satisfied by on-hand or on-order inventory. This item showed no actual demand during the analysis period.
- *Non-forecast issue*. Nineteen items (28 percent) had other reasons for the shortfall and were not attributable to inaccurate forecasts. All 19 items were new (in the system for less than 3 years) with stock due-out requirements, but all requirements were covered by on-order inventory.
- *Forecast-related*. Thirty-nine items (58 percent) had inventory shortfalls attributable to inaccurate forecasts. These items are further divided into two categories: 22 items had limited history and were identified as having a *forecastability* issue; 17 items had sufficient actual demand and were identified as having a *forecast error* issue.

NAVY

The 40 Navy-managed GAO-identified shortfall items fall into one of the following categories (see Figure 2-20):

Figure 2-20. Causes for Navy-Managed GAO-Identified Shortfalls



- *Short covered by on-order*. Nine items (22 percent) did not have stock due-out requirements and had all requirements covered by inventory that was on-order.

- *Unsupported non-forecast requirements*. Fifteen items (37 percent) had numeric stock objective requirements that were not fully satisfied by on-hand and on-order inventory. Thirteen of these items showed no actual demand during the analysis period, and the remaining two items showed that actual demands declined. Only one of these items had a stock due-out requirement in the base year.

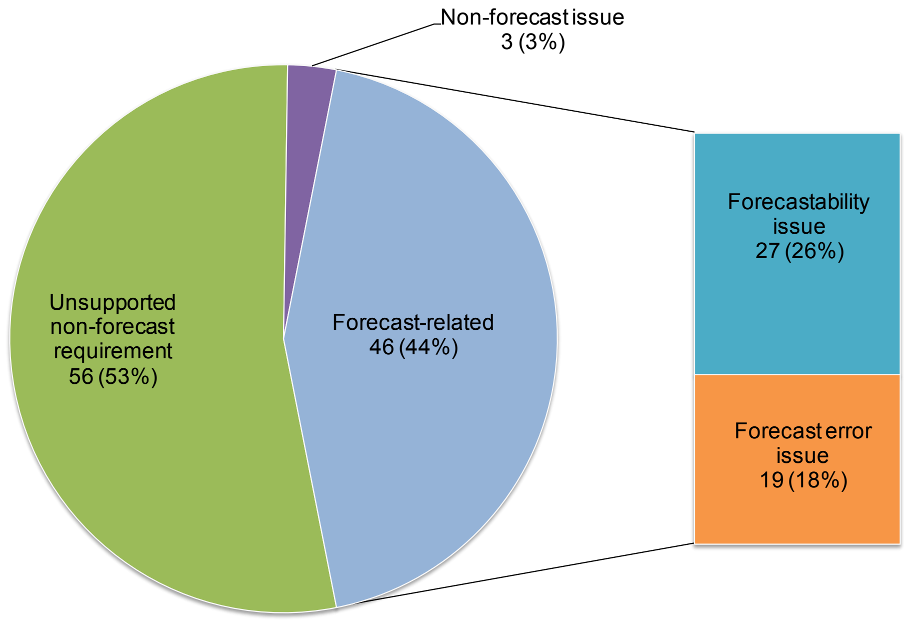
- *Non-forecast issue*. Five items (13 percent) had other reasons for the shortfall and were not attributable to inaccurate forecasts. Four of these items were new (in the system for less than 3 years) with stock due-out requirements, but all requirements were covered by on-order inventory. The remaining item had stock due-out requirements that appear to be caused by the timing of returns or repairs.

- *Forecast-related*. Eleven items (28 percent) had inventory shortfalls attributable to inaccurate forecasts. These items are further divided into two categories: 6 items had limited history and were identified as having a *forecastability* issue; 5 items had sufficient actual demand and were identified as having a *forecast error* issue.

AIR FORCE

The 105 Air Force-managed GAO-identified shortfall items fall into one of the following categories (see Figure 2-21):

Figure 2-21. Causes for Air Force-Managed GAO-Identified Shortfalls



- *Unsupported non-forecast requirements*. Fifty-six items (53 percent) had non-forecast requirements that were not fully satisfied by on-hand or on-order inventory (36 with numeric stock objective and 20 with safety level). Twenty-four of these items showed no actual demand during the analysis period. Only two items had stock due-out requirements in the base year.

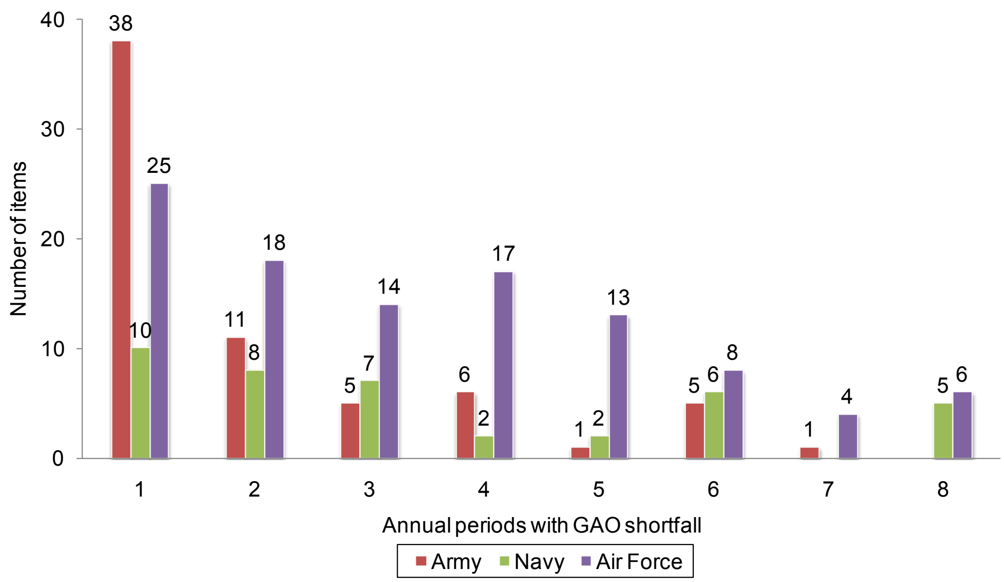
- *Non-forecast issue*. Three items (3 percent) were short because of the timing of returns or repairs. Two of these items had stock due-out requirements.

- *Forecast-related*. Forty-six items (44 percent) had inventory shortfalls attributable to inaccurate forecasts. These items are further divided into two categories: 27 items had limited history and were identified as having a *forecastability* issue; 19 items had sufficient actual demand and were identified as having a *forecast error* issue.

Length of Shortfall

To understand how long items had inventory shortfalls, we looked at the number of consecutive annual stratification periods with GAO-defined shortfalls for each of the sample items (see Figure 2-22). While the largest population of items only had an inventory shortfall for 1 year, many experienced multiple years of inventory shortfalls.

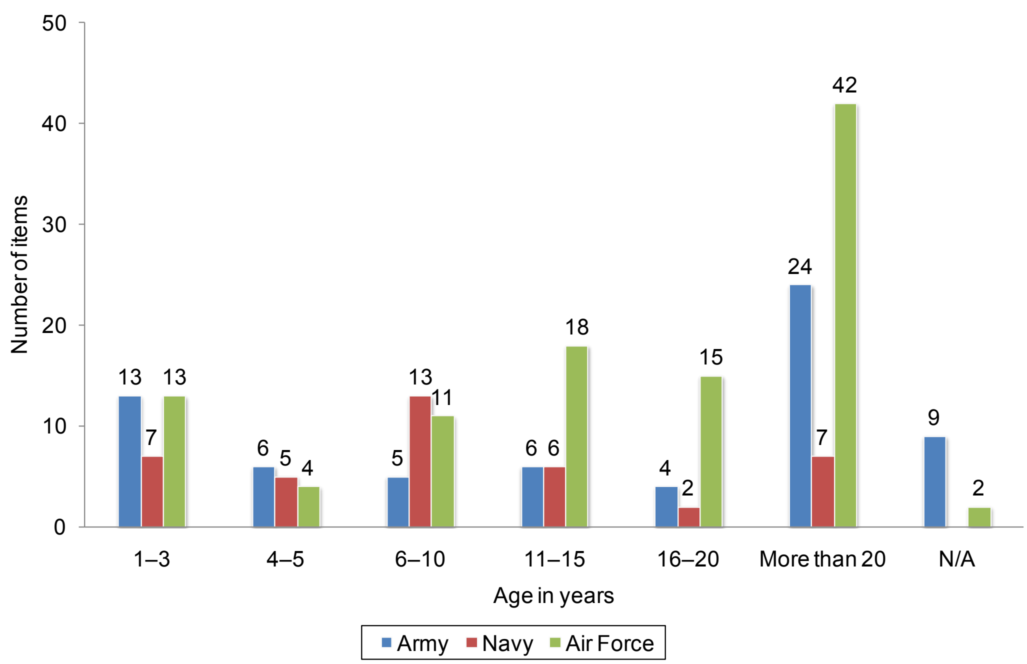
Figure 2-22. Consecutive Periods with Shortfalls for GAO Sample Items



Item Phase

To understand the relationship between item phases (introduction, sustainment, retirement) and shortfall inventory, we looked at the age of items during GAO's audits using the system entry date from the Federal Logistics Information System. From this data, we were able to approximate the life phases for items. Figure 2-23 shows the age of all items identified by GAO as having an inventory shortfall. While our causative findings did highlight some new items in the introduction phase, inventory shortfalls do not appear to be tied to a specific item phase.

Figure 2-23. Age of All GAO Shortfall Items



Additional Item Attributes

To further characterize the items identified by GAO as having inventory shortfalls, we looked at inventory type, ICP, and FSG. Our review did not indicate that any of these factors was a leading indicator to whether items will have inventory shortfalls.

Figure 2-24 shows the number and percentage of items by inventory type that were identified by GAO as having shortfalls.

Figure 2-24. GAO Shortfall Items by Inventory Type

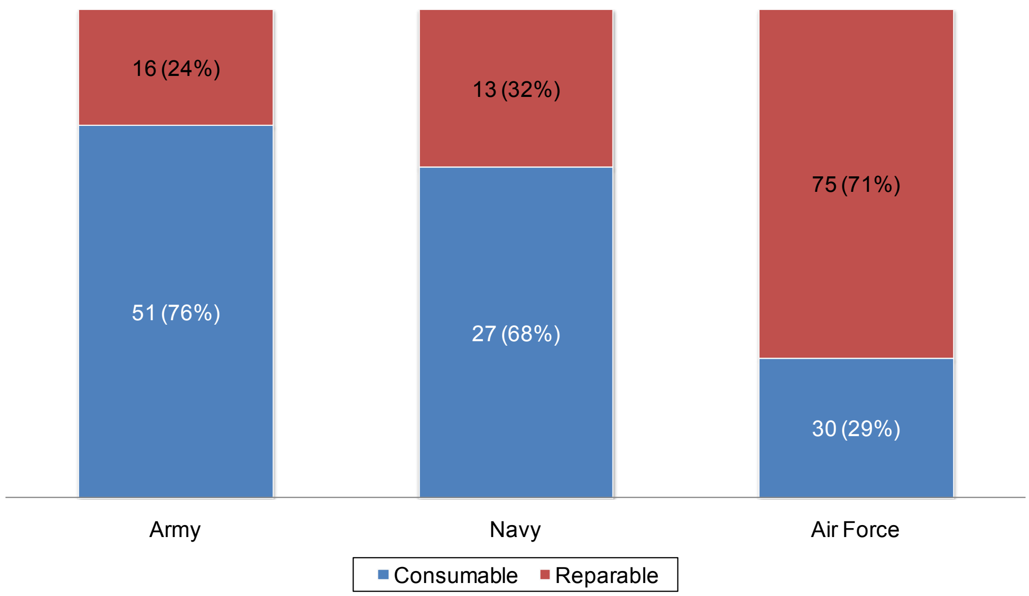


Table 2-3 shows the inventory control point for the GAO-identified shortfall items.

Table 2-3. Inventory Control Points of GAO Shortfall Items

Military service	Inventory control point	Number of items	Percentage of items
Army	AMCOM (Aviation)	27	40%
	ACALA (Rock Island)	17	25%
	TACOM (Warren)	17	25%
	AMCOM (Missile)	6	9%
Navy	Mechanicsburg (Maritime)	26	65%
	Philadelphia (Aviation)	14	35%
Air Force	Oklahoma City	35	33%
	Ogden	31	30%
	Warner Robins	30	28%
	San Antonio	9	9%

Table 2-4 shows the top five federal supply groups within each military service for the GAO-identified shortfall items.

Table 2-4. Top Five Federal Supply Groups for GAO Shortfall Items

Military service	FSG	Description	Number of items	Percentage of items
Army	61	Electric wire and power and distribution equipment	9	13%
	25	Vehicular equipment components	8	12%
	53	Hardware and abrasives	8	12%
	59	Electrical and electronic equipment components	6	9%
	31	Bearings	5	7%
Navy	59	Electrical and electronic equipment components	7	18%
	53	Hardware and abrasives	5	13%
	16	Aircraft Components and accessories	3	8%
	15	Aircraft and airframe structural components	2	5%
	31	Bearings	2	5%
Air Force	59	Electrical and electronic equipment components	25	24%
	15	Aircraft and airframe structural components	18	17%
	58	Communication equipment	10	10%
	16	Aircraft components and accessories	8	8%
	61	Electric wire and power and distribution equipment	7	7%

ANALYSIS OF METRICS

GAO identified a shortcoming in DoD metrics, noting “a lack of metrics and targets focusing on the cost efficiency of inventory management.” It recommended DoD “conduct systematic evaluations of demand forecasting used for inventory management to identify and correct weaknesses and establish goals and metrics for tracking and assessing the cost efficiency of inventory management.”[10]

[10] GAO, *DoD’s High-Risk Areas: Actions Needed to Reduce Vulnerabilities and Improve Business Outcomes*, GAO-09-460T, March 12, 2009, p. 19.

All DoD components have systems in place to compute the minimum-cost inventory they need to meet performance goals. They track supply effectiveness in terms of fill rates, customer wait times, or backorders (unfilled orders), and they all go through an inventory stratification process that compares requirements to assets to determine shortfalls and overages. Collectively, these processes establish, track, and control DoD's inventory investment. What DoD lacks is a systemic method for evaluating inventory efficiency from a classical business perspective.

In economics, efficiency is defined as the cost of inputs for each unit of output. For DoD inventory investment efficiency, the cost of inputs can be computed as the total of inventory purchases,[11] but the unit of output is more difficult to define. DoD's output is neither profit nor production. The "product" of the DoD inventory enterprise is readiness. But what is a unit of readiness? In an environment where the DoD components' collective objective is to maintain the current level of readiness, there is no change to measure, even though investments continue to be made. Unlike a manufacturing operation in which we can develop a ratio of cost per unit produced, we are challenged to define equivalent efficiency metrics for the overall DoD environment.

What we can measure is the efficiency of the demand forecasting process in a way that sheds some light on the overall impact of forecasting errors. It is important to keep in mind that, even if forecasts for a group of items are, on average, accurate (high errors cancel out low errors), the effect on inventory of over-forecasting is different than that of under-forecasting.

Typically, forecasters or demand planners use statistical metrics to show how well their forecasting processes perform. To be meaningful and actionable, planners need to understand how the forecast is affected by the choice of algorithm and parameters, rules for outliers, customer collaboration information, and planner judgment.[12] While these metrics are important, they only address the statistical accuracy of the forecasts.

[11] One could argue the total operating cost, including workforce and facilities, should be included; but the purpose of the metrics described here is the efficiency of the inventory investment itself.

[12] Metrics for this purpose are based in the statistical processes and include such statistics as mean absolute percent error (MAPE), mean square error (MSE), mean absolute deviation (MAD), mean percent error (MPE), and some measure of bias.

For a forecast cost efficiency metric, we must introduce a cost factor and then aggregate that factor across groups of items. A demand dollar–weighted average of a signed (i.e., not absolute value) statistic, such as MPE, can provide this information. Examples of appropriate metrics include demand dollar weighted mean percent error (DWMPE) and dollar value of positive errors (DVPE):

- Demand dollar weighted mean percent error, is computed as the sum of the dollar value of forecast errors divided by the sum of the demand dollar value.

$$DWMPE = \frac{\sum_{i=1}^{n} (F_i - D_i) \times C_i}{\sum_{i=1}^{n} D_i \times C_i}, \qquad \text{[Eq. 2-1]}$$

where
F_i = forecast for item i
D_i = actual demand for item i
C_i = acquisition cost of item i.

- Dollar value of positive errors is computed by summing the total dollar value of forecast errors, only where the error is positive.

$$DVPE = \sum_{i=1}^{n} (F_i - D_i) \times C_i, \qquad \text{[Eq. 2-2]}$$

where $F_i > D_i$

In both of these examples, we sum item-level forecast metrics across a group of items, without addressing the question of what time period to evaluate for error. DoD lead times and procurement cycles are generally longer than those of a commercial enterprise; therefore, traditional one-period-ahead forecast errors are neither relevant nor informative. To produce meaningful forecast efficiency metrics, DoD components should measure forecast error over two time frames: the lead time period and the lead time plus procurement cycle period. The lead time period determines the timing of a buy, and the procurement cycle period determines the size of the buy. Both factors are important in measuring the cost impact of forecast errors.

Limitations of Assessment

Our assessment leveraged GAO's findings and focused on the sample items identified by GAO as having inventory excesses or shortfalls. We obtained and reviewed 8 years of inventory stratification records (FY2002–FY2009). These stratification records detail quantity and timing of inventory and requirements in different categories. From this information, we could identify increases and decreases in the various inventory requirements and note when items moved in and out of excess and shortfall states.

Because we were limited by the data available, we could not assess why a requirement increased or decreased unless it was clearly indicated by an item attribute in our review. We were given the survey questions GAO asked in the inventory audits, but we were unable to obtain copies of the responses given by the military services. The data we analyzed reached back only to 2002, which prevented us from seeing what happened to items before the 8-year period. In addition, 52 percent of the Army items in our analysis were transferred to the Army's Logistics Modernization Program from 2007 to 2009, and removed from the stratification records. We were unable to assess what happened to these items after the transition. Despite these limits, we were able to identify findings relevant to the overall population of items.

SUMMARY

Our review and analysis of excess and shortfall items resulted in several findings and highlighted actions that should be taken:

- *Excess inventory is a greater problem with older items*. Our analysis showed that the majority of the items with excess have been in the system for more than 10 years, and many have been in the system for more than 20 years. This indicates increased challenges with items in the sustainment and retirement phases. It also highlights the importance of understanding and addressing the changing influences of different lifecycle phases when developing forecasting and inventory improvements.
- *Most of the excess inventory includes reparable items in unserviceable condition.* Unserviceable condition inventory indicates the items have been used, sometimes repeatedly. This highlights the need to specifically address unserviceable inventory when developing effective and efficient inventory management approaches.
- *Forecastability is an issue with both excess and shortfall items*. Our analysis revealed opportunities for improving forecast accuracy using standard forecasting techniques; however, there is an even greater need for forecasting methods that address items with limited forecastability. This highlights the need to identify and implement ways to more effectively and efficiently set inventory levels for low-demand items.
- *Forecasting is not the only driver for excess.* There are reasons other than inaccurate forecasts that can lead to excess inventory, such as reductions in readiness objectives or safety levels and unserviceable returns that exceed current demand rates. This highlights the importance of a comprehensive inventory management approach that addresses timely review of

declared excess, pre-screening of returns, and review and validation of current retention methods.

- *Forecasting is not the only driver for shortfalls.* There are reasons other than inaccurate forecasts that can lead to inventory shortfalls, such as increases in lead times, repair cycle times, and safety levels and changes in operational availability targets. This again highlights the importance of a comprehensive inventory management approach—one that reduces unnecessary inventory, but does not affect readiness objectives.

- *There is no universal agreement on inventory stratification terminology*. Congress and the Department of Defense disagree with GAO on what constitutes excess inventory, and there are no standard measures for shortfalls. Furthermore, the military services do not interpret stratification terms uniformly, and visibility of stratification data continues to diminish with system modernization. This highlights the need for defining and establishing a new inventory segmentation method that will better capture the rationale behind inventory decisions and improve inventory reporting and tracking.

As noted in Chapter 1, all of these findings are addressed by actions in the DoD *Comprehensive Inventory Management Improvement Plan*.

Chapter 3
Demand Forecasting Procedures for New Items

Our review focused on demand forecasts for new item introductions.

New items are introduced in two ways:

- New acquisitions of a weapon system or equipment
- Modifications to an existing weapon system and equipment.

Although DoD in recent years has acquired fewer new weapon systems and equipment than in past decades (particularly in comparison to the Cold War years) with a greater proportion of new item introductions now the result of modifications to existing systems, we examined demand forecasting for both new and modified systems.

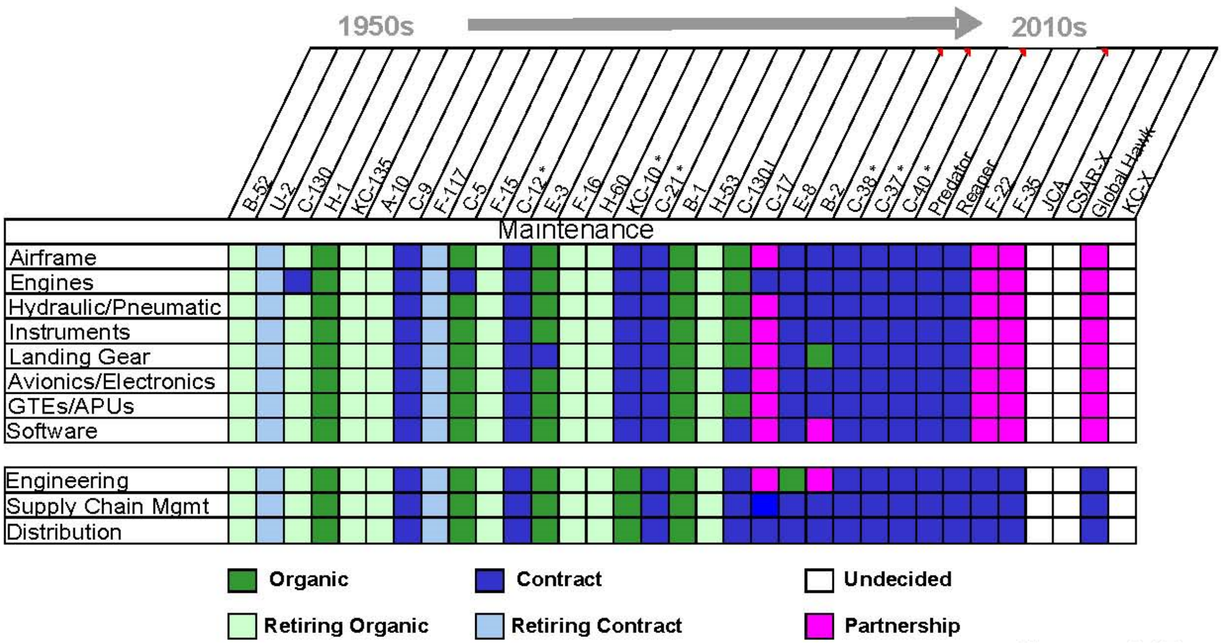
Provisioning, the term most commonly used by DoD to refer to the processes for introducing new items into inventory, generally applies to new acquisition programs, although the processes are fundamentally similar for modifications, especially major system modifications. When new systems are introduced, a greater proportion of the systems are supported by a contractor, in whole or in part. Some contract support is only for the short term only, but other systems and equipment are supported by contractors indefinitely. Figure 3-1 illustrates this trend in the Air Force.

With fewer weapon systems being introduced into DoD organic inventory management, less provisioning for new weapon systems is occurring within the military services and more provisioning is being performed by contractors. In many cases, interim support[1] is employed for the initial support of a program to provide time for the equipment design to mature and the military service's organic logistics capabilities to develop. But sometimes, the services opt to leave the system under contract support indefinitely. In either case, the initial demand forecasts are accomplished predominantly by the contractor that uses procedures similar to those of the military services. When the choice is to transition a system from interim support to organic support, the military service performs provisioning and a separate demand forecast is performed for the initial organic support period.

Both interim support and provisioning forecasts are considered subsets of initial item forecasts because sustainment forecasting rules do not apply. Our review evaluated both.

[1] Interim support is a term used to describe the support a contractor may provide for a new or modified system early in its acquisition, generally for a defined interim period.

Figure 3-1. Air Force Weapon System Management Comparison



Source: Jan Mulligan, "Ensuring an Adequate Infrastructure to Execute Assigned Maintenance Workload," HQ U.S. Air Force Logistics, Installations & Mission Support, briefing November 15, 2007.

OUR TASKING

We were tasked to examine provisioning and interim support demand forecasting procedures used by the Army, Navy, and Air Force. DLA does not perform interim support or provisioning. Through a process involving supply support requests (SSRs), DLA receives demand forecasts for new items from the military services.

APPROACH TO THE REVIEW

Our review included the following steps:

- Literature review
- Field visits
- Data call
- Analysis and documentation
- Recommendations development.

Step 1: Literature Review

Our background research included a review of relevant literature about inventory management and demand forecasting, including the following:

- DoD and military services policy and procedural guidance
- Past studies of military service forecasting practices
- GAO audit reports that documented problems areas within DoD
- Articles and briefings on public and private best business practices.

Step 2: Field Visits

We visited weapon system management offices and inventory management activities for the systems identified by the military services for inclusion in this study. We used information gathered through interviews to document and evaluate the current forecast methods used by the military services in their interim support and provisioning processes. The descriptions for each service, as well as a data analysis of their forecasts, are included in Appendixes C–E.

We also conducted field research interviews with four leading defense contractors to determine how they conduct forecasting and inventory management for newly designed and delivered equipment. Those practices are described in Appendix F.

Step 3: Data Call

We asked the Army, Air Force, and Navy to identify two weapon systems and provide data on these systems. We also devised an interview questionnaire that we used to gather data during our field visits. We evaluated the forecast methods used by the military services in their interim support and provisioning processes using the two weapon systems identified by each service. We then analyzed the forecast accuracy of the individual items that are part of each weapon system to measure how well the military services are forecasting demand for initial spares.

We experienced difficulties in gathering weapon system data. Some of the systems identified by the services are currently being provisioned, and no actual demand history was available to evaluate forecast accuracy. All of the systems had only a small number of items provisioned, and the samples were too small to provide reliable conclusions. In attempting to gather data from older systems, it became apparent that historical data on initial spares forecasts were not always available.

Because of data limitations associated with the weapon system programs, we needed to supplement the data we obtained from the program offices with additional data sources. Therefore, we expanded our original data analysis to include a larger sample of provisioning items within the military services over a 5-year period to identify overall trends in initial forecasting and how they relate to the specific weapon systems.

Step 4: Analysis and Documentation

We used the information obtained through data call and field visits to evaluate the military services' item introduction demand forecasting programs. The final results are documented in this report. We also conducted a case study of a frontline weapon system to determine and illustrate how variables considered in demand forecasts and inventory computations contribute to forecast errors. We used lessons learned from this case study to develop our recommendations for improvement.

Step 5: Recommendations Development

Based on our evaluation, we developed policy and procedural recommendations for improving the forecasts used for item introduction and provisioning. They appear in Chapter 6.

INITIAL DEMAND FORECASTING IN DOD

This section summarizes what we found relative to policy, procedures, and processes associated with demand forecasting for new items.

Policy and Implementation

DoD policy provides guidance on forecasting goals, techniques, and implementation, with a strong emphasis on collaboration. As challenging as forecasting is during sustainment, it is even more difficult during item introduction. During this early stage, the military services generally must use original equipment manufacturer (OEM) engineering estimates to predict demand rates for spare parts to support new or modified weapon systems.

DoD forecasting policy reflects the need to collaborate with supply chain partners. For example, DoD 4140.1-R[2] requires the following:

- Program managers should set system performance goals based on customer requirements.
- Inventory control points should collaborate with their customers and suppliers to determine optimal support strategies to meet performance goals.
- All supply chain partners should have timely access to planning information, including operating programs, customer requirements, supply chain resources, and total asset information.

[2] Office of the Deputy Under Secretary of Defense for Logistics and Materiel Readiness, DoD 4140.1-R, *DoD Supply Chain Materiel Management Regulation*, May 23, 2003.

For new acquisitions and major system modifications, program managers define readiness goals for a weapon system based on customer-defined operational requirement documents developed as part of the acquisition process. Program managers and ICPs use integrated product teams to facilitate collaboration among supply chain partners and customers to determine support strategies. From a forecasting perspective, most data inputs used by ICPs to compute item introduction forecasts come from supply chain partners. For example, OEMs provide the initial anticipated failure rates and program managers provide expected operating hours, numbers of equipments, and site locations. Of course, the resulting forecasts are only as good as the inputs used in their computation.

DoD policy provides detailed guidance on which stock levels are authorized and how they will be computed. As a result, stockage computations across the military services are very similar. The Department of Defense requires the use of quantitative models to forecast future demands, except in cases when there is a lack of demand history to support the model. During sustainment, when demand history is usually available, a plethora of models can be used for forecasting. But little or no demand data is available during the earlier phases of the acquisition lifecycle, and interim support demand forecasts rarely have sufficient demand data upon which to base accurate forecasts.[3]

Provisioning and Interim Support Forecasts

When the Department of Defense introduces a new weapon system or equipment, the acquiring military service must determine a logistics strategy to support it. The most basic decision is whether the system will be supported organically or through a contractor. If a military service decides that its supply system will be used to support a new system, it is referred to as organic support. The process for developing initial materiel support is referred to as provisioning. Generally, the military services forecast demand and compute spare parts requirements for provisioning organic support.

The military service may also elect to rely on contractors to support a system, either through interim support until organic support capabilities can be developed, or for the entire life cycle of the weapon system. In either case, the military services generally rely on the contractor to forecast demand, compute inventory levels, and acquire spare parts during the contractor-supported period. Regardless of who performs initial demand forecasts, the methods and inputs are similar. The difference is that, with interim support, the support period is limited. The end date for interim support is called the material support date (MSD), at which time the military service ICP assumes organic supply support responsibility.

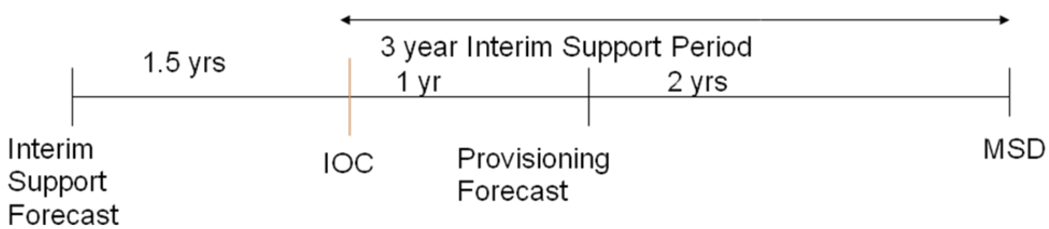
Provisioning forecasts and requirements computations usually occur during the interim support period if interim support is used. In some cases, interim support is

[3] Quantitative methods can sometimes be used during the later stages of provisioning, when limited demand data is available.

not used, particularly when there is sufficient lead time before the initial operating capability (IOC) date to accomplish provisioning.

The interim support forecast, requirements computation, and procurement must occur well in advance of the IOC of a new system, and the provisioning forecast, requirements computation, and procurements well in advance of the MSD. Figure 3-2 provides a notional timeline of the relationship between interim support and provisioning.

Figure 3-2. Notional Provisioning and Interim Support Timeline



PROVISIONING

As stated in DoD 4140.1-R,

> Provisioning involves the planning and acquisition of initial spares to support a new major system. Provisioning is the management process of determining and acquiring the range and depth of organic support items necessary to operate and maintain an end item of material.

Normally, provisioning forecasts predict demand for an initial demand development period, which is typically 2 years for organic support.

There are few significant differences among the military services on how they approach initial provisioning demand forecasts. Appendixes C–E provide detailed descriptions of provisioning processes in each of the military services. Demand forecast statistical models have limited application for initial forecasts due to the paucity of quantified demand data available. Current policy, which does not proscribe a single model—even for sustainment—is consistent with the generally held belief that there is no single best forecasting model that the military services should use for all programs and in all conditions.

Provisioning demand forecasts use methods similar to sustainment forecasts. The main difference is in the data inputs. Provisioning forecasts are largely based on OEM failure rate estimates, which may be combined with limited actual demand data when available. The initial provisioning forecast is smoothed over the demand development period by phasing actual demand observations into the forecast calculation. Usually, after a 2-year demand development period, the forecast uses only actual experienced demands.

INTERIM SUPPORT

The military services utilize interim support for a new or modified weapon system primarily when they are unable to provide full organic support at the time of a system's initial operating capability. However, the military services may also use the interim support option to intentionally delay provisioning to give a system's design time to stabilize, organic maintenances capabilities time to mature, and complete data to become available for forecasting.

Interim support forecasts are usually based on OEM failure rate estimates. In the earliest stages, there is very limited data available, and only a few of the provisioning technical data elements. Military services only purchase retail stock during interim support to provide support prior to the date they transition to organic support.

DoD has established little policy guidance on interim support. While interim support is mentioned as an option, DoD policy offers no direction regarding when it should be used or how it should be implemented. The reason for this is likely to be the variety of support situations. A number of support options are available, and a solution that works in one case may not work in another.

DoD policy also treats interim support as a subset of provisioning. Interim support typically occurs before items are cataloged, technical data is available, or organic logistics support capabilities are fully developed. In most cases, the interim support period is used to acquire failure data for provisioning forecasts for organic support. In other cases, interim support becomes the first step toward full lifecycle contractor logistics support.

There are several differences between how the initial forecasts are computed during interim support and how they are computed during provisioning. For example, contractors frequently use their own models to forecast demand and set stock levels for interim support. The military services can review these levels and compare them to their own calculations, if they desire, to assess their reasonableness.

Another significant difference is the basis for the demand rates used. During interim support, programs usually have only reliability and maintainability engineering estimates or demand rates for similar items and logistics support analysis to determine the expected demand rates. Provisioning forecasted demand rates may include some actual demand history based on usage during interim support or a warranty program. The military services review the contractor's estimates to determine if they are reasonable; however, the services seldom make changes to a contractor's estimates.

It is during this initial period when most items are cataloged. The items should be cataloged before provisioning. In some cases, the items can't be fully described because the technical documentation has not been completed.

The military services largely rely on contractors to perform the interim support list inventory computations; however, our interviews with contractors indicated that their calculations did not differ much from the calculations used by the military services, and the military services do not differ much from each other. For example, if contractors use readiness-based sparing (RBS) to compute requirements, the military services can run their own RBS models to validate the quantities recommended by contractors for procurement.

RESULTS OF DEMAND AND FORECAST DATA ANALYSIS

DoD Demand Variability

DoD demand data, even if it is available, is typically much more variable than demand data in private sector manufacturing and sales environments. One explanation for this is that DoD items are largely for spare and repair parts.

Unlike forecasting for manufacturing and overhaul programs, repair actions do not have defined bills of material for components. Rather, the bill of material is depends on which items fail, each of which must be forecast based on estimated probabilities.

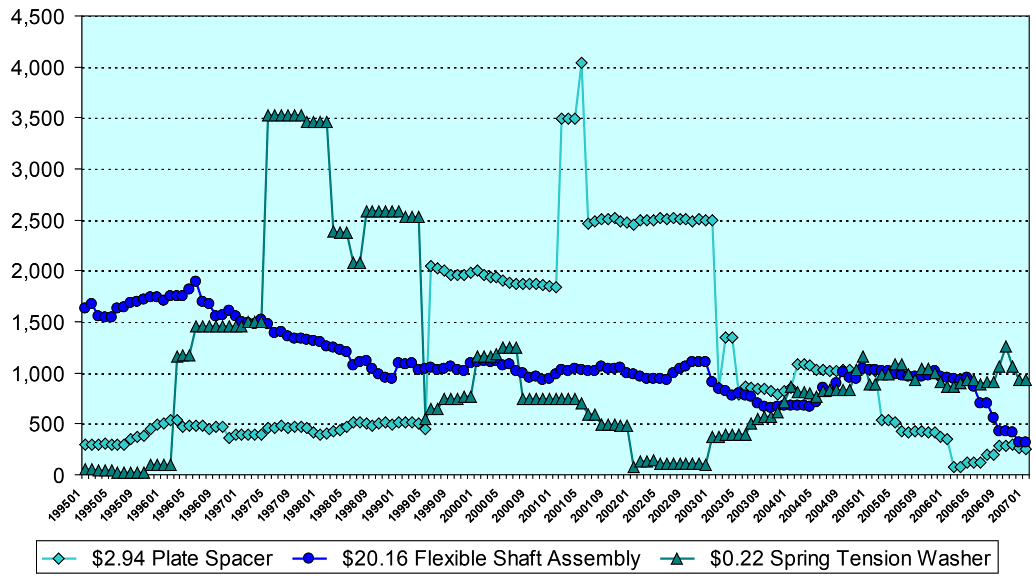
Spare parts demand is typically intermittent. Demand patterns are characterized by a number of zero-demand observations, followed by erratic spikes in demand. This pattern, where demand is both intermittent and erratic, is referred to as "lumpy demand."[4]

Figure 3-3 shows the 11-year demand pattern for three randomly selected DLA items. Inventory forecasting models generally assume a variance-to-mean ratio of 1:1. Previous DoD studies[5] concluded that DoD demand is much more erratic. This is true for items throughout all phases of an item's life-cycle, not just during item introduction. For example, DLA's variance-to-mean ratio is 32:1, and the Air Force's variance-to-mean ratio is 6:1. The Navy and Army have variance to mean ratios that typically lay between these two numbers.

[4] John E. Boylan and Aris A. Syntetos, "Spare Parts Management: A review of Forecasting Research and Extensions," *IMA Journal of Management Mathematics*, November 12, 2009.

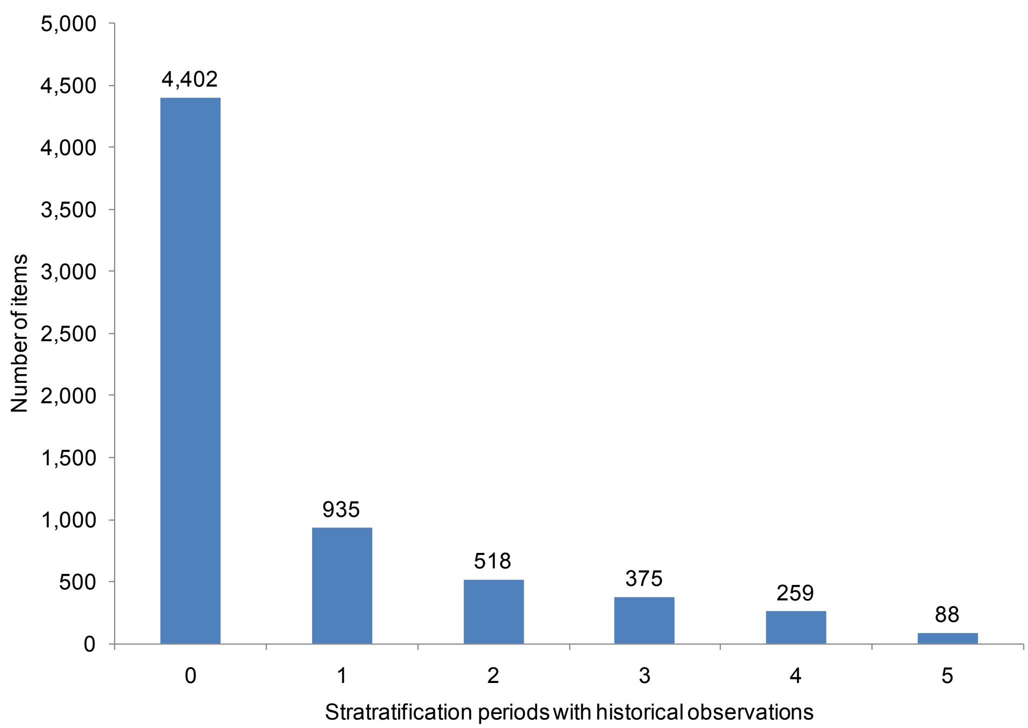
[5] LMI, *Economic Retention within the Department of Defense*, Report LG301T1, Dennis L. Zimmerman, December 2003.

Figure 3-3. Demand History for Three Random DLA Items



To illustrate further, we used stratification and historical demand data to determine how intermittent demand is for the Navy. We evaluated 6,577 items that appeared in both the Navy's FY2005 and FY2009 stratifications and then determined the number of years each item experienced demand during that period. Figure 3-4 depicts the result.

