NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

STUDY OF USING EXCESS STOCK TO REDUCE NAVAL AVIATION DEPOT-LEVEL REPAIRABLE PIECE PART BACKORDERS

December 2016

By: Jennifer L. Custard
Quentin E. Lease
Jan D. Schotman

Advisors: Geraldo Ferrer
Eddine Dahel
Peter Ward

Approved for public release. Distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704–0188*

1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2016	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report

4. TITLE AND SUBTITLE STUDY OF USING EXCESS STOCK TO REDUCE NAVAL AVIATION DEPOT-LEVEL REPAIRABLE PIECE PART BACKORDERS	**5. FUNDING NUMBERS**
6. AUTHOR(S) Jennifer L. Custard, Quentin E. Lease, and Jan D. Schotman	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) Naval Supply Systems Command, Weapon Systems Support 5450 Carlisle Pike, PO Box 2020, Mechanicsburg, PA 17055-0788	**10. SPONSORING / MONITORING AGENCY REPORT NUMBER** 2016-12

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB number N/A

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.	**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

Naval Aviation Depot Level Repairables (AVDLRs) are repairable subassemblies for Naval aircraft weapon systems. The Fleet Readiness Centers' primary task is to repair non-functional AVDLRs. Such repairs usually require replacement of components, known as bit-piece parts or consumables. Technicians requisition any bit-piece parts not on hand through the Defense Logistics Agency (DLA). As weapon systems age, sources for bit-piece parts become more difficult to identify. As a result, as of July 2016, DLA has approximately 15,000 bit-piece part requisitions backordered. Naval Supply Systems Command (NAVSUP) Weapon Systems Support (WSS), the organization responsible for managing AVDLRs, is concerned that the significant quantity of bit-piece part backorders is negatively affecting aviation operational readiness. A potential alternative source for acquiring bit-piece parts is Navy excess material. Excess material is inventory designated by Navy organizations as meeting excess classification criteria. Since the Navy has already purchased the excess material, it represents a cost-effective sourcing option. The goals of this project are to determine if existing excess material can fulfill any current bit-piece part backorders, and if excess material represents a sustainable source of bit-piece parts for future requisitions.

14. SUBJECT TERMS naval aviation AVDLRs, backorder, excess, DLA, WSS, FRC, Python, piece part	**15. NUMBER OF PAGES** 77
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN 7540–01-280-5500 Standard Form 298 (Rev. 2–89) Prescribed by ANSI Std. 239–18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release. Distribution is unlimited.

STUDY OF USING EXCESS STOCK TO REDUCE NAVAL AVIATION DEPOT-LEVEL REPAIRABLE PIECE PART BACKORDERS

Jennifer L. Custard, Lieutenant Commander, United States Navy
Quentin E. Lease, Lieutenant Commander, United States Navy
Jan D. Schotman, Lieutenant Commander, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2016

Approved by: Geraldo Ferrer

Eddine Dahel

Peter Ward

Bryan Hudgens
Academic Associate
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