Figure 3-4. Historical Observations for Navy Provisioning Items



Source: Naval Inventory Control Point (NAVICP) stratification and item demand data.

Only 1 percent of the items (88 of the 6,577) had a demand in each of the 5 years we examined. In other words, 99 percent of the Navy items experienced intermittent demand. Because statistical forecasting models work best with items with continuous and stable demand history, the sporadic demand pattern is challenging to forecast.

Forecast Accuracy

Methodology

We evaluated the forecast accuracy of each of the military services' item introduction forecasts. We originally attempted to base this evaluation on two weapon systems from each military service; however, the weapon system data alone was insufficient to produce much insight. Overall, for each weapon system, only a small number of data points could be observed because of the small number of provisioning items for each system and the limited number of years. In some cases, it was also difficult to determine whether the forecasts provided were the actual initial forecasts the service used for provisioning decisions. In other cases, items were missing some or all actual demand data. In the end, we were unable to draw any conclusions from the data analysis of the military services weapon systems due to the data limitations.

To compensate for the limitations associated with the weapon system data, we developed an alternative strategy, one that used DoD stratification data to evaluate the quality of initial demand forecasts. Using the stratification files for each of the military services, we looked at all provisioning items with forecast and actual demand data (i.e., we were no longer constrained to the two weapon systems).

We used percent error as our main metric to measure forecast accuracy. The percent error of a forecast is calculated by subtracting the actual demand from the forecasted demand and dividing quantity by the actual demand. Not only does percent error provide the percentage the forecast was off from the actual demand, it also provides the direction of the difference (i.e., a positive percentage is an over-forecast and a negative percentage is an under-forecast).

To assess the overall percent error of the military services' forecasts, we compared the number of observations of over- and under-forecasts in histograms on an annual basis. The histograms allowed us to understand the distribution of forecast underage and overage and, at least to some extent, the extent of the error.

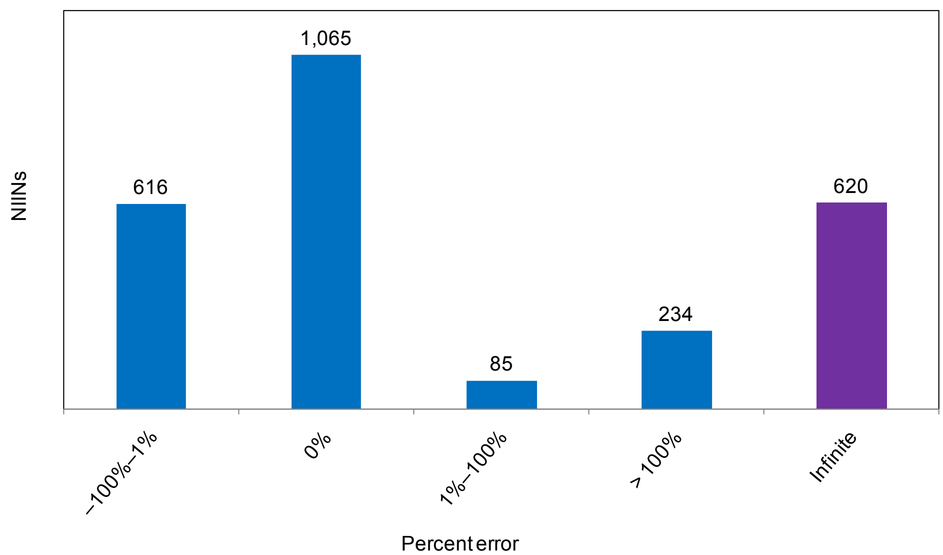
Results and Findings

Despite data limitations, we are still able to make inferences from the data we had. Overall, we found a slight bias toward over-forecasting across all of the military services. While the detailed analysis of each weapon systems, along with the DoD stratification files, are located in the respective appendix for each military service (Appendixes C–E), the following sections provide an overview of the results along with the key findings.

Army

Figure 3-5 is a histogram showing the percentage error for the 2,620 Army items identified as being in provisioning from the FY2006–FY2007 stratification files.[6] The Army forecasted 1,065 items correctly (there was a 0 percent error). Most of these were instances in which the Army forecasted zero demand and the actual demand was zero.

Figure 3-5. Army Stratification Data (FY2006–FY2007)



Source: AMCOM and TACOM stratification data FY2006–FY2007.
Note: NIIN = National Item Identification Number.

Figure 3-5 also shows the Army has an apparent under-forecast bias; however, when we look at the column labeled "Infinite" we get a different interpretation. The "infinite" column displays the number of instances when there was a positive forecast but no actual demand. Although we cannot compute a mean percent error for these items due to the mathematical limitations, we should not ignore them because they do represent an over-forecast. When we look at the entire histogram, including the "infinite" column, we see a total of 939 over-forecasts compared to

[6] The FY2006–FY2007 Army stratification files only include AMCOM and TACOM, so our analysis is limited to these two commands. We also removed all National Stockage Objective (NSO) items, insurance, and non-stocked items from the sample because the Army does not forecast for these items.

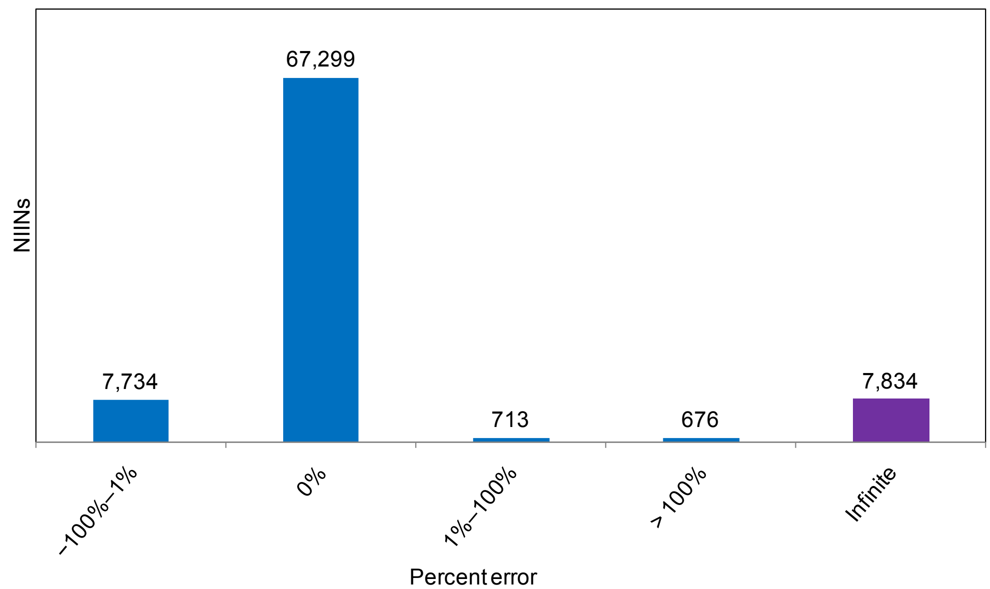
616 under-forecasts, suggesting more of a bias toward over-forecasting in the Army. Similar results were observed for the Navy and Air Force.

Navy

The Navy data set included all maritime items identified as new item introductions between FY2005 and FY2009. This data set does not include aviation items.

The histogram in Figure 3-6 shows the Navy had 66,729 items with a 0 percent error; 9,223 items that were over-forecasted; and 7,734 items that were under-forecasted.

Figure 3-6. Navy Maritime Data (FY2004–FY2009)



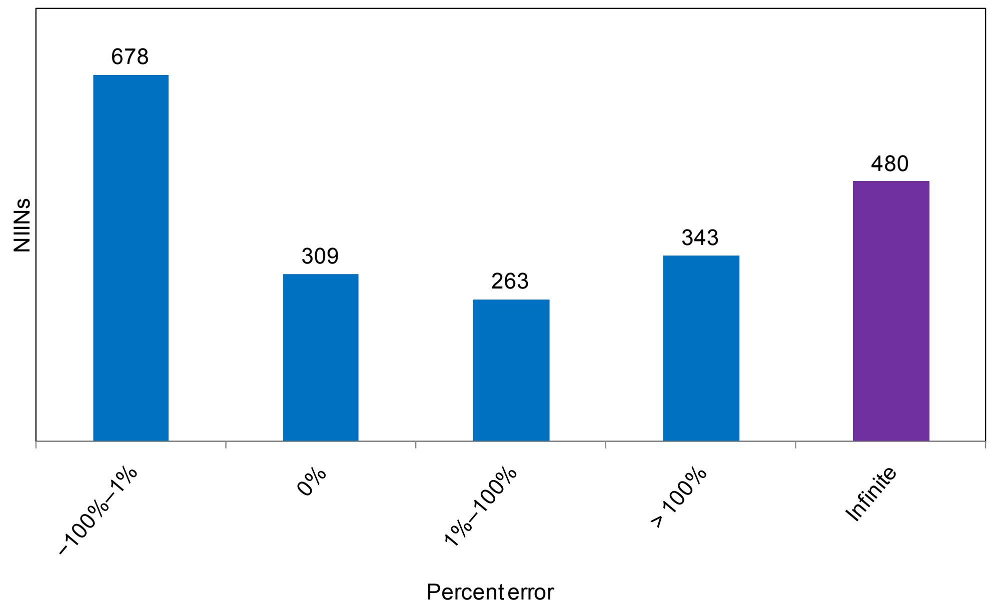
Source: NAVICP Stratification and Item Demand Data.

While the vast majority of Navy item forecasts had 0 percent error, like the Army, most were instances when the Navy forecasted zero and the actual demand was zero. If we look only at the range from −100% to >100%, there is an apparent tendency toward under-forecasting; however, when including the "infinite" column (which tells us there were 7,834 instances when an item had a forecast greater than zero but no actual demand for that item), it is obvious there were a large number of over-forecasts. Comparing the total number of over-forecasts (9,223) and under-forecasts (7,734) suggests the bias is, in fact, toward over-forecasting.

Air Force

Figure 3-7 shows the results from the Air Force data analysis. The data set includes all items identified in the Air Force D-200 Secondary Item Requirement System (SIRS) as new item introductions between FY2002 and FY2009.[7] The data set excludes new item introductions for Air Force systems managed by contractors that are not in D-200.

Figure 3-7. Air Force Data (FY2002–FY2009)



Source: Secondary Item Requirement System (SIRS).

The Air Force had 309 items with 0 percent error. The majority of these were instances in which the Air Force forecasted zero demand and the actual demand was also zero. The Air Force also had 480 instances in which it forecast for an item, but there was no actual demand for that item. In total, 1,086 items were over-forecast and 678 items were under-forecast, suggesting bias toward over-forecasting.

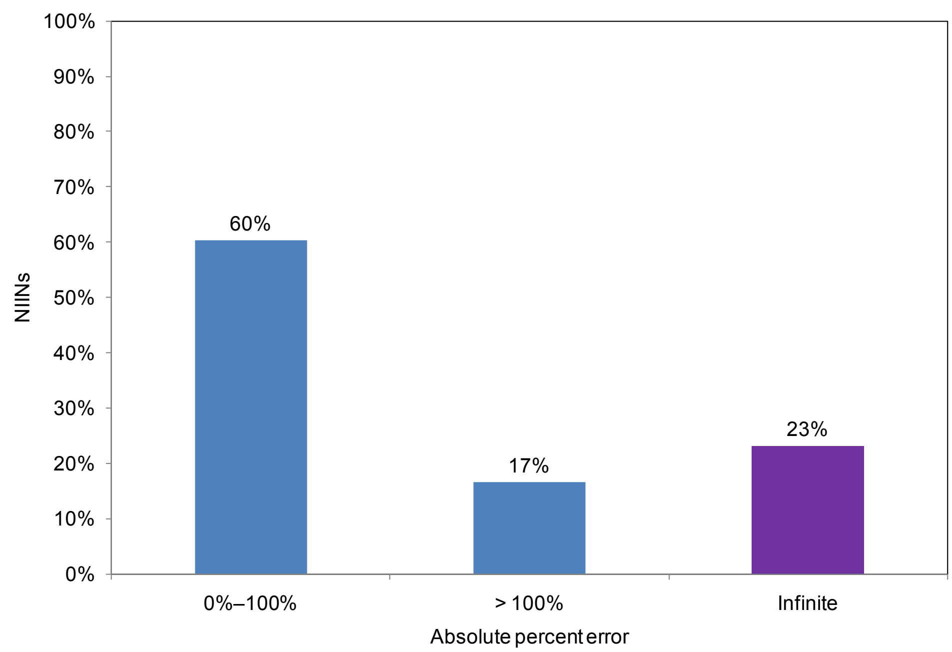
[7] We removed all NSO, insurance, and non-stocked items from the sample since the Air Force does not forecast for these items.

Item Introduction versus Sustainment Forecast Accuracy

Our research indicated that item introduction forecasts are based primarily on engineering estimates developed by contractors. This is particularly true for interim support, although some provisioning forecasts incorporate limited historical demand data when it is available. The contractors we interviewed indicated they primarily used experience with analogous systems (e.g., similar or same systems and components) to develop their engineering estimates. One DoD contractor indicated his initial demand forecasts were based on commercial usage. When available, contractors adjust their estimates based actual demand experience, logistics support analysis, consideration of the operating environment and maintenance concept of the new system, and personal judgment based on past experience.

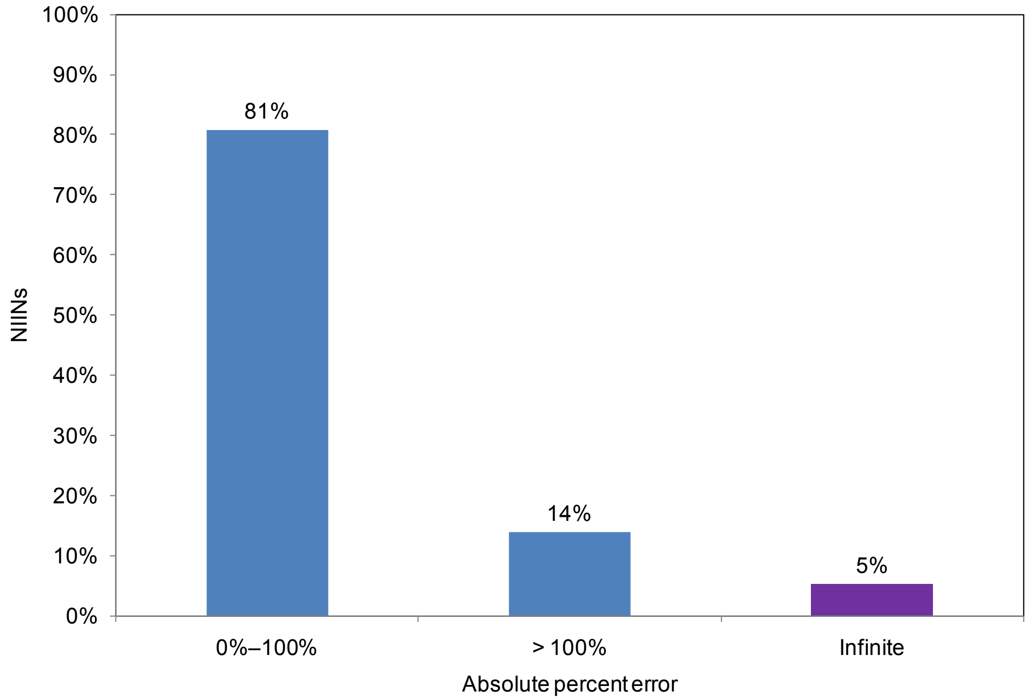
Both the Department of Defense and contractors consider engineering estimates less reliable than actual historical demand data as a basis for demand forecasts. Several contractors indicated their contracts required DoD to procure and own interim support spares partially to offset the greater risk associated with initial demand forecasts. Figure 3-8 and Figure 3-9 support this finding using a large sample of Air Force items. Item introduction forecasts had significantly higher absolute percent errors[8] than sustainment forecasts.

Figure 3-8. Item Introduction Forecast Error (2,073 Air Force NIINs)



[8] Absolute percent error is the absolute value of (forecast demand – actual demand) ÷ actual demand.

Figure 3-9. Sustainment Forecast Error (20,484 Air Force NIINs)



SUMMARY

Forecasting is an imperfect prediction of the future. The military services tend to over-forecast demands for new item introductions. Among the reasons for this is the fact the majority of demands managed by the military services are intermittent, making them very difficult to forecast—even with the best statistical models.

Forecasts for new item introductions are less reliable than forecasts for sustainment items because they are largely based on engineering estimates. As actual usage data becomes available, combining historical demand data with engineering estimates can improve the forecasts.

In the next chapter, we review how the military services use demand forecasts to set inventory requirement levels.

Chapter 4
Influence of Forecasting on Inventory

By its narrowest definition, demand forecasting is limited only to those processes used to predict future demands. From a broader perspective, demand forecasting also may include the inventory requirement computation processes that determine how much inventory will be stocked to fill demand forecasts. The study examines demand forecasting from this broader definition for two reasons:

- The basis for GAO and congressional interest in demand forecasting is a concern about the inventory excesses and shortfalls created by inaccurate forecasts.
- The models the military services use to forecast demand and compute requirements are often the same, making it difficult to separate the two processes when they are integrated in the inventory management systems.

This chapter describes how the military services use forecasts to determine inventory requirement levels. We begin by describing the inventory requirement computation process and its various inputs. We then discuss the risks associated with the uncertainty of requirement computation inputs, which are the result of both forecasts and policy decisions. We close with an examination of the relationship of initial forecast accuracy and its affect on inventory levels.

REQUIREMENT COMPUTATIONS

Requirement computation, or level-setting, is the next step after forecasting. In DoD and the private sector, the goal is to try to minimize inventory by balancing cost against achieving supply chain performance goals.

Inventory Planning

The private sector equivalent to requirement computation is inventory planning. Inventory planning is defined as "the activities and techniques of determining the desired levels of items, whether raw materials, work in process, or finished products including order quantities and safety stock levels."[1] Ideally, the goal is to stock no inventory. The only reasons to have inventory are to meet future demand, cover fluctuations in demand, fill the pipeline, hedge against price fluctuations, or achieve economies of scale. Types of inventory include raw materials, work in process, finished goods, and maintenance, repair, and overhaul.

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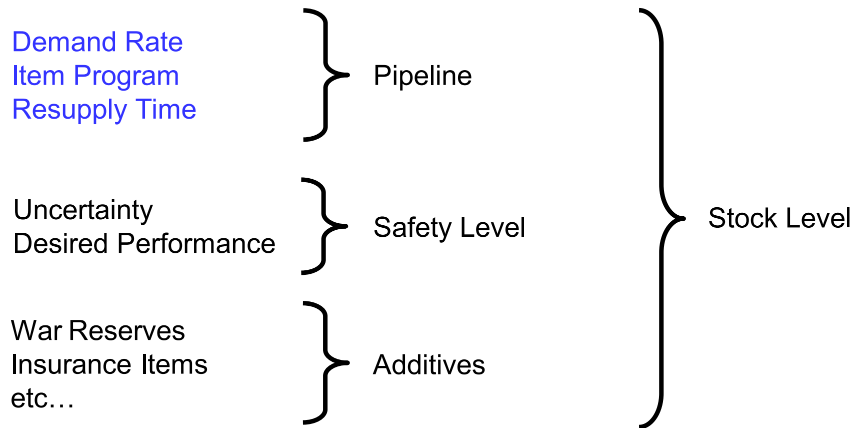
[1] *APICS* (Educational Society for Resource Management —formerly American Production and Inventory Control Society) *Dictionary*, 12th edition.

Requirement Computation Process

In the Department of Defense, the purpose of the requirement computation process is to determine how much inventory will be required to support the demand forecast. To explore the role that forecasting plays in excess inventory, it is important to also understand the larger context of DoD level-setting processes.

Stock levels consist of three basic components: pipeline stocks, a safety level, and additives. Figure 4-1 shows these basic components and some of the key input data elements.

Figure 4-1. Components of DoD Requirement Levels

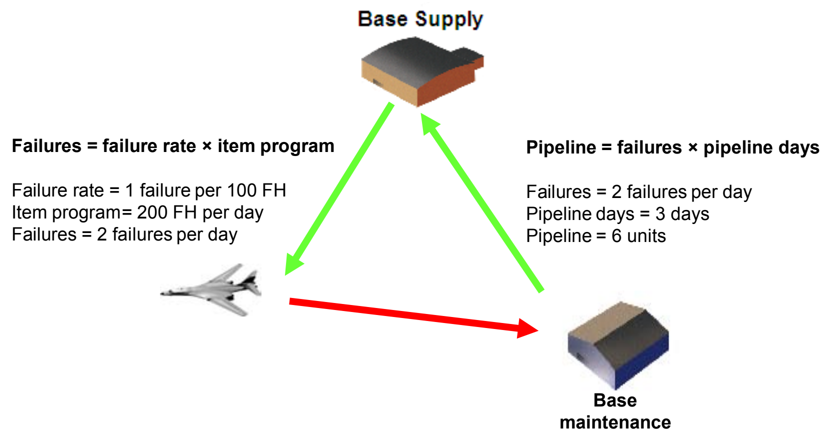


To compute inventory requirement levels, the military services generate the required input data elements using a combination of forecasting and policy decisions. For example, the input for an item’s demand rate is a forecast of how many items will fail as a function of program factors, such as usage hours, equipment-months, or rounds-fired. On the other hand, an input like the desired performance level is derived strictly from policy.

PIPELINE

Pipeline levels are computed based on the demand (or forecasted failure) rate, item program data, and resupply time. Figure 4-2 shows a simplistic example of a reparable item at a single-base with 100 percent base repair and no condemnations. The expected number of failures over any period is the forecasted item program for that period multiplied by the forecasted failure rate.

Figure 4-2. Simplistic Pipeline Example



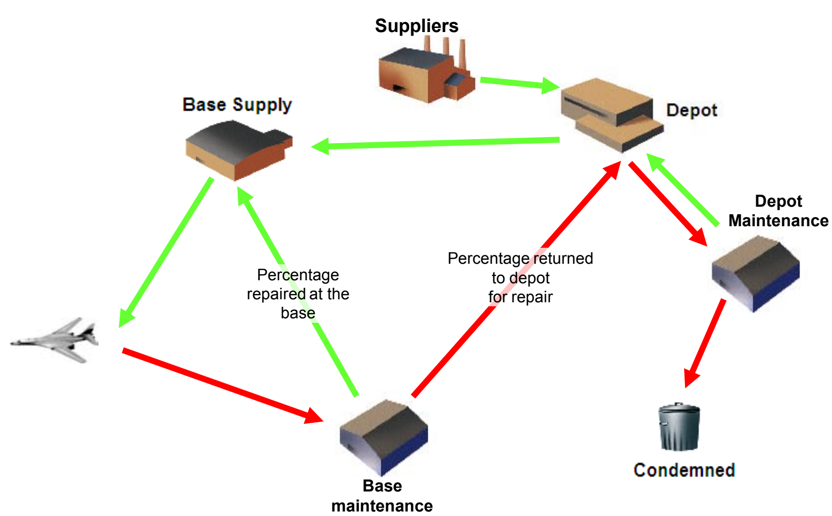
Note: FH = flying hour.

The base repair cycle pipeline is the number of spares that are expected to be tied up in the base repair cycle at any given time. To satisfy customer demand while these spares are in base repair, the base would need a stock level equal to or greater than the number of spares expected to undergo base repair.

An example with numbers will help illustrate the pipeline concept better. If we forecast that a given component will fail one time every 100 flying hours (FHs), and if we forecast that we will fly 200 hours per day, then we would expect two failures per day. If we expect the repair to take 3 days, then we need a stock level of 6 to cover customer demand during the base repair cycle.

Next, we look at the more realistic pipeline structure shown in Figure 4-3. In this example, only a portion of the failures are repaired at the base. Some are returned to the depot for repair and some are condemned by the depot. The base repair cycle time only applies to failures that are repaired at the base.

Figure 4-3. More Realistic Pipeline Example



For the failures that are returned to the depot, DoD applies resupply times that cover base processing and shipment to the depot, the depot repair cycle time, and the depot processing and shipment back to the base. For failures that are condemned at the depot, DoD applies a pipeline time that includes administrative lead time at the depot, production time at the supplier, and shipment time back to the base.

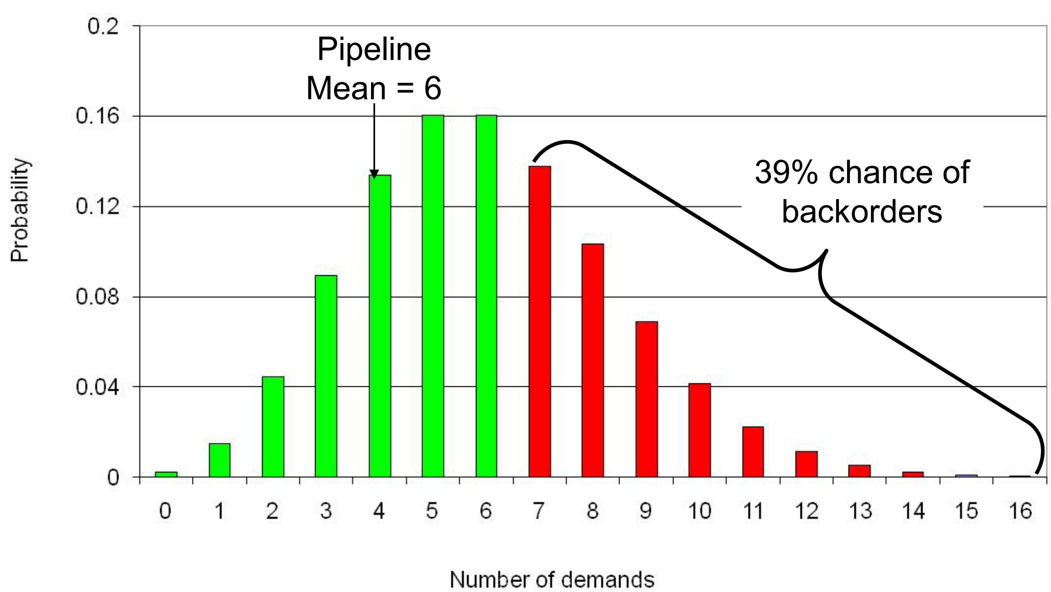
In some cases, the depot uses the same parts during scheduled maintenance that it uses for repairs. Just as the base has a failure rate expressed as a function of flying hours, the depot has a corresponding replacement percentage that expresses the number of failures as a function of the number of scheduled maintenance actions. For example, if the depot expects to perform 24 scheduled maintenance actions over the next year, and the forecasted replacement rate is 50 percent, the depot would expect 12 failures over the course of the year. If the depot repair cycle time is 30 days, then the depot would have a scheduled maintenance pipeline of 1 spare.

Safety Level

Unfortunately, stocking just the pipeline quantity does not protect against variability in demand rates and item programs. Therefore, a safety level considers pipeline inventory, uncertainty, and desired performance.

Figure 4-4 shows the probability of experiencing a given number of demands during the pipeline time. In this example, we used a Poisson distribution with a mean of 6 demands. In this case, if DoD only stocked the pipeline quantity, there would be a 39 percent chance of at least one backorder.

Figure 4-4. Probability of Number of Demands



As Table 4-1 shows, as the stock level increases (i.e., a safety level is added), the chance of having a backorder decreases. The military services apply complex RBS algorithms to balance the cost of adding another unit of safety level for a given item against the effect adding another unit of stock (and thereby reducing backorders for that item) would have on weapon system availability.

Table 4-1. Stock Level and Probability of Backorders

Stock level	Chance of backorders
7	26%
8	15%
9	8%
10	4%
11	2%
12	1%

ADDITIVES

An item's stock level can include a wide range of different additives. The following are among the more common:

- *Contingency spares*. These spares packages provide readiness capabilities for wartime contingencies above and beyond the forecasted peacetime level of activity.
- *Insurance items*. Because of their criticality to the system, the military services stock some items with low demand rates at a level of "one-per-base" even if the forecasted demand rates don't support that inventory level.
- *Shop spares*. Repair shops will often use a component that is known to be functioning properly as part of its testing process.
- *Government-furnished material*. As part of contractual arrangements for repair, testing, and development, the government agrees to provide assets to contractors.
- *Other service or foreign military sales* (FMS). For Non-Consumable Item Material Support Code 5 items, the primary inventory control activity maintains stock in anticipation of the other services' requirements. The Department of Defense also maintains additives for FMS.

RISK FACTORS IN FORECASTING DEMAND

Forecasting is always an imperfect estimate of future demand, and a general forecasting rule is that "all forecasts are wrong."[2] The data inputs into forecasting and inventory requirement computations derive from a combination of estimates and policy decisions determined a lead time in advance of the forecasted period. Based on administrative and procurement lead times, item introduction forecasts must generally be made 2 to 3 years before the required support date. As with most future predictions, the more time between the forecast and the actual event, the greater the risk that changes will occur that may invalidate the prediction.

The risk that forecasted estimates and policy decisions will be incorrect creates supply chain risks for the Department of Defense, particularly inventory risks. This is especially true of initial forecasts, where there is little or no historical data and forecasts are made well in advance of the forecast period—when the end-item program is most volatile due to the lack of equipment design stability. As explained earlier, this difficult situation is complicated by the fact that DoD spare parts demand has a high rate of variance.

The primary supply chain risks during item introduction are as follows:

- Demand forecast reliability
- Design instability
- Operating hour changes
- Maturing maintenance capabilities.

Demand Forecast Reliability

As demonstrated in Chapter 3, demand forecasts for new item introductions, which heavily depend on engineering estimates, are less reliable than sustainment forecasts. Further, item introduction demand forecasts can be improved by incorporating actual demand data as usage data becomes available.

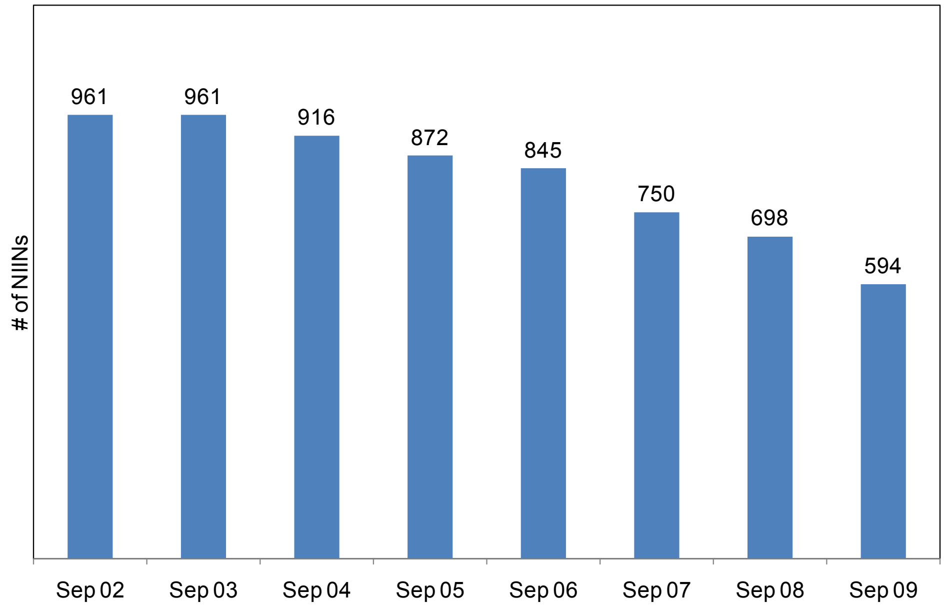
Design Instability

A weapon system's design is generally less stable early in its life cycle than it is during sustainment. Investing in spares during item introduction, therefore, introduces the risk that spares may subsequently either require modification or become obsolete.

[2] *APICS Certified Supply Chain Professional, Learning System Module 2*, "Building Competitive Operations Planning and Logistics," Version 2.0, 2009 edition.

In an attempt to quantify this risk of design changes, we took a sample of new items introduced into the Air Force inventory during FY2002 and tracked the number of those item that remained in the Air Force inventory in each subsequent year through FY2009. We used the Air Force's D-200 database to identify and track the new items during this period. Figure 4-5 depicts the results.

Figure 4-5. New Air Force Reparable Items in September 2002



Cumulative % change from baseline	Baseline	0%	5%	9%	12%	21%	27%	38%

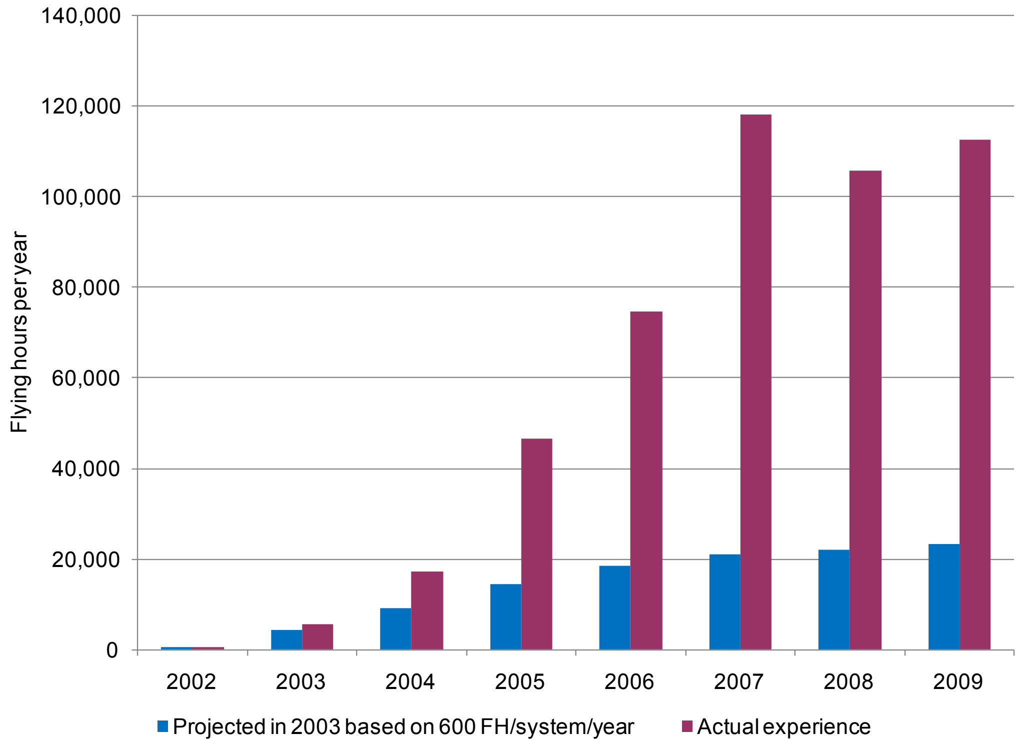
Figure 4-5 suggests that the risk of spares obsolescence for new items is not great in the short term, but the risk increases over time, particularly beginning about the 5-year mark. After 3 years, 91 percent of the items introduced in FY2002 were still in the inventory; but after 5 years, only 79 percent remained.

Our data was insufficient to determine what happened to the inventory for the items the Air Force ceased to stock (e.g., whether the spares were modified to a new stock number, replaced by a preferred item when inventory was exhausted, or sent to disposal because they became obsolete). Because of the durable nature and higher cost of reparables, the impact of obsolescence on inventories should be greater for reparables than for consumables.

Operating Hour Changes

Program data changes, including variation from the projected operational tempo, increases forecast risk. Figure 4-6 and Figure 4-7 illustrate the potential variability of actual program data versus the predicted program data that was an input to the demand forecast for two current DoD weapon systems. In the first example, actual flight hours per year far exceeded the planned levels. The second example shows the opposite case where actual operating hours were less than projected.

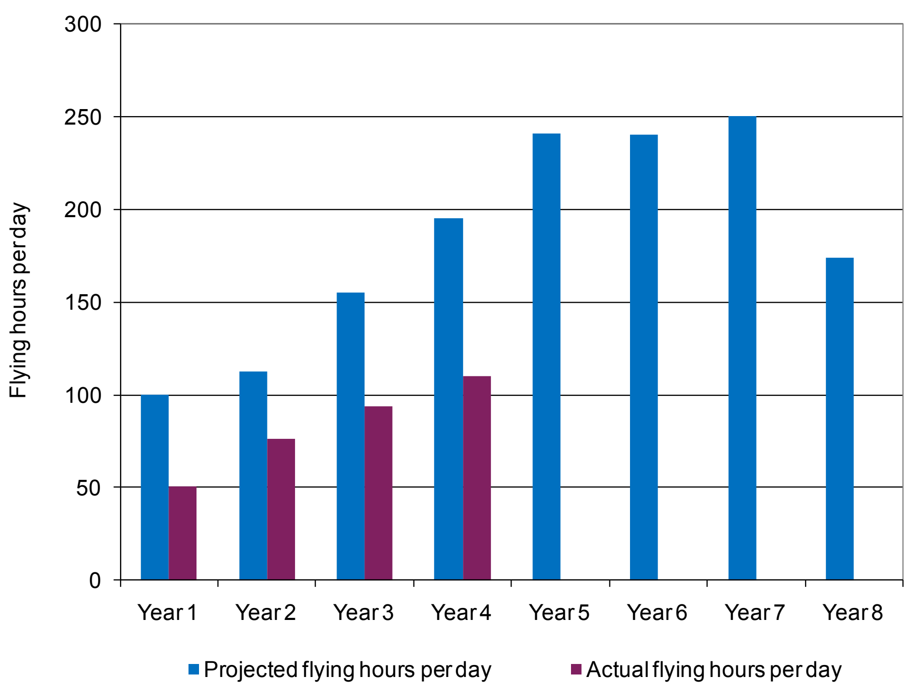
Figure 4-6. Higher Than Predicted Operating Hours



Source: "How AAI Is Making Performance Based Logistics (PBL) Work for Its Most Important Customers–America's Troops!" Jim Glowacki, AAR–A Textron Company, February 25, 2010.

Note: Actual through May 2009; projected through December 2009.

Figure 4-7. Lower Than Predicted Operating Hours



Alone, the underestimation of operating hours would be expected to produce a proportionate underestimation in demand forecast quantities, inventory levels, and ultimately significant backorders and reduced readiness. All else being equal, an overestimation of operating hours would lead to an over-forecast of demand, which would result in too much inventory and unnecessary costs.

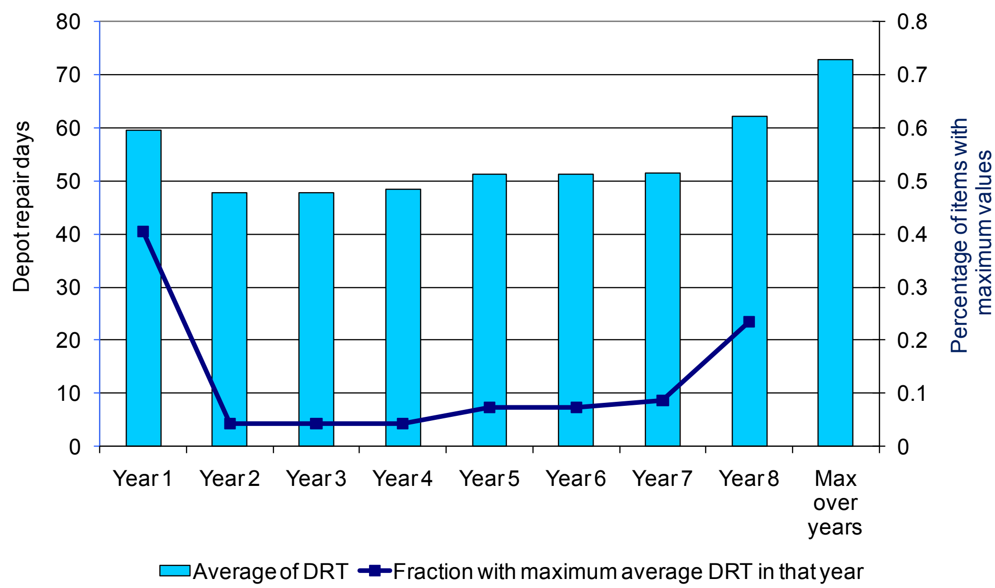
The examples in Figure 4-6 and Figure 4-7 also illustrate how accurate demand forecasts depend on the accuracy of input forecasts, and error in any one input can dramatically affect the accuracy of the entire demand forecast. The type of uncertainty reflected in these examples makes forecasting, especially during item introduction, a significant challenge.

Maturing Maintenance Capabilities

Just as engineering estimates of demand rates are frequently wrong, so too are estimated repair rates and times. Initial forecasts of repair rates and repair cycle times are based on planned maintenance concepts and capabilities that are usually still in development. Frequently, intermediate repair capabilities do not mature as quickly as forecasted, resulting in a greater number of unserviceables returned to the depot, inaccurate initial forecasted repair rates and times, and an inappropriate inventory mix.

Figure 4-8 depicts the average depot repair times for all reparables for a current DoD weapon system.

Figure 4-8. Depot Repair Times



Note: DRT = depot repair times.

In this example, the initial average depot repair times are longer in the first year than in the next several years, which is consistent with the trend discussed above. The jagged line depicts the percentage of items that experienced their maximum depot repair times over all years in that year (approximately 40 percent of all depot-level reparables achieved their maximum value in year 1).

RISK OF EXCESSES—CONSUMABLE AND REPARABLE ITEM DIFFERENCES

There are two key categories of DoD inventory items: consumable items and reparable items. Each category has specialized characteristics related to the level-setting process. Because of these level-setting differences, and the differences in basic item characteristics, forecasting has different ramifications for each.

Consumable items are items that are replaced when they fail. They are less complex than reparable items and less expensive. Once the supply system issues a consumable item to an end user, the item is expended from inventory records. Ordering for consumable items is usually performed using a set of business rules that are based on an economic order quantity and a reorder point. These ordering parameters may be optimized according to an enterprise perspective that takes into account trade-offs across a multi-echelon inventory infrastructure.

The risk of initial forecasts producing excess inventory is not as great for consumable items as reparable items for two reasons. First, demand forecasts and requirement computations for new item introductions typically produce conservative inventory buys because end item densities are small. Even when over-forecasts occur, most excesses are likely to be short-term because end item programs are expanding. "Extra" consumables from year one can be used to preclude future procurements and used to support consumption in subsequent years. Second, the financial impact of any excesses is less because consumables are less expensive than reparables.

By definition, when a reparable item fails, it is repaired and reused over and over, whereas consumable items can only be used once. In setting levels for reparable items, the DoD methods must take into account the structure and performance characteristics of the repair cycle including the return of unserviceable assets.[3] Because reparables are typically characterized by very low condemnation rates, once a reparable item enters the system, it is going to be there for a long time. While some excesses from over-forecasting will be short-term (because end item programs are expanding), an error in level setting for a reparable item can have long lasting and costly ramifications.

[3] If the forecast for unserviceable returns is based on the demand forecast for an item and the initial spares lay-in for a new item or new application is erroneously included in that forecast, then the unserviceable returns would be adversely affected. Unlike normal sustainment demand for an item, the initial lay-in does not have a return of unserviceable assets.

In the next chapter, we present a case study that further examines the impact of forecasting and inventory over a long period.

THE ROLE OF POLICY DECISIONS

While some elements of the requirement computation process are based on forecasts alone (e.g., demand rates) other elements are largely based on policy decisions. For example, the operating hour program begins as a policy decision regarding how often the weapon system will be used and how many systems will be operating. These decisions are not immutable, and frequently forecasts based on such decisions are inaccurate.

Because policy decisions can have a significant influence over the computed levels, they represent an important opportunity to mitigate the risk of excess during the provisioning phase of an item's life cycle; however, these policy decisions often come with trade-offs.

For example, the choice of availability readiness targets is a policy decision. When the military services use RBS models to set levels, a key input is the level of weapon system availability that the RBS tool is trying to achieve. Lower availability targets will generate lower stock levels, and, by extension, will lower the risk of excesses. But they also expose the weapon system to a higher risk of spares shortages.

The selection of a maintenance concept is also a policy decision that can affect inventory levels. Consolidating repair at a single location creates economies of scale and reduces the requirement for maintenance personnel, test equipment, and component parts. Of course, by lengthening the pipeline time, the computed stock levels for line-replaceable units increase. Initial forecasts of repair and attrition rates based on planned maintenance concepts often turn out to be wrong because maintenance capabilities do not mature as quickly as planned.

Finally, assumptions regarding cannibalization can influence requirements levels. In theory, cannibalization could be used in the short term to reduce inventory levels; however, none of the military service maintenance or supply plans routinely rely on cannibalization to offset requirements, because cannibalization is considered an uneconomical strategy that is detrimental to readiness. Operationally, the military services limit the use of cannibalizations to a stopgap measure when readiness requirements dictate it is necessary to obtain components when other sources are not available.

SUMMARY

Inventory overages and shortages are not solely due to inaccurate demand forecasts. Rather, inventory levels are largely determined based on a combination of forecasts of demand, resupply times, and operating hours. An error in any one of these forecasts will likely result in an inventory imbalance.

Even under the best conditions, demand forecasting methods will inevitably produce overages and shortages for reparable items because of the randomness of demand each year. The advent of RBS modeling that considers on-hand inventory further blurs the distinction as to what constitutes excess inventory. The reason is, in computing the optimum mix of inventory to achieve a weapons system readiness goal, RBS models apply what would have been excesses of one item to offset the need to procure other items.

In the next chapter, we present a case study that provides more quantitative findings on the topics discussed in this chapter.

Chapter 5
Initial Forecasting Case Study

This chapter describes a case study that tracks demand forecasting of a DoD weapon system over time and how a multitude of factors affect the forecasts, spares procurements, and ultimately inventory required to support the system. The case study addresses the following questions:

- How do basic forecasted inputs for all DoD items (demand rates, resupply times, operating tempo) influence spares requirements, procurements, and inventory?
- How do inventory overages evolve and how can they best be measured?
- Are some inventory overages inevitable?

INTRODUCTION

Errors in demand forecasting are often associated with procurements of too much or too little inventory. But demand forecasting is just one factor that influences spares procurement decisions. To demonstrate how inventory overages evolve and how they can best be measured, we collected 8 years of typical spares requirements data for a set of weapon system items.

We first determine the overages over time for this data set, and then identify what factors influence those overages by examining the demand rates, resupply times, operating hours, and the multiplication of all the inputs into an interim data value called the pipeline. Finally, we show how even with good forecasting methods, some inventory overages are inevitable. We can minimize—but not eliminate—overages with improved forecasting processes for all critical parameters that drive spares requirements.

The case study covers three tasks:

- Quantify the different definitions of overages (excesses) created by any spares modeling over time.
- Estimate how the three key inputs to spares modeling (demand rates, resupply times, and operating hours) contribute to those overages.
- Estimate the natural overages that occur in a perfect world even if average demand rates do not change over time and items in the inventory experience the expected randomness of the demand process.

Background

Inventory mangers must walk a tight rope between ordering

- too few spares, and possibly grounding a multimillion dollar weapon system for months, or
- too many spares, and having millions of dollars of inventory go unused.

Forecasts try to guess the future and demand forecasts with its great volatility are usually too high or too low. Projecting demands for the thousands of components of a new weapon system is, in some ways, more complicated than trying to pick winners and losers in a stock portfolio, many of which are brand new. Obviously, we would want to invest more in stocks for a company that might become the next Microsoft or Google, and less in stocks that will lose money over time, and the least in stocks for a company that will go out of business.

Forecasting inventory requirements for a new weapon system may be analogous to forecasting stock performance, but perhaps it is even more difficult. Some components will perform better over time than expected, some components will do worse, and some may drop out of the inventory altogether. Inventory managers try to improve the item portfolio to get the best inventory performance for the dollar.

There are also three important differences that make spares forecasting even more difficult than forecasting stocks:

- Even if we knew which poorly performing items would be replaced by more modern versions, we would need to buy them to support readiness until the newer versions arrive.
- If we buy too many spares, we usually cannot sell the overages back. Although the larger than needed inventories of consumables will be reduced through consumption in future operations, "excess" inventories of reparables will decline slowly because of typically low condemnation rates.
- The decision to buy spares must be made 2, 3, or even 4 years before the spares are needed to accommodate the long lead times and DoD's budget process.

We all look back at our stock portfolio and say, "If I only bought more of Google when I first had the chance," or "If I only knew then what I know now, I wouldn't make the same mistakes." Over time, inventory managers get better information on the past behavior of items, which allows them to make better forecasts and more informed decisions, but exogenous factors are constantly changing.

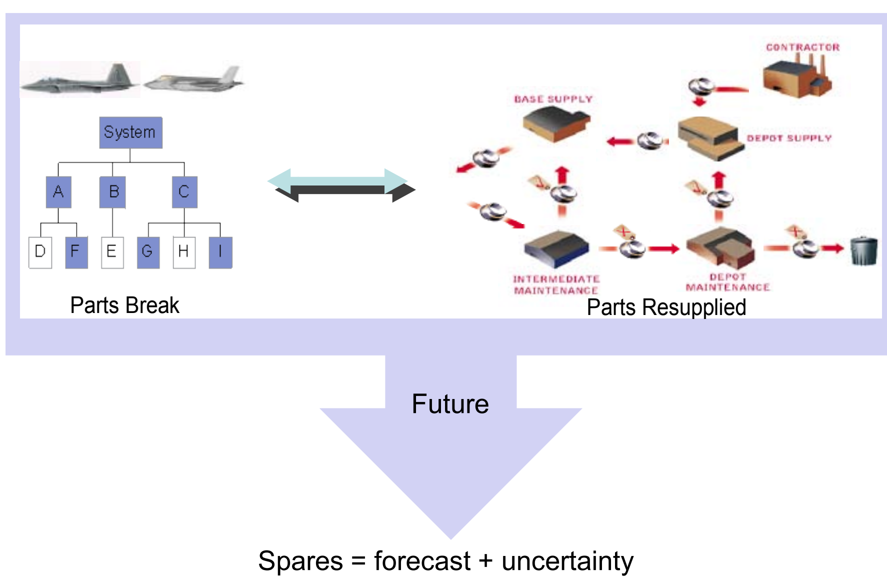
Scope of Case Study

All the military services use readiness-based sparing models to compute initial spares requirements. Other portions of this report demonstrate with real data how to best identify when inventories are larger than necessary and how the inherent data variability is the *raison d'être* for large inventories. This case study analyzes how RBS modeling impacts inventory growth over time. Specifically, we discuss the systemic issues that drive procurements of too much stock.

RBS systems help quantify the lowest investment in spare part inventory required to achieve weapon system readiness goals. In general, RBS models employ three different types of data:

- *Parts structure data*. These data describe the number and type of parts on the weapon system, as well as the parts and its subparts, or the indenture data (see Figure 5-1).
- *Parts forecast data.* Besides each part's demand forecasts, there are a number of other parts forecasts that specify the flow of broken parts through the supply chain for repair and replacement (see Figure 5-1). RBS models require critical information for each item, such as the price, resupply times for each supply chain link, and the percent of demand that flows through that link. For a weapon system, there are tens of thousands of forecasts of these part characteristics.
- *System assumptions*. Assumptions describe inputs, such as an estimate of future operating hours, performance targets (number of weapons systems operational at any time), retail locations, or the number of systems at each location.

Figure 5-1. RBS Data Inputs



Approach

To demonstrate how inventory overages evolve and how they can best be measured, we collected 8 years of data for a set of items from a current weapon system. The data we obtained is a consistent set of thousands of data points for a weapon system during a period in which many of the spares procurements were made as delivery schedules ramped up. These data change significantly over time as better estimates are developed from demand history, as items move in and out of the data systems, and as improvements are made.

Pipelines are based on the elements that affect the time needed to deliver material to an operating customer from point of manufacture, storage, or repair. We used the following data elements of this data set to compute the critical pipelines:

- Failure rates for each year
- Repair fractions (field and depot rates) and operating hours for each year
- Resupply times for each year (order and ship time, base and depot repair times, procurement lead times)
- The quantity of each part on the weapon system
- Expected operating hours for the fleet of weapon systems.

To better identify changes in the key factors over time, we restricted the set of items to the 1,022 for which we had program data for each of the 8 years.[1] For instance, if demands increase over time, it could be from increased failure rates, or from growth in the force structure, or both. Alternatively, demands can decrease even with growth in the force structure if there are significant improvements in item reliability.

We developed procurement programs for each year, starting with a zero inventory in year 1 and, using the model-derived inventory requirement for the prior year, building the procurement programs for subsequent years. The reasons we used a typical spares model (an RBS model) to generate spares inventories instead of using actual inventory were two-fold:

- We wanted to exclude exogenous factors not related to demand forecasting or the requirements determination process (e.g., item managers may override RBS-suggested buys, production line assets may provide extra spares, and special buys or extra additives from external sources may cause extra assets to enter the inventory).
- We wanted to isolate the effects of using RBS modeling and processes in a controlled environment.

[1] Some items had data for the first few years and then no data thereafter. Others had data in the last years, with none in the early years. Items with incomplete data across all years were eliminated.

Inventory Overages

As discussed earlier, the term "excess inventory" has specific, albeit different, connotations to GAO and the Department of Defense. Rather than focus on these differences, we use the term "overage" to refer to an item with too many spares from an RBS computation perspective. Using an RBS model, there are at least three different ways to measure when an item has an overage:

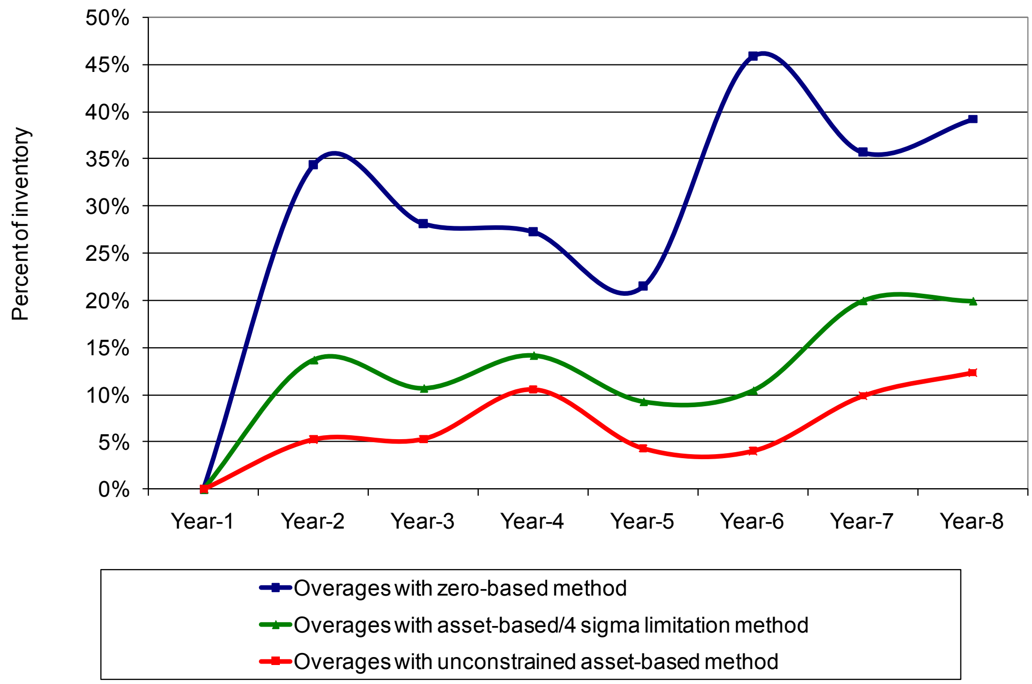
- *Zero-based computations.* This method identifies overages as inventory that is above an optimal target, assuming no inventory is on hand. For example, we would go to the last year of data (the eighth year in our analysis) and run the RBS analysis as if it was the first year, ignoring on-hand inventory. The difference between the requirement (8 spares) and the actual inventory after 8 years (12 spares) is an overage of 4 spares (12 minus 8). The problem with this method is that it overestimates overages because it gives no credit to the extra 4 spares for item A that can reduce the procurement requirement for item B.

- *Asset-based computations.* This method determines an overage as any spare that no longer has an impact on availability. In our previous example, all spares above the optimal requirement of eight can still improve availability but not as much as other items the model selected. So maybe the ninth, tenth, and eleventh items that are "free" (to the extent they are already procured) have an effect on availability, but the twelfth spare has virtually no effect based on current demand projections. This method may underestimate overages since the criteria may be too extreme.

- *Middle ground.* This method falls between the two previous methods and estimates the likelihood of ever needing the part. In our analysis, we define overage as the number of standard deviations above the mean pipeline (the average number of parts in resupply for a particular item). Our middle ground method limits overages to four standard deviations; in other words, it eliminates overages when the likelihood of needing the spare is less than 0.01 percent.

Figure 5-2 shows a comparison of inventory overages for the weapon in our case study using the three methods described above. Depending upon the method, the calculated overages for this weapon system at the end of 8 years range between 12 percent and 40 percent, with a the "middle ground" estimate of about 20 percent.

Figure 5-2. Inventory Overages as a Percent of Inventory over Time as a Function of Method



IMPACT OF FORECASTS ON INVENTORY

This section describes the variability of the key forecasts on inventory:

- Demand rates
- Resupply times
- Operating hours
- Total pipelines—the ultimate driver of requirements and the product of the three above factors.

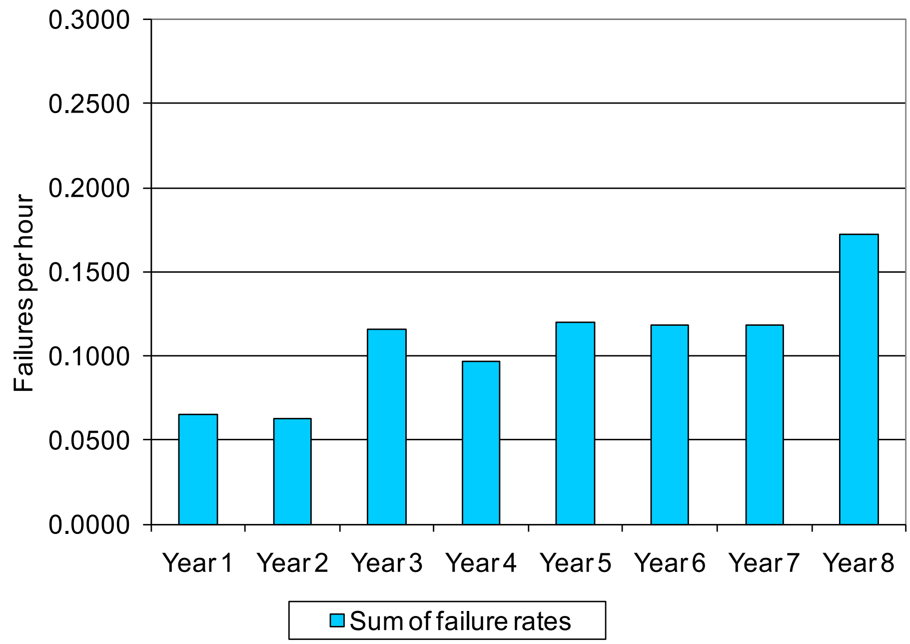
Demand Rates

We evaluated two key factors for each of the above elements that affect spares requirement over time:

- The sum or average of the values for each year
- The percentage of items that attain their maximum value in each year. For instance, if 100 of the 1,000 parts reached their maximum demand for all years in year 7, then the maximum plot would show 10 percent (100 ÷ 1,000) in year 7.

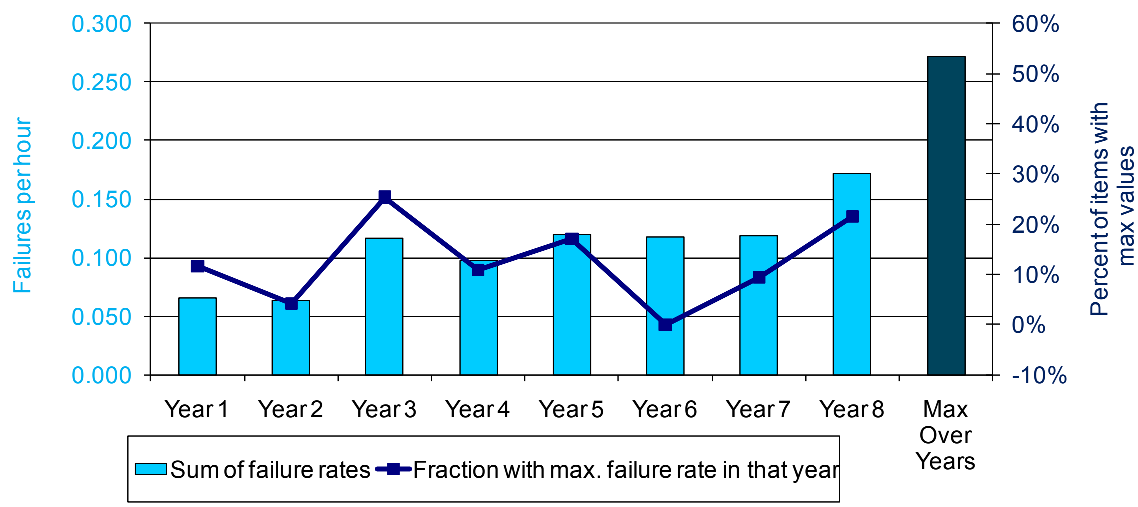
Figure 5-3 depicts the variability of the sum of demand rates (failure per operating hour) for the 1,022 items common to all eight data sets over an 8-year period. The figure shows that the sum of the failure rates across all 1,022 items tended to grow over the 8-year period.

Figure 5-3. Failure Rates



But that is only part of the picture. Figure 5-4 shows the fraction of the items in each year for which the maximum value (i.e., peak failure rate) occurred in that year (dark blue line; right scale). The last column shows the sum of the maximum of these rates.

Figure 5-4. Sum of Failure Rates with Sum of Maximum Values



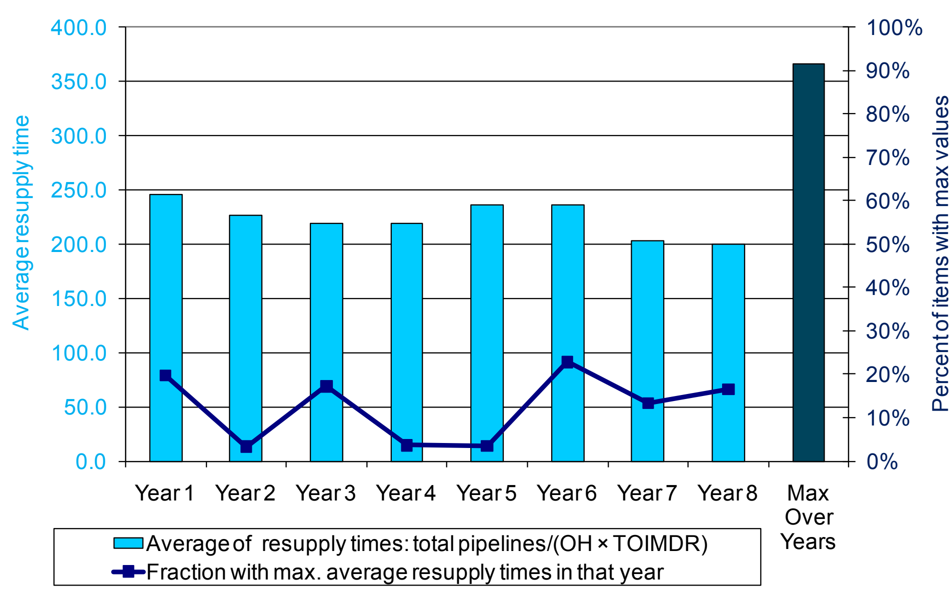
The key point of this figure is that the sum of the maximum failure rates is significantly larger than the sum in any one year. In particular, the maximum over all years for failure rates is almost 60 percent higher than the largest year (year 8). The last column in the figure explains why our current inventory is more than would be needed to support any of the prior years since it is always the maximums that drive the procurements, all other things being equal. For instance, let's say only the demand changes over time and all other variables remain constant. Combining all the maximum demands together (the last column) provides a general indication of the total asset position you would have at the end of the 8-year period, while the other columns provide a general indication of the zero-based inventory required for each year.

A common hypothesis is that earlier demand rates are notoriously high and cause excess procurements. In this example, the first year shows 12 percent of the parts with maximum demand, and although this is one of the higher values in the group, a random process would show a 12 percent value (1 ÷ 8). The next figure expounds on this issue.

Resupply Times

Another critical component of total pipelines is the resupply time. Figure 5-5 shows the variability of the average resupply times. The figure shows that the average resupply times in any year are relatively stable between 200 and 250 days; however, there is still considerable variability in the resupply times among the items themselves, as seen by the percentage of items that have a maximum resupply time in each year. Almost 50 percent of the items had their largest resupply times in years 1–5, with 23 percent of the items experiencing their maximum resupply time in year 6.

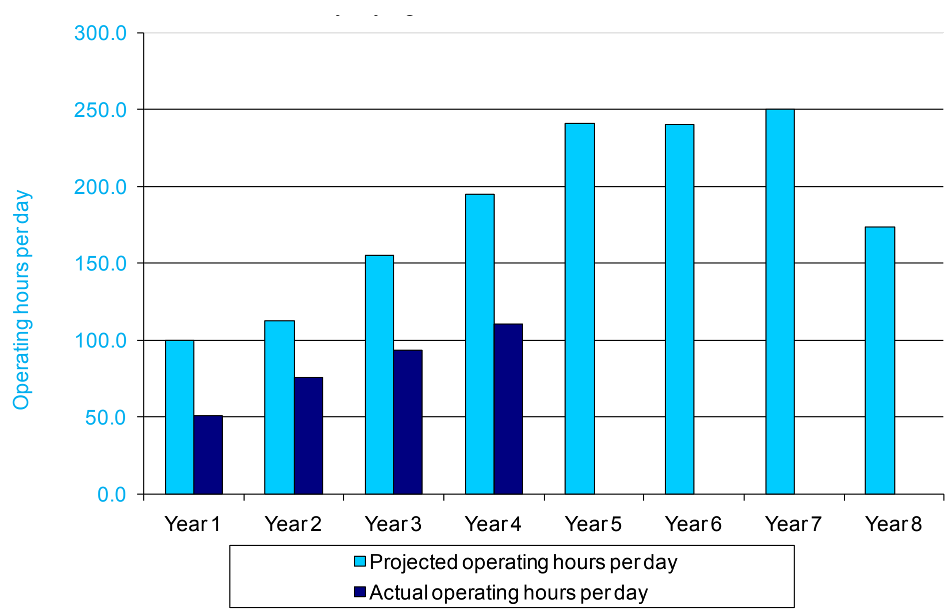
Figure 5-5. Average Resupply Times



Operating Hours

Although system operating hours are not spare part–oriented, they are an important factor in inventory level setting. Notice in Figure 5-6 how programmed hours (light blue) more than double from year 1 to year 5, and how actual operating hours (dark blue) are almost half as much.

Figure 5-6. Operating Hours

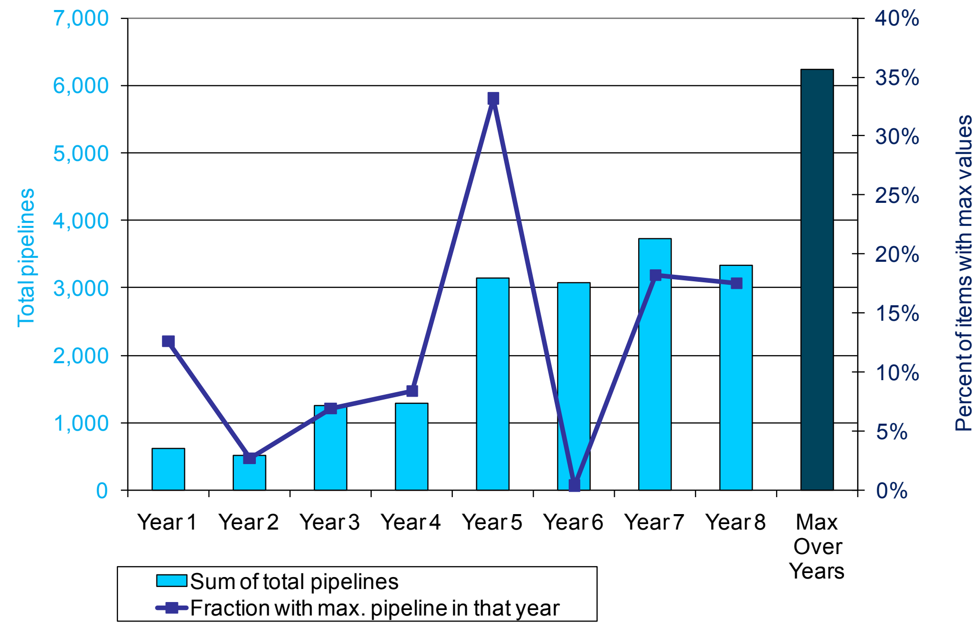


It appears the drop in operating hours in year 8 resulted from a more cautious and prudent projection based on actual experience in years 1–4. Remember, the estimate of operating hours for a particular year is made many years earlier. For instance, the spares required in 2013 and the estimate of operating hours, are really developed and put on order in 2010.

Total Pipelines

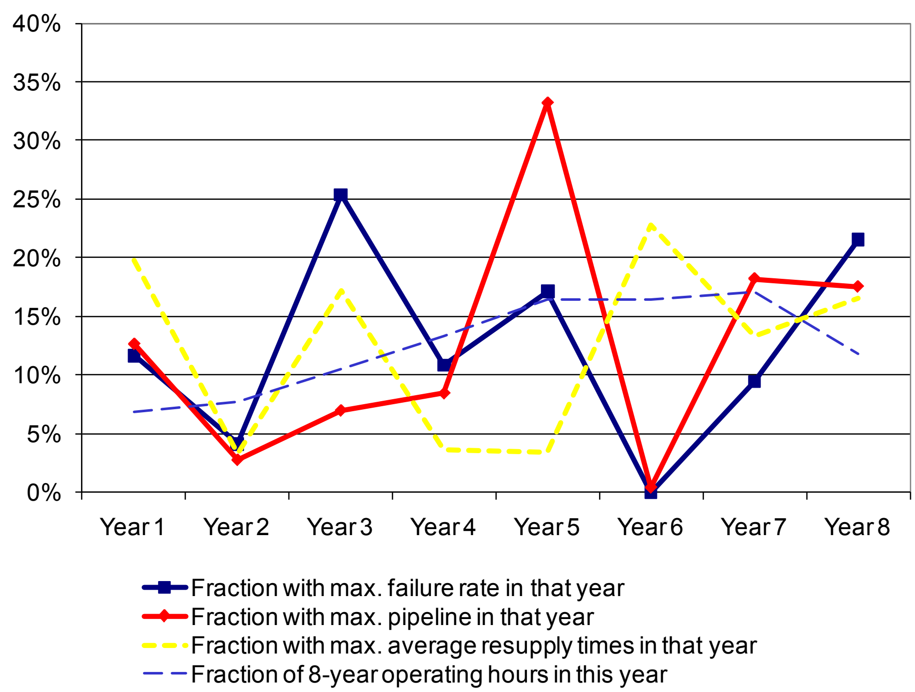
Figure 5-7 shows how the variability of the total pipeline reflects the composite variability of all parameters; and the composite variability of the total pipeline is the most critical driver of required inventory levels. Sixty-four percent of the maximum pipelines occur in the first 5 years, half of which occur in year 5. This explains the large overages in each prior year; the procurement programs try to support larger requirements that decrease in subsequent years.

Figure 5-7. Total Pipeline



In summary, there are a number of factors that impact pipelines, and thus inventories. Figure 5-8 displays the pipeline (Red) and all the factors that make up the pipeline. There are three peaks in pipelines: years 1, 6, and 7. Year 6 shows the greatest peak, probably due to hours and demand rates (though demand rates and hours where as high in other years as far as the maximums goes, and pipelines did not peak).

Figure 5-8. Summary of Findings



From an item introduction forecasting perspective, year 1 is also interesting. Year 1 has only 6 percent of the operating hours, yet 12 percent of the peak pipeline requirements—the key inventory driver. It appears the combination of peak demand with peak resupply times cause the pipelines, and thus inventory levels, to be disproportionate to the operating hours. This observation is consistent with our earlier finding that the military services tend to over-forecast inventory requirements for new item introductions, but the inventory impact is not significant in the longer term for an expanding program.

INHERENT INVENTORY GROWTH FROM DEMAND FORECASTING

Demand forecasting is critical to providing weapon system readiness at the lowest cost and maintaining the smallest inventories with the fewest "overages." In the experiment below, we test what happens to RBS inventory requirements when all parameters that drive inventory requirements are held constant over time, with the exception of demand forecasts.

The experiment assumes perfect knowledge of demand; that is, the mean future demand is known, as is the distribution around that mean. Demand forecasts change as the actual demand used to compute those forecasts occurs in accordance with the known mean and variance. For example, if an item has a yearly mean of four demands over the 8 years of the experiment, we should experience, on average, four demands—with some years experiencing more and some years less, depending on the known distribution of demand. Thus, the experiment answers the question: What happens to inventory over time with perfect information of the future demand mean and variance?

In this experiment,

- the year 1 (starting year) inventory level is based on the known mean demand;
- the forecasted demand rate going into year 2 is initialized at the known mean;
- the actual demand for years 2 through 8 is randomly generated from a Poisson distribution with the known mean and is only known to the user when it occurs; and
- single exponential smoothing is used to generate the demand forecasts that the RBS model uses to set inventory levels.

In this artificial and best-possible representation of the world, where we know the unvarying demand rate of every item, the required inventory levels would be those developed from the year 1 data; however, we assume the user does not know this fact and reacts to each item's demand as it varies according to its Poisson distribution.

For our experiment, we tested three weight schemes (comparable to three exponential smoothing constants widely used by current DoD processes) that perform an average weighting using different weights for the current and previous forecasts:

- *Exponential smoothing weight 0.2*—Gives the current data the least weight (i.e., current 20 percent and the previous 80 percent).
- *Exponential smoothing weight 0.5*—Weights the prior estimate of demand rate equally with the demand rate for the last year to determine the new forecast (i.e., current 50 percent and the previous 50 percent).
- *Exponential smoothing weight 1.0*—Ignores all prior demand estimates and uses the last year's demand rate (i.e., current 100 percent and the previous 0 percent).

Table 5-1 shows the results of our experiment, which are inventory growth as the item forecasts react to expected variances in demand. The growth is greater for larger weights; that is, when more of the variance is included in the forecast the greater the growth in inventory.[2] In this case, when the starting inventory is the optimal amount of inventory needed to support the known average demand, the growth is above optimal.

Table 5-1. Inventory Growth as Forecasts React to Demand Variances (inventory dollars in millions)

	Exponential smoothing constant		
	0.2	0.5	1
Year 1	$754.4	$754.4	$754.4
Year 2	$755.0	$760.1	$772.6
Year 3	$756.2	$764.9	$787.5
Year 4	$759.2	$771.3	$805.5
Year 5	$760.3	$773.7	$810.0
Year 6	$761.2	$775.7	$813.9
Year 7	$761.6	$776.5	$816.1
Year 8	$765.0	$783.5	$829.9
Real inventory overage	$10.6	$29.1	$75.5
Overage as a percentage of true requirement	1.4%	3.9%	10.0%

[2] Dampening is the technique of reducing or excluding demand observations outside of a given range from being considered by a forecasting model. If we had included dampening as part of the forecasting process in our experiment, the results would be less growth in inventory.

The last row of Table 5-1 shows that, even with a very good forecasting estimate of demand and no variability among any other variables, we expect the RBS models to identify real inventory overages of about 1.4 percent of the true requirement (Year 1). With lesser forecasting methods, we'd expect the excesses would be at least as large as 10 percent of the true requirement.

The question remains as to what the user, who is unaware of the true requirement and the real overages, would identify as overages using the methods described above. Table 5-2 shows these overages as a percentage of the final inventory for the low range (asset-based requirement) and the high range (zero-based requirement) indicating the overages would be somewhere in between.

Table 5-2. Perceived Percent Overages for Analytic Excursion with Known Demands

	Exponential smoothing constant		
	0.2	0.5	1
Zero-based	1.33%	4.70%	9.51%
Asset-based	0.03%	0.18%	0.89%

The bottom line is that, even when we know the demands with certainty, we could expect to observe overages in the range of 1–10 percent, depending on the forecasting method. Given the analytic nature of the above and the lack of any unknown variability, an excess of 10–20 percent would not seem to be unreasonable.

This section demonstrated the following:

- Demand forecasting methods will inherently produces overages from 1 to 10 percent over the 8 years.
- Demand forecasting methods that overreact to the latest data can provide large (10 percent) overages, compared to forecasts that are less responsive.

CASE STUDY SUMMARY

The case study revealed the following:

- Inventory overages vary depending on the method of the measurement. For the weapon in the case study, overages ranged between 12 percent and 40 percent, with the most likely value ending at about 20 percent.
- Inventory overages are a result of a combination of demand, resupply, and operating hours, as well as their interaction, and they are not solely the result of demand rates. For instance, analysis demonstrated that high spares requirements occurred in the early years of a system, when operating hours are very low because demand rates and resupply times were very large.

Even under the best of conditions, demand forecasting methods will produce overages. The better forecasting methods, which apply proven statistical methods, yield only a 1 percent overage; whereas, methods that over-react to the latest demands could produce overages of 10 percent.

Chapter 6

Opportunities for Improving Item Introduction Forecasting

This chapter describes applications of DoD and industry best practices that offer opportunities for DoD to improve item introduction forecasting. Based on our research and analysis, we offer recommendations to improve forecasting during the item introduction phase in the following areas:

- Statistical models
- Collaboration
- Measurement
- Demand management.

These recommendations are aimed at improving initial forecasting accuracy and, thereby, reducing the potential for inventory excesses and shortfalls.

STATISTICAL MODELS

Although forecasting always has a degree of associated error, improvements in forecasting can both decrease inventory investment and increase customer service. The following are some general forecasting principles[1] that should be applied to improve DoD materiel demand forecasts:

- Use simple averages to combine the results of multiple forecasting methods. This practice tends to reduce the likelihood of large errors, especially when the methods differ significantly.
- Use a combination of both quantitative and qualitative models. Judge the inputs to quantitative models rather than adjusting their outputs.
- Be conservative when making forecasts in uncertain situations. For example, dampen trends over the forecast period.

[1] Scott Armstrong and Kesten C. Green, "Demand Forecasting: Evidence-Based Methods," January 13, 2006, a chapter for the forthcoming book, *Strategic Marketing Management: A Business Process Approach* (edited by Luiz Moutinho and Geoff Southern).

- Incorporate actual demand into forecasts as soon as possible.
- Use aggregate level forecasts, which are generally more accurate for groups of items than for single items.[2]

During sustainment, there is a significant amount of demand data and a correspondingly wide selection of available forecasting models and algorithms. Forecasting model alternatives during item introduction are much more limited due to the lack of historical data. Despite this challenge, item introduction forecasts can be improved by incorporating historical demand as soon as possible rather than using the current fixed timetable.

Current DoD Approach

Item introduction forecasts are based initially on engineering estimates. As discussed in Chapter 3, engineering estimates produce less reliable forecasts than those based on historical data. For this reason, as the military services accumulate actual usage data about a new weapon system, they incorporate historical demand data into their updated forecasts, using a time-weighted approach during a demand development period. While DoD policy prescribes a 1-year demand development period, it allows demand periods up to 5 years.[3] The policy also stipulates that a demand development period measured against equipment operating hours is preferred over a merely time-based period;[4] however, the policy provides no guidance on how this would be accomplished. With the exception of the Air Force F-22 program, our research indicated that all the military services currently use a 2-year demand development period with the time-weights depicted in Table 6-1.

Table 6-1. Current Forecast Weighting Schedule

Time	Engineering estimates	Historical demand
6 months	75%	25%
12 months	50%	50%
18 months	25%	75%
24 months	0%	100%

For example, after 6 months, the military services weight engineering estimates 75 percent and historical demand data 25 percent. At the end of the 2-year period, demand forecasts are based exclusively on historical demand data.

[2] APICS Certified Supply Chain Professional, Learning System Module 2, "Building Competitive Operations Planning and Logistics," Version 2.0, 2009 edition.

[3] Office of the Deputy Under Secretary of Defense for Logistics and Materiel Readiness, DoD 4140.1-R, *DoD Supply Chain Materiel Management Regulation*, May 23, 2003, para. AP2.1.4.2

[4] Ibid, para. AP2.2.3.3.

While the current DoD time-weighted approach produces more accurate forecasts than forecasts based on engineering estimates alone, the approach does not utilize all available data to improve the forecast accuracy. For example:

- It uses only demand data at the item level and does not take advantage of aggregate operating hour data at the weapon system level.
- It does not consider that, as the number of observations increase, so too should the confidence in the data.

The next section describes an alternative weighting approach the Air Force has used to overcome both of these shortfalls.