STUDY OF USING EXCESS STOCK TO REDUCE NAVAL AVIATION DEPOT-LEVEL REPAIRABLE PIECE PART BACKORDERS

ABSTRACT

Naval Aviation Depot Level Repairables (AVDLRs) are repairable subassemblies for Naval aircraft weapon systems. The Fleet Readiness Centers' primary task is to repair non-functional AVDLRs. Such repairs usually require replacement of components, known as bit-piece parts or consumables. Technicians requisition any bit-piece parts not on hand through the Defense Logistics Agency (DLA). As weapon systems age, sources for bit-piece parts become more difficult to identify. As a result, as of July 2016, DLA has approximately 15,000 bit-piece part requisitions backordered. Naval Supply Systems Command (NAVSUP) Weapon Systems Support (WSS), the organization responsible for managing AVDLRs, is concerned that the significant quantity of bit-piece part backorders is negatively affecting aviation operational readiness. A potential alternative source for acquiring bit-piece parts is Navy excess material. Excess material is inventory designated by Navy organizations as meeting excess classification criteria. Since the Navy has already purchased the excess material, it represents a cost-effective sourcing option. The goals of this project are to determine if existing excess material can fulfill any current bit-piece part backorders, and if excess material represents a sustainable source of bit-piece parts for future requisitions.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AAO	Approved Acquisition Objective
AS	Acquisition Specialist
ATC	Allowance Type Code
AVDLR	Aviation Depot Level Repairable
AWP	Awaiting Parts
CAS	Customer Account Specialist
CIMIP	Comprehensive Inventory Management Improvement Plan
COG	Cognizance Code
COMFRC	Commander, Fleet Readiness Centers
COMNAVAIRFOR	Commander, Naval Air Forces
CRS	Contingency Retention Stock
CWT	Customer Wait Time
DDS	Defense Logistics Agency Disposition Services
DLA	Defense Logistics Agency
D-LEVEL	Depot Level
DOD	Department of Defense
DODAAC	Department of Defense Activity Address Code
DOD(IG)	Department Of Defense Inspector General
DRMS	Defense Reutilization and Marketing Service
EBS	Enterprise Business System
ERP	Enterprise Resource Planning
ERS	Economic Retention Stock
FRC	Fleet Readiness Center
FY	Fiscal Year
GAO	General Accounting Office/Government Accountability Office
ID	Identifier
MSL	Maximum Stock Level
NAMP	Naval Aviation Maintenance Program
NAVAIR	Naval Air Systems Command

NAVSUP	Naval Supply Systems Command
NDAA	National Defense Authorization Act
NIIN	National Item Identification Number
NSN	National Stock Number
OEM	Original Equipment Manufacturer
O-level	Organizational Level
PR	Purchase Requisition
PRS	Potential Reutilization Stock
USMC	United States Marine Corps
WCF	Working Capital Fund
WSS	Weapon Systems Support

ACKNOWLEDGMENTS

We wish to sincerely thank our advisors, Dr. Geraldo Ferrer, Dr. Eddine Dahel, and Commander Peter Ward, SC, USN, who gave us the guidance and motivation to keep pushing forward. When faced with an overwhelming volume of data, CDR Ward came to our rescue with his Python computer-programming knowledge, allowing us to provide a higher level of fidelity to our analysis.

On the note of data, we would like to thank LCDR Isaac May, Director Customer Operations N42, and CDR John Bredenkamp, Industrial Support Code N983 at NAVSUP WSS, for helping us narrow our research question to something manageable and providing the excess inventory data. We would also like to thank CDR Matt Brickhaus, Commander DLA Aviation San Diego, and his team, Demand Supply Chain Analysts Elaine Houston and Lacey Carpenter, for providing the backordered requisition data and explaining the process to our team. Additionally, we would like to thank Mr. Chuck Bloom, F/A-18 A-G Weapon System Program Manager (and retired Supply Corps officer), at DLA Aviation, who generously helped with confirming and providing information pertaining to DLA Aviation’s business practices.

Professor Bryan Hudgens and Dr. Mark Eitelberg’s Defense Research Methods class gave us the early motivation to knock out our first 30 pages during the fourth quarter.

Finally, we would like to thank our families who supported our pursuits of higher education. Without their dedication, we could not have finished this project.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

Naval Supply Systems Command (NAVSUP) Weapon Systems Support (WSS) in Philadelphia, Pennsylvania, manages aviation-specific parts for the Navy and Marine Corps. As of July 2016, NAVSUP WSS had 23,000 aviation repairable item-specific backorders. Commander, Naval Air Forces (COMNAVAIRFOR) Instruction (2013) defines a repairable item (repairable) as “a durable item which, when unserviceable, can be economically restored to a serviceable condition through regular repair procedures” (p. A-65). Two categories of backorders exist, growth requirements (designated by QZ fund code document identifier {ID}) and in-place programs (Non-QZ fund code document IDs). Growth requirements represent an approved change in the allowance authorization for a given item. Put another way, when the allowable inventory is increased, QZ-coded requisitions indicate orders to fill the difference, but not for any previous stock shortage. In-place program requisitions are for deficiencies in authorized inventory levels; the stock on hand is lower than the allowance and the requisition is to fill a shortage (COMNAVAIRFOR, 2013). Of the 23,000 repairables backordered, 14,790 requisitions are non QZ-coded aviation requirements that require bit-piece part support and fall under the responsibility of Defense Logistics Agency (DLA). The bit-piece parts are usually consumables, most commonly identified with the cognizance (COG) code 9B, however, they could also be repairable sub-assemblies designated as a 7R or 1R COG code.