The Bayesian Approach

The Air Force F-22 aircraft program uses an adaptation of the Bayesian approach[5] to incorporate historical demand into item introduction forecasts that provides a more balanced forecast than the current DoD approach. A previous study[6] explains in detail the advantages of the Bayesian approach. Appendix G provides a more complete explanation of the steps and weighting formulae.

A simplified version of the Bayesian weighting formula is as follows:

$$\frac{\textit{Historical hours} + \textit{MTBD}}{\textit{Historical demand} + 1},$$

where MTBD = mean time between demands.

The Bayesian approach produces better forecasts because it uses all the available data; the current DoD approach does not, as illustrated in Table 6-2.

Table 6-2. Bayesian Approach Example

1 year after initial forecast	Eng. estimate (MTBD)	Actual operating hours	Demands	DoD's forecast	Bayesian forecast	DoD forecast bias
Few demands	20,000	80,000	1	$\frac{80{,}000+20{,}000}{2}=50{,}000$	$\frac{100{,}000}{2}=50{,}000$	None
No demands	20,000	80,000	0	$\frac{20{,}000}{2}=40{,}000$	$\frac{100{,}000}{1}=100{,}000$	Over-forecast
Many demands	20,000	80,000	20	$\frac{40{,}000+20{,}000}{2}=12{,}000$	$\frac{100{,}000}{21}=4{,}760$	Under-forecast

Note: MTBD is the inverse of the demand rates; we use MTBDs for explanatory purpose.

[5] Air Force Logistics Management Agency, *Review of F-22 Spares Forecasting Techniques: Part 1, Peacetime Spares*, Report LR200729600, Rob Kline, R., Dr. Doug Blazer, and John Dietz, July 2008.

[6] LMI, *Toward Improved Initial Provisioning Strategies: The F-16 Case*, Report ML108, John B. Abell, Joan E. Lengel, and F. Michael Slay, April 1982.

In the example presented in Table 6-2, we compare both the current DoD method and the Bayesian approach 1 year after the initial forecast for one item with few demands, no demands, and many demands. The original engineering estimate was the item would fail after 20,000 hours. The actual weapon system operating hours after 1 year were 80,000 hours.

- In the case of few demands, the results using either method are similar; in fact in this example, they are identical.
- In the case of no demands, the current DoD time-weighting method (at 1 year, 50 percent engineering estimate and 50 percent historical data) tends to over-forecast demands because it has less data on which to base an estimate. In our example, the system operated 80,000 hours without a failure, but the DoD forecast estimates the item will fail every 40,000 hours. In contrast. the Bayesian approach estimates the item will more likely fail at 100,000 hours because it uses the actual operating hours in its calculations. This is an important difference between the two approaches because many items on new systems will not experience initial demands. For example, on the F-22, 75 percent of the forecasted items had no demands, even after 2 years.
- With multiple demands, the DoD method also produces inferior forecasts, but the tendency is to under-forecast demands. While in our example, the system operated 80,000 hours, and the item experienced 20 failures (in other words, the item failed an average of 4,000 hours), the DoD forecast estimated the failure rate at 12,000 hours. The reason is that the DoD weighting method doesn't account for the number of observations, only their average failure rate during a period. In contrast, the Bayesian approach takes into account that we had a considerable number of observations, and it estimates the item will more likely fail every 4,760 hours, which is much closer to the actual failure rate. This difference is also significant because the high-failure items cause the greatest readiness problems.

Table 6-3 summarizes the similarities and differences between the two methods.

Table 6-3. Comparison of Bayesian and DoD Weighting Approaches

	Bayesian approach	DoD time-weighting method
Similarities	◆ Both use a weighted average to combine historical data with engineering estimates (EE) ◆ Both transition from EE to historical data and can produce similar results	
Items with no demand *typical for many items* (e.g., F-22)	Reliability increases proportionally to operating hours without failure; gives credit for operating hours without failure	Cannot properly account for operating hours without failures; uses only the EE when a part does not experience a demand or assumes no demand ever
Weights for EE and historical demands	Automatically adjust weights based on demands; more historical demands mean more information, and thus, more weight (importance) for historical data	Based on an arbitrary period where weights vary linear from all EE to all historic
Normalization	Prevents systematic under-/over-forecasting by normalizing all demand rates to a historical system rate; the system rate contains data for thousands of parts—creating the most reliable estimate	

There are no significant obstacles to implementing the Bayesian approach within the Department of Defense, although it likely cannot be applied to every item. The Bayesian approach is not proprietary, and the calculations can be automated as easily as the current time-weighting method. The most significant additional prerequisite is that the Bayesian approach requires weapon system operating hour data. For most weapon systems, this information can be obtained from the military services' program managers. When operating hour data is not available, the current time-weighting approach could be retained.

Recommendation: Determine the best way to expand the use of a demand weighting method that relies on operating hours and the number of demands to incorporate historical demand data into initial demand forecasts.

Commercial Models

We did identify several methods (such as Cisco System's new product introduction (NPI) forecasting approach and SAS's structured analogies approach) that purport to improve the quality of initial forecasts. The proprietary nature of the models and insufficient data to conduct detailed simulations precluded an evaluation of such techniques in this review. Before a recommendation can be made to use such technique, the Department of Defense would need evidence that proves they are efficient and cost-effective in the defense environment.

COLLABORATION

Although our research suggests the opportunities to improve forecasting through collaboration are more limited during item introduction than sustainment, we still see opportunities for additional improvements, namely when

- basing forecasting reviews on demand value and
- resolving supply support request collaboration deficiencies.

Collaboration with Suppliers and Customers

According to a GAO audit of the Navy, "Problems with demand forecasting that contribute to excess inventory include incomplete and inaccurate data and a lack of communication and coordination among key personnel."[7]

Collaboration is a widely recognized supply chain management best practice, both in DoD and industry. APICS defines supply chain management (SCM) as

> the design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally.[8]

A general rule of SCM is that collaboration among organizations is superior to an individual organizational perspective.

SCM includes coordination and collaboration with supply chain partners integrating activities across organizations. This integrated network is often referred to as the extended enterprise. For example, the military services coordinate with DLA, a supplier, the warfighter, and the customer to get the most complete picture regarding future demand.

COLLABORATIVE FORECASTING

Collaborative forecasting is collection and reconciliation of information within and without an organization to come up with a single forecast of demand. As with collaboration in general, collaborative forecasting is preferred over individual forecasting. From a supply chain management point of view, each organization along the supply chain has a unique perspective regarding demand. Good collaborative forecasts combine the best of qualitative and quantitative approaches using an integrated supply chain management approach.

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[7] GAO, *Defense Inventory: Management Actions Needed to Improve the Cost Efficiency of the Navy's Spare Parts Inventory*, GAO-09-103, December 2008.

[8] *APICS Dictionary*, 12th edition.

Successful collaboration depends on building relationships with suppliers and customers. These partnerships must be based on trust, and each organization must be willing to share information. Opportunities for collaboration are greatest when actual demand is occurring. The intent is to replace estimates—and unneeded inventory—with timely information regarding actual demand.

The manufacturer of the individual system, component, or part usually has the best information on projected failure rates. During provisioning, supplier collaboration can be achieved through a relationship between DoD and the prime contractor. The prime contractor must have established working relationships with its subcontractors. For new systems, there are few customers with whom to collaborate. For this reason, it is important that the inventory control point consult with the program manager (who represents the customers' interest) to ensure customer-related inputs to the initial provisioning forecast, such as projected operating hours and maintenance rates, are as accurate as possible.

A recent PRTM report[9] based on a study of commercial best practices in supply chain collaboration concluded that DoD should address collaboration to improve supply chain performance. PRTM recommended that DoD do the following:

- Prioritize collaboration partners based on measurable potential benefits, including improved operating performance.
- Establish business plans and rules of engagement with the selected partners to guide the collaborative relationship.
- Integrate individual sales and operations planning processes to synchronize demand and supply planning.
- Establish performance measures and use effectiveness feedback to continuously improve the collaboration process.

PRTM concluded that the value proposition for implementing these recommendations will result from a single view of customer demand. This single view will lead to reduced inventory levels, lower costs, shortened lead times, and improved customer satisfaction and readiness.

Data Cleansing and Validation

Generally, for initial spares, the contractor estimates the replacement rates for items which, when combined with the end-item operations tempo, computes an expected demand rate. The military services' equipment specialists routinely review these rates. However, the amount and quality of review and the degree of collaboration varies considerably among the program and individual equipment specialists. Often such reviews are rudimentary (e.g., do the projected failure rates

[9] "Best Practices for Collaborative Supply Chain Planning in DoD," PRTM Management Consultants, LLC, September 19, 2007.

appear reasonable?). A best practice is a rigorous review of these rates. If the contractor provides only the expected replacement rates without the data or method used to compute the rate, an equipment specialist may have difficultly determining the accuracy of the forecasted rate. A better practice would require the contractor to provide the associated data so the equipment specialist can review and validate the legitimacy of the forecast.

Once the demand forecast is made, it is used to compute requirements. To do this calculation, other factors are needed, such as repair times, repair rates, procurement times, and shipping times. All these factors should be checked by the ICP or program office to ensure the data is as accurate as possible and the resulting spares requirements are computed correctly.

Dollar Value Groups

Prioritizing management attention based on its financial impact is a well established management principle.

The study found that the Army has applied this principle to its forecasting process by segmenting forecasts into dollar-value groups. As stated in Army Regulation (AR) 701-1,

> Secondary items are managed by dollar-value groupings. Assignments are based on the dollar value of the item's forecasted gross annual demands. Items will be reassigned to a new category when the annual dollar value varies from the previous dollar value forecast grouping by 10 percent or more.[10]

Table 6-4 shows the group breakdowns.

Table 6-4. Army Dollar Value Groups

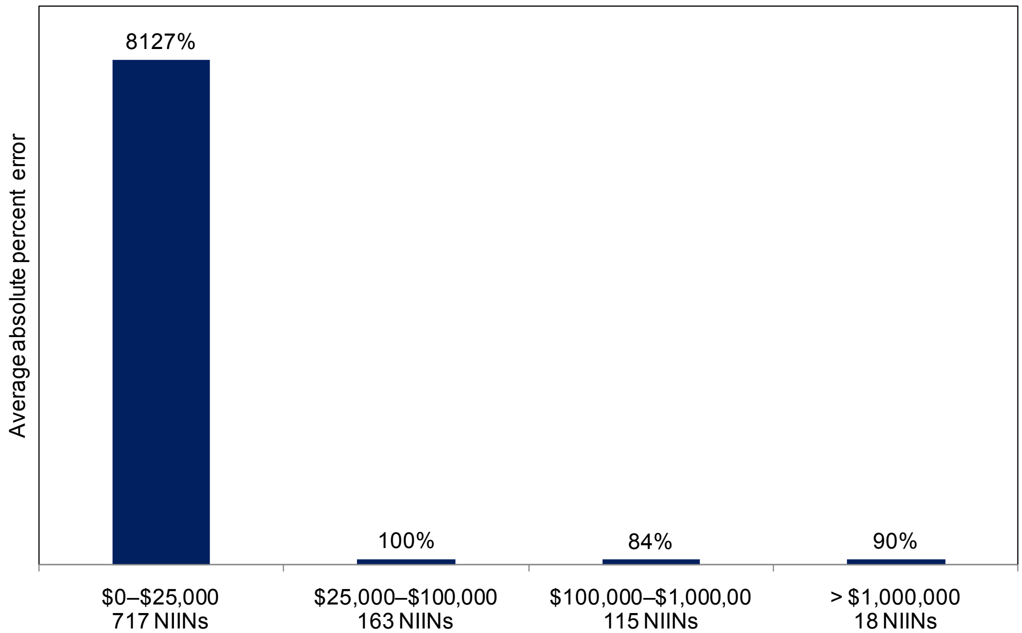
Group	Demand forecast value	Forecast frequency
Low	\$0–\$25,000	Annual
Medium	\$25,000–\$100,000	Semi-annual
High	\$100,000–\$1 million	Quarterly
Very high	> \$1 million	Monthly

The Army uses the dollar value grouping to prioritize its forecast management reviews and to vary the frequency of the forecasts. As dollar value groups increase, Army policy requires inventory managers to increase forecast input validations, and management to elevate the review levels.

[10] Headquarters Department of the Army, Inventory Management Centralized Inventory Management of the Army Supply System, Army Regulation 710-1, September 20, 2007.

To assess the impact of this policy, we calculated the absolute percent error based on the dollar value groupings using Army forecast and demand data for new item introductions. Figure 6-1 presents the findings.

Figure 6-1. Absolute Percent Error Rates for Army Dollar Value Groupings



Not surprisingly, we found the absolute percent error decreases as the dollar-value group increases. Item managers and management scrutinize more closely the engineering estimates and other elements that go into the demand forecast for items with the greatest cost impact. Some improvement also may be attributable to the increased frequency of the forecasts, although probably to a lesser degree in this analysis. Even though we evaluated only new items, some may have been forecast more than once because we used annual stratification data as our data source.

While the absolute percent error for the low-value items may appear high, provisioning forecasts with initially low actual demand rates can produce large percent error rates. More important, the dollar impact of the percent error is low. While we were unable to determine the value of the percent error rate per se, we estimated the procurement value of all items in the low value group as less than $9 million.[11] In contrast, the value of medium value group is $63 million; the high: $52 million; and the very high: a minimum of $18 million, but likely much more. In summary, the Army achieved significantly better forecast accuracy by focusing its forecast reviews on less than a third of its items that represented over 90 percent of the forecasts value.

[11] Assumes the average value of each forecast for each of the 717 items is $12,500, the midpoint of the dollar value group.

Current DoD supply policy essentially treats all forecasts as equal because it does not address forecast prioritization. Based on the success of the Army's dollar value group policy, we believe the approach should be expanded to all the military services. Each military service should be allowed to determine the thresholds of the value groups based on the items that they manage since the value of the items that the military services manage varies considerably.

Recommendation: Revise DoD supply chain management policy to prioritize forecast reviews based on the dollar value of the forecasts.

Supply Support Requests

Poor communication, whether internal to the military services or external to customers, and suppliers, is a barrier to collaboration. The most significant communication issue we observed was the lack of collaboration between the military services and DLA, particularly with regards to the SSR process.

CURRENT SSR PROCESS

An SSR is a statement or transaction of estimated requirements generated by the military services and transmitted to DLA to communicate provisioning requirements for consumables.[12] The SSR includes the following:

- *Retail quantity*. Initial quantity expected to be requisitioned and in place when the end-item or weapon system is fielded.
- *Replenishment* (wholesale) *quantity*. Estimated quantity of repair parts to be used by the military services during the first year of sustainment following the provisioning support date.
- *Program data*. Information and quantities pertaining to the end-item or new weapon system.
- *Line item data*. Information and quantities concerning the spare and repair parts.

DLA is required to notify the military services of the acceptance or rejection of the SSR.[13] DLA's role during provisioning also includes the following:

- Attend and participate in provisioning meetings and conferences.
- Ensure cataloging data is received.
- Assign national stock numbers (NSNs).
- Establish the material master record and maintain required stock levels.

[12] DoD 4140.26-M, *Defense Integrated Material Management Manual for Consumable Items*, Volume 6, September 2010.

[13] DLA Provisioning Briefing presented at LMI, August 19, 2009.

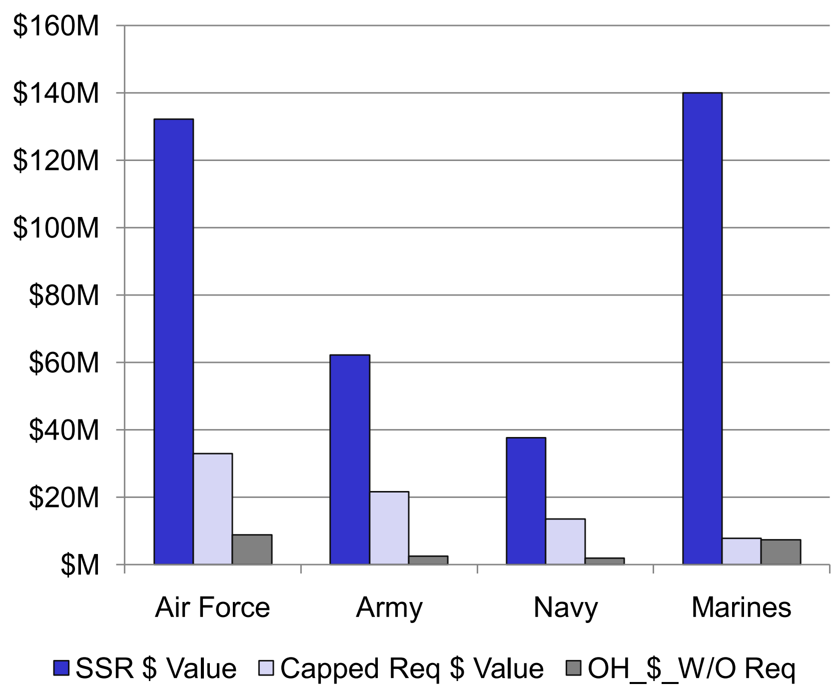
Despite the established operating procedures, DLA constrains purchases of new provisioning NSNs that have not yet had a demand. This policy automatically leads to a backorder if a military service places an order. DLA stated that it makes an exception and may purchase a provisioning item if weapons system support managers have special knowledge about a requirement for a particular NSN.

DLA cites the following provisioning challenges that influence its decision to not purchase provisioning quantities based on service SSRs:

- Insufficient funding to support all provisioning requests
- Low buy-back rates
- Lack of notification of configuration changes.

The most significant issue is historically low buy-back rates. In short, there is a fundamental trust issue. DLA does not think that the services' provisioning forecasts are accurate, so it doesn't buy new NSNs until there is a funded requisition. Currently, DLA rarely participates in provisioning conferences; therefore, it has limited knowledge of how the requirements were computed or their reliability. Figure 6-2 shows the SSR buy-back rates by military service.

Figure 6-2. SSR Buy-Back Rates by Military Service



SSR processing is a financial policy issue as well as a supply policy issue. The DoD Financial Management Regulation (FMR) requires that new acquisition program fully identify and budget all requirements directly attributable to an acquisition.[14] This requirement includes inventory augmentation directly attributable to the introduction of a new weapon system.[15] While program managers routinely fund the military service ICPs to augment inventories of initial spares for new weapons, our research indicated they do not routinely fund DLA to augment consumable inventories. According to the FMR, stock augmentations can be funded either by working capital funds or appropriated dollars, but the FMR does not provide specific guidance on SSR funding.[16]

DoD supply policy for processing SSRs was recently updated to improve SSR processing; however, the changes do not appear to be sufficient to correct this problem entirely.[17] While the revised policy requires the SSR submitter to budget and procure retail SSR stock requirement shortfalls when DLA indicates that it cannot meet the submitters requested support date, it does not address wholesale stock requirements. Therefore, for items without retail stock, initial service requisitions will likely continue to be backordered for a procurement lead time. For items with retail stock requirements, the services would presumably be a budget lead time away from funding and procuring those requirements if they don't become aware that DLA cannot support the requirements until DLA responds to a service's SSRs.

ALTERNATIVES

A recent GAO audit found that processing of SSRs is a long-standing problem and GAO recommended that the DASD(SCI) resolve the problem.[18] DLA chairs a DoD-wide group that has been attempting to resolve such problems for many years, but it has made little progress.

There are at least three potential solutions to the SSR processing problem. The current proposed solution entails the military services funding only a portion of the SSRs. DLA is currently working with the Marine Corp and Navy on a shared investment risk pilot program for provisioning requirements for the UH-1Y helicopter. For this pilot, the Marine Corp has agreed to make an initial 50 percent investment of total SSR requirements; DLA will fund the balance. The pilot program was originally scheduled to begin in July 2010, but it has been delayed. The proposed end date for evaluation of the pilot is April 2013.

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[14] Department of Defense *Financial Management Regulation*, DoD 7000.14-R, Volume 2A, Chapter 1, Section 010202, September 2008.

[15] DoD 7000.14-R, Volume 2B, Section 090203: "Provisioning Item (Outfitting). That portion of Provisioning consisting of items for which a sale is anticipated to an appropriated outfitting (buy-out) account. Direct appropriations are required to establish inventory levels for these items until requirements can be forecast based on actual demands for their replenishment using obligation authority."

[16] DoD 7000.14-R, Volume 2B, Chapter 9, p. 36.

[17] DoD 4140.26M, Volume 6, requires SSR submitters to "Budget for and procure support quantities as required to support retail if required to support fielded equipment until the support date indicated in the accept advice transaction."

[18] GAO, *Defense Inventory: Defense Logistics Agency Needs to Expand of Efforts to More Effectively Manage Spare Parts*, GAO-10-469, May 2010.

The pilot approach has two drawbacks. First, it will be some time before we know whether the pilot was successful. Considering the lead times between the forecast period, procurement lead times, and the time required to accumulate actual demand, the proposed evaluation date is reasonable. Secondly, and perhaps more importantly, not all the military services support this approach, regardless the success of the pilot program. In light of the services' reticence, the pilot SSR funding approach may simply be kicking the problem down the road.

One alternative is to expand the current Navy practice of NAVICP retaining management of new maintenance-significant consumables for the first year after interim supply support before transferring their management to DLA. The advantage of this approach is that the military service is responsible for funding the initial forecasts for these crucial items, not DLA; and, when the items are subsequently transferred to DLA, they are transferred with a full pipeline, if warranted.

An alternative variation of the Navy aviation approach in all the military services might be the easier and better solution. To reduce duplicative effort, a variation of this approach could be for the military services to send fully funded SSRs to DLA for new items that they deem most critical to readiness. In this variation, lower-risk consumable items would continue to be managed as they are today. The military services would budget and fund only the most critical consumables via fully funded SSRs. For provisioning items that DLA already manages and new items that are considered less important, the military services would continue to forward unfunded SSRs. Since the former items are already in the system and the latter items are deemed less critical, the risk of initial backorders would be much less. This approach would also appear to fulfill the FMR requirement for full funding of provisioning items, provide accountability for military service SSR forecasts, and minimize the risk of readiness degradation due to backorders.

Recommendation: Form a joint working group to revise DoD supply and financial policy to determine the best SSR policy alternative.

MEASUREMENT

None of the military services currently measure the forecast accuracy of item introduction forecasts. In this section, we discuss why they should and propose a metric that should be used for evaluating these forecasts across the DoD.

A second topic related to measurement is the role of stratification in evaluating inventory management, including forecasting. We state a case for revising stratification policy and processes to rectify emerging problems.

Metrics

Metrics are an important part of any business process. As the saying goes, "if you're not keeping score, you're just practicing, not playing." Metrics provide a feedback mechanism that helps managers decide what process changes might be needed. Appropriate metrics accomplish the following:

- Align business activities to the vision and strategy of the organization
- Improve internal and external communications
- Monitor organization performance against strategic goals.

In any supply operation, there are inherent trade-offs between the cost of inventory and the level of customer service. In general, more stock on hand equates to higher cost, but also higher customer service levels (i.e., fewer backorders). A supply chain management approach seeks to balance these two factors to achieve desired performance levels.

DoD has a number of customer service—or readiness—metrics to measure the availability of the inventory required to keep systems operational; however, GAO has repeatedly criticized the department for placing less emphasis on the inventory costs required to achieve readiness. Partially in response to this criticism, DoD recently committed to establish DoD-wide forecast accuracy metrics and goals in the *Comprehensive Inventory Improvement Plan*.

Our research determined that none of the military services currently track the accuracy of item introduction forecasts. DoD inventory management personnel make initial inventory investment decisions based on provisioning and interim support demand forecasts. Over-forecasting leads to excess inventory and higher costs, while under-forecasting causes shortages and decreased readiness. Unless past performance is tracked and assessed, it is difficult for provisioning managers to determine how good or bad forecasts are or what changes may be necessary to improve them.

DoD 4140.1-R, *DoD Supply Chain Materiel Management Regulation*, requires the military services to maintain a number of provisioning metrics, including the measurement of the accuracy of provisioning buys,[19] but it does not stipulate the specific metrics to use for this purpose.

[19] DoD 4140.1-R, *DoD Supply Chain Materiel Management Regulation*, C2.2.2.6, May 23, 2003.

To be useful, metrics must meet certain criteria:

- *They must be clearly defined.* Metrics must be specific in what they are measuring, with no ambiguity.
- *They must be measurable*. The data needed to assign values to the metrics must be available.
- *They must be actionable*. The information provided by the metric must be sufficient to indicate a course of action.
- *They must be relevant.* The metric must measure some aspect of the business such that meeting or exceeding the metric's goals will provide some benefit.
- *They must be timely.* The metric must be calculated and made available soon enough that the information can be acted upon.

The accuracy of provisioning forecasts is more difficult to measure than the accuracy of sustainment forecasts. Data tends to be sparse, approaches vary among organizations, and actual demands may not occur for several years after the provisioning forecast is developed. Many traditional forecast metrics used for sustainment may not apply.

Traditional Demand Forecast Metrics

In most cases, when inventory managers discuss forecast accuracy, they are referring to the sustainment phase of an item's lifecycle, when accumulated demand history is used in statistical models to predict coming demand. The provisioning phase does not fit that mold since there is often little or no demand history to use in statistical models. Instead, provisioning forecast accuracy is a simple matter of comparing the forecast used to make the initial investment decision versus the actual demand that occurred in subsequent years. The repetitive process that characterizes the sustainment phase does not apply. Still, some of forecast metrics used in the sustainment phase may be useful for the provisioning phase.

In the following sections, we describe commonly used metrics for measuring forecast error at an aggregate level and discuss their applicability to provisioning and interim support phases.[20]

[20] This chapter does not provide an all-inclusive list of forecast error metrics. Other metrics, such as the Theil's U index of inequality, are commonly used to measure forecast error at an item level.

Mean Deviation

Mean deviation, or MD (sometimes called simply the average error), is computed as the simple average of the set of forecast errors. Positive and negative errors will cancel each other out in the average, so a small mean deviation does not necessarily mean the errors themselves are small or the forecasts are accurate. It simply means the system has no forecast bias. A large MD in either a positive or negative direction is an indication not only of error, but also that the forecasting system has bias in that direction.

Applicability to Provisioning: Poor, because provisioning involves a one-time forecast; the notion of an average of errors over time does not apply.

Percent Error

Percent error, or PE, is the error quantity (forecast − actual demand) divided by the actual demand. The benefit of using the percent error rather than the error quantity itself is it allows a comparison of high and low demand items on an equal footing.

Applicability to Provisioning: Good. Retaining the sign of the error allows users to determine whether the process is over- or under-forecasting.

Absolute Percent Error

Absolute percent error, or APE, is the absolute value (i.e., remove the positive or negative sign) of the percent error.

Applicability to Provisioning: Poor, since part of our objective is to estimate the contribution provisioning forecasts make to excess inventories; it is unwise to ignore the sign of the error.

Mean Percent Error

The mean percent error, or MPE, is simply the average of the percent error statistics over time.

Applicability to Provisioning: Poor, because provisioning involves a one-time forecast; the notion of an average of errors over time does not apply.

Mean Absolute Percent Error

Mean absolute percent error, or MAPE, is one of the most commonly used forecast metrics. It is the average over time of the absolute percent error.

Applicability to Provisioning: Poor, because provisioning involves a one-time forecast; the notion of an average of errors over time does not apply. Also, absolute value error metrics do not indicate whether forecasts are biased high or low.

Mean Absolute Deviation

The mean absolute deviation, or MAD, is the smoothed average of absolute errors. It is similar to the mean deviation, except that the sign of the error is ignored.

Applicability to Provisioning: Poor, because provisioning involves a one-time forecast; the notion of an average of errors over time does not apply.

Mean Square Error and Root Mean Square Error

The mean square error, or MSE, is calculated as the average of the squares of the errors. The root mean square error, or RMSE, is the square root of the MSE. In either case, the squaring has the effect of nullifying the sign of the error. In most cases, the MSE and RMSE are not used as forecast metrics, but rather as estimators of demand variance for use in safety level calculations.

Applicability to Provisioning: Poor, because both metrics effectively ignore the sign of the error. Also, provisioning involves a one-time forecast; the notion of an average of errors over time does not apply.

Demand Plan Accuracy

Demand plan accuracy, or DPA, is not a metric so much a synonym for forecast accuracy—a general term with no specific formula. The metrics described above, represented as forecast accuracy metrics, are more correctly called forecast error metrics. Many organizations prefer to use metrics that show how accurate the forecast is, not how much error. In general, DPA is computed by subtracting some percent error metric (e.g., MAPE) from 100 percent. The problem with this approach is the DPA metric will be negative when percent errors are greater than 100 percent, which is confusing for many managers. To resolve this confusion, some organizations cap the percent error at 100 percent so the lowest possible DPA is then zero. This practice understates the extent of forecast error.

Applicability to Provisioning: Poor. Subtracting percent error from 100 percent adds no value, and averages of time are not relevant for provisioning.

Non-Traditional Error Metrics

The section above describes traditional forecast metrics and how they might apply to provisioning. They measure the quality of the forecast, but not the impact on the inventory system. Whatever metrics are used to measure forecast accuracy, they should be supplemented with measures of the impact on the inventory system (i.e., investment and supply performance). They should also be supplemented with specific metrics that isolate the cause of growth in excess inventory. We recommend the following supplementary provisioning metrics.

Number and Dollar Value of Over-Forecasted Items

For a given group of items, count the number for which forecasted demand exceeds actual demand. Compute the dollar value of the difference between forecasted and actual demand. Exclude insurance items, which, by design, are bought with no expectation of use.

Inventory versus Support

This is a "bang for the buck" system of metrics. For a given group of items (e.g., all provisioning items on a newly deployed system), sum the total investment in inventory. During the first years after deployment, track fill rate, average customer wait time, and average backorder time.

Inventory Purchased above Demand

Compute the total dollar value by which provisioning purchases exceed actual demand. Exclude insurance items, which, by design, are bought with no expectation of use.

Unfilled Orders

Count the number and dollar value of demands which exceeded the forecast and resulted in backorders.

AGGREGATING ERROR METRICS

There are several methods of aggregating individual forecast error over a collection of items.

Simple Average

Simple average of the forecast errors (by whatever measure) is computed over a range of forecasted items. Problems with this approach can arise when large numbers of low-demand items are involved. When actual demand is low, an error of a few units can translate to very high percent errors. A large number of such items can distort the resulting average percent error.

Weighted Average

Individual errors can be weighted by some measure of demand, such as demand quantity, dollar value, or frequency. By weighting the average based on demand dollar value, for example, we can assess the potential financial impact. Weighting can eliminate the low-demand item distortion that might occur in the simple average.

Summary

Many of the metrics used to assess forecast accuracy for sustainment are not useful for item introduction when little historical demand data is available. At the item level, the percent error metric is the most appropriate metric to measure forecast accuracy for new item introductions because it measures both the magnitude and the direction of the error. Similar to the dollar value groups, dollar-value weighting percent error at the weapon system level provides more useful information than weighting all items equally because it focuses management attention on the most important forecasts.

While the above areas were developed in the context of the item introduction phase, the strengths of these metrics are equally applicable to all phases of an item's lifecycle, and they should be considered as primary candidates for the DoD forecast accuracy metrics required by the DoD *Comprehensive Inventory Improvement Plan*. The use of error metrics for initial forecasts and a data repository for collecting initial demand data and error measurements would provide an important feedback mechanism to permit process improvement.

Recommendation: Consider adopting percent error as a primary metric for evaluating demand forecast accuracy at the item level and dollar-weighting percent error at the aggregate level.

Stratification Capabilities

DoD inventory stratification has long been a valuable tool and resource for DoD inventory management and budget analysis, including this study. It is also a primary source of data for the DoD annual supply system inventory report. DoD policy requires each DoD ICP to accomplish inventory stratification for every item it manages;[21] however, the usefulness of stratification as an analytic tool is rapidly declining for two reasons:

- The commercial enterprise resource planning systems (ERPs) that are replacing DoD components' legacy inventory management systems do not feed stratification without reprogramming.
- Weapon system inventories managed by contractors are generally not stratified.

ERP

Of the ERPs, the Army's Logistics Modernization Program (LMP) implementation presents the most imminent stratification problem. Army has not mapped the LMP to stratification at the item level. Consequently, as Army ICPs migrate to LMP, the capability to retrieve item-level stratification data is lost. For example, we were unable to evaluate the forecast accuracy for the two weapon systems selected by the

[21] DoD 4140.1-R, *DoD Supply Chain Management Regulation*, Chapter 9, May 23, 2003.

Army because the ICP, the Communications-Electronics Command (CECOM), uses LMP and could not provide item stratification demand data. Likewise, we were unable to obtain 5 years of forecast and demand history for all Army-managed items for the same reason. Within the next year, all Army ICPs are expected to migrate to LMP, and without reprogramming, all item-level stratification analysis capabilities will be lost for Army items.

This problem is less acute in the other military services, mostly because their ERP implementation lags the Army's; however, the issue deserves attention across all DoD components.

CONTRACTOR-MANAGED INVENTORY

The second problem, exclusion of contractor-managed inventories from the military services' inventory stratifications, is not a new development, but the extent of the problem is.

In the past, contractor supply support was confined to a few years of interim support. This is no longer true, particularly for the Air Force, which is relying on contractors to perform inventory management for most new systems for extended periods. For this reason, most new item introductions in the Air Force stratification and D-200 requirement systems that we evaluated were the result of modifications.

The lack of clarity in stratification terminology is partially responsible for the disagreement between GAO and DoD on what constitutes excess inventory. Stratification terminology can be misleading. For example, DoD disagrees with GAO's use of the stratification term "requirements objectives" when determining excess inventories.

DoD policy indicates the goal of stratification is to uniformly portray the materiel requirements and assets of individual items.[22] However, the military services do not interpret stratification terms uniformly. For example, the Army includes life-of-type inventories in contingency retention stocks, but the other services do not.

Given the above problems, the need to map ERPs to stratification presents an opportunity to ensure stratification terms are uniformly interpreted by all DoD components and to clarify terms so they more clearly describe what they represent.

Recommendation: As part of the implementation of the DoD *Comprehensive Inventory Improvement Plan*, DoD should update its stratification policy and processes to clarify terminology and standardize systemic application across DoD.

[22] Ibid.

DEMAND MANAGEMENT

Supply Chain Risks

A number of potential disruptions can negatively impact supply chain performance. Potential disruptions can either be internal (e.g., insufficient quality, unreliable suppliers, machine break-down, uncertain demand) or external (e.g., flooding, terrorism, labor strikes, natural disasters).

As discussed in Chapter 4, the primary supply chain risks during item introduction are that changes will occur during the forecast lead time and will alter required inventory levels from what was originally forecasted.

- *Demand forecast reliability risks.* Changes between the forecasted demand rates of components and what is actually achieved.
- *Design instability risks*. Changes in design configuration can cause parts to become obsolete, alter lead times, and lead to inaccuracies in technical data and cause flawed item identification.
- *Operating hour risks*. Changes in weapon program data, including end item densities, planned operating hours per unit, site deployments, and operating hours.
- *Maintenance risks*. Changes in maintenance capabilities, often not achieved as planned; can lead to discrepancies between forecasted and actual maintainability rates, unserviceable return rates, and other forecasting inputs.

Managing Supply Chain Risk

Although DoD supply policy has adopted a supply chain management framework, DoD generally uses safety stock and a well-stocked supply pipeline to mitigate the risks of not having sufficient spare parts inventory to meet readiness goals. The drawback of this strategy can be increased total costs. Using inventory to mitigate risks can mask supply chain problems.

DoD initial forecasts occur well in advance of the forecast period, when the end-item program is most volatile due to the lack of equipment design stability. This difficult situation is complicated by the fact that spare part demand tends to be more volatile than private sector consumer items because of the high variance in demand.

A supply chain best practice is to develop a comprehensive end-to-end risk management approach to identify, analyze, and mitigate risks. Rather than simply using high inventory levels to manage risk, a best practice is to employ supply chain risk management techniques.

The Supply Chain Council defines supply chain risk management as, "the systematic identification, assessment and mitigation of potential disruptions in logistics networks with the objective to reduce their negative impact on the logistics network's performance."[23]

The following are common and relevant supply chain risk management techniques:

- Adopt an overarching, end-to-end risk management approach.
- Accelerate resupply times.
- Delay inventory investment until the program stabilizes.
- Share the risk with supply chain partners through alternative support strategies.

OVERARCHING MANAGEMENT APPROACH

The Supply Chain Council considers both internal and external risk in its three-phase approach for supply chain risk management:[24]

- *Phase 1—Risk Identification*. What can go wrong? What is uncertain? Based on a description of a supply chain with the Supply Chain Operations Reference (SCOR) model, each single process should be looked at with regards to potential disruptions that may negatively harm the performance and which countermeasures are already in place. Result of this phase is a list of the relevant supply chain risks.
- *Phase 2—Risk Assessment*. How likely is it that a certain potential incident will occur? What is the impact? The likelihood of occurrence and the negative impact on SCOR performance measures of each supply chain risk should be qualitatively or quantitatively evaluated. The result of this phase is a list of serious risks that can be visualized in a risk portfolio with the dimension probability of occurrence and negative impact.
- *Phase 3—Risk Mitigation*. How can the risks be controlled and monitored? Mitigation measures (e.g., improved planning methods, alternative suppliers, response plans, redundant infrastructure) should be evaluated for the serious risks. After having checked the cost-efficiency of the alternative measures, the appropriate measures should be chosen and implemented. A risk can be mitigated by decreasing the likelihood that it will occur or by decreasing its impact if it does occur. Alternatives to mitigation include acceptance, transfer, and risk sharing.

[23] Supply Chain Operations Reference (SCOR) model, Version 9.0, Supply Chain Council Inc., 2008.

[24] Ibid.

The *Risk Management Guide for DoD Acquisitions* includes a similar risk management process model with the following five phases:[25]

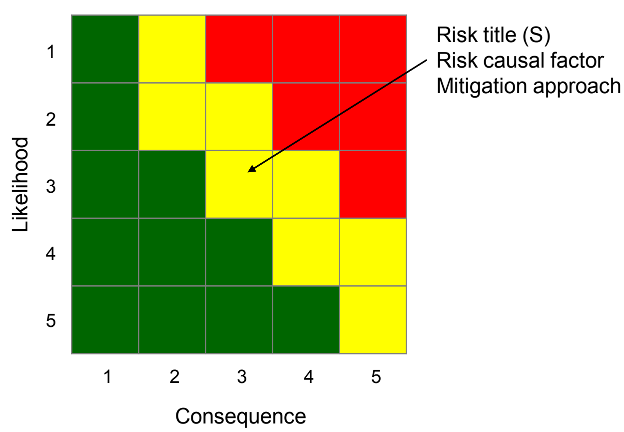
- Risk identification
- Risk analysis
- Risk mitigation planning
- Risk mitigation plan implementation
- Risk tracking.

The guide states that DoD can't transfer risk to a development, production, or support contractor; the risk can only be shared. The program manager retains responsibility to the system owner; therefore, the program office must assess and manage all risks throughout the lifecycle of a system.

The key to this process is the risk identification and analysis. After identifying all potential risks, DoD should quantify them. How likely is it that the risk will occur? What will the impact be on performance, schedule, and cost if the risk does occur?

The next step is to assign a level of risk likelihood and a measure of the potential consequences. For example, a risk could be assigned a "1" if it is unlikely to occur, a "3" if it is likely to occur, and a "5" if it will almost certainly occur. Similarly, a consequence of "1" would be minimal, "3" would be moderate, and "5" would be severe. Figure 6-3 shows an example[26] of a risk reporting matrix.

Figure 6-3. Risk Analysis Example



[25] Defense Acquisition University (DAU), *Risk Management Guide for DoD Acquisitions*, sixth edition, August 2006.

[26] DAU, *Risk Management Guide for DoD Acquisition*, sixth edition, August 2006.

In this example, the risk scored a “3” for both likelihood and consequences and is categorized as a schedule (S) risk.

Managing supply chain risk early in product design and manufacturing yields more options and is most cost effective in reducing total lifecycle risks and costs. The following are examples of supply chain risk management (SCRM) strategies[27] available during the product design phase:

- Involving supply chain personnel (manufacturing, aftermarket, and purchasing)
- Reducing complexity by standardizing parts and maximizing cross-product commonality
- Monitoring and avoiding obsolescence in parts, technologies, and processes
- Involving suppliers in design of systems or products and parts
- Negotiating with potential suppliers on ownership of technical rights of design.

Leading supply chain organizations are introducing supply chain performance goals into their product design process.