When a unit identifies an unserviceable AVDLR, the broken item—or carcass—is turned in to the nearest Advanced Traceability and Control site, who forwards it to the appropriate Fleet Readiness Center (FRC) for repair. After a technician diagnoses the carcass, the required parts are ordered and the AVDLR carcass remains in the Awaiting Parts (AWP) bin until the parts arrive. The AWP personnel are responsible for receipt, storage, and control of all AVDLRs in AWP status. Technicians service the AVDLRs once the required parts arrive. The technician re-designates the carcass as Fully Mission Capable upon confirmation that it is in working condition.

Maintenance of AVDLRs is dependent on the acquisition of requisite bit-piece parts. FRCs requisition through DLA any bit-piece parts not immediately available in inventory held onsite. DLA maintains its own inventories of bit-piece parts, but when quantities on hand are insufficient to meet customer needs, DLA acquires the bit-piece parts from industry through contracted acquisitions.

Most acquisitions are fulfilled promptly by industry, but in some instances, the material ordered is not readily available. Reasons for non-availability are numerous. For example, weapon systems have life cycles measured in decades and sometimes outlive the companies that make the component parts, making sourcing of the components difficult. In addition, high demand variability makes accurate forecasting difficult and higher than anticipated demand can result in supplier shortages. Finally, many repairable piece parts are low-cost, low-margin products that reduce their attractiveness to potential manufacturers, therefore limiting sourcing availability. Unsatisfied acquisitions are placed in backordered status until the contract can be fulfilled.

In 2011, NAVSUP launched the Navy Enterprise Resource Planning (ERP) system, designed to consolidate system-wide visibility of the naval supply chain. The goal was to facilitate information sharing and more efficient use of worldwide inventory of spare parts. Additionally, aggregating demand information across a wide array of locations generally allows more robust forecasting capability. This is particularly significant in Department of Defense (DOD) inventory management, as unit demand for spare parts is exceptionally variable. The aggregation of system-wide data provides an opportunity to "smooth out" wild demand swings.

In 2013, in order to utilize existing Navy resources more effectively, NAVSUP directed all naval activities to submit their requisitions through the Navy ERP system. However, FRCs do not utilize ERP and continue to route all requisitions through DLA due to an agreement, stemming from the 2005 Base Realignment and Closure directive, to co-locate warehousing. Because DLA operates under Defense Working Capital Funds (DWCF), it receives a small surcharge on every requisition it fulfills, which helps fund the co-located warehouses. While this surcharge incentive ensures funding for the required logistics infrastructure, the consequence for the FRCs is the inability to utilize material already available elsewhere in the naval supply system, including excess material.

DLA backorders cause the delay of thousands of FRC requisitions. Navy stock, including excess material could fulfill many of these backorders. Unfortunately, until a more efficient process, such as automation is in place, the only way to source the backorders involves manual intervention, such as system stock check, physical stock check, DLA contact, or referral. This method requires significant effort and is usually conducted for the most challenging backorders, commonly known as “head-hurters”, on a case-by-case basis when a particular requisition has garnered exceptional attention. This most often occurs when a deployed or pre-deployment unit has aircraft down for maintenance and cannot afford to wait for backordered parts to arrive.

This action has cascading effects on the supply system. Not only does the identification of the excess material require significant effort, but also re-directing the original requisition to the excess source requires significant effort as well. In addition to the orders taking place at the depot level, many times a unit simply submits a separate requisition specifically sourced to the excess location, bypassing DLA altogether. Leaving the original requisition open creates a “catch-22” situation. If the unit cancels the requisition, DLA fails to capture that demand history for future consideration of demand forecasts. However, if the requisition remains open and eventually delivers, that particular unit may have now created its own excess inventory if it does not have an allowance to carry that second part in their storeroom.