A RAND briefing[28] listed the following emerging best SCRM practices:

- Begin with product design and development.
- Quantify prospective disruptions’ impact on the enterprise, products, and customers.
- Require key suppliers to
  - develop business continuity plans which are regularly reviewed and
  - commit to a time to recover.
- Develop standard, enterprise-wide metrics for SCRM.
- Assess business units and personnel on their SCRM plans.

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[27] Adapted from Chenoweth, Mary E., Arkes, Jeremy, and Moore, Nancy Y., *Best Practices in Developing Proactive Supply Strategies for Air Force Low-Demand Service Parts*, RAND MG 858-AF, forthcoming.

[28] RAND, *Identifying and Managing Manufacturing and Sustainment Supply Chain Risks*, Nancy Young Moore, Elvira Loredo, and Amy G. Cox, April 2010.

According to APICS,

> Viewing the supply chain from a risk management perspective allows the organization to more accurately understand the risks posed by such unforeseen events as emerging technologies, new regulations, or shifts in consumer demands.[29]

APICS also suggests using fewer suppliers and longer-term contracts to facilitate closer relationships and better partnerships. Contracts with performance improvement incentives tend to lead to continuous improvement.

Metrics can be used to help manage risk. As the *Comprehensive Inventory Management Improvement Plan* indicates, DoD must balance improvements to efficiency against any degradation in customer support.[30] The Plan includes the identification and reporting of high-level readiness metrics. The intent is to use those materiel readiness indicators to quantitatively assess whether the attainment of targets established for inventory management improvement and efficiency will result in any adverse impact on materiel support to the operating forces.

Table 6-5 lists the specific readiness and risk metrics included in the *Comprehensive Inventory Management Improvement Plan*, which will be tracked over time as part of the its implementation.

Table 6-5. Readiness and Other Risk Metrics

Readiness metrics	Readiness-related metrics	Other risk metrics
• Not mission capable rates (casualty reports for ships) • Weapon system availability • Not mission capable or MICAP hours	• Cannibalization rates • High priority backorders • Aged backorders • Customer wait time • Perfect order fulfillment • Supply materiel availability/ fill rates	• Procurement lead times • Dollar amount of re-procurement of materiel disposed of previously • Maintenance rob-backs (shop cannibalization) • Local purchase buy-around counts

ACCELERATING RESUPPLY TIMES

One way to mitigate the supply chain risks associated with item introduction is to reduce resupply times. Resupply times impact forecasts in two ways. First, the greater the lead-time between a system's forecast and the forecasted period when demands are predicted to occur, the greater the uncertainty that the forecast inputs will accurately reflect reality. In other words, the longer the forecast lead time, the greater the risk that the forecasting inputs, and the resulting forecasts, will be inaccurate. Item introduction forecast lead times are largely predicated on the resupply

[29] APICS Certified Supply Chain Professional, Learning System Module 3, "Managing Customer and Supplier Relationships," Version 2.0, 2009 edition.

[30] *DoD Comprehensive Inventory Management Improvement Plan*, Chapter 1.

lead times for the items being forecasted. The reason is that once the forecast quantities have been determined, sufficient time must be allotted to compute, procure, and deliver the inventory required to fill the forecasted demands. Reducing resupply times can reduce forecast lead times and, concomitantly, the risk of inaccurate forecasts.

The second way that lead-times impact forecasts is resupply times at the item level. The amount of inventory required to support forecasted demand depends on the length of the pipeline times. Pipeline times are the amount of time it takes to get an activity accomplished, such as how long it takes to procure an item, how long it takes to repair an item, how long does it take to pick, pack, and ship an item, and how long it takes to return an item from repair.

Reducing pipeline times means less spares would have to be bought. For instance, in a recent study with LMI and the Air Force Logistics Management Agency, we found that, if the order and ship time could be reduced by half (from 8.8 days to 4.4 days) for Air Force-managed items, the cost of the spares could be reduced by $132 million. If pipeline times could be shortened during initial provisioning, then less stock would be required and there would be less risk of overbuying based on an inaccurate forecast.

There are several ways to reduce resupply times:

- Put in place pre-negotiated contracts to reduce procurement lead times.
- Negotiate with the contractors to obtain the shortest possible lead times.
- Pay contractors to establish the capability and capacity to quickly produce new items and repair broken items.
- Use premium transportation to ship items to the customer and to return them to a repair facility.
- Ensure the initial spares are distributed to locations with access to transportation hubs and where they would be as close as possible to the point of use to decrease ship times.

A 2007 GAO report found the "military components' estimated lead times to acquire spare parts varied considerably from the actual lead times experienced."[31] In the same report, GAO stated that, "absent actions to address these problems, lead time estimates will continue to vary from actual lead times and will contribute to inefficient use of funds and potential shortages or excesses."[32]

[31] GAO, *Defense Inventory: Opportunities Exist to Improve the Management of DoD's Acquisition Lead Times for Spare Parts*, GAO-07-281, March 2007.

[32] Ibid., GAO-07-281.

GAO recommendations from that study included the following:

- Emphasize lead time reduction initiatives.
- Update lead time data.
- Consider buying directly from manufacturers rather than intermediaries to reduce lead times.

Past military service initiatives to reduce lead time can be placed in the following three categories:

- *Streamlining administrative processes*. Examples include information technology initiatives, process redesign efforts, and lead time reduction teams.
- *Oversight efforts*. Examples include setting and tracking reduction goals and holding managers accountable.
- *Strategic supplier relationships*. These efforts have included direct vendor delivery, longer-term contracts, and strategic planning and alliances. For example, the Navy had an initiative to consider lead time for spare parts as criteria for contract award.

DELAYING INVENTORY INVESTMENT DECISIONS

Another method for mitigating item introduction supply chain risks is to delay inventory investment decisions until the weapon system design stabilizes and actual demand rate cans be better determined. Early provisioning, which is based on estimates that are less reliable and planned maintenance capabilities that are not initially achieved, results in "less accurate support system definition and less than optimum investment of available resources."[33]

The primary method for forecasting demand is to multiply projected failure rates by the projected operating hours and the system density. For reparable items, estimates of the percentage of items that will be fixed in the field and depot and their repair cycle times must also be factored. Each input to the forecast is at risk of being incorrect. The expected failure rates are estimates and actual demand rates could be higher or lower. Some items may not be demanded at all because the design was unstable and the item has been replaced by another item. The system density may not be what was initially forecasted due to reductions to weapon system cost growth, and delays in system production and site activations. The system may not operate as much as forecasted due to technical problems or changes in operational needs. The repair capabilities that are planned may not be initially available. One answer to avoid the pitfalls of early provisioning is to delay investment decisions until the design is more stable and actual demand data is available and maintenance

[33] Charles F. Youther, "A Case for Eliminating the Initial Provisioning of Spares," *Air Force Journal of Logistics*, 1994.

capabilities are more mature. Several support strategies allow DoD to defer some or all provisioning, including interim support, phased provisioning, incremental provisioning, and stratified provisioning.

Interim Support

One of the advantages of interim support is it manages risk during the instability of initial weapon system roll-out. Interim support is one option the military services can use to minimize the need for early investments in inventory by utilizing the flexibility of contractor support to offset the need for inventory. By initially relying on a contractor's capabilities (to borrow from production line assets to compensate for spares shortfalls, develop engineering fixes for items with poor reliability, quickly transport assets to reduce order ship times, and transport engineers and repair technicians to operating locations when necessary to compensate for repair capability shortfalls), initial inventory levels can be much more conservative and provisioning buys can be deferred until a later date and there is less risk of buying stock that may not be needed. The military service still maintains system availability and the ability to respond to unforeseen changes. Contractors indicate they are often able to reduce the need for inventory by investing in the supply chain instead.

Phased Provisioning

Phased provisioning provides another means of providing supply support for items that are not design stable. Phased provisioning is a selective management technique associated with the provisioning process that allows a military service to delay procurement of the total computed provisioning requirement for spares or repair parts until the provisioning activity can more reliably predict the requirement.

During the production of the system and while phased provisioning is in effect, the selected items are supplied by the stockage of minimal quantities of the selected support items in the contractor's facility and arranging with the contractor to accelerate production and set-aside of these items. Such arrangements create a production buffer stock that is available to replace failed items in system with significant reductions in lead times. An indefinite delivery, indefinite quantity or other requirements-type contract is generally used for procuring stocks for phased provisioning.

The utilization of phased provisioning defers the procurement of all or part of a normal initial computed requirement for selected spare and or repair parts pending the following:

- Stabilization of design
- Development of firm operational and maintenance plans and deployment programs
- Application of in-service experience and test data to the computation of requirements for these items.

Incremental Provisioning

Incremental provisioning is a management technique associated with the provisioning process that allows completion of provisioning on portions of the end item that are stable and deferring provisioning for those portions which are not. Incremental provisioning allows a military service to identify and procure assemblies and subassemblies and provides the following management advantages:

- Reduces reliance on interim contract support (ICS) for accelerated acquisition or non-developmental items programs.
- Reduces surges in workload in the provisioning of the end item.
- Develops the in-house logistic support earlier by phasing delivery of logistics support analysis data rather than waiting for design stability before initiating provisioning action.

Stratified Provisioning

Similar to incremental provisioning, stratified provisioning is a management technique that allows a military service to identify and procure logistics support for a portion of a weapon system and defer for others based on maintenance capabilities. For example, in the Army, stratified provisioning may provide spare and repair parts for a unit and direct support (DS) levels and defer procurement of general support (GS) and depot parts until those maintenance capabilities are more mature. Where there is no planned DS, selected GS parts may be procured in sufficient quantity to assure sustainability.

Stratified provisioning provides a capability to concentrate resources on development of logistics support at the most critical level and defers action on levels that least affect initial readiness. Planning for deferment of depot or intermediate maintenance and depot support, requires detailed attention to the quantities of parts needed at lower levels. Sufficient stock must be fielded to allow for utilization of ICS. Deferment of depot or depot and intermediate maintenance parts provisioning will provide the capability to provision these levels with more mature data. Contractors can deliver interim parts consumption data to the provisioning activity in a useable format for augmenting contractor estimates and updating database files.

RISK SHARING

One way to reduce the risk of inaccurate demand forecasts is to share the risk with the contractor and give them sufficient incentive to make an accurate forecast. However, there is a trade-off. When contractors accept risk, they expect to be compensated for it. The trade-off is how much risk the contractor will be willing to take and how much they will charge for taking the risk versus how much savings the government could expect by lowering risk. These factors must be considered in a business case analysis, which evaluates the total cost of the various support options. Two related strategies for sharing risk are Performance Based Logistics and the use of warranties.

Performance-Based Logistics

PBL is the preferred support strategy for new weapons. DoD policy requires

> When the DoD components are selected as the preferred source of supply for a new major system, they shall integrate provisioning requirements and activities with the system acquisition process through PBL agreements with the Program Manager.[34]

The philosophy behind PBLs is for the government to contractually specify the desired performance outcome and let the service provider, usually a contractor, determine how best to achieve that outcome. For example, a contractor might achieve a specified operational availability goal by designing for greater reliability, by increasing field repair capabilities, by accelerating order and ship times or repair cycle times, or some combination of the above. In theory, a pure PBL program could transfer the entire risk of achieving defined support goals to the contractor, including the risk of buying the wrong initial spares.

In practice, we did not find a single instance in which a PBL transferred the entire risk of spares support to a contractor. In every case reparable spares are required, we found the contracts required the government to procure and own the inventory, even if the contractor recommended the buys and managed the inventory for the government. Various sources provided different reasons for this. Some sources contend the reason is contractual; that any spares procured by the contractor would become government furnished material. Another source indicated the reason is financial; if the contractor owned the inventory, the government would tax its value, making it prohibitively too expensive. At least one contractor understood the risk of buying spares early in a program but was unwilling to assume the risk at a price affordable to the government. Regardless of the reason, PBLs may reduce the need for government inventory, but they do not eliminate it entirely.

The results of PBL contracts have been inconclusive. To determine the overall effects of PBL contracts, we studied the reliability and cost performance of repairable components supported under PBL contracts. We found that reliability increased 10 percent under PBL contracts, but cost increased 12 percent.[35] Clearly, the application of PBLs is not the solution for risk mitigation in every case, but it should be considered.

[34] DoD 4140.1-R, *DoD Supply Chain Management Regulation*, p. 26.

[35] LMI, *Analysis of the Effect Performance Based Logistics Arrangements Have on Reliability and Price*, Keenan K. Hardy and Peter R. Raymond, Report SAN85T2 (revision 1), November 2009.

Warranties

Similar to PBL contracts, equipment warranty contracts give contractors incentive to guarantee a certain level of performance for a predetermined price. Both weapon system programs identified by the Army for this study had 5-year warranties. Similar to PBL contracts, however, both contracts required the government to purchase spares to replace failed units in the field while the unserviceable assets were returned to the contractor's facility for repair and return. Only the repair was covered by the warranties. In effect, from an inventory perspective, there was little difference between the PBL program and Army warranty programs.

SUMMARY

DoD can mitigate supply chain risks by adopting a supply chain risk management approach throughout all lifecycle stages. Current DoD supply policy was revised to adopt a supply chain approach several years ago, but the policy still relies on inventory to mitigate supply chain risks. The policy is silent on supply chain risk management.

Recommendation: Revise DoD supply chain management policy to adopt a supply chain risk management approach to identify and mitigate supply chain risks throughout all lifecycle stages.

SUMMARY OF RECOMMENDATIONS

Table 6-6 provides a summary of LMI's recommendations for each of the item introduction forecasting improvement areas.

Table 6-6. Summary of Recommendations

Improvement area	Recommendation
Statistical models	◆ Task the DoD *Comprehensive Inventory Improvement Plan* team to determine how best to expand the use of a demand weighting methodology that relies on operating hours and numbers of demand to incorporate historical demand data in to initial demand forecasts.
Collaboration	◆ Revise DoD supply chain management policy to prioritize forecast reviews based on the dollar value of the forecasts. ◆ Form a joint working group to revise DoD supply and financial policy to determine the best SSR policy alternative.
Measurement	◆ Consider adopting percent error as a primary metric for evaluating demand forecast accuracy at the item level and dollar-weighting percent error at the aggregate level. ◆ Update DoD stratification policy and processes to clarify terminology and to standardize its interpretation across the DoD.
Demand management	◆ Revise supply chain management policy to adopt a supply chain risk management approach to identify and mitigate supply chain risks throughout all life-cycle stages.

Appendix A
DoD Program to Improve Demand Forecasting

In June 2009, the Office of the Secretary of Defense initiated a program to improve demand forecasting throughout the lifecycle of secondary items managed by the military services and the Defense Logistics Agency (DLA). The program responds to the following:

- Accurate forecasts result in effective and efficient inventories while inaccurate forecasts result in inventory excesses and shortfalls.
- Beginning in 2002, wartime operations caused an increase in demand for materiel. As a result, demand forecasts, inventory requirements levels, and on-hand inventories all increased. The increases in on-hand inventories initially affected both active and inactive stocks. Since then, the department reduced inactive stocks down to pre-war levels; but, in the future, as wartime operations draw down, demand forecasts and inventory requirements levels will likely decrease and active stocks could become inactive stocks that will take time to attrite. By improving forecasting processes now, the department should be better able to deal with the effects of a drawdown and have less active stocks become inactive.
- The military services and DLA have ongoing efforts to modernize their inventory management systems with enterprise resource planning (ERP) software. This software offers opportunities to improve demand forecasting that the department wants to take advantage of as well as challenges to demand forecasting that the department needs to respond to.
- In 2008 and 2009, the Government Accountability Office (GAO) conducted its latest series of audits on inventory excesses and shortages for items managed by the military services and DLA. GAO found the military services and DLA have billions of dollars of spare parts in excess of current requirements that it attributed to a weakness in demand forecasting.

Overview of Demand Forecasting

Forecasting is the process of estimating future demand. A forecast can use quantitative methods, qualitative methods, or a combination of the two,[1] and it can be based on extrinsic (external) or intrinsic (internal) factors. The demand forecast is used to make business decisions, such as quantifying the appropriate amount of

[1] APICS Certified Supply Chain Professional, Learning System Module 2, "Building Competitive Operations Planning and Logistics," Version 2.0, 2009 edition.

materiel to produce, purchase, or hold in inventory to meet the expected customer requirements. A more accurate forecast results in reduced inventory and better customer service, which in the case of the Department of Defense, equates to enhanced readiness.

Demand can be defined as a need for a particular part, component, or end item. This need is seldom the same over time. Rather, demand tends to be variable. The four primary characteristics of demand variability are as follows:[2]

- *Cyclical*—long-term upward or downward movement associated with the business cycle
- *Random*—non-predictable change in demand based on chance
- *Seasonal*—demand variability by time of year or season
- *Trend*—steady movement up or down.

Organizations typically use a combination of both informed analysis and mathematical techniques to forecast in an uncertain environment.

According to APICS,[3] there are four basic principles of forecasting:

- Forecasts are (almost) always wrong.
- Forecasts should include an estimate of error.
- Forecasts are more accurate for groups than for single items.
- Forecasts of near-term demand are more accurate than long-term forecasts.

A general tenant of supply chain management is that collaborative forecasts made by multiple activities in the supply chain are an improvement over-forecasts made by individuals or single entities of the supply chain.

Quantitative Forecasting

When historical data is available, quantitative (e.g., formulaic) techniques are the preferred method for forecasting demand. Quantitative forecasting is "an approach to forecasting where historical demand data is used to project future demand."[4] The two types of quantitative techniques are intrinsic and extrinsic.

[2] APICS Certified Supply Chain Professional, Learning System Module 2, "Building Competitive Operations Planning and Logistics," Version 2.0, 2009 edition.

[3] Ibid.

[4] *APICS Dictionary*, 12th edition.

Intrinsic forecasts are based on internal factors, such as demand history. These techniques include a large group of time-series models, including weighted moving average and exponential smoothing. All time series models incorporate an analysis of a data set over an interval of time.

Extrinsic forecasts are based on a correlated leading indicator. For example, a manufacturer may forecast demand for its product line using the number of housing starts or weather patterns. Extrinsic methods are generally used for forecasting overall demand rather than individual products.

Qualitative Forecasting

A qualitative approach may be used either to supplement a quantitative technique or to forecast when historical demand is unavailable. Qualitative forecasting is "an approach to forecasting that is based on intuitive or judgmental evaluation."[5] DoD could use qualitative techniques when data is scarce, not available, or no longer relevant:[6]

- Personal insight forecasts based on intuition of most experienced and knowledgeable person
- Management-level estimates that rely on the consensus of panel members
  - Pyramid forecasts made at the aggregate level and then disaggregated to individual items.
  - Historical analogy forecasts for new items based on a study of past patterns of demand for similar items.

Other common private sector qualitative techniques may not be directly applicable to DoD. Examples include the following:

- Sales-force estimates—forecast reviewed and validated by those that are closest to the customer
- Market research—market analysis, sales analysis, and customer research
- Delphi method—structured method of panel forecasting to keep individual forecasts anonymous.

[5] Ibid.

[6] Op. cit., APICS Module 2, 2009 edition.

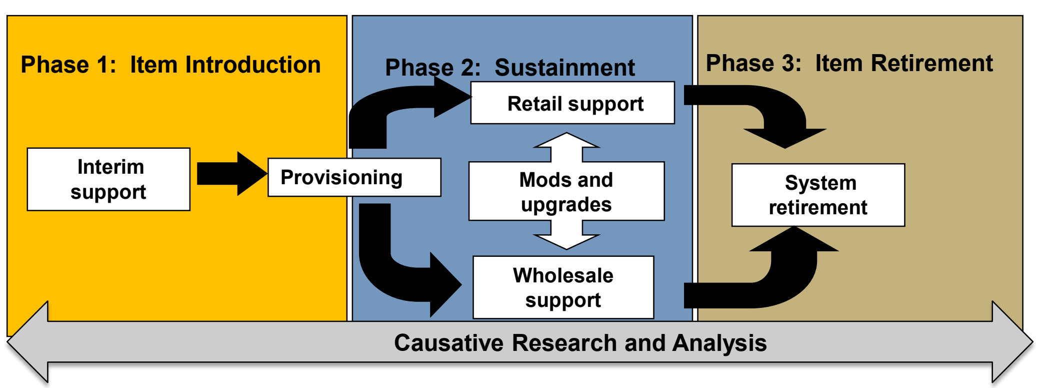
Demand Forecasting over the Lifecycle of an Item

The challenges faced by DoD in forecasting materiel demand change over the lifecycle of a weapon system and the lifecycle of the items that support the weapon system. Consequently, the department tailors its forecasting approaches based on the unique challenges at the three primary stages of an item's lifecycle:

- *New item introduction*. When an item is first introduced, no actual demand data exists for building a demand forecast, even when its weapon system application is fairly well defined. The range of available forecasting models is very limited. Opportunities to collaborate with customers and suppliers to improve forecast data are minimal.
- *Sustainment*. After an item is in the system for some time, actual demand data is available for forecasting, but an item's application may be clouded by modifications and upgrades. A full range of forecasting models is available, but dynamic operations require the use of filters to deal with non-recurring outliers. Opportunities to collaborate with customers and suppliers are more plentiful.
- *End of life*. When an item is leaving the system, actual demand data is no longer representative of future demand, and uncertainty of the application may make it difficult to determine exactly when it will no longer be needed. Forecasts from models must be constrained to account for the declining demand. Customer and supplier collaboration opportunities remain but may be declining.

Figure A-1 depicts the three lifecycle phases relative to DoD's approaches to forecasting.

Figure A-1. Forecasting across an Item's Lifecycle Stage



This report addresses initial forecasting for item introductions only (i.e., Phase 1 interim support and provisioning).

Appendix B
GAO Findings

From 2007 to 2009, the Government Accountability Office (GAO) conducted a series of inventory audits on items managed by the military services to determine the extent to which on-hand and on-order secondary inventories support current requirements.

GAO's Findings on Excess

In each of the inventory audit on items managed by the military services, GAO found significantly more secondary inventory than was needed to support current requirements. Specific GAO findings are outlined below for each military service.

Army

While analyzing FY2004 to FY2007 stratification data for the Army's Aviation and Missile Command (AMCOM) and Tank-automotive and Armaments Command (TACOM),[1] GAO characterized inventory exceeding current requirements when existing inventory levels were greater than the requirements objective based on the opening position table of stratification data. GAO found an annual average of about $3.6 billion (22 percent of total value) in inventory exceeding current requirements.[2] It found 30,222 (39 percent) of the Army's 77,869 unique items to have parts in excess of current requirements for fiscal year 2007.[3]

Navy

While analyzing FY2004 to FY2007 stratification data for Navy secondary items, GAO characterized inventory exceeding current requirements when inventory levels were greater than the requirements objective based on the opening position table. GAO found an annual average of about $7.5 billion (40 percent of total value) in inventory exceeding current requirements.[4] It found 121,380 (65 percent) of the Navy's 186,465 unique items to have parts in excess of current requirements.[5]

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[1] GAO did not include the Army's Communication and Electrons Command (CECOM) in its analysis because item-specific data was not available.

[2] GAO, *Defense Inventory: Army Needs to Evaluate Impact of Recent Actions to Improve Demand Forecasts for Spare Parts*, GAO-09-199, January 2009, p. 4.

[3] GAO-09-199, p. 29.

[4] GAO, *Defense Inventory: Management Actions Needed to Improve the Cost Efficiency of the Navy's Spare Parts Inventory*, GAO-09-103, December 2008, p. 9.

[5] GAO-09-103, p. 10.

Air Force

While analyzing FY2002 to FY2005 stratification data for Air Force secondary items, GAO characterized unneeded on-hand inventory when inventory levels were greater than requirements for war reserves, stock due-outs, safety levels, numeric stock objective, and repair cycle based on the opening position table. GAO characterized unneeded on-order inventory when inventory levels were greater than on-hand requirements and administrative and production lead time requirements. GAO found an annual average of about $20 billion (64 percent of total value) in inventory not needed to support on-hand or on-order requirements.[6] It found 89,637 (66 percent) of the Air Force's 135,170 unique items to have parts in excess of current requirements.[7]

GAO'S FINDINGS ON SHORTFALLS

In each of the military service inventory audits, GAO found substantial inventory shortfalls for some items. Specific GAO findings are outlined below for each military service.

Army

While analyzing AMCOM and TACOM secondary inventory for FY2004 to FY2007, GAO identified items as having an inventory shortfall when the amount of on-hand and on-order inventory fell below the baseline established in the requirements objective. GAO found an annual average of about $3.5 billion in inventory shortfalls.[8] GAO found 14,485 (19 percent) of AMCOM and TACOM's unique items to have inventory shortfalls in FY2007.[9] During GAO's audit, Army officials pointed out that, even though inventory levels may fall below requirements, managers are often able to use parts designated for safety-level requirements with little or no operational impact.[10]

Navy

While analyzing Navy secondary inventory for FY2004 to FY2007, GAO identified items as having an inventory shortfall when the amount of on-hand inventory fell below the reorder point threshold. GAO found an annual average of about $570 million in inventory shortfalls, which represented about 7 percent of the Navy's annual reorder point requirement.[11] GAO found an annual average of about 15,000 (8 percent) of the Navy's unique items to have inventory

[6] GAO, *Defense Inventory: Opportunities Exist to Save Billions by Reducing Air Force's Unneeded Spare Parts Inventory*, GAO-07-232, April 2007, pp. 10 and 12.

[7] GAO-07-232, pp. 11 and 13.

[8] GAO-09-199, p. 4.

[9] GAO-09-199, p. 30.

[10] GAO-09-199, p. 14.

[11] GAO-09-103, p. 4.

shortfalls.[12] While commenting on a draft of GAO's report, the Navy stated that some of the shortfall items will not be procured because they are obsolete or have been replaced by other items.[13]

Air Force

While analyzing Air Force secondary inventory for FY2002 to FY2005, GAO identified items as having an inventory shortfall when there was not enough inventory to meet on-hand and on-order requirements for war reserves, stock due-outs, safety levels, numeric stockage objective, repair cycle, and administrative and production lead time. GAO found an annual average of about $1.2 billion (8 percent of total value) in inventory shortfalls.[14] GAO found an annual average of about 7,866 (6 percent) of the Air Force's unique items to have inventory shortfalls in FY2005.[15] During GAO's audit, among the reasons identified by Air Force officials for inventory shortfalls were increases in demand, plans to upgrade systems, plans to replace items, and lost or delayed repair capability.[16]

[12] GAO-09-103, p. 16.
[13] GAO-09-103, p. 16.
[14] GAO-07-232, p. 5.
[15] GAO-07-232, p. 3.
[16] GAO-07-232, p. 5.

Appendix C
Army Provisioning Process

The Army's provisioning process is managed within the framework of the acquisition and integrated logistics support (ILS) management processes. The acquisition process provides the framework in which Army materiel systems are initiated, validated, developed, fielded, supported, modified, and retired from use. To accomplish the desired results, the acquisition process considers the life of a weapon system or end item as evolving from a concept to the eventual obsolescence within the context of five distinct phases:

- Concept exploration and definition (CE&D)
- Demonstration and validation (D&V)
- Engineering and Manufacturing Development
- Production and deployment (PD)
- Operation and support (O&S).

Within each phase, the roles of Office of the Secretary of the Army (OSA), Headquarters, Department of the Army (HQDA), the operational tester, the combat developer (CBTDEV), the materiel developer (MATDEV), the trainer, and the logistician are defined. In addition, the research, development, test and evaluation (RDTE) program, and the hardware configuration are also defined.

In this appendix, we describe the policies, procedures, and systems currently used by the Army to perform provisioning of new or modified end items. This discussion begins with the overall provisioning process as defined in Army regulations. It continues with the various types of provisioning allowed by this regulation. Figure C-1 provides an overview of how provisioning interacts with the acquisition cycle during the production phase of the end item. Figure C-2 and Figure C-3 provide additional details of this process.

This appendix provides information about Phoenix and SMART-T, the two systems used at the Communication-Electronic Life Cycle Management Command (LCMC). This appendix also provide information and data on the overall Army provisioning process based on stratification item and summary data available to LMI.

DEFINITION OF PROVISIONING

The Army defines provisioning as a management process for determining and acquiring the range and quantity of support items necessary to operate and maintain an end item of materiel for an initial period of service. The specific types of provisioning are

- initial provisioning (first-time provisioning of a new end item),
- follow on provisioning (subsequent provisioning of the same end item from the same contractor), and
- reprovisioning (subsequent provisioning of the same end item from a different contractor.

Figure C-1 through Figure C-3 provides sample overviews of the provisioning process at various stages of the end item production cycle.

Figure C-1. Army's Provisioning Cycle—Production Phase

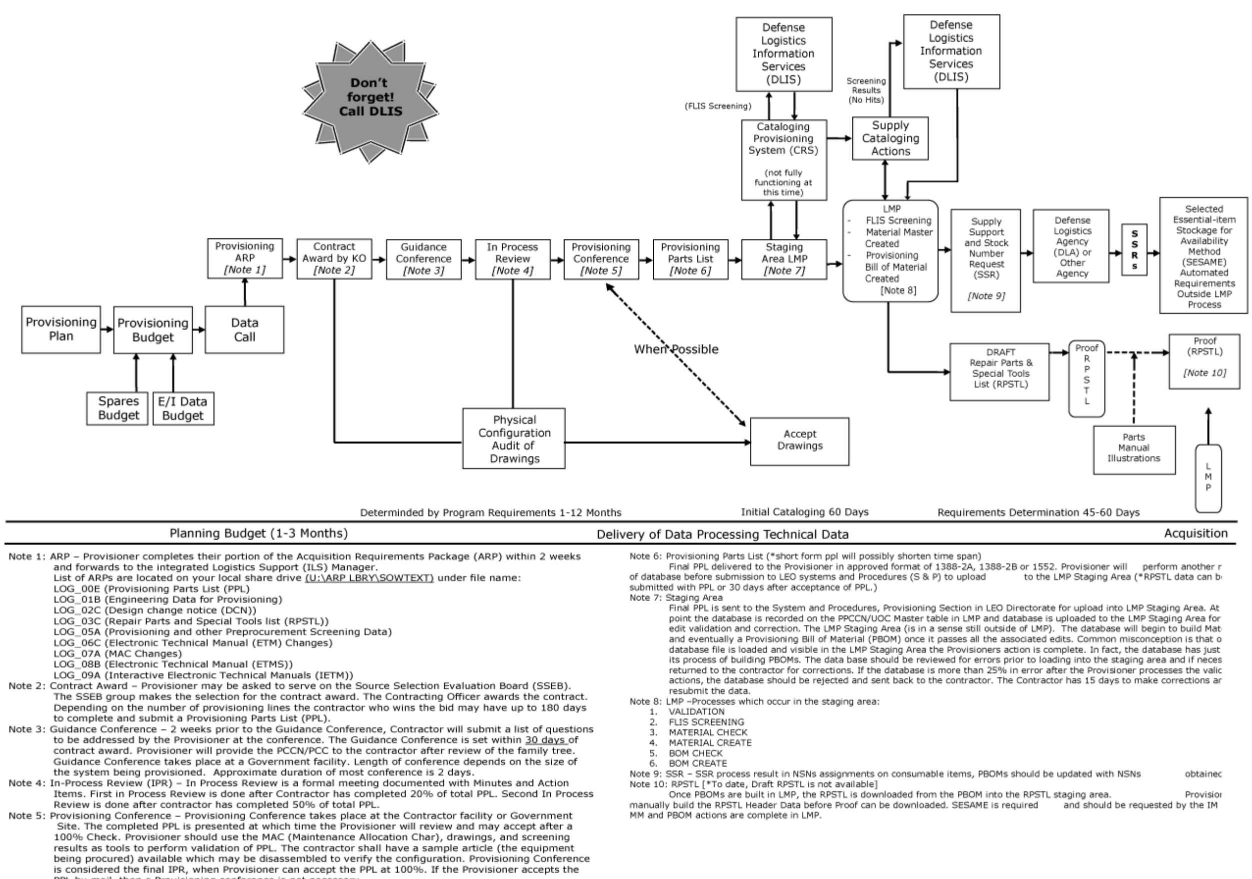


Figure C-2. Army's Sample Provisioning Cycle

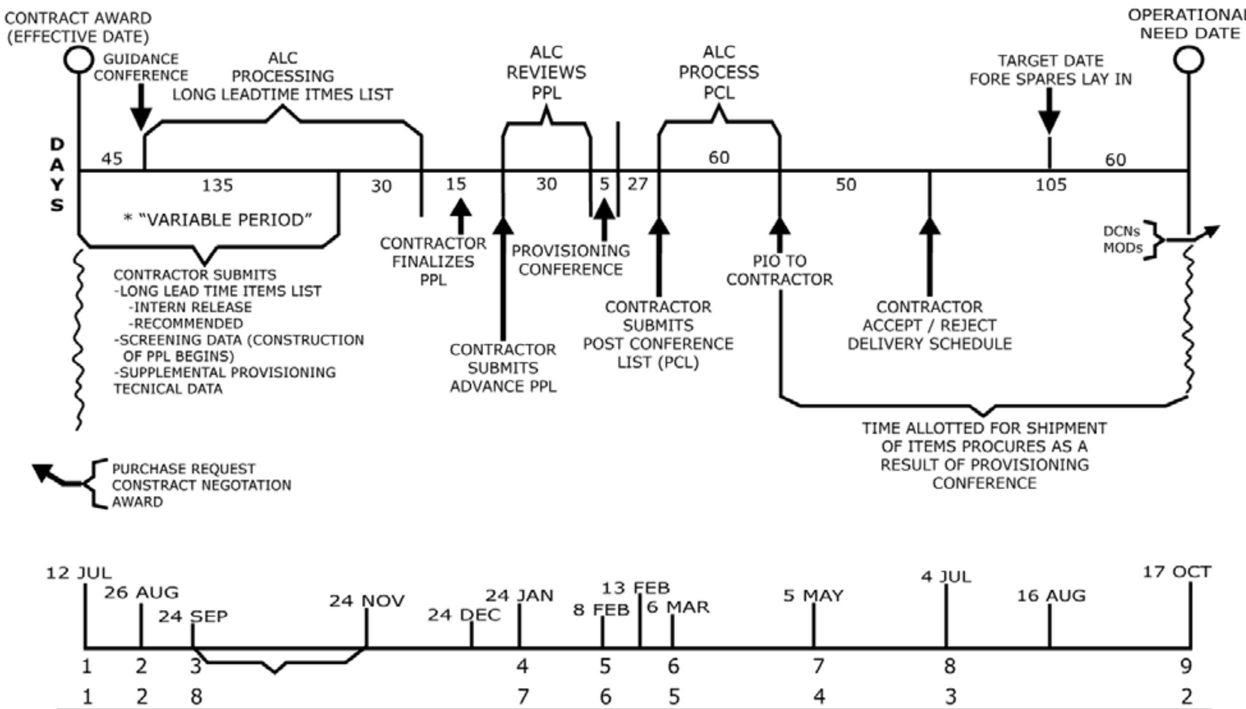
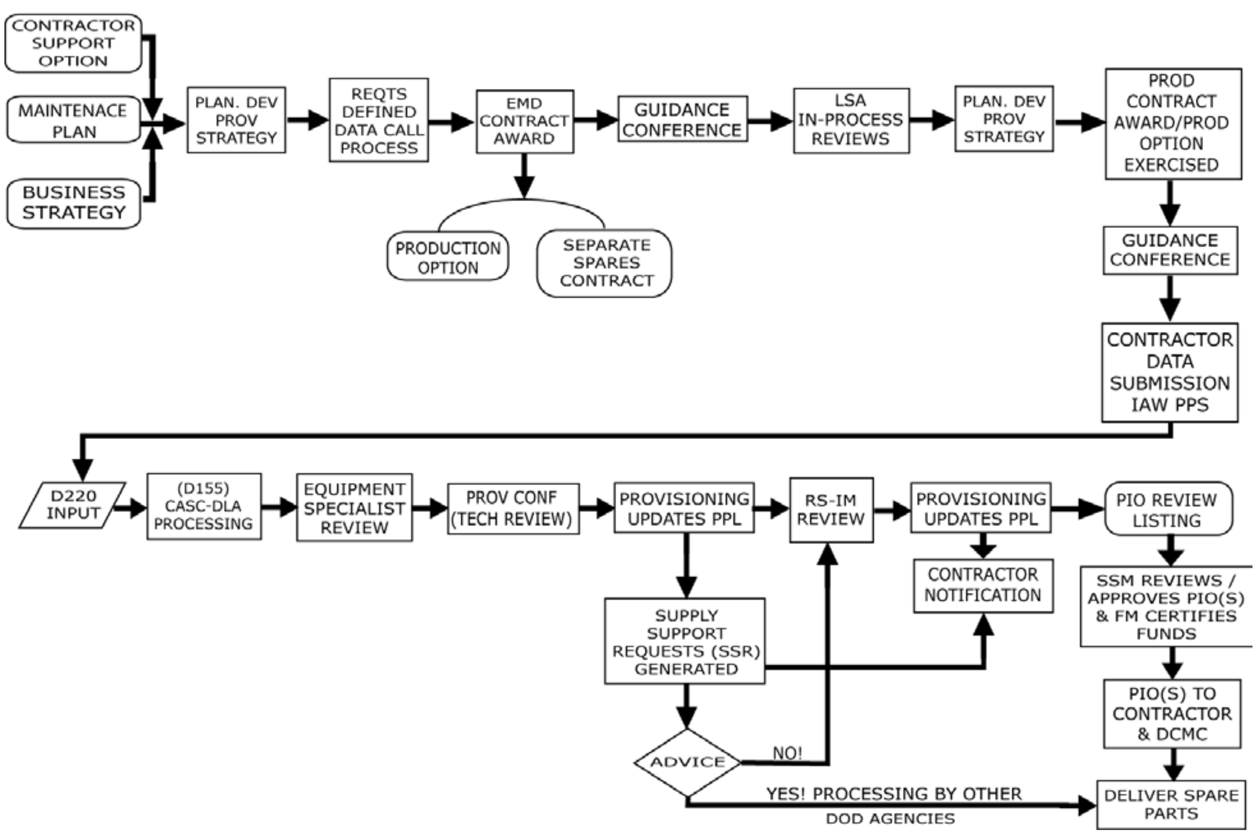


Figure C-3. Provisioning Process Flow



TYPES OF ARMY LOGISTICS SUPPORT

The Army recognizes three types of logistics support:

- *Interim contract support* (ICS), in which commercial support resources are used in lieu of organic capability for a predetermined amount of time (goal is not to exceed 3 years). This includes the use of contractor support for initial fielding. Funds for ICS are provided by the procurement appropriations.
- *Life cycle contract support* (LCCS), which is a method of providing all or part of a system's logistics support by contract with the intention of continuing this support throughout the lifecycle of the end item. The LCCS differs from ICS in that it is a support concept rather than an acquisition technique. LCCS is paid for with operation and maintenance, Army funds.
- *Organic support*, which is a method of providing all of an end item logistics support using in- house resources.

POLICY GUIDANCE

The following are the key policy guidance for the Army's provisioning processes:

- Army Regulation 700-18, *Provisioning of U.S. Army Equipment*, September 20, 2009, provides the guidance for the Army provisioning process.
- AR 710-1, *Centralized Inventory Management of Army Supply System*, September 20, 2007. Chapter 4 of this regulation outlines the requirements computation methodologies used in determining spares and repair parts requirements.
- AR 700-142, *Type Classification, Materiel Release, Fielding and Transfer*, March 28, 2008, assigns responsibilities and prescribes policies for the Army's type classification (TC), materiel release (MR), materiel fielding, and materiel transfer processes. The TC process ensures the materiel is acceptable for Army use prior to spending of procurement funds at the full rate production (FRP) decision review.

Provisioning specifically applies to the following:

- Weapon systems and end items acquired for Army use for which any maintenance service, repair, or overhaul is anticipated. These include
  - systems and end items for which the Army is the lead service or DoD's integrated manager on multiple-service acquisition of materiel;
  - developmental, non-developmental, and product-improved Army materiel systems and equipment, to include standalone or embedded

automatic data processing equipment (both hardware and software) and all support ancillary and associated equipment comprising the total materiel system;

- training devices that are maintained by an organic maintenance capability; and

- medical material developed and procured by the Surgeon General (TSG).

TYPES OF ARMY PROVISIONING

Within the Army, provisioning of end items support can be accomplished using one of the following techniques:

- *Phased provisioning*. A selective management technique associated with the provisioning process. This technique process allows the Army to delay procurement of the total computed provisioning requirement for spares and/or repair parts until the provisioning activity can more reliably predict the requirement. Phased provisioning does not provide a means to develop an Army inventory, but it is an interim measure to replace parts or assemblies that fail during the production contract period. The utilization of phased provisioning allows deferment of the procurement of all or part of a normal initial computed requirement for selected spare and or repair parts pending the following:

  - Stabilization of design

  - Development of firm operational and maintenance plans and deployment programs

  - Application of in-service experience and test data to the computation of requirements for these items. This deferral of quantity identification of the selected items until the later stages of production of the system, or of the end item to be supported, enhances the ability of the provisioning activity to predict requirements for the selected items more reliably.

- *Incremental provisioning*. A management technique associated with the provisioning process that allows completion of provisioning on portions of the end item without waiting for complete design stability. The utilization of incremental provisioning enables the identification and acquisition of assemblies and subassemblies without waiting for total end item stability and provides the following management enhancements:

  - Reduces reliance on ICS for accelerated acquisition or non-developmental items (NDI) programs.

  - Reduces surges in workload in the provisioning of the end item.

- Develops the in-house logistic support earlier by phasing delivery of logistics support analysis (LSA) data rather than waiting for design stability before initiating provisioning action.

- *Stratified provisioning*. A management technique associated with the provisioning process that allows the identification and procurement of logistic support for unit and direct support (DS) parts and defers procurement of general support (GS) and depot parts. Where there is no planned DS, selected GS parts may be procured in sufficient quantity to ensure sustainability. Stratified provisioning provides a capability to concentrate resources on development of logistic support at the most critical level and defers action on levels that least affects initial readiness.

  Planning for deferment of depot, or GS and depot support, requires detailed attention to the quantities of parts needed at lower levels. Sufficient stock must be fielded to allow for utilization of ICS. Deferment of depot or depot and GS parts provisioning will provide the capability to provision these levels with more mature data. All interim contractor parts consumption data are procured and delivered in a useable format to the provisioning activity for augmenting contractor estimates and to update the database.

- *Spares acquisition integrated with production* (SAIP). Used to combine procurement of selected spares with procurement of identical items produced for installation on the primary system, subsystem, or equipment when the result will be a reduction of total cost.

ROLES AND RESPONSIBILITIES OF KEY PLAYERS

The Deputy Chief of Staff, G–4, has Army General Staff responsibility for provisioning, and assigns responsibilities and monitors implementations of Army provisioning training.

The TSG is responsible for overall management of an Army-wide health services system, to include lifecycle management of medical material. Specific management responsibilities related to provisioning include planning, programming, and acquiring material in support of all TSG-managed items.

Army project, program, and product managers (PMs) and total life cycle system managers (TLCSMs) are responsible for the development and fielding of Army weapon systems and end items. PMs matrix with U.S. Army Materiel Command (AMC) supply support and ensure provisioning personnel and inventory managers are functional members of the weapon system integrated product team (IPT) and coordinate the provisioning requirements.

Additional roles and responsibilities are outlined in the Army Regulations cited in the Policy Guidance section of this appendix.

PROVISIONING PLANNING

Within the Army, two principal documents, the *Integrated Logistics Support Plan* (ILSP) and the *Provisioning Plan* (PP), are required to plan and coordinate the activities involved in provisioning:

- The ILSP is a planning and coordinating document that identifies the integrated logistics support requirements. The ILS process requires that an ILSP be developed and that it be the foundation upon which provisioning and programming are developed. To ensure integration of all logistics elements, the ILSP includes a summary of the *Provisioning Plan*.

- The PP is the planning and management document identifying provisioning actions and responsibilities. Provisioning is incorporated into the acquisition process and the ILS process through a series of lifecycle events associated with the requirement to provide support to an end item, to have adequate support items available when the end item is initially deployed, and to provide the basis for maintaining adequate support throughout the lifecycle of the end item.

Provisioning planning includes early identification, scheduling, communication, and control of all provisioning tasks. Such planning is essential to effective development and execution of a responsible, cost-effective provisioning program.

SUPPORT FOR COMMERCIAL EQUIPMENT

Army plans logistic support items for commercial equipment as follows:

- Commercial supply support and servicing capabilities are used for commercial end items, but consideration is also given to combat readiness, combat effectiveness, and worldwide supportability. In any case, organic support is planned when the equipment is envisioned to have a wartime maintenance support mission forward of the corps' rear boundary.

- Commercially available end items or end items acquired in small quantities (10 or fewer) may not be provisioned without first validating a need for on-hand inventories of support items.

All interim contractor support or contractor logistics support efforts contractually mandate that participating contractors collect and provide to the government specified logistics data in the prescribed format to enter current and future (approved) automated logistics operating systems, and that logistics data provided will be readily acceptable to Army system processes without adjustments, refinements, or conversion processes.

Provisioning Performance Schedule

A provisioning performance schedule (PPS) is prepared to guide program monitoring. The provisioning milestones are included in the ILS milestone schedule in the ILSP. Provisioning milestones for those systems and items that must be reported through Acquisition Management Milestone System (AMMS) are summarized in therein. The schedule may be included with the solicitation or initiated at the guidance conference.

Provisioning Review and Evaluation

The Army provides a number of techniques to assist in the review and evaluation of provisioning decisions:

- The logistics support analysis record (LSAR) serves as source data to the provisioning process. Participation in the LSA review allows the provisioning activity to become involved early on in the review of this data.
- During the maintenance evaluation program, the maintenance engineering organization will schedule and make arrangements for the availability of materiel for use in analysis and verification of support items, test measurement and diagnostic equipment (TMDE), tool kits, and special or common tool selection decisions.
- Organizational spare or repair parts lists, tool lists, lubrication orders, and sections I–IV of the maintenance allocation chart (MAC) are part of the preliminary draft equipment publications (PDEP) and are evaluated during unit test. The test provides an initial determination of whether below depot maintenance level can be adequately accomplished with the selected support items.

When selecting secondary items to support tests, the appropriate provisioning requirement model should be utilized, if adequate data is available. This procedure should provide a preview of the supply support that the field will receive when the system is deployed.

Post-Provisioning Review

A review of the adequacy and validity of provisioning determinations is accomplished on all systems for which the sparing to availability (STA) concept is employed. The purpose of the review is to improve the sustainability of newly fielded equipment through review, analysis, evaluation, and correction of logistics data, thereby improving follow-on support. The PPR planning is initiated during the low rate initial production (LRIP) and engineering and manufacturing phase of the lifecycle, concurrent with the update of the PP, and is documented in the appropriate section of the PP. For NDIs, PPR planning is initiated at the time the contractual provisioning requirements are prepared. All provisioning evaluation programs include a routine feedback or review of logistics data through the normal logistics reporting channels.

PROVISIONING METHODOLOGIES

Contractor logistics support (CLS) may be performed as planned interim contract support or as planned life cycle contract support. ICS is the use of commercial support resources in lieu of organic capability for a predetermined amount of time (goal is not to exceed 3 years). This includes the use of contractor support for initial fielding.

The Army acquires ICS when it is cost effective and when such coverage can be tailored to meet the intended conditions of use in geographical locations and storage requirements of the end item. Army combat developers identify desired performance characteristics which are measurable as part of a system performance-based logistics (PBL) strategy. These performance characteristics should include desired levels of CLS integration to be addressed as part of a PBL business case analysis.

The decision to use ICS is based on analyses of tradeoffs of alternative support concepts that are performed as part of the early development or support system analysis process. These support analyses must show that ICS is the optimum strategy among feasible alternatives. ICS is considered when desired military support capability cannot be fully provided by first unit equipped date because of time or acquisition program constraints. ICS is used only for the length of time specified in the supportability strategy.

Plans and justification for ICS are identified, fully documented in the supportability strategy and the decision memorandum, and coordinated before milestone B. When program issues or constraints requiring the use of ICS arise after milestone B, the ILS managers obtains the necessary documentation and coordinates required actions as soon as possible. All plans for ICS must be completed before the milestone C production decision to allow for necessary budgetary lead times. ICS planning include plans and milestones for transition to organic support, where applicable; contingency plans for operation in a hostile environment; and administration and funding procedures. The transition plans/milestones are documented in the supportability strategy.

Army combat and materiel developers are required to minimize the burden and sustainment complexity, as well as the sustainment footprint, for unit or field maintenance organizations by limiting the use of contractors for maintenance of field equipment that can be maintained by soldiers. Ease of supportability in the field environment must be paramount.

The ICS contract will identify minimum data to be provided to the government by the contractor (such as defective or nonconforming parts, task frequency, parts usage, and repair times at each maintenance level, mean units between maintenance events, engineering changes, and skills/training needed). The ICS contract must also establish measurement criteria and include provisions to monitor contractor activities to ensure compliance.

Provisioning Screening and Support Item Selection and Coding

The Army requires that reference numbers for all support items, recommended or being considered for procurement, be screened against data elements maintained in the Defense Logistics Information System (DLIS) files prior to the formal provisioning conference. The contractor may conduct the provisioning screening; however, this screening must include requirements for the DoD Replenishment Parts Breakout Program and the selection of support items. The total life cycle system manager, who is assigned prime responsibility for the provisioning of the end item or system, has overall responsibility—in coordination with the item manager, maintenance engineer, provisioning personnel, and other functional area support personnel—for the final determination of the range and quantity of support items required to support the end item or system.

This responsibility may be delegated to another Army agency or DoD component by written mutual consent, but such delegation is not made to a contractor; however, this does not preclude requesting contractor recommendations on the range and quantity of support items required for support of an end item or system (as part of the Provisioning Technical Documentation). The final range and quantity determination must be based on a thorough review of the data submitted by the contractor.

Determining Maintenance Replacement Rates

The Army supportability analysis provides for three maintenance replacement rates (MRRs) to be determined and defined. MRRs are assigned during the support item selection process. For multiple-service end items or systems, and for end items or systems that requiring provisioning support from more than one Army activity, the assignment of support item MRRs is coordinated among the commands and agencies.

Demand Forecasting and Requirements Computation

Requirements for secondary item spares and repair parts begin with initial provisioning and are based on clearly defined weapon system or end item readiness objectives. Secondary items are grouped two ways for determining requirements. Items are either acquired before demands are received (stocked items) or only on demand (non-stocked). Historical demand data is retained for at least six years, with the latest two years' history as an active database to compute the demand forecast.

A demand base period, the length of which may vary from a standard of 24 months by command, weapon system and individual item, is used to determine the average monthly demand (AMD) using past demand history.

For new end items, initial and replenishment forecast of demands are determined using the readiness based sparing (RBS) model Selected Essential Item Stockage for Availability Method (SESAME). Forecast of demands are computed to achieve an operational availability (Ao) for the end item. The initial and replenishment demand forecasts from SESAME are used as a part of the demand forecast for an NSN in determining what to stock and when to stock. For new items for which demand data is not available, maintenance replacement rates are used. Mission essential items have a minimum stockage level of one.

Demand forecasts may vary based on a program change factor, which are changes to program data (in-use end item density, flying hours, operating hours, rounds fired, etc.). The program change factor is a ratio of future program data over a period up to the next 5 years divided by past program data, usually for 2 years.

Using program data to compute the program change factor depends on identifying a repair part with each application and maintaining program data for each application. Use of program data allows orderly increases in forecast demands for items with increasing use. It also allows orderly decreases in forecast demands for items being phased out of the DoD supply systems.

Initial Issue Stockage at Retail Levels

A support list allowance computation (SLAC) is used to determine the initial retail stockage required to support end item or weapon system fielding. SESAME is used to compute SLAC. The initial requisitioning objective (RO), that is, the initial issue stockage quantity, is based on the following:

- An order and ship time (OST) quantity based on the Department of Army-(DA) established parameters direct support system (DSS) or air line of communication (ALOC) OST objectives for issue priority designator (IPD) 09–15 requisitions, or the most recent actual 6-month moving average OST for IPD 09-15 requisitions without backorders.
- An initial operating level (IOL) quantity of one. Operating level (OL) days authorized for retail days of supply (DOS) computation will be used in the computation of IOL quantity. If the computed IOL quantity exceeds one, it will be reduced to one.
- A below-depot-level repair cycle quantity for reparables.

Low density, high reliability systems may require that the integrated materiel manager (IMM) establish stock levels for the life of the systems. The sparing to availability (STA) method is used to compute and update these recommended stockage lists, as required.

DEPOT-LEVEL REPAIR

Initial-issue allowance quantities for continental United States (CONUS) depot-level spares are provided in those cases where spares can be anticipated to undergo repair (depot overhaul or rebuild) during the Demand Development Period (DDP). Such anticipated repairs are shown as a special requirement in provisioning determinations and in the requirements determination process.

During the DDP, contractor facilities are used, when possible, for the repair of high dollar-value spares. This precludes the premature or uneconomical establishment of an organic capability; however, demand data is captured and provided to the materiel developer (MATDEV).

BUDGETING AND FUNDING FOR PROVISIONING

Funds required to provision a system or end item are identified during the demand development period. Provisioned items are identified with the materiel category (MATCAT) code associated with the provisioning process. When a spare or repair part experiences adequate actual demands, it is passed from provisioning to replenishment and is assigned the replenishment MATCAT code of 1 for reparable and 2 for consumables. Items that migrate from provisioning to replenishment will be reviewed to ensure that requirements are not duplicated in both provisioning and replenishment budget submissions. All funded acquisition and obligations are outlined in the *Provisioning Plan*.

The PP also outlines the funding responsibilities of the acquisition manager and each major subordinate command. The agreement includes such items as

- associated funding, training, or training devices;
- special tools;
- RDT&E or stock funding, system support packages (SSP);
- basic issue items (BII);
- additional authorization list (AAL);
- component of end item (COEI);
- temporary duty (TDY) travel to provisioning meetings and conferences;

- prescreening and screening functions; and
- data calls.

The acquisition manager also establishes funding Points of Contact (POCs) within the acquisition arena. Budget submissions are based on individual line item computations using the approved mathematical model. The use of the model for forecasting support items and associated funding is approved by HQDA. Forecasting must be aligned to support the stated system Ao within the requirements document. If the requirements document does not contain a stated system Ao, the requirements are computed to support an equipment status level of ready.

All requirements computed for secondary item on-site reviews for budget and program objective memorandum (POM) submissions must state the Ao that they are supporting. If minimum necessary provisioning data are not available to make complete line item computations, the following procedures are used to present the most accurate budget request possible:

- A budget based on similar equipment that was previously provisioned may be used if an appropriate inflation factor is applied.
- Procurement lead times and repair cycle times are established based on the latest available information.

If sufficient time is not available to prepare budget requests using the above methods, gross budget estimates for secondary items are developed using an average percentage factor. This factor is obtained by using data from a similar fielded weapon system.

Provisioning budgets are revised during subsequent budget reviews as better provisioning data become available. Commands may adjust provisioning requirements when firm guidance is received from HQDA or HQ AMC that changes the major item deployment program. These adjustments may be made without waiting for official POM adjustment.

The materiel developer ensures the following minimum data are available and used in the provisioning budget submission:

- Mission need statement (MNS) concept
- Supply and maintenance concept
- Washout rate (end item and major components).

SECONDARY ITEM STRATIFICATION

All secondary items with a NSN or a management control number are included in the secondary item stratification process. The stratification process is a uniform portrayal of requirements priorities and asset application that is a computer-generated, time-phased simulation of actions causing changes in the supply position (e.g., procurement, repair, receipt, issue, terminations, and disposal of materiel).

METRICS

In the Army legacy system, an intensity factor is computed for each newly provisioning item. The intensity factor is a ratio that measures the difference between the demands forecasted by the use of the item maintenance replacement rate and the actual demands recorded in the historical demand file for the same period. The intensity factor is provided to give the inventory manager an idea of the accuracy of the maintenance replacement rate used to compute the initial demands; however, the Army does not routinely monitor or report this information elsewhere. The Army does calculate and report standard supply availability, backorder, and not-mission capable rates.

DATA ANALYSIS

This section documents the data analysis conducted as part of the study. We start with the analysis performed on the data from two weapon systems provided to us by the Army. Next, we discuss the analysis performed on the stratification files, which we used to supplement that data provided on the two weapon systems.

Army Weapon Systems

The Army selected two weapon systems for study analysis: the SMART-T and Phoenix Systems. Both systems are managed by CECOM and they are described below.

While CECOM was able to provide us with some forecast data for both systems, they were unable to provide actual demand data we could use to evaluate the forecasts for either system. Since 2002, CECOM has accomplished its supply chain management using LMP, the new Army's ERP system. Unlike its predecessor, LMP does not provide inventory managers with actual demand data. Eventually, all Army ICPs will employ LMP, and without changes, the capability to retrieve actual demand data will be lost for all Army items. Due to the lack of actual demand data for the SMART-T and Phoenix, we were unable to evaluate the quality of the forecasts for either weapon system.

SMART-T (AN/TSC-154)

The SMART-T is part of the multiple-service, Military Satellite Communications (MILSATCOM) program for satellite communication systems consisting of satellite (procured by the Air Force) and terminals. The SMART-T meets the requirements for data/voice communications system and provides secure, mobile, worldwide, anti-jam, reliable, low probability of intercept, tactical communications, not subject to terrain masking or distance limitations. The terminal, mounted on a high mobility multi-purpose wheeled vehicle (HMMWV), provides a range extension capability to the Army's mobile subscriber equipment (MSE).

SMART-T is Level I–managed by Program Manager (PM) Warfighter Information Network-Tactical (WIN-T). The fielded systems came out of warranty in FY2007, and the Logistics Readiness Center (LRC) mission became to supply support to the warfighter through spares and repair parts as required.

The advanced extremely high frequency (AEHF) SMART-T will be fielded in FY2010 with a 2-year warranty period. There are 550 provisioning line item stock numbers (PLISNs). Users consist of the Air Force, Army, Marine Corps, Navy, and the White House Communication Agency (WHCA). Customers obtain field-level spares by submitting funded requisitions. Unserviceable items are returned to Tobyhanna Army Depot for repair.

The system has undergone a PBL review of the spares procurement and national maintenance contracts. PM WIN-T has agreed to do a management analysis of the system instead of a full-blown PBL and is currently preparing Justification and Approval and reviewing Acquisition Plan for extension of the LRC Procurement and Maintenance Contracts to 2014.

THE PHOENIX (AN/TSC-156A/B/C/D)

The Phoenix is an HQDA-directed procurement based on an approved operational need statement (ONS)–accelerated program. The Phoenix system consists of one primary vehicle (contains tri-band or quad-band system electronics) and one mobile power unit (MPU) support vehicle. The primary vehicle also supports satellite communication using an external Lightweight High Gain X-Band Antenna (LHGXA) (unit provided). Both vehicles can tow a 4,200 pound trailer. It is intended to meet a wide range of requirements, not a specific unit/user.

The contractor was required to perform the provisioning tasks and provide data support to the program and the system/equipment furnished under the contract. The contractor prepared a provisioning plan, performed DLIS prescreening for all reference numbers appearing on all applicable provisioning technical documentation parts lists. Data elements obtained as result of valid NSN matches through DLIS screening were inserted into the provisioning technical documentation (PTD) for review by government personnel at each interim program review. A total of 150 PLISNs were provisioned for the Phoenix.

The AN/TSC-156A/B/C/D is a transportable multi-band, multi-channel Tactical Satellite (TacSat) terminal that operates in the C, X Ku, and Ka bands over commercial and military satellites. It provides high-capacity, inter- and intra-theater range extension. The terminal provides a highly mobile, strategically transportable, wide band communications capability and displaces selected AN/TSC 85/93 terminals at Engineer Special Brigade (ESB) active components and complements the AN/TSC-85/93 Service Life Extension Program (SLEP). There are four models, A, B, C (Marine Corps) and D.

The system was an ONS-based, NDI/commercial off-the-shelf (COTS) development. It is operated by a four-person military occupation specialties (MOS) 25S crew. The contractor is L-3 Communications System. The original contract began in April 2003. Provisioning began in 2004. Since FY2004, 119 Phoenix systems have been fielded.

The system employs a two-level maintenance concept. In the field, MOS 25S, satellite operator/maintainer, performs preventive maintenance checks and services (PMCS), isolates defective line-replaceable units (LRUs), and replaces defective LRUs. The contractor currently provides sustainment-level maintenance, repairing defective LRUs and any maintenance beyond the capability of the field-level maintenance.

The Phoenix components have a 24-month warranty starting at the end of fielding; however, this does not apply to government-furnished equipment, such as trucks, trailers, crypto, Defense Advanced Global Positioning System Receiver (DAGR), CX-11230. L3 repairs and returns failed LRUs under warranty, and L3 provides on-site repair, when necessary. Army units fund the cost of shipping to L3, and L3 funds the cost of shipping to the units.

The supply support concept uses the Standard Army Supply System. The Army is the primary inventory control activity. Sustainment consists of a 5-year indefinite delivery, indefinite quantity contract with L3 Communications for sustainment spares. A 5-year time and materials maintenance contract is in place for repair of components, overhaul of end items, technical assistance, and a field team.

STRATIFICATION ANALYSIS

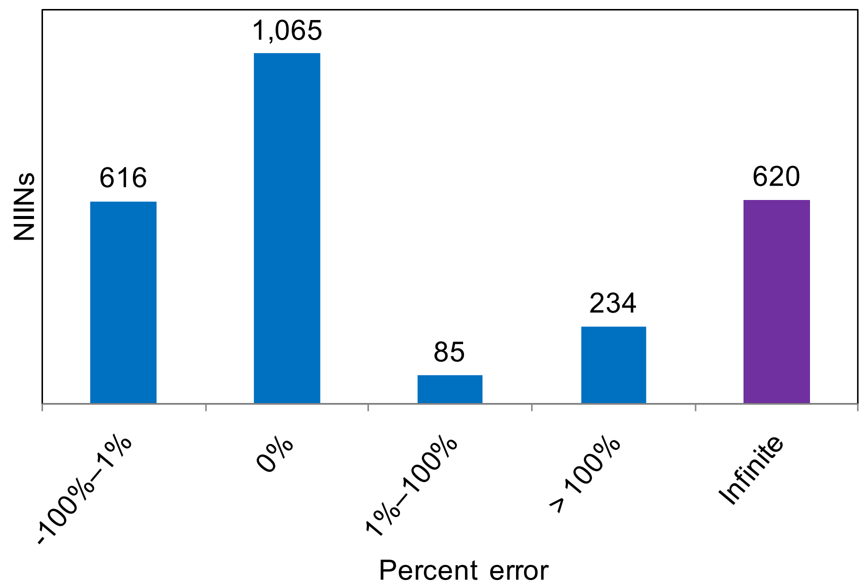
Figure C-4 is a histogram showing the percent error for the 2,620 Army items identified as being in provisioning from the FY2006–FY2007 stratification files.[1] The figure shows that there are 1,065 instances when there is a 0 percent error, meaning the Army forecasted these items correctly. Of these, most are instances in which the Army forecasted zero demand and the actual demand was zero, as well. When only looking from −100% to >100% on the horizontal axis, it appears

[1] The FY2006–FY2007 Army stratification files only include AMCOM and TACOM, so our analysis is limited to these two commands. We also removed all NSO, insurance, and non-stocked items from the sample since the Army does not forecast for these items.

there is a under-forecast bias; however, when we look at the column labeled "infinite" we get a different interpretation.

The "infinite" column displays the number of instances when there was a positive forecast, but no actual demand. Due to mathematical limitations, we cannot compute a mean percent error for these items. Nonetheless, we cannot ignore them either since they were over-forecast. When we look at the entire histogram, including the "infinite" column, we see a total of 939 over-forecasts compared to 636 under-forecasts, suggesting there is a bias toward over-forecasting in the Army.

Figure C-4. Army Stratification Data FY2006–FY2007



Source: AMCOM and TACOM Stratification Data FY2006–2007.

Dollar Value Groups

As stated in AR 701-1,

> Secondary items are managed by dollar-value groupings. Assignments are based on the dollar value of the item's forecasted gross annual demands. Items will be reassigned to a new category when the annual dollar value varies from the previous dollar value forecast grouping by 10 percent or more."[2]

Table C-1 shows the different groups.

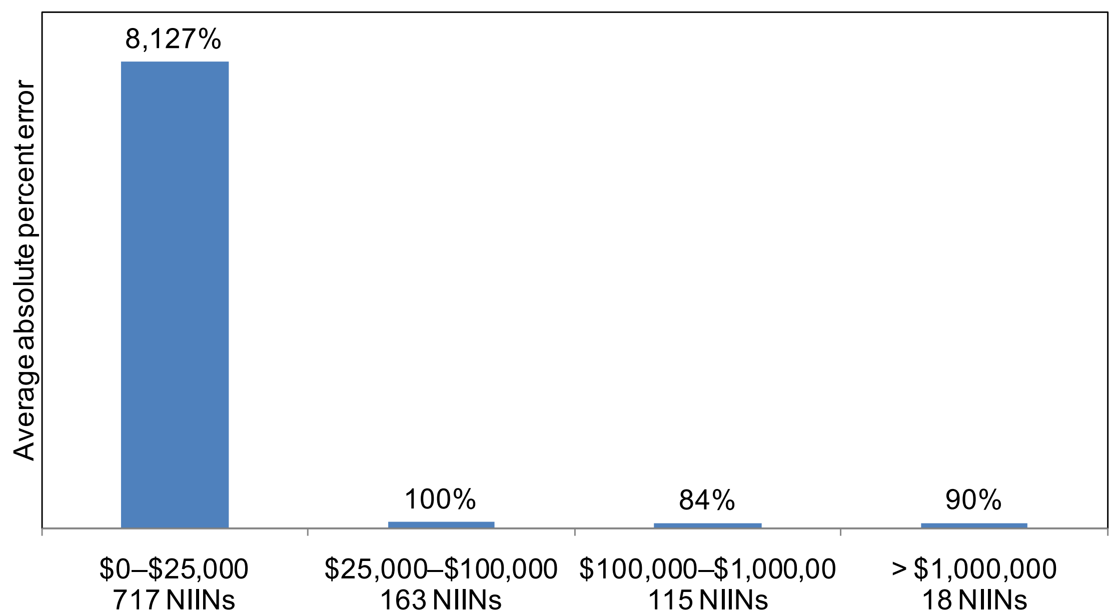
[2] Headquarters Department of the Army, Inventory Management Centralized *Inventory Management of the Army Supply System*, Army Regulation 710-1, Washington D.C., September 20, 2007.

Table C-1. Army Dollar Value Groups

Group	Demand forecast value	Forecast frequency
Low	$0–$25,000	Annual
Medium	$25,000–$100,000	Semi-Annual
High	$100,000–$1,000,000	Quarterly
Very High	> $1,000,000	Monthly

When only considering the instances when the forecast was greater than the actual demand, the percent error decreases as the dollar-value group increases. This is consistent with current Army policy, which requires items in higher dollar-value groups to be forecasted more frequently than those in the lower dollar-value groups. Also, item managers are more likely to scrutinize the engineering estimates and other elements that go into the demand forecast for items with the greatest cost impact. Figure C-5 presents the findings.

Figure C-5. Army Average Percent Error Over-forecast by Dollar Value Group



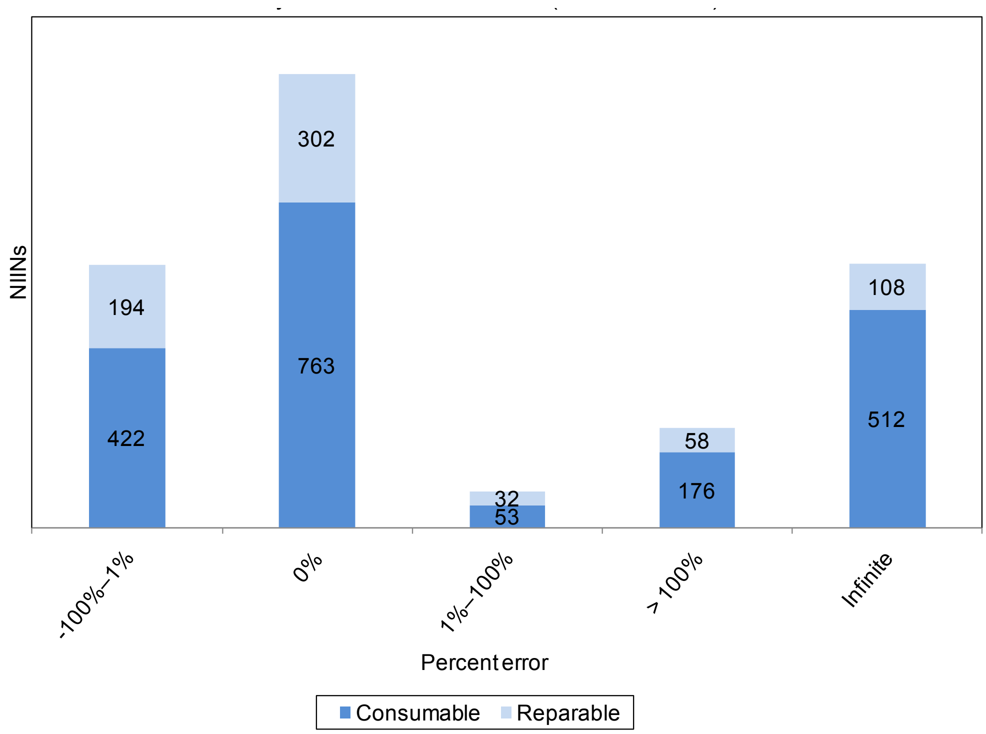
Source: AMCOM and TACOM Stratification Data FY2006–2007.

The Army is the only service which specifically uses the dollar-value groupings when forecasting demand.

Consumables Versus Reparables

We further broke the data down between consumables and reparables; Figure C-6 presents the findings.

Figure C-6. Percent Error for Army Consumable and Reparable Items



Source: AMCOM and TACOM stratification data FY2006–FY2007.

Graphically, there is not much of a difference in percent error between consumable and reparable items. For both sets of items, the largest category is 0 percent error with the majority of these items being zero forecast and zero actual demand.

Appendix D
Navy Provisioning Process

When the Navy determines that a system will be organically supported, it plans for supply support, forecasts demand, and computes spare part requirements through the provisioning process. The Navy, especially for aviation systems, often uses interim supply support (ISS) to make retail inventory available before transitioning to organic support at the material support date (MSD). In the sections that follow, we discuss the Navy's item introduction processes for both interim support and provisioning.

INTERIM SUPPORT

Interim support is a logistics support strategy that utilizes a product support provider, usually a contractor, on an interim basis during the introduction of a new or modified weapon system until its design stabilizes and maintenance and other logistics support capabilities mature. Interim supply support includes the supply, repair, and inventory management support from initial operating capability (IOC) date to the MSD. ISS is used for the management of equipment and systems when acquisitions are either

- new to the Navy,
- major modifications to existing systems,
- initial limited quantity procurements,
- not design stable, or
- on a compressed schedule that make timely Navy supply support impractical.

If ISS is used, it is primarily to purchase retail inventory, not wholesale materiel or safety stock. The Navy uses ISS for most new and modified aviation weapon systems. Maritime programs rarely use ISS because the need for interim support for ships is less for several reasons. First, the long lead times required to activate a new ship generally provide sufficient time to acquire and stock its initial outfitting list before the ship begins operations without the need for interim support. Secondly, due to comparatively low demand rates and space availability constraints aboard ships, maritime systems have lean retail stocks and rely primarily on wholesale stock for support. In contrast, aviation systems are supported mostly with retail stock and little wholesale stock. Consequently, for aviation systems, readiness-based sparing (RBS) models are used about 85 percent of the time to forecast retail demand and compute retail spares requirements while for maritime systems, RBS models are only used about 15 percent of the time.

For ISS inventory management, Navy aviation uses a third-party logistics (3PL) contractor that uses two contractor-operated bonded warehouses to store and distribute ISS inventory. These ISS warehouses act as stock points for contract receipts and for satisfying fleet Interim Support Allowance List (ISAL) requisitions. NAVICP logistics element managers (LEMs) buy to support retail requirements for the ISS period. If it is an extended ISS period, the LEM may budget and buy for multiple years.

Policy Guidance

The following documents are the key policy guidance for Navy ISS:

- Naval Supply Systems command (NAVSUP) Instruction 4400.93A, *Interim Supply Support* (ISS) *for Weapon Systems and Equipment*
- NAVICP Instruction 4400.18D, *Interim Supply Support for Aviation Weapon Systems and Support Equipment*
- Naval Sea Systems Command (NAVSEA) Technical Specification 9090-1500, *Provisioning, Allowance, & Fitting-Out Support* (*PAFOS) Manual*, Chapter 5, "Interim Support."

Roles and Responsibilities of Key Players

The following organizations play a key role in ISS:

- Naval Aviation Systems Command (NAVAIR) and NAVSEA
  - Develop policies and procedures to implement ISS program.
  - For aviation systems, delegate ISS program management to NAVICP-Philadelphia.
- Program executive officer (PEO) and program manager (PM)
  - Approve NAVICP-proposed materiel support plans in a supply support management plan (SSMP).
  - Ensure contract statements of work (SOWs) include ISS requirements, including mandatory data elements.
  - Review planned sparing levels to ensure they are consistent with system mission and reliability data.
  - Negotiate with NAVICP to determine MSD and duration of ISS.

- Budget for ISS.
- Coordinate and communicate engineering change proposals (ECPs).
- Develop, monitor, and implement a ISS transition plan to transfer supply support to the government system.

- Technical Support Activity (TSA) (Maritime)
  - Review Provisioning Technical Documentation (PTD) submissions, submitted via the Interactive Computer Aided Provisioning System (ICAPS), for accuracy and completeness.
  - Work with NAVICP to determine the range and depth of ISS requirements using approved Navy sparing models.
- NAVICP
  - Review PTD submissions, submitted via ICAPS, for accuracy and completeness. (Aviation)
  - Work with NAVAIR to determine the range and depth of ISS requirements using approved Navy sparing models. (Aviation)
  - For aviation systems, serve as NAVAIR's ISS Manager.
  - Screen parts to determine if there is an existing national stock number (NSN).
  - Work with TSA to establish the range and depth of the interim spare requirements using Navy-approved sparing models.
  - Procure non-standard parts and ensure that they are available to provide system support throughout the ISS period.
  - Submit supply support assessment of each ECP, including cost of procuring or modifying parts.
  - Coordinate asset management at ISS facilities and maintain all ISS related data.
  - Transition ISS material into the government system at MSD.
- Original Equipment Manufacturers (OEMs)
  - Provide PTD.
  - Provide the interim support item list (ISIL).

Communication Processes

AUTOMATED SYSTEMS

The Aviation Retail Requirements Oriented to Weapon Replaceable Assemblies (ARROWs) model is a RBS model for developing retail-level inventory requirements for Navy aviation systems. Based on the limited number of data elements available during ISS and NAVAIR planning data, including system delivery schedule, the model forecasts demand and computes and evaluates RBS spare and repair part requirements.

At a high level, ARROWS input is the configuration data for aircraft, materiel support and cost information, and projected failure rates. The output is a recommended allowance list, considering the number of applications along with the criticality, failure rate, and cost of material.

Tiger-Availability Centered Inventory Model (Tiger-ACIM) is the equivalent of ARROWS for maritime systems; however, most maritime systems do not use RBS models. For these non-RBS systems, the Navy uses a demand-based levels setting model. In these circumstances, the Navy either purchases planned maintenance items or they wait for a failure to record demand.

Because of the installation of Navy enterprise resource planning (ERP), both ARROWS and TIGER-ACIM will be replaced by MCA Solutions' Service Planning and Optimization (MCA SPO) over the next year. MCA SPO is a commercial off-the-shelf (COTS) product and is a bolt-on to the ERP system. MCA SPO, an optimization system, will determine RBS retail and wholesale quantities in a single application and conduct trade-off analysis.

CONFERENCES

If interim support is required, an interim support conference may be held to determine how ISS will be accomplished. The conference is chaired by the TSA or LEM under the approval of the PM. The conference results in an ISIL and clarified responsibilities.

NAVICP LEMs or the TSA are members of various integrated product teams (IPTs). The program manager leads the team. The IPT is composed of representatives from a number of disciplines, such as the following:

- Support equipment
- Technical publications
- Facilities
- Depot support
- Maintenance planning
- Packaging, handling, storage, and transportation.

The TSA or LEM is the supply support stakeholder that determines the ISS strategy in conjunction with the IPT leader.

ECPs and Weapon System Program Changes

Program managers communicate design changes via the ECP process. TSAs and NAVICP review ECPs to determine the costs of both procuring new parts and modifying existing parts. NAVICP will submit a supply management assessment of each ECP.

Similarly, the program manager must advise NAVICP if there is a change to deployment schedules or a change in the system's expected use (e.g., planned operating hours). NAVICP actively participates on IPTs to ensure they receive this information as early as possible.

Data Requirements

The data required to initiate ISS is a subset of PTD. Provisioning data requirements for ISS include the following:

- ISS SOW provisioning language
- Engineering Data for Provisioning (EDFP) for ISS
- PTD for Interim Support Items List
- Mandatory data elements for a preliminary allowance list (PAL).

ISS Methodology

Planning and Scheduling

Early in the acquisition process, PMs will request that NAVICP serve as the life-cycle supply agent for the system or equipment. The PM and NAVICP determine the MSD and the duration of the ISS period. The PM and NAVICP determine the ISS stocking point before developing contract requirements for ISS. The PM approves the materiel support plans in the supply support management plan.

Item Screening and Selection

The ISIL received from the contractor is a candidate list of contractor-recommended items needed to support a weapons system during the ISS period. NAVICP validates the ISIL before requesting NSNs. A contractor may provide buy recommendations, but NAVICP determines how many (if any) of each candidate item is procured by executing the applicable forecasting model (e.g., ARROWS for RBS aviation systems). Although failure rates are requested, ISILs may or may not contain replacement factors because the ISIL may be submitted before design is frozen and before failure analysis is completed.

After receiving the ISIL and determining ISS items, NAVICP performs Federal Logistics Information System (FLIS) screening of all parts to determine if there is a previously assigned NSN. For maritime systems, NAVICP will assign a Navy interim control number (NICN) to new items. For aviation systems, NAVICP immediately requests that the Defense Logistics Information Service (DLIS) assign a new NSN. In either case, NAVICP accumulates demand data on new items through Military Standard Requisitioning and Issue Procedures (MILSTRIP) requisitions.

DEMAND FORECASTS AND REQUIREMENTS COMPUTATIONS

The original equipment manufacturer (OEM) provides reliability and maintainability engineering estimates that are used in ISIL demand forecasts and requirements computations. Program data is provided by the PM. NAVICP and the TSA determine the range and depth of interim spares requirements using Navy-approved sparing models. The ISIL computations determine outfitting and interim supply support period requirements, and the non-standard items to be procured directly for the OEM for ISS. The PMs review planned sparing levels to ensure consistency with the system's mission and reliability data. ISS allowances are calculated based on predicted usage and failure data provided by the OEM.

FUNDING

Program managers budget for ISS under the Aircraft Procurement, Navy (APN), Other Procurement, Navy (OPN), or Weapons Procurement, Navy (WPN), appropriations. Program managers fund spares purchases and approved staging facilities. Issues during ISS are free to the fleet.

TRANSITION TO GOVERNMENT SUPPORT

The PM, with assistance from NAVICP, develops an ISS transition plan to ensure an orderly transfer of supply support responsibilities at MSD. The ISS transition plan includes the following:

- System or equipment being transitioned
- The ISS period, including the IOC and MSD dates
- Location of the ISS stock
- Members of the transition team
- Schedule of transition conferences and event schedule
- Detailed description of inventory transfer plans and actions.

ISS assets are transferred to fleet activities to offset initial retail requirements generated during the provisioning or item selection process. Materiel in excess of planned requirements is sent to disposal or turned in to appropriate residual materiel management programs. Demand data accumulated during ISS is recorded in NAVICP files and used in post-MSD spares computations.

Metrics

The Navy does not routinely track ISS demand forecast metrics. It calculates and reports standard backorder and supply management assessment (SMA) metrics.

PROVISIONING

Provisioning is the management process of determining and acquiring the range and depth of organic support items necessary to operate and maintain an end item of materiel beginning at MSD and lasting throughout its lifecycle.

Policy Guidance

NAVSEA Tech Spec 9090-1500, *PAFOS Manual*, Chapter 4, "Provisioning," is the key policy document for maritime provisioning. We requested the aviation equivalent to this document. According to Navy aviation provisioning officials, the only formal written material regarding aviation provisioning was documented in the manual for the Integrated Computer Aided Provisioning System (ICAPS).