A. DLA PROCESS

National Stock Numbers (NSNs) are ordered by FRCs and the requisitions show in both the DOD EMALL system and DLA’s Enterprise Business System (EBS). These requisitions usually process through the system and fill automatically. When an order becomes backordered, DLA designates the order with status code BB if the requisition is backordered due to no stock on the shelf. Another backorder status code used is BZ when a NSN is a direct-vendor delivery item (not centrally stocked) and is waiting for a contract to be awarded to a supplier.

There are three customer-facing divisions at DLA Aviation: Naval (including Navy and Marines Corps), Air Force, and Army. When an item is backordered, the customer-facing division at DLA Aviation manually handles the requisition. Within the Naval division, there are various customer service cells (e.g., aircraft carriers, air stations, aviation squadrons, and FRCs). A Customer Account Specialist (CAS) assigned to a customer service cell initiates procurement actions to satisfy the backorder. If necessary, the Weapon System Program Manager, who has overall responsibility for the health of a Weapon System Designator Code, may get involved to ensure timely receipt. When a high-priority (Issue Priority Group 1) requisition is backordered, a CAS investigates to determine the best way to get that requisition filled. If the NSN is on contract, but the delivery date is not near, the CAS inquires through the post-award acquisition specialist (AS), or directly through the vendor, whether or not an earlier shipment is possible. If there is no contract but only a purchase requisition (PR), the CAS requests a prioritization on the PR for an acquisition specialist to award. A PR is a procurement document defining the required NSN and quantity needed. If the NSN is neither on contract, nor close to award, the CAS looks for excess stock in the naval asset availability systems such as Afloat Total Asset Availability and OneTouch. If there are no assets available for transfer, the CAS checks the availability of excess commercial assets. However, due to aviation criticality requirements, only new certified stock may be used. If excess commercial assets are available and deemed to meet criticality requirements, the CAS notifies an AS (a buyer) to initiate a PR for an emergency contract.

Issue Priority Group 2 backordered requisitions are only manually handled if a large amount of backorders or a high-level of interest exists, such as from a Naval Air Systems Command (NAVAIR) program office or Flag Officer. Issue Priority Group 3 backorders are the lowest priority and receive manual intervention only as a side effect of getting the high priority backordered NSN on contract in a quantity to fill those backorders.

B. RESEARCH QUESTION

Previous studies have focused on the cost savings potential of various inventory management policies including redistributing excess material. While cost savings is an important consideration, especially in light of sequestration and continual budget constraints, our study focuses on the impact to readiness that long lead-time backorders cause to the aviation community. The importance of this research question is to determine if the availability of excess material, visible in Navy ERP, warrants a long-term change to the requisition Standard Operating Procedure currently employed by the Navy FRCs. Previous studies, including those by McNulty (2012) and Oswald (2013), examined how to proactively redistribute excess material across the enterprise to satisfy standard requirements prior to fulfillment through normal channels. This study focuses on the following question:

Is excess material an effective source of supply for backordered requisitions?

For the purposes of this study, the definition of an effective means the supply of Navy excess material would replenish often enough, with the appropriate material, to sustain a long-term change to the requisition process that incorporates mandatory screening of excess material.

C. ORGANIZATION OF THE PAPER

The remainder of this work is organized as follows. Chapter II discusses the background and literature review and provides a roadmap for this study. Chapter III discusses the methodology used to quantify our data. We analyzed 24 months of backorder history collected from DLA Aviation's San Diego, California, location for requisitions submitted by the FRCs. Next, we compared this data to the excess material data collected from NAVSUP WSS specifically through the ERP system. Chapter IV discusses our analysis and results. Chapter V summarizes our study, details the limitations, discusses our conclusions, and provides recommendations both for current policy changes and for future studies.