Roles and Responsibilities of Key Players

The following organizations play a key role in provisioning:

- NAVAIR and NAVSEA
  - Establish and maintain policy and instructions so that PMS can properly contract for provisioning data.
  - Assist in provisioning budgeting.
- PEO and PM
  - Ensure correct and complete provisioning requirements are included in contracts.
  - Plan and budget for the acquisition of required PTD and ensure NAVICP receives all PTD.
  - Designate an engineering activity to act as the TSA.
  - Establish and chair provisioning conferences when required to better understand provisioning guidance and data requirements needed for a successful provisioning (maritime systems).

- Provide maintenance and planning documents to TSA and NAVICP.
- Establish and participate in IPTs.

- TSA (maritime systems)
  - Acts as representative for technical matters related to provisioning.
  - Reviews and accepts or rejects PTD from the OEM based on its adequacy to complete provisioning.
  - Participates in provisioning conferences and on IPTs as required.
- NAVICP
  - As primary provisioning activity, forecasts demands and computes, procures, stocks, and manages the requirements during provisioning.
  - Loads data files and establish wholesale/retail system stock, as applicable.
  - Coordinates NSN assignment, performs FLIS screening, performs supply management coding, and produces allowance lists.
  - Establishes and chairs provisioning conferences, when required, to better understand provisioning guidance and data requirements needed for a successful provisioning (aviation systems).
  - Acts as representative for technical matters related to provisioning (aviation systems).
  - Reviews and accepts or rejects PTD from the OEM based on its adequacy to complete provisioning (aviation systems).
  - Participates in provisioning conferences and on IPTs, as required.
- OEM
  - Develops PTD for the system or equipment and delivers it to the government in accordance with contract requirements.
  - Includes all contract provisioning requirements in any subcontracts.
  - Submits provisioning data to NAVICP or TSA.
  - Attends or hosts provisioning conferences and participates as a member of IPTs.

Communication Processes

Plans

Provisioning planning begins early in the weapon system development process. The program office notifies NAVICP of the IOC date when supply support will be required for a new or modified system. NAVICP then determines the MSD, the date that the provisioning process can provide full support through the Navy supply system. The following is required to begin provisioning:

- An approved maintenance plan
- Configuration design freeze
- PTD.

Pre-provisioning starts with the approved maintenance plan. Provisioning begins with data determination, including the OEM's submission of the PTD.

Automated Systems

ICAPS is a Navy-developed system that is used to transmit initial spares data from OEMs to NAVICP. This data is then formatted by ICAPS for upload into Uniform Inventory Control Point (UICP) files and for calculating initial wholesale forecasts.

The Item Manager Toolkit (IM Toolkit) is a set of applications that present requirements data to item managers. The system provides recommendations for procurement, termination, redistribution, and disposal recall, as well as for the following types of repair: emergent repair; workload forecasting for organic, commercial, and inter-service repair; and commercial repair contract renewal. During provisioning, the IM Tookit is a Tier 2 application that serves as an interface to NAVICP's enterprise application, UICP. IM Toolkit allows inventory managers to manage inventory levels, including scheduling and requesting buys and repairs, planning, and conducting "what if" scenarios.

UICP updates the wholesale demand forecast using a combination of engineering estimates and actual demand data to smooth forecasting over the 2-year demand development interval (DDI). It is important to note that UICP will be replaced by Navy ERP functionality over the next 2 years. Navy ERP will allow item managers to adjust the DDI, at the item level, within a range of 2 to 5 years. UICP has a fixed 2-year DDI.

CONFERENCES

The following is a list of some of the conferences that may be used to clarify the contract's provisioning requirements and to discuss issues during the provisioning process:

- Provisioning guidance conference
- Preparedness review conference
- Provisioning conference
- General conference
- Long lead time items conference.

INTEGRATED PRODUCT TEAMS

The Navy establishes IPTs early in the provisioning process to improve information exchange. At a minimum, the team includes members from the PM, TSA, NAVICP, and OEM. The team is formed before contract award so they can determine the program's specific provisioning requirements based on the supply support method. The team approach allows the TSA and NAVICP to be involved in decisions early in the acquisition process that will later affect supply support.

DATA REQUIREMENTS

PTD refers to the various types of provisioning data provided by the OEM. The PTD may include the following elements:

- Long Lead Items List (LLIL)
- Provisioning Parts List (PPL)
- Common and Bulk Items List (CBIL)
- Design Change Notices (DCN)
- Post Conference List (PCL)
- Electronic Data for Provisioning (EDFP).

Through the contract, the Navy may also request engineering diagrams, government or industry specifications or standards, schematics and wiring diagrams, and commercial catalogs and descriptions.

Provisioning Methodology

Planning and Scheduling

NAVICP or the TSA provide input to the PM for defining contract data requirements and the PM contracts with the OEM to provide PTD. NAVICP uses the PTD and the supply support management plan as inputs to the provisioning process. NAVICP uses ISS demand and assets to develop wholesale requirements to fill the pipeline and set up post-MSD repair contracts. Initial provisioning must be completed no later than 2 years before MSD. At MSD, support is transitioned from ISS to wholesale supply support.

Item Selection

The Navy uses ICAPS to establish top-down breakdown structure; assign supply maintenance coding; load the master data file (MDF), weapon system file (WSF), and FLIS; and generate allowance products.

To prevent duplication, NAVICP screens all provisioning items against the FLIS database. If an item is not in the current inventory system, NAVICP requests a new NSN. If the item has an NSN, it continues to be managed by the current inventory manager.

When the Navy determines an item will be organically supported, it must be identified, cataloged, and purchased so the spare part will be available when the first equipment is installed. If the item is Navy-unique, a planned program requirement (PPR) is loaded into the NAVICP files. If it is not Navy-unique, a supply support request (SSR) is sent to DLA.

Forecasting and Requirements Computation

After developing an initial forecast based on engineering failure rates and item population, the Navy uses the following schedule to smooth the demand forecast over the two-year DDI:

- First year of DDI—100 percent provisioning forecast, 0 percent mean of new observations.
- Year 1 through 18 months—75 percent provisioning forecast, 25 percent mean of new observations.
- 18 months through year 2—50 percent provisioning forecast, 50 percent mean of new observations.
- Year 2 through end of sustainment period—0 percent provisioning forecasts, 100 percent mean of new observations.

The DoD and Navy policy is to use RBS models whenever possible to compute wholesale levels of initial stock of spare and repair parts at a level to achieve specified readiness goals, or alternatively to compute inventory requirements to optimize readiness for a fixed cost. For demand-based items, Navy models rank items based on demand, lead-time, and cost and compute buys based on available funding. Item managers can also buy small amounts of stock for items with low or zero demand. For example, if an item is an essential component of a piece of equipment, the Navy is allowed to stock at least one minimum replaceable unit (MRU).

Initial provisioning formally ends when items are loaded into NAVICP's files post-MSD. Follow-on or re-provisioning, as a result of ECPs, may continue throughout a system's lifecycle. Provisioning is aimed at providing support for an initial period (1–2 years) following MSD. Subsequent requirements computations phase in actual demand data over a 2-year demand development period. After 2 years, all forecasts are based solely on demand data.

FUNDING

Post-MSD, Provisioning Item Orders (PIOs) are funded with the Navy Working Capital Fund (NWCF), but reimbursed by other appropriations, such as procurement appropriations for new initial outfittings. The fleet is charged for asset issues after MSD.

Metrics

The Navy does not routinely track provisioning demand forecast metrics. It calculates and reports standard backorder and SMA metrics.

DATA ANALYSIS

This section documents the data analysis conducted as part of the study. We start with the analysis performed on the data the Navy provided from two weapon systems. Next, we discuss the analysis performed on the stratification files, which we used to supplement that data.

Navy Weapon Systems

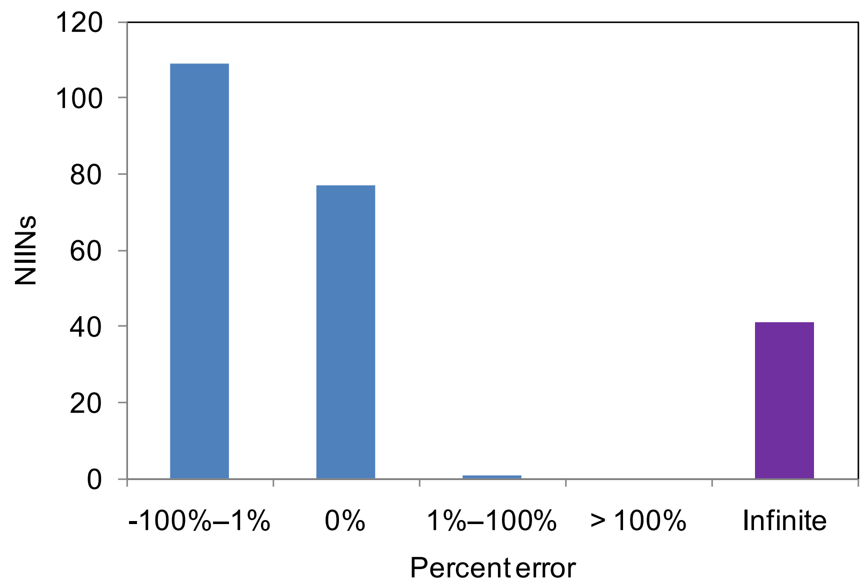
The Navy identified the E-2 Evaporation System modification program as its aviation system, and the Ship Service Diesel Generator (SSDG), a commercial diesel generator manufactured by Caterpillar and used on Navy ships, as its maritime system for evaluation.

E-2 Evaporation System Data

In response to our data request, the Navy provided us an interim support forecast, a provisioning forecast, and actual demand data for the E-2 Evaporation System.

The provisioning forecast included 53 line items, of which 18 had a forecasted demand greater than zero. During the FY2005–FY2009 period, 38 line items experienced demands. The results are presented in Figure D-1.

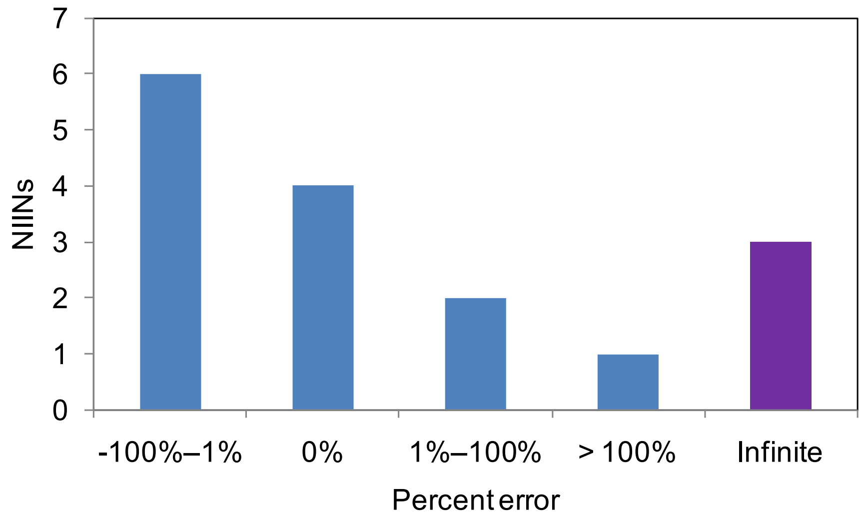
Figure D-1. Percent Error for E-2 Evaporation System Provisioning Forecast



The figure shows that there were a large number of instances (77 in total) in which there was a 0 percent error due to a zero demand forecast and no actual demand. Based on the number of under- and over-forecasted times, there appears to be an under-forecast bias; however, there were 41 instances of a forecast greater than zero but with no actual demand.

Figure D-2 presents the results of the analysis on the interim support forecast data provided to us.

Figure D-2. Percent Error for E-2 Evaporation System Interim Support Forecast



The Navy only provided 1 year of data (FY1999), which included 16 line items. Overall, there appears to be an under-forecast bias, offset somewhat by three instances of a forecast greater than zero but no actual demand. Due to the small number of observations, we are unable to make any meaningful conclusions from this data.

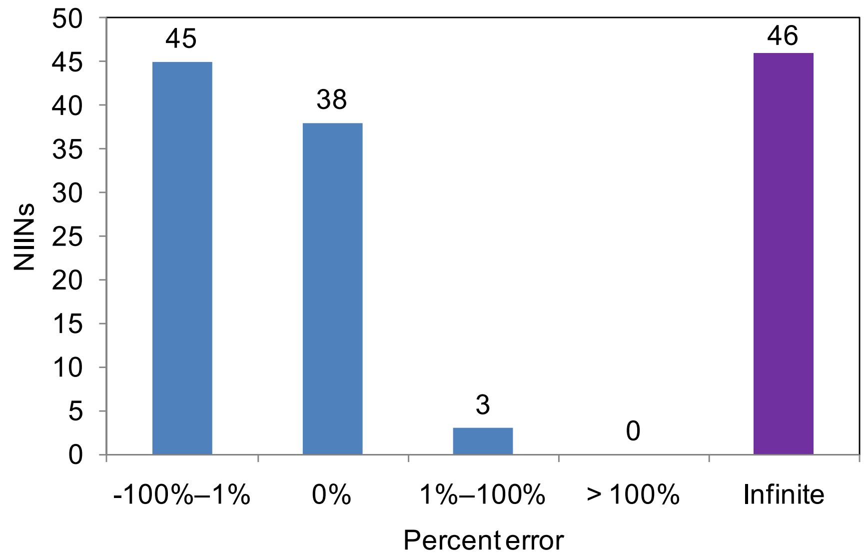
Ship Service Diesel Generator

The Navy provided us with a provisioning forecast and actual demand data for the SSDG. Neither an interim support forecast nor demand data was available for the system. The provisioning forecast included 63 line items, of which 45 had a forecasted demand greater than zero. During the FY2004–FY2009 period, 23 items experienced demands.

Unlike most provisioning forecasts, which are based on engineering estimates, the SSDG forecasts were based on its commercial system's demand experience. Consequently, we would expect this forecast to be more accurate than forecasts based solely on engineering estimates; however, we were told that fleet customers frequently order SDDG parts from NAVICP on a fill-or-kill basis because, when an item is not in stock at NAVICP, it is possible to procure them more quickly directly from Caterpillar using a TACOM blanket purchase agreement. While the demands for fill-or-kill requisitions would still be captured by NAVICP, it is possible that some fleet customers may bypass NAVICP altogether. For this reason, we are unsure if NAVICP's demand data reflects all historical demands. Considering the SSDG is a commercial generator whose configuration changes frequently, the Navy may have been better off relying exclusively on commercial support rather than provisioning the system and stocking parts that could rapidly become obsolete.

Figure D-3 shows there were 38 instances when there was a 0 percent error due to a zero forecast and zero actual demand. There appears to be an under-forecast bias; however, there were 46 instances when there was a forecast greater than zero but no actual demand.

Figure D-3. Ship Service Diesel Generator Percent Error

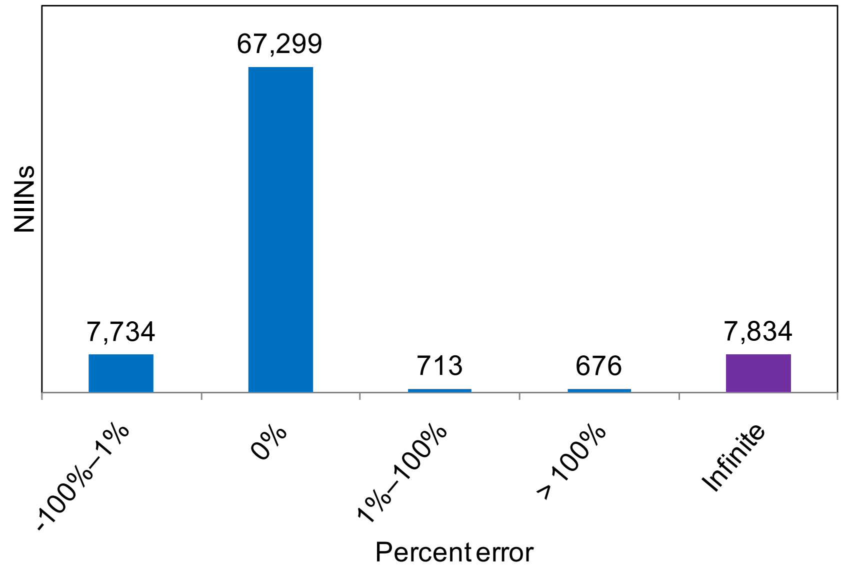


Stratification Analysis

The Navy data set included all maritime items identified as new item introductions from FY2005–FY2009. This data set does not include aviation items.

As depicted in Figure D-4, 66,729 items had a 0 percent error, 9,223 items were over-forecasted, while 7,734 items were under-forecasted. While the largest number of instances had a 0 percent error, most were instances of the Navy forecasting zero demand with the actual demand being zero. If we look only at the range from −100% to >100%, there is evidence of a tendency to under-forecast; however, when including the "Infinite" column, it is obvious there were a large number of over-forecasts. In fact, there were 7,834 instances when an item had a forecast greater than zero but no actual demand. Comparing the total number of over- and under-forecasts suggests a bias toward over-forecasting.

Figure D-4. Navy Maritime Data (FY2005–2009)

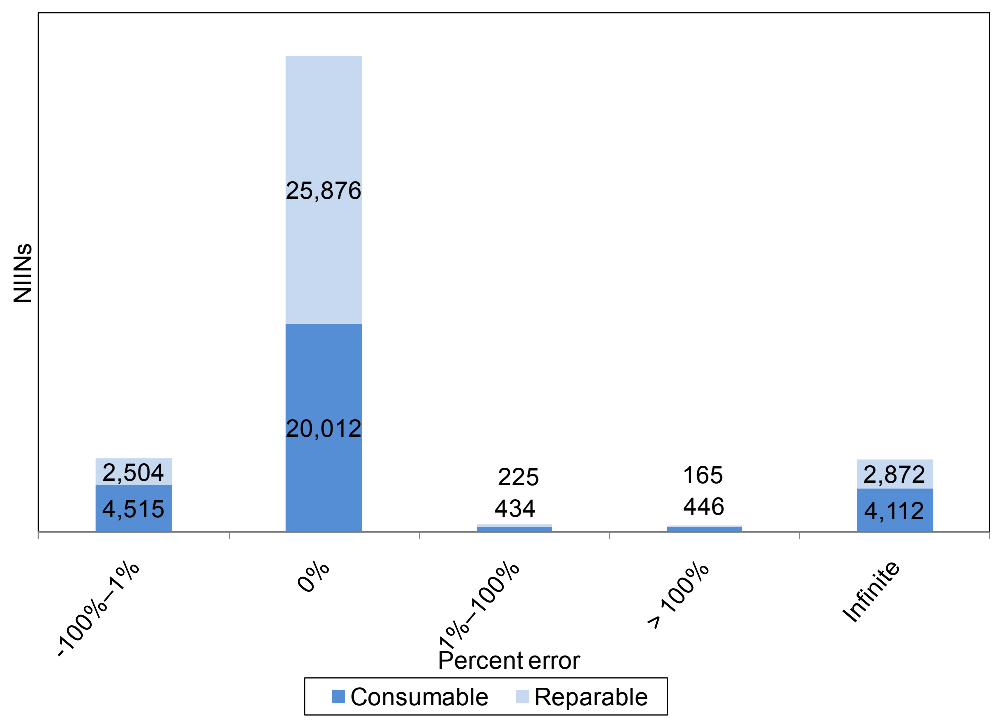


Source: NAVICP Stratification and Item Demand Data.

Consumables versus Reparables

We further broke the data down between consumables and reparables and found no significant differences in the percent error between the two. Figure D-5 depicts the results.

Figure D-5. Percent Error for Navy Consumable and Reparable Items



Source: NAVICP Stratification and Item Demand Data.

Appendix E
Air Force Provisioning Process

Interim contractor support (ICS) is a temporary support method for an initial period of the operation of the system, equipment, or end-item. This strategy is utilized for controlling capital investment costs while design stability is being achieved and complex logistics support elements are being developed. In some instances, interim support entails government interim supply support (ISS) and contractor repair support until repair lines can be established. In other cases, the contractor will perform both ISS and repair operations until the functions can be transferred to the government. The government may opt to retain ISS and/or contractor repair into sustainment, in which case interim contractor support transitions into contractor logistics support (CLS).

Contractor Supported Weapon System (CSWS), formerly the Reformed Supply Support Program (RSSP), is a supply support approach used during ICS for establishing contractor inventory control points and then integrating them into the Air Force's overall support structure as ISS. CSWS is the Air Force's preferred approach for bringing initial spares into the government inventory for new weapon systems, and making modifications to existing weapon systems. This approach provides the flexibility of using best industry practices for achieving combat readiness while providing the structure required to support combat forces in a deployed environment. Under CSWS, a contractor is the inventory control point (ICP) and source of supply (SOS) of peculiar spare parts that apply to an entire system.

There are nine steps to the CSWS process:

- Establish supply support integrated product team.
- Perform pre-award contracting activities.
- Perform post-award contracting activities.
- Identify and update spares data.
- Compute spares and budget requirements.
- Acquire spares.
- Provide spares and collect data.
- Perform supply support program assessment.
- Transition to ICP and operations and support.

Not all CSWS tenets are applicable to all acquisitions. In some acquisitions, CSWS may not be cost effective or appropriate.

Spares ownership is an important consideration that is addressed early in the acquisition planning process. Before entering into a contract, the parties determine what processes should be followed in obtaining the property or material required to perform the contract, who owns residual material and spares, and how property should be transferred to the government when the contract is completed or when item management responsibility transfers from the contractor to the government. Ultimately, determining title is a function of the type of contract and payment provisions.

POLICY GUIDANCE

CSWS guidance is provided in the CSWS user's guide. Additional guidance is provided in AFMCI 23-101, *Air Force Provisioning Guide*, and AFI 63-101, *Acquisition and Sustainment Life Cycle Management*.

CRITERIA FOR EMPLOYING ICS

ICS is a temporary support method for an initial period of the operation of the system, equipment, or end item. The ICS strategy controls capital investment costs while design stability is being achieved and complex logistics support elements are being developed. It also may be used when there is uncertainty in the type and level of support required because of system, equipment, or end-item design instability that may put the logistics support elements at risk.

ROLES AND RESPONSIBILITIES OF KEY PLAYERS

Program Executive Office, Project Manager, and System Program Office

The primary goal of system program managers (PMs) is to effectively manage programs to ensure the warfighter has the best performing system that is efficiently sustained and cost effective. The system program office (SPO) is the chairman of the product team and is responsible for managing the acquisition of the spares support and coordinating the actions of the other players.

Item Manager

If the item is managed by the original equipment manufacturer (OEM), a contractor item manager (IM) will ensure customer support is provided for the item. A government item manager will take over management once the item is transferred to government management. The IMs are involved in planning the transition.

Original Equipment Manufacturer

For interim contractor support under CSWS, the OEM provides all support functions until the management is assumed by the government. The OEM is responsible for maintaining consumption data and interfacing with government data systems as appropriate.

COMMUNICATION PROCESSES AMONG KEY PLAYERS

The supply support integrated product team (SSIPT) is a consortium of government and industry logistics experts that plans, implements, and manages spares support until transition to sustainment using government or contractor logistics support (CLS) ICP support. The SSIPT sets up a review process to preclude omission of supply support requirements during the acquisition phases of the program. Supply support is addressed in acquisition strategy planning. The SSIPT develops the supply support plan that becomes a part of the single acquisition management plan or acquisition plan.

The SSIPT is established early in an acquisition to facilitate better communication between all functional areas and to ensure supply support is addressed during the planning stages of a system acquisition or modification. During the early phases of an acquisition, and until a SPO is established, a senior logistician in the acquisition office is responsible for defining supply support requirements. Once a SPO is established, the program manager is responsible for ensuring supply support issues are addressed until an SSIPT is established. After reviewing program documents, the system program director (SPD) decides when supply support is required and when to establish an SSIPT. A limited number of personnel are assigned to the program to consider supply support during conceptual studies. The initial capabilities document (ICD) is reviewed, possible materiel solutions are considered, and approval is sought to proceed to concept refinement. Modernization programs are typically in the technology development or system development and demonstration phase of the acquisition cycle. The SSIPT supports the acquisition through the production and deployment phase, until the transition to a government ICP or CLS is complete. The SPD ensures a team is established no later than the end of the concept refinement phase.

The SPD appoints the SSIPT chairperson, who determines SSIPT composition. Core membership includes functional areas that are an integral part of the supply support planning and implementation, and organizations with a vested interest in the program that are a part of the SSIPT throughout the program. Advisory members attend meetings, as required, and provide specific expertise and information. Air logistics center (ALC) participation on the SSIPT is crucial. Several ALCs may be involved at some point in the program. Once the contract is awarded, the contractor becomes a member of the SSIPT and participates in supply support activities. After determining core and advisory organizations, the chairperson requests representatives for appointment to the SSIPT.

DATA REQUIREMENTS

The CSWS Data Exchange (D375) system was chartered to provide a method by which each weapon system SSIPT could collect peculiar spares information from contractor and legacy systems during the initial acquisition stage. The data could then be moved into a temporary storage area to enable better asset visibility, more accurate program assessments, demand-based forecasting and budgetary projections to support a transition package. The collected data could also be a source for metrics and analysis to enable better-informed decisions. Since its original establishment, the data exchange (DE) role has expanded to provide an online bridge for sharing basic management (non-transactional) data between contractor ICPs and Air Force legacy systems. The Data Exchange is the HQ USAF/IL–approved method for moving contractor information through the Air Force and Defense Information Systems Agency (DISA) firewalls to applicable legacy systems. It is also the approved method for contractor ICPs to view spares-related information residing in Air Force legacy systems. The Data Exchange segregates spares data by weapon system, and provides a single interface to Air Force systems for authorized users. In short, the CSWS Data Exchange provides the capability to acquire contractor information and store and utilize that data to support online logistics processes and decision-making within an enterprise logistics environment.

ICS METHOD

Planning and Scheduling

The logistics needs of the program are briefly defined by the operating or using command in the initial capabilities document and the capabilities development document (CDD). As the acquisition program matures, supportability requirements are refined and incorporated into program documents. Supply support considerations include parts standardization, reliability and maintainability, maintenance concept, operational concept, life cycle costs, and use of commercial off-the-shelf (COTS) and non-developmental items.

Item Screening and Selection

The contractor provides a parts breakdown structure for the end item. This list is then screened to determine which items are currently stock-listed and which items will be initially provisioned.

Data Review and Updating

Under CSWS, the contractor is required to feed data to Air Force legacy systems, thereby, providing visibility of support data to the government.

Support Period

At a designated point during ISS, the SSIPT, major command (MAJCOM), and SPD make a recommendation whether to transition to a government ICP or to remain with the contractor. If the decision is made to remain with the contractor, a CLS contract is established for an indefinite period.

The SSIPT performs a spares review using the wholesale contractor's recommended spares list to determine peculiar and common items and the quantities required adjusted stock levels (ASLs) replace the Initial Spares Support List (ISSL) process for ISS. The wholesale contractor provides ASLs for peculiar items to the SBSS/ILS-S to maintain level quantities. The contractor may also provide the item record load (FIL), part number detail record load (1AA), and the ASL Load (1F3L). This process is coordinated with the SPO and the MAJCOM.

Initial Demand Forecast and Requirements Computations

The contractor is responsible for computing peculiar item demand forecasts and requirements for ISS, and for management of the peculiar items. Contractors may use their own computation models to determine sufficient inventory to support the performance standards outlined in the ISS contract. The government provides the contractor access to the data in the standard computation models, which the contractor can use to monitor spares transition package requirements. In addition to the contractor's data, the contractor may use data provided by the D375 or government systems to perform their spares computations. The primary reason for not requiring the contractor to support to the levels generated from the government computation models is that the contractor may use production line assets to satisfy customer demands that generally have shorter pipeline times and are not a true projection for Air Force computational requirements. In addition, if the government determines the spares requirements, the government is liable for costs and performance measures.

Forecasting and Computation Models and Procedures

Once all the required data is collected in the CSWS D375 on the contractor-managed peculiar items, a computation can then be run to determine spares transition package buy and repair requirements. The contractor will be required to provide the data required to compute the spares requirement. The basis for the demand forecast is the estimate of reliability computed by the contractor. The government is required to budget for the initial spares. The SSIPT determines whether the contractor or the government will actually run the requirements computations. These contractor-provided spares will most likely consist of the current peculiar spares on-hand during ISS and a delta quantity representing the remaining balance needed to fill government pipeline requirements. The appropriate SSIPT member, usually a contractor item manager, accesses the computation models through the CSWS D375 to run the computations on a quarterly basis.

The SSIPT must then determine the validity of the requirements before they can be used for budgetary projections.

The following tools are available to the weapon system SSIPT through the data exchange (available via the web and segregated by weapon system):

- *Secondary Item Requirement System* (SIRS). The D200A computation model that may be used for computing Air Force reparable and consumable spares requirements and budget projections for the CSWS transition package.
- *ASM®*. The Aircraft Sustainability Model (ASM)[1] may be used for computing DLA-managed consumable spares for the CSWS transition package.
- *SAW*. The Spares Acquisition Worksheet (SAW) is available to government program offices for identifying their program budget requirements.
- *D087H*. The Weapons System Management Information System, (WSMIS) Requirements Execution/Availability Logistics Module (D087H), is a mandatory tool for computing readiness spares packages (RSPs), which are wartime-deployable spare kits. D087H collects and preprocesses data from interfacing systems and provides for use in requirements computations and budget allocation listings. This system currently is not available through the Data Exchange but is being considered as a future D375 requirement.

Funding

Weapon systems, end items, peculiar support equipment, and ICS requirements are currently put into the program objective memorandum (POM) and budgeted and funded in various appropriations and budget program (BP) lines within the Central Procurement (CP) accounts. The type of weapon system being procured determines the appropriation and budget program. Relevant appropriations are 3010 (BP10) for aircraft, 3020 (BP20) for missiles, and 3080 (BP83E) for communication-electronics and space systems. Modifications, associated peculiar support equipment, and ICS requirements are submitted to the POM, then budgeted and funded in 3010 (BP11) for aircraft, 3020 (BP21) for missiles, and 3080 (BP83M) for communication-electronics and space systems.

The initial spares requirements determination (both peacetime operating stock and readiness spares packages for wartime) managed by the Air Force are based on percentages of flyaway costs or equipment costs early in the acquisition process. At execution, the requirements are based on the contractor's recommendation for sparing levels or the use of estimated failure rates, lead times, costs, maintenance philosophy, and so forth. These projections are submitted to the POM, budgeted

[1] Aircraft Sustainability Model and ASM are registered trademarks of the Logistics Management Institute.

and funded in both the Air Force Working Capital Fund (AFWCF) and the CP accounts (3010 BP16 for aircraft, 3020 BP26 for missiles, and 3080 BP86 for other). First, obligation authority (OA) is budgeted through the AFWCF. The OA is issued by OSD and used to fund the actual purchases of the initial spares. When the assets are delivered, the AFWCF pays the bill; however, because the AFWCF is a revolving account, it requires a means of revenue to reimburse the expense of the initial spares. CP accounts are used for this reimbursement. CP funds are submitted to the POM and budgeted to reimburse the AFWCF after deliveries are made and bills are paid. Since reimbursement occurs only after the AFWCF incurs the expense, the budget authority is requested on a projection of receipt via anticipated delivery schedule or a predetermined 5-year outlay pattern.

For initial spares managed by DLA, the Air Force passes forecasted requirements to DLA via the SSR process. Obligation authority from OSD is used to purchase common consumable spares for stock without a corresponding reimbursement from appropriated funds.

Management of ICS Spares

While the end item is supported by interim supply support managed by the contractor under CSWS, the contractor is responsible for all supply support, including spares support, data collection, and asset distribution. The contractor is required to share data and provide visibility to Air Force systems so the contractor's processes are fully integrated with the governments.

Transition to Government Support

During ISS, as reliability experience is gathered and assessed for demand stability and reliability performance, management of those items/subsystems deemed stable by the SSIPT transfer to the government ICP or CLS. The transfer includes technical and management responsibilities, data packages, and inventory needed for supply support. All facets of government management, including cataloging, distribution, and availability of a capable repair source, are considered before transition.

The SSIPT develops a comprehensive transition plan before fielding and updates it during ISS. The plan must address sustainment options that will follow ISS. The SSIPT programs and budgets for the plan as soon as the ISS decision is made. The transition options must include (at a minimum) (1) complete transfer of spares management workload to a G-ICP, or incremental transfer of spares management to a G-ICP, (2) continued spares support under CLS arrangements, and (3) an extended ISS. Once the SSIPT determines the appropriate transition option and all requirements in the transition plan have been met, transition takes place and ISS ends.

The program manager uses the SAW for submitting requirements for the spares transition package, common spares, and data reprocurement to the POM and budget. The SAW is completed and submitted as soon as possible in the Future Years Defense Plan (FYDP) to ensure proper programming of funds. The forecasts address both the transition package and the post-ISS workload.

Metrics

While metrics are maintained on the contractor's performance, there are no metrics specifically related to forecast accuracy.

AIR FORCE PROVISIONING

Provisioning is the management process for determining and acquiring the range and quantity of support items necessary to operate and maintain an end item of materiel for an initial period of service. The goal of this process is to have the support items available in time to meet or accommodate the operational need date.

Provisioning requires the active participation of personnel in the acquisition office, the provisioning office, the contractor, and the using command. Close cooperation among these activities is essential to ensure timely support is achieved. Support items are items subordinate to, or associated with, an end item (i.e., spares, tools, test equipment, and sundry materials) and required to operate, service, repair, or overhaul an end item.

Policy Guidance

Guidance is provided in AFMCI 23-101, *Air Force Provisioning Guide*, and AFI 63-101, *Acquisition and Sustainment Life Cycle Management*. Guidance for initial requirements determination is found in AFMCI 23-106.

Provisioning Approaches

Various provisioning situations require different techniques. In some situations, the contractor may require a long lead time to produce the items. In other cases, buying items during production or from the actual manufacturer can lower costs. The following are among the techniques that will be considered to ensure spares are available by the operational need date at a reasonable cost:

- *Interim release.* The interim release can be used to allow the contractor to start work on spares with a long production or procurement lead time prior to receipt of a provisioned item order.
- *Spares acquisition integrated with production (SAIP)*. Spares acquisition incorporates Air Force orders for spares and recoverable assemblies with the contractor's orders for production installs (DODI 5000.2) to maximize quantity buys, thereby reducing costs. The decision to use or not use the

SAIP technique must be documented in the ILSP and in provisioning guidance conference minutes.

- *Breakout of initial spares.* The objective of this technique is to reduce cost by procuring initial spares directly from the actual manufacturer. This policy applies if the prime contractor recommends that items be procured directly from the actual manufacturer, or enough information is available to make a responsible management decision that breakout will be cost-effective and will not degrade the Air Force mission.
- *Deferred procurement.* During the initial support period, provisioning activities may defer procurement of partial quantities of computed requirements for selected support items when operating program uncertainties or other special circumstances make such risks acceptable in the context of available resources and readiness goals.

Provisioning Methodologies

The provisioning conference is the normal method for accomplishing data verification for larger systems. The conference may be held at the contractor's facility. An in-house or depot committee provisioning conference, held at the ALC, is preferred for smaller systems. An Air Force provisioning team is permanently assigned to the contractor's facility. Occasionally, there is a resident provisioning team (RPT) or resident integrated logistics support activity (RILSA).

Planning and Scheduling

Provisioning events begin depending upon the design stability of the item or interfacing items being provisioned. Provisioning begins after the physical configuration audit for acquisition category (ACAT) I and II acquisition or modification programs which have a high degree of instability. For all other acquisition or modification programs, provisioning begins after critical design review.

The System Support Manager (SSM)/End Article Item Manager (EAIM) ALC provisioning activity usually schedules provisioning guidance conference soon after the contract award, normally within 60 days. The guidance conference provides a means by which the contractor, major vendors, and Air Force personnel can gain a mutual understanding of the contractual requirements. Responsibilities should be clearly defined and the various deadlines in the provisioning cycle should be specifically identified. This sets the stage for a successful provisioning conference when the item transfers from interim support.

Provisioning Screening and Item Selection and Coding

The prime contractor will provide a Provisioning Technical Document (PTD) in top down breakdown sequence or as specified. The parts on the PTD are viewed by the government. Part of this review is accomplished by the equipment specialist (ES) who will be responsible for post-acquisition support of each major assembly, subassembly, line replaceable unit (LRU), shop replaceable Unit (SRU), or piece part in conjunction with single manager ES and using command representatives. Changes to source, maintenance, and recoverability (SMR) codes are coordinated with the SPD and using command when repair-level decisions are affected. The SMR coding of components that make up an end item are based on the maintenance concept desired and the design of the items being coded. The maintenance concept (including repair-level analysis, or RLA, when applicable) is discussed in depth before assigning the SMR codes. The concept discussed includes integrated support and the objectives of direct vendor contact. The failure factors are thoroughly discussed with the contractor.

Assignment of Maintenance Replacement Rates and Forecasting Demand

Initial replacement rates are used to forecast demand. Knowing how often an item will be replaced based on use and the expected operations tempo for the end item, the expected demand can be computed. The initial replacement rates are provided by the contractor. These rates are viewed by the equipment specialist. Comparisons are made against like items to estimate the validity of the data.

In accordance with AFMCI 23-106, factors developed by the contractor cannot be changed by the ES without complete justification. Under no circumstances are any changes permitted to be made to contractor furnished maintenance replacement rates (MRRs) by the ES if the factors were developed as part of a reliability and maintainability program unless there is a change in mission or maintenance concept. Such changes require the approval of the system program director. The MRR should always represent the latest information available (test data, design change information, a like-item experience, etc.). The ES must notify the end article system manager of their intent to deviate significantly (e.g., ±10 percent) from contractor-estimated failure rates on major systems or subsystems being provisioned.

The MRRs derive from the total organizational and intermediate maintenance demand rate (TOIMDR), which is an indication of the number of failures to occur for every unit of program (flying hours × 100 or per installed unit). MRRs include base repair rates and depot demand rates as well as the TOIMDR. The base repair rate determines the number of failures that will be repaired at the base maintenance facility. The depot demand rate determines the number of units to be repaired at a depot repair facility. Actual experience may determine the appropriate MRRs when at least 3 months of usage history is available. For example, when 3 months of data are available, a new MRR should be developed. The actual data should be weighted at 25 percent and the estimated MRR should be weighted at 75 percent. When 12 months of data are available, the new MRR should be developed, weighting the actual MRR at 50 percent and the estimated MRR at 50 percent. When 18 months of data are available, the weighting for the actual MRR should be 75 percent and the estimated MRR 25 percent. After 2 years of data are is available, the maintenance replacement rate is based entirely on actual data. In some cases, actual experience may not be indicative of future demands. The ES reviews these items and determines the appropriate MRRs. The ES may select one year of usage history to indicate future demands.

Requirement Computations

Data Review and Updating

Data is reviewed during the provisioning conference when the contractor and government personnel discuss each item. The following are examples of the type of data that are reviewed during the course of initial provisioning:

- Maintenance repair level codes
- Recoverability codes
- Replacement factors
- ERRC codes
- ISSL recommendations for retail stock levels.

Demand Development Period

The demand development period (DDP) starts on the end item's preliminary operating capability (POC) date and ends when the accumulated demand or usage history is sufficient to predict future demands. The DDP is no less than 12 months and no more than 24 months long. The POC is the date the first operational user receives the first end item. If there is ICS, then data is collected from the contractor. If an item only supports depot-level overall, the DDP begins on the date the first end item is scheduled for overhaul.

Initial Stockage and Retail Levels

The required item quantity relates to a demand forecast or the item's essentiality. The demand forecast is derived from replacement rates, projected programs, and maintenance factors. Acquisition quantities computed outside of the initial requirements determination (IRD) process are permitted if quantity discounts or other acquisition techniques make them more economical. Any decision to buy a larger quantity must consider the risks of overstockage and obsolescence. The item manager must document the reasons for the different buy quantity.

Development of Program Data

Program data form the basis for requirements computations and budget estimates. There are two types of programs, operational and overhaul. Operational programs are normally expressed as operational (flying) hours or as the monthly average number of end items in the inventory (inventory months). Overhaul programs are expressed as the number of end items or higher assemblies scheduled to undergo repair or overhaul. In either case, monthly flying hour projections, the end item delivery schedule, the number of end items at each site, the overhaul schedule, and the program forecast period (PFP) determine how the IRD system time-phases program data.

Programs must consider requirements for the depot and base and will be developed in 3-month increments, beginning with the month that includes POC as month 1. To support depot overhaul requirements the system develops an adjusted month program (AMP) over the program time base (PTB). The PTB begins with a period equal to a review cycle and is measured with each review. The PTB expands until it equals the item's program forecast period (PFP). For example, an item with a review cycle of 6 would have PTBs of 6, 12, 18, etc., until the PFP is reached.

For base-level requirements, the adjusted month program is developed according to the contracted end item delivery schedule to sites being activated during the PFP.

After considering the total costs involved in ordering initial requirements, the development of item program data should be tailored to indicate the manner in which orders are to be processed. A decision to deviate from the incremental release of orders policy should be made on an item-by-item basis. The Air Logistics Center Financial Management (ALC/FM) must grant approval.

Initial Requirements Computations

The purpose of the initial requirements determination process is to provide spares support just prior to or in conjunction with the delivery of the weapon system. Initial spares and repair parts requirements provide support for anticipated end article deliveries through a program forecast (i.e., PFP).

When ICS supports a newly fielded weapon system, contractual arrangements ensure that the contractor collects spare and repair parts usage data and delivers them in a format compatible with AFMC systems. Where possible and practical, the contractor's usage data, rather than engineering estimates, should forecast spare and repair parts requirements.

Generally, the initial requirements determination process does not apply to items already in the Air Force inventory (e.g., assigned a national stock number, or NSN). The replenishment systems compute requirements for these items. Some stock listed items may have experienced usage and developed demand rates with other system applications. When computing demand rates for initial requirements determination, the equipment specialist considers the computed rates with the factors received from the provisioning documents and, if necessary, develops a weighted factor.

The D200H Initial Requirements Determination system uses the following formulas to compute each requirements segment for initial spares. These formulas are part of the approved methodology for computing Air Force initial spares requirements and should be used when computing requirements outside of the IRD. The ALC Office of Primary Responsibility (OPR) may approve deviations from these formulas after reviewing justifying documentation.

- *Adjusted month schedule*. The adjusted month schedule is used to develop the average and adjusted month inventory, operating (flying hour), and overhaul program for the programming checklist (PCL) computations. Overhaul programs are depot-level maintenance (DLM) programs and include program depot maintenance (PDM), engine overhaul (EOH), and management of items subject to repair (MISTR) programs. For any quarter, the adjusted month schedule is the quarterly program divided by three.

- *Average month schedule.* The average month schedule is the current adjusted monthly schedule plus the previous adjusted monthly schedule, divided by two.

- *Organizational and intermediate maintenance (OIM) annual demands*. This is the number of annual demands expected to be placed on organizational and intermediate maintenance (i.e., base level) activities. The first step is to determine the program time base that contains the adjusted month program that will apply to the OIM demand projection. Each PTB is numbered in threes from 3 to 48 (3, 6, 9…48). To select the appropriate PFP, add the number of months in the administrative and production lead times, plus the number of months in the procurement cycle (3) plus 1 month.

- *The projected annual demands*. This equals the total OIM demand rate, times the application percent, times the quantity per end item, times the accumulated operating program (flying hours or inventory) at the selected PFP.

- *OIM procurement cycle*. The 3-month procurement cycle requirement within each PTB is the number of months in the procurement cycle (3) times the average month program in the PTB, times the quantity per end item, times the item application percent, times the TOIMDR, times product of the base Not Repairable This Station (NRTS) percentage, times the depot overhaul condemnation percentage, plus the remainder of the 1 minus the base NRTS percentage multiplied by the base condemnation percentage.

- *OIM lead time.* This requirement covers demands expected to occur during the item's acquisition lead time and is computed within each program time base. It is the number of months in the administrative lead time and the production lead time, plus one additional month, times the average month program in the PTB, times the quantity per end item, times the item application percentage, times the TOIMDR, times the product of the base NRTS percentage, times the depot overhaul condemnation percentage, plus the remainder of the 1 minus the base NRTS percentage multiplied by the base condemnation percentage.

- *Base order and ship time.* This determines the number of assets required to support demands expected to occur during the base order and ship time (O&ST). It is the number of days in the O&ST divided by 30, times the adjusted month program at the item's PFP, times the quantity per end item, times the item application percentage, times the total OIM demand rate, times the base NRTS percentage plus the remainder of the 1 minus the base NRTS percentage multiplied by the base condemnation percentage.

- *Base repair cycle*. This determines the number of assets required to support demands expected to occur during the base repair cycle (BRC) time. It is the number of days in the BRC divided by 30, times the adjusted month program at the item's PFP, times the quantity per end item, times the item application percent, times the total OIM demand rate, times the base NRTS percent plus the remainder of the 1 minus the base NRTS percent multiplied by the base condemnation percent.

- *Depot repair cycle.* This determines the number of assets required to support demands expected to occur during the depot repair cycle (DRC) time. It is the number of days in the DRC divided by 30, times the adjusted month program at the item's PFP, times the quantity per end item, times the item application percentage, times the total OIM demand rate, times the base NRTS percentage.

- *Base stock level*. The base stock level is the sum of the base order and ship time requirement and the base repair cycle requirement.

- *DLM annual demands.* The depot-level maintenance (DLM) annual demands are a projection of expected requirements to support DLM programs that are associated with the overhaul of aircraft, engines, equipment, or recoverable secondary items. The programming checklist includes separate PDM programs for aircraft, EOH programs, and MISTR programs for equipment and recoverable secondary items. The demand projection includes separate forecasts for job-routed and non-job-routed requirements.

- *The DLM demand projection for items with job routed programs*. This equals the total DLM program minus the item non-job-routed program, times the job routed condemnation percentage.

- *The DLM demand projection for items with non-job routed programs*. This equals the total DLM program times the item non-job routed program percent, times the non-job routed replacement percentage.

- *MISTR DLM item requirements*. The first step in computing depot-level maintenance item requirements is to determine the average month

MISTR program. This is the sum of projected DLM reparable generations and OIM reparable generations within any PTB. The projected DLM reparable generations are the average month MISTR program for the next higher reparable assembly (NHRA) in the PTB, identified on the programming checklist provisioning list item sequence number (PLISN) for the NHRA, times the quantity per NHRA, times the MISTR non-job-routed program percentage, times the item application percentage in the PTB, plus the product of the average month PDM and EOH programs, times the quantity per end item, times the EOH or PDM non-job-routed program percentage, times the EOH or PDM non-job-routed replacement percentage, times the item application percentage in the PTB.

- *The OIM reparable generations.* These are the average month OIM (flying hours or inventory) program in the PTB, times the quantity per end item, times the total OIM demand rate, times the base not repairable at this station percent, times the item application percent in the PTB.

- *The average month MISTR program within any PTB*. This is the OIM reparable generations, plus the DLM reparable generations, times the remainder of 1 minus the depot overhaul condemnation percentage.

- *DLM procurement cycle* (ERRC C and T items only). This process computes the DLM procurement cycle requirements for all job routed and non-job routed DLM programs. This process involves two steps.

  - Step 1 is computation of the MISTR job-routed and non-job routed procurement cycles in each PTB. The MISTR job-routed procurement cycle equals the job-routed condemnations, times the remainder of 1 minus the MISTR non-job routed program percentage, times the average month MISTR program in the PTB, times the quantity per next-higher reparable assembly, times the item application percentage at the PTB, times 3. The MISTR non-job-routed procurement cycle equals the non-job-routed replacements and depot overhaul condemnations, times the remainder of 1 minus the MISTR non-job routed program percent, times the average month MISTR program in the PTB, times the quantity per next higher reparable assembly, times the item application percent at the PTB, times 3.

  - Step 2 is computation of the job routed and non-job routed EOH and PDM procurement cycles. The EOH/PDM job-routed procurement cycle equals the job routed condemnations times the remainder of 1 minus the EOH/PDM non-job routed program percentage, times the average month EOH/PDM program in the PTB, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times 3. The EOH/PDM non-job-routed procurement cycle equals the non-job routed replacements and depot overhaul condemnations times the remainder of 1 minus the EOH/PDM non-job routed program percent, times the average month EOH/PDM program in the PTB, times the quantity per next higher reparable assembly, times the item application percent at the PTB, times 3.

- *DLM lead time requirement* (ERRC C and T items only). This process computes the DLM lead time requirements for all job routed and non-job routed DLM programs. This process involves two steps.
  - Step 1 is computation of the MISTR job-routed and non-job-routed lead time requirements in each PTB. The MISTR job-routed lead time requirement equals the job routed condemnations times the remainder of 1 minus the MISTR non-job routed program percentage, times the average month MISTR program in the PTB, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the number of months in the acquisition lead time plus 1.The MISTR non-job-routed lead time requirement equals the non-job-routed replacements and depot overhaul condemnations times the remainder of 1 minus the MISTR non-job-routed program percent, times the average month MISTR program in the PTB, times the quantity per next higher reparable assembly, times the item application percent at the PTB, times the number of months in the acquisition lead time plus 1.
  - Step 2 is computation of the job-routed and non-job-routed EOH and PDM lead time requirements. The EOH/PDM job-routed lead time requirement equals the job-routed condemnations times the remainder of 1 minus the EOH/PDM non-job-routed program percentage, times the average month EOH/PDM program in the PTB, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the number of months in the acquisition lead time plus 1. The EOH/PDM non-job-routed lead time requirement equals the non-job-routed replacements and depot overhaul condemnations times the remainder of 1 minus the EOH/PDM non-job-routed program percent, times the average month EOH/PDM program in the PTB, times the quantity per next higher reparable assembly, times the item application percent at the PTB, times the number of months in the acquisition lead time plus 1.
- *DLM depot repair cycle (*ERRC C and T items only). This process computes the DLM depot repair cycle requirements for all job-routed and non-job-routed DLM programs. This process involves two steps.
  - Step 1 is computation of the MISTR depot repair cycle requirement. The MISTR depot repair cycle requirement equals the depot repair cycle days divided by 30, times the average month MISTR program in the PTB, times the MISTR non-job-routed program percentage, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the MISTR non-job-routed replacement percentage.

- Step 2 is computation of the job-routed and non-job-routed EOH and PDM depot repair cycle requirements. The EOH/PDM depot repair cycle requirement equals the depot repair cycle days divided by 30, times the average month EOH/PDM program in the PTB, times the EOH/PDM non-job-routed program percentage, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the EOH/PDM non-job-routed replacement percent.

- *DLM stock level* (ERRC C and T items only). This process computes the DLM stock levels for all job-routed and non-job-routed DLM programs. This process involves two steps.

  - Step 1 is computation of the MISTR job-routed and non-job-routed stock levels in each PTB. The MISTR job-routed stock level equals the job-routed condemnations times the remainder of 1 minus the MISTR non-job-routed program percentage, times the average month MISTR program in the PTB, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the number of JR stock level days. The MISTR non-job-routed stock level equals the non-job-routed replacements and depot overhaul condemnations times the remainder of 1 minus the MISTR non-job-routed program percentage, times the average month MISTR program in the PTB, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the NJR stock level days.

  - Step 2 is computation of the job-routed (JR) and non-job-routed EOH and PDM stock levels. The EOH/PDM job-routed stock level equals the job-routed condemnations times the remainder of 1 minus the EOH/PDM non-job-routed program percentage, times the average month EOH/PDM program in the PTB, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the JR stock level days. The EOH/PDM non-job-routed stock level equals the non-job-routed replacements and depot overhaul condemnations times the remainder of 1 minus the EOH/PDM non-job-routed program percentage, times the average month EOH/PDM program in the PTB, times the quantity per next higher reparable assembly, times the item application percentage at the PTB, times the NJR stock level days.

Computation Models and Procedures

Readiness-based sparing (RBS) models can be used, if approved for Air Force use. The models and procedures for initial spares are very similar to sustainment forecasting, except estimated failure rates instead of actual rates are used.

Not all initial spares are computed based on expected demand. Insurance item quantities consider item application, quantity per end item, expected distribution of the end item, and criticality of the item to the operation of the end item. Based on the item essentiality, wholesale stockage of insurance items is limited to items that apply to high priority weapon system or end items, technically critical items necessary to ensure weapon system availability, and items necessary for safety.

Items that are essential to program support because a lack of the item would prevent mission accomplishment or cause a safety hazard may be designated a numerical stockage objective (NSO) item. The IMs determine the NSO level. The ES documents the rationale used to designate the item NSO. NSO items can be stocked at the base levels part of the retail stock level. Since NSO items have demand rates, justification for additional quantities can be based on end item distribution. Only recoverable items can be NSO items.

SYSTEMS

The D200H Requirements Data Bank (RDB) Initial Requirements Determination subsystem is the approved automated tool for computing recoverable and consumable item requirements. The D200H is an interactive, online system that builds and displays system and sub-system programming checklists (PCL) and item worksheets. Use of D200H is preferred for initial spares computation for provisioning because it accommodates multiple weapon systems and includes a simulation capability

SOURCES OF DATA

The D220 system provides all failure, maintenance, wear-out, replacement, and condemnation rates. The primary contractor furnishes these rates and factors. The ES approves or changes the rates and then provides the factors to the IMS, who uses them to develop initial support requirements. Rates and factors should represent the latest information available (for example, test data, design change information, or experience with a similar item).

Although the D220 input includes contractor-recommended buy quantities, the IMS must compute item requirements according to the guidelines specified in AFMCI 23-106. This ensures that the contractor has provided accurate estimates and that the necessary data are available to establish of items in the Air Force inventory. The quantity computed in the D200H is the quantity bought.

The IRD (D200H) receives input from other systems via electronic file transfer in batch mode. The IRD receives data from the D220 Provisioning Data System, the K004 Past/Projected Programs System, and from user file maintenance.

FUNDING

Early planning for the availability of funds to purchase spares, provisioning data, etc., is critical. Starting in FY 1994, most initial spares requirements were stock funded as directed by DMRD 904. Initial spares excluded from stock funding are fully delineated in the January 1993 DMRD 904 Implementation Plan, and include spare engines and classified depot-level reparables. Central procurement initial spares funds (BPs 16, 26, 82, 83, and 84), will reimburse the Reparable Support Division (RSD) of the stock fund for acquisition costs incurred.

Metrics

The Air Force currently does not collect metrics on initial spares forecast accuracy.

DATA ANALYSIS

This section documents the data analysis conducted as part of our study. We start with the analysis performed on the data the Air Force provided for its two sample weapon systems. Then, we discuss the analysis performed on the stratification files, which we used to supplement the data provided on the two weapon systems.

Air Force Weapon Systems

The Air Force selected the B-2 aircraft radar modification and the Advanced Medium-Range Air-to-Air Missile (AMRAAM) programs for the evaluation. During field research of the B-2 radar, we learned the modification program was still under interim support and had not yet been provisioned. Moreover, while a contractor had forecasted interim support spares requirements for the program, no actual demand data existed to evaluate the forecasts against. Due to the unsuitability of the program for data analysis, we requested the Air Force identify an alternative aircraft program for data analysis.

The Air Force selected the F-15 aircraft program as the alternative program for data analysis. While the F-15 program was provisioned many years ago, the intent was to evaluate provisioning requirements associated with modifications to the aircraft. The specific modification that the Air Force proposed for data analysis was limited to nine line items, only three of which had a forecasted requirement. Although the modification was discarded because it does not provide sufficient data for analysis, using the D200 database, we were able to identify a larger data set of F-15 provisioning items to analyze.

AMRAAM DATA

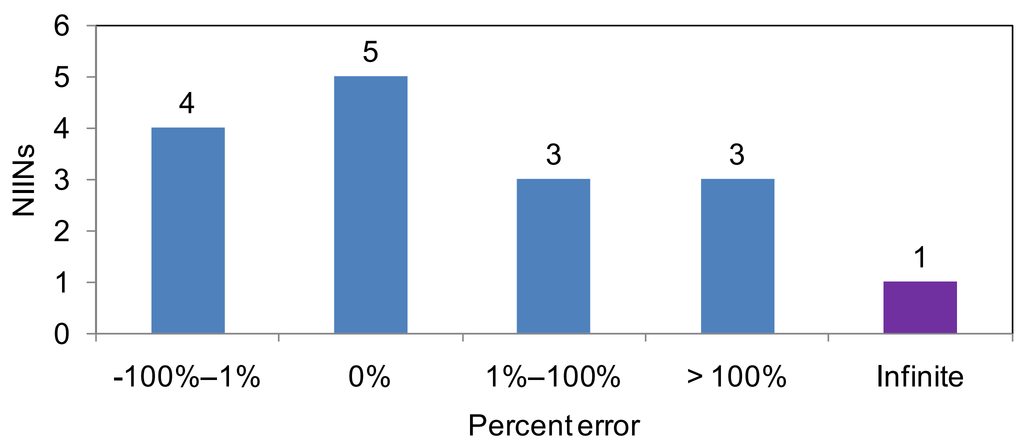
The provisioning forecast included eight line items for the years FY1999–FY2009. Table E-1 lists the eight items for which we received data.

Table E-1. Eight AMRAAM Items

NIIN	Item
013369017	Connector, plug, electrical
014116300	Cover, electrical connector
013966870	Lock, pin attachment
013960339	Wing assembly, guided missile
013970140	Fin, guided missile
012761847	Screw, externally relieved body
014226767	Fin, guided missile, training
013955321	Nut, plain, round

The results of the analysis are presented in Figure E-1.

Figure E-1. AMRAAM Percent Error



The AMRAAM experienced five instances when there was a 0 percent error due to a zero forecast and zero actual demand. There were four instances when items were under-forecast and seven instances of items being over-forecast, suggesting a slight bias toward over-forecasting. However, limited conclusions can be drawn from the analysis of the AMRAAM data for several reasons.

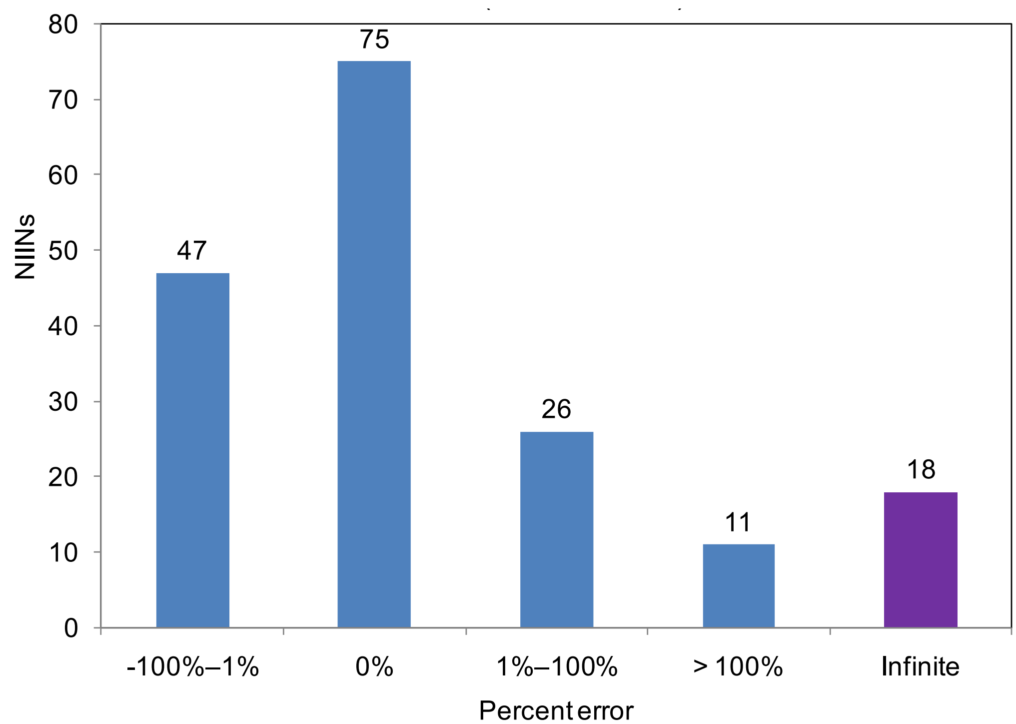
First, the Air Force only provisioned eight items on the AMRAAM. Consequently, the 11 years of actual demand data produced only 88 data points (8 items over 11 years). While we used this data to determine how the forecasts differed from actual demand for the eight items, we cannot draw causal conclusions about the percent error for items that were part of previous AMRAAM modifications (the first AMRAAM was delivered to the Air Force in 1989).

Secondly, the AMRAAM is a missile program, and, as such, is somewhat atypical of Air Force weapon system programs, which are predominantly aircraft. Unlike aircraft, missiles are generally fired only once, and if internal components fail, there is no need to replace them. Unlike aircraft, the parts that are provisioned on a missile are limited to exterior components that may be damaged before the missile's use rather than fail through use. In general, the program proved less than ideal for in-depth forecasting analysis.

F-15 Data

Using the D200 database, we were able to identify a data set of provisioning items for the F-15 to perform the data analysis on. Figure E-2 presents the results of that analysis.

Figure E-2. F-15D Percent Error



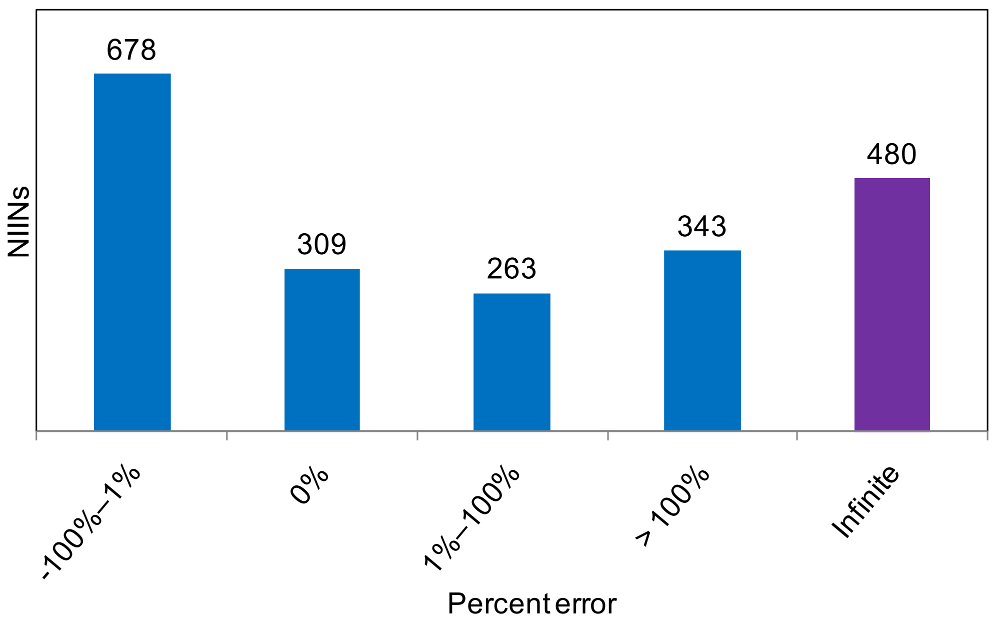
Source: Air Force D-200 Secondary Item Requirement System (SIRS).

Figure E-2 shows that there were 75 instances when there was a 0 percent error due to a zero forecast and zero actual demand. There were 18 instances when there was a forecast greater than zero but no actual demand. Forty-seven items were under-forecast and 55 items were over-forecast, suggesting an over-forecasting bias.

Secondary Item Requirement System Analysis

Figure E-3 shows the results from our analysis of Air Force data. The data set includes all items identified in the Air Force D-200 Secondary Item Requirement System as new item introductions between FY2002 and FY2009.[2] The data set excludes new item introductions for Air Force systems managed by contractors that are not in D-200. There were 309 instances of a 0 percent error. The majority of these were instances when the Air Force forecasted zero demand and actual demand was also zero. There were 480 instances when the Air Force had a forecast for an item greater than zero but no actual demand for that item. In total, there were 1,086 items with over-forecasts and 678 items with under-forecast, suggesting an over-forecast bias.

Figure E-3. Air Force Data (FY2002–FY2009)



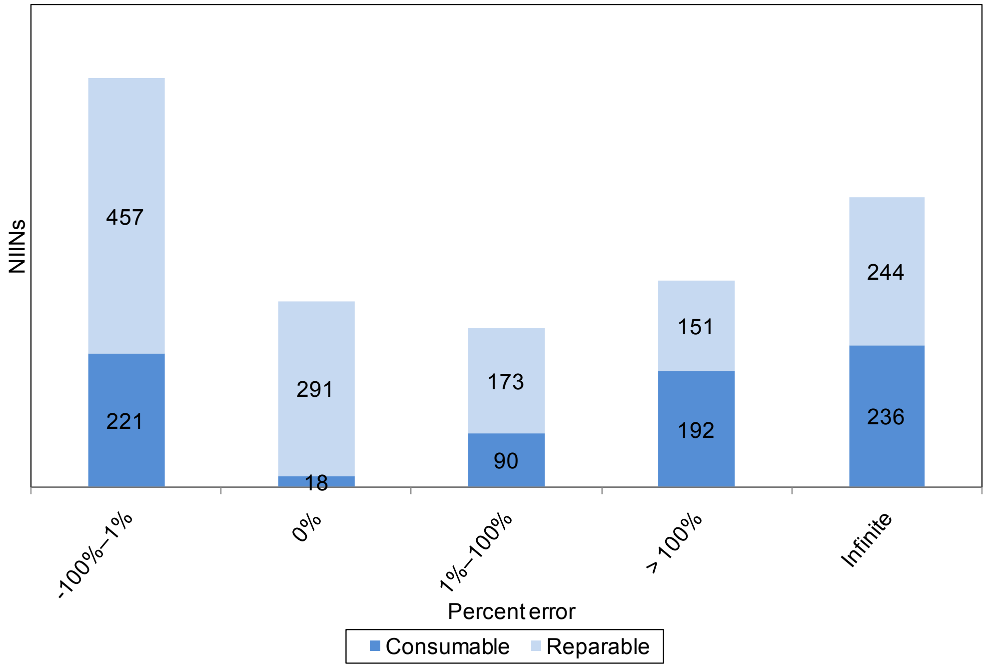
Source: Secondary Item Requirement System (SIRS).

CONSUMABLES VERSUS REPARABLES

We further broke the data down between consumables and reparables, Figure E-4 presents the findings.

[2] We removed all NSO, insurance, and non-stocked items from the sample because the Air Force does not forecast for these items.

Figure E-4. Percent Error for Air Force Consumable and Reparable Items



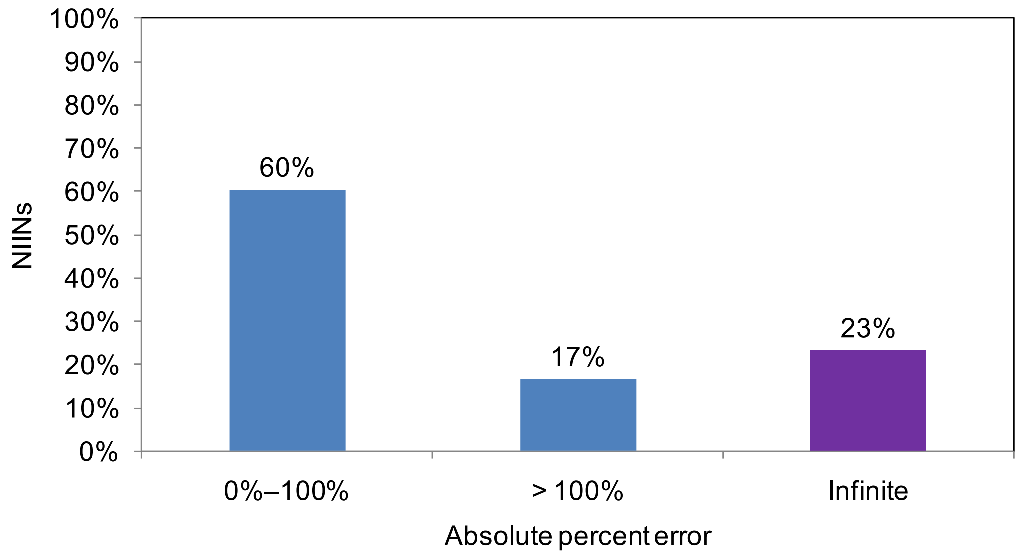
Source: Secondary Item Requirement System (SIRS).

There does not appear to be much of a difference in percent error between consumable and reparable items.

Forecast Accuracy for New versus Existing Items

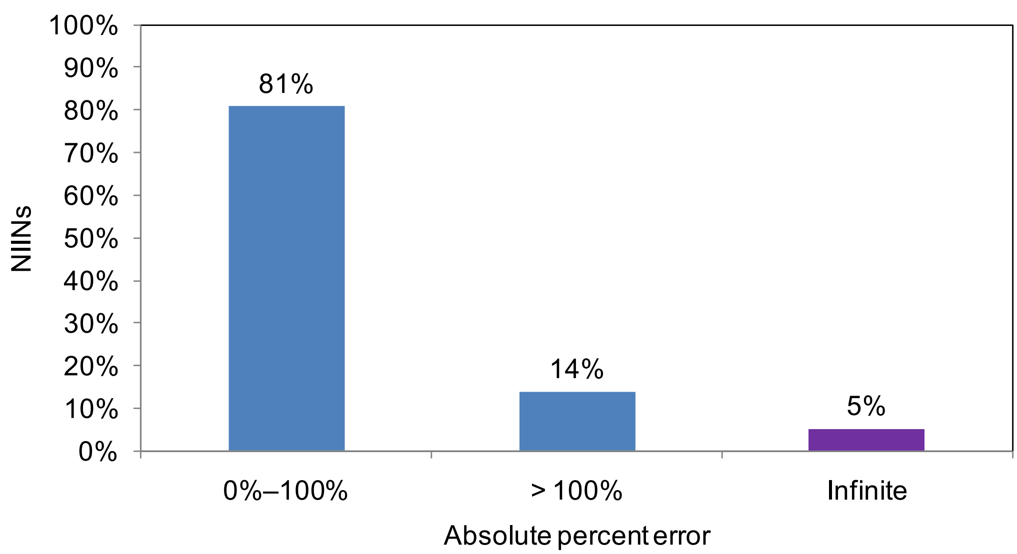
Using the D200 database, we were able to compare the forecast accuracy for new versus existing items over the same period. Figure E-5 and Figure E-6 present the findings.

Figure E-5. Absolute Percent Error for New Items



Source: Secondary Item Requirement System (SIRS).

Figure E-6. Absolute Percent Error for Existing Items



Source: Secondary Item Requirement System (SIRS).

When we look at the histograms for new versus existing items, we see a significant difference in the right tail between the graphs. There were a high number of instances when the absolute percent error is greater than 100 percent and there was a forecast but no actual demand for new items.

Appendix F
Industry Practices

Interviews with Leading Defense Contractors

We interviewed representatives from four leading defense contractors to determine how they accomplish demand forecasting and inventory management for new weapon systems, and to ascertain whether any of their practices could be applied to improve DoD's practices.

The companies represented a good cross-section of the defense industry, both in terms of the types of equipment manufactured and the military services they served. We agreed not to disclose the names of the contractors to promote frank and open discussions. Collectively, the companies included aviation, maritime, and ground equipment manufacturers, and the customers included all the military services. In addition to military customers, all four companies had significant private sector customers. In addition to seeking insights on how they supported DoD customers, we asked for information about how they supported their private sector customers and whether those practices might be transferrable to DoD.

Findings

Table F-1 summarizes the results of the interviews. It is followed by a more detailed discussion of what we learned. Although the contractors interviewed were willing to discuss their general approaches, they were not willing to provide specific information that they considered proprietary.

Table F-1. Summary of Interviews

Contractor	Basis for initial estimates	Demand and supply planning	Reliability improvements	Resupply times	Alternatives to spares investment
A	Analogous systems and components	Flexible response to customer demands	Reengineer bad actors	Accelerated resupply times	Borrow from production line Delay inventory investment
B	Analogous systems and components	Flexible response to customer demands	Reengineer bad actors	Accelerated resupply times	Borrow from production line Delay inventory investment
C	Commercial equipment usage	Consider customer environment	Reengineer bad actors	Commercial distributors	Direct vendor delivery
D	Analogous systems and components	Flexible response to customer demands DLA included in initial planning	Reengineer bad actors	Use internal stock currently being held for other equipment	Borrow from production line Direct vendor delivery

Basis for Initial Estimates

Three of the contractors provided engineering estimates to DoD customers that were used by the Services as a basis for item introduction forecasts. The companies based their estimates primarily on similar or identical DoD weapon systems, equipment, or components. The approach is often referred to as a structured analogies approach, and it is widely used for estimating demand for new products in both the defense and private sectors.

The equipment that the fourth contractor provided DoD was commercial equipment adapted for DoD use, and the company's estimates were based on commercial demand rates. The contractor representative indicated he did not develop any equipment for DoD, but when he developed a new product for a commercial customer, the initial demand estimates were based on engineering estimates similar to those used by the other contractors.

All four companies adjusted their estimates based on the specific application of the items, the operating environment, and judgments based on prior experience with similar equipment. All indicated that engineering estimates were inherently less reliable than actual usage data. The three that used engineering estimates recommended conservative buys initially until actual usage data became available.

Demand and Supply Planning

Three of the contractors provide wholesale and retail interim supply support to DoD customers during new equipment introduction. The fourth contractor, the commercial equipment provider, developed recommendations for retail-level support packages but supplied no other interim support.

When developing initial spares recommendations for new equipment, all four contractors tailored their demand and resupply time forecasts based on collaboration within their companies and externally with DoD customers. One contractor indicated that DLA actively participated in developing their interim support strategy and spares recommendations for one of its new equipments, but our research suggested this happens for a minority of systems.

Reliability Improvements

For items with high failure rates, the companies generally do not attempt to spare to those rates. Rather, during interim support they will rely on other supply chain alternatives, such as accelerating resupply times or borrowing spares from other sources, to compensate for spares shortfalls while attempting to fix the reliability problem.

Resupply Times

All of the contractors indicated they accelerate resupply times when necessary to minimize spares investments, but they differed in their approaches. Two mentioned using premium transportation, interim repair capabilities, and expediting production lead times as typical strategies. One indicated he was usually able to borrow spares from sources. The commercial equipment contractor indicated that he could usually rely on the commercial distributors to fill any DoD retail parts shortfalls.

Other Alternatives to Spares Investment

Three of the contractors mentioned they also borrowed from their production lines when necessary, particularly during interim support, to minimize initial spares investment. Two indicated they typically recommended conservative spares buys initially until the equipment design and support capabilities stabilized and actual demand data became available. The commercial equipment contractor, and another contractor whose defense equipment often has commercial origins, indicated that they can often fill spares shortfalls through direct vendor delivery contracts.

One of the contractors stated that his spares recommendations are less conservative for contracts in which the government funded the spares procurements than for contracts in which the company was incentivized to limit spares investments (e.g., performance based logistics contracts).

IN SUMMARY

The contractors that we interviewed all developed initial spares demand forecasts based on similar or same equipment or components using a structured analogies approach. All agreed that engineering estimates are inherently less reliable than actual usage data. During interim support, contractors rely on a variety of supply chain alternatives to delay investing in inventory until new programs stabilize.

Appendix G
Bayesian Approach

Under the current DoD method, demand forecasts are initially computed based on reliability and maintainability (R&M) estimates. At 6 month intervals over the next 2 years, forecasts are recalculated with more emphasis being placed on actual demand.[1] In contrast to the current 2-year time-weight forecasting method being used by the military services, the Bayesian approach combines R&M estimates with historical data to achieve a more balanced forecast. As more demand data becomes available, the Bayesian approach places more weight on the actual demand data and less on the R&M estimates.

The Bayesian approach is a two step process. Equation G-1 illustrates Step 1 of the approach to develop the mean demand rate ($DR1_i$ = failures per operating hour for Step 1) for each item *i*, which is the inverse of the mean time between demands (MTBD).

$$DR1_i = \frac{Historical\ demands_i + 1}{\left(OH \times QPA_i \times FAP_i\right) + R\,\&\,M\ \ MTBD_i}, \qquad \text{[Eq. G-1]}$$

where

OH	=	operating hours of weapon system (or weapon system operating hours)
QPA	=	quantities per application of item *i* on weapon system
FAP	=	future application percentage for item *i*
R&M MTBD	=	reliability and maintainability mean time between removal estimates for item *i*.

After $DR1_i$ has been determined, Step 2 normalizes all demand rates to obtain the final demand rate (DRF_i) based on overall system reliability. This step is included to improve demand estimates at an aggregate level. At an item level, limited historical data is available and some estimates are too high or too low. At the system level, the overall system reliability data is more accurate, since the over and under

[1] At six months, 75 percent emphasis is on R&M estimates and 25 percent is on actual demand; at 12 months, 50 percent is on R&M and 50 percent on demand; at 18 months, 25 percent on R&M and 75 percent on demand; and at 24 months, 100 percent of emphasis on demand. When actual demand data isn't available, the forecast is computed the same as the interim support forecast (i.e., 100 percent of emphasis is on R&M estimates).

estimated demand rates balance out. Equation G-2 shows the equation that is used to normalize the demand rates, Step 2 of the Bayesian formula.

$$DRF_i = DR1_i \times \frac{\sum_{i=1}^{No.\,of\,items} Historical\ demands_i}{\sum_{i=1}^{No.\,of\,items} DR1_i \times OH \times QPA}. \quad \text{[Eq. G-2]}$$

To illustrate the Bayesian approach, we use historical demands for three items that are part of the same aircraft. The input data is historical demands for 80,000 OH with QPA and FAP both equal to one. Following the steps described above, the complete results are presented in Figure G-1 and Table G-1.

Figure G-1. Bayesian Approach Example

	Input Data			Step 1: Bayesian			Step 2: Normalize		
Item	**Historic Demand**	**Operating Hours**	**R&M MTBD**	**Operating Hours + R&M MTBD**	**Historic Demands+1**	**DR1= Step 1 Failures with DR1**	**Expected Failures with DR1**	**DRF= Step 2 Normalized Failure Rate to Actual Failures**	**Expected Failures**
A	1	80,000	20,000	100,000	2	0.00002	1.6	0.000022	1.76
B	0	80,000	20,000	100,000	1	0.00001	0.8	0.000011	0.88
C	20	80,000	20,000	100,000	21	0.00021	16.8	0.00023	18.4
Total	21			**Total Failures From DR1**			19.2		21.04
				Normalize Factor Applied to DR1			1.09375		

Table G-1. Mean Time between Demand

Item	Historical MTBD	R&M	Bayesian
A	80,000	20,000	41,479
B	?	20,000	82,959
C	4,000	20,000	3,968

Note the Bayesian method avoids the problem for items with no historical demands (Item B). The R&M method ignores the historical values, while the Bayesian method is able to find a balance between the two. As more demand becomes available, emphasis shifts away from R&M estimates towards the historical data. In summary, the Bayesian method corrects for systematic under- or overestimating demand.

Appendix H
Abbreviations

AAO	approved acquisition objective
ACALA	Armament and Chemical Acquisition and Logistics Activity
APE	absolute percent error
APICS	American Production and Inventory Control Society
AR	Army Regulation
CECOM	Communications-Electronics Command
COTS	commercial off-the-shelf
DAGR	Defense Advanced Global Positioning System Receiver
DASD	Deputy Assistant Secretary of Defense
DAU	Defense Acquisition University
DLA	Defense Logistics Agency
DPA	Demand Plan Accuracy
DS	direct support
DVPE	dollar value of positive error
DWMPE	dollar weighted mean percent error
EE	engineering estimate
ERP	enterprise resource plan
ESB	Engineer Special Brigade
FMR	Financial Management Regulation
FMS	foreign military sales
FSG	federal supply group
GAO	Government Accountability Office
GS	general support
ICP	inventory control point
ICS	interim contractor support
IOC	initial operating capability
LMP	Logistics Modernization Program
MAD	mean absolute deviation

MAPE	mean absolute percent error
MCA SPO	MCA Solutions' Service Planning and Optimization
MD	mean deviation
MICAP	mission capable
MOS	military occupation specialty
MPE	mean percent error
MSD	material support date
MSE	mean square error
MTBD	mean time between demands
NAVICP	Naval Inventory Control Point
NIIN	National Item Identification Number
NSN	national stock number
OEM	original equipment manufacturer
OSD	Office of the Secretary of Defense
PBL	Performance Based Logistics
PE	percent error
PMCS	preventive maintenance checks and services
PRS	potential reutilization stock
RBS	readiness-based sparing
RMSE	root mean square error
SCI	Supply Chain Integration
SCM	supply chain management
SCOR	Supply Chain Operations Reference
SCRM	supply chain risk management
SIRS	Secondary Item Requirement System
SSR	supply support request
TacSat	Tactical Satellite
Tiger-ACIM	Tiger-Availability Centered Inventory Model
TSG	Surgeon General
WIN-T	Warfighter Information Network-Tactical