THIS PAGE INTENTIONALLY LEFT BLANK

II. BACKGROUND

NAVAIR created the Naval Aviation Maintenance Program (NAMP) to manage the repair and material condition of all U.S. Naval aviation weapon systems. The primary goal of NAMP is to improve the overall performance of naval aviation readiness support by focusing on performance elements such as effectiveness, efficiency, and quality. The elements are typically measured comparisons of the value of input resources, such as labor hours and repair part costs, and the value of outputs, such as customer wait time (CWT) and the reliability of repaired systems. Because of this improvement-centered approach, NAVAIR organized maintenance functions into three tiers to achieve an optimized allocation of resources: organizational, intermediate, and depot.

Organizations allocated aviation weapon systems conduct Organizational level (O-level) activities. These include inspection, service, and preventive maintenance of systems, as well as all associated recordkeeping. Intermediate level activities include component assessments, limited manufacturing and fabrication, calibration, technical assistance to O-level activities, as well as any maintenance functions not accomplished at the O-level. Depot level (D-level) activities are the highest tier and are responsible for the most complex maintenance functions, such as system modifications, engine repair, and Scheduled Depot Level Maintenance (SDLM). D-level activities are synonymous with industrial activities (Naval Aviation Maintenance Program, 2013).

The Navy has two principal D-level, or industrial, activities. Naval shipyards, which support maritime weapon systems, and FRCs, which support aviation weapon systems. There are eight FRC Area Commands: FRC Southwest in North Island, California; FRC West in Lemoore, California; FRC Northwest in Whidbey Island, Washington; FRC Mid-Atlantic in Oceana, Virginia; FRC Southeast in Jacksonville, Florida; FRC East in Cherry Point, North Carolina; FRC WestPac in Atsugi, Japan; and FRC Aviation Support Equipment in Solomons Island, Maryland. As implied by their titles, the FRCs provide support to their respective geographic regions, with the exception of FRC Aviation Support Equipment, which specializes in D-level activities for aviation support equipment Navy-wide. FRCs fall under Commander, Fleet Readiness Centers

(COMFRC), who is responsible for all FRC operations Navy-wide. COMFRC is subordinate to both Commander, Naval Air Systems Command and COMNAVAIRFOR (Commander, Naval Air Forces, 2013).

This paper uses the same definition as Volume I of the NAVSUP Publication 485, "Afloat Supply." Excess inventory as discussed in this study refers to material above the approved allowance level, held on-station at various naval units or warehouses. An allowance is the amount of any particular item a naval organization is authorized to hold in inventory. Excess is any material categorized under allowance type codes (ATC) 6, 7, or 8. An ATC describes why the material is stocked; these particular codes identify items that are not currently part of the authorized inventory list (Afloat Supply, 2005).

A review of General Accounting Office/Government Accountability Office (GAO) reports shows that excess inventory has been a major concern for the Navy for decades. Prior to July 2004, the GAO meant either the General Accounting Office or Government Accountability Office. For the purposes of this report, the acronym GAO will refer to the name at the time of a given report. As early as 1990, the GAO classified DOD inventory management process as "high-risk" (Gilmore, Klemm, Sweetser, 2011). Furthermore, a 2004–2007 study on the Navy's excess material found an average of $7.5 billion of inventory exceeded current requirements (GAO, 2008). Unfortunately, the Navy's excess inventory continues to grow. As of July 2016, the Navy has approximately 40,000 line items of excess aviation inventory worth nearly $500 million dollars. The Navy runs level settings quarterly and designates any material that exceeds forecasted demand as excess. The excess is stored around the world at the various Naval Air Stations and other unit-level activities until eventually offloaded to DLA's Defense Disposition Services (DDS) sites. Unfortunately, the FRCs and DLA do not have automated visibility of these excess items or DLA Disposition Services inventory**.**

Items qualify as excess for a number of reasons. Referencing the work of Gilmore, Klemm, and Sweetser (2011), researchers McNulty, Dillion, and Mourning (2011) organized these reasons into five categories and described them as follows:

- <u>Configuration changes.</u> The Navy replaced one piece of equipment with another, and the old items do not support the new piece of equipment.

- Allowance changes. An Automated Shore Interface file reduced the allowance quantity because the installed equipment requires fewer items to support it (e.g., actual usage is less than expected).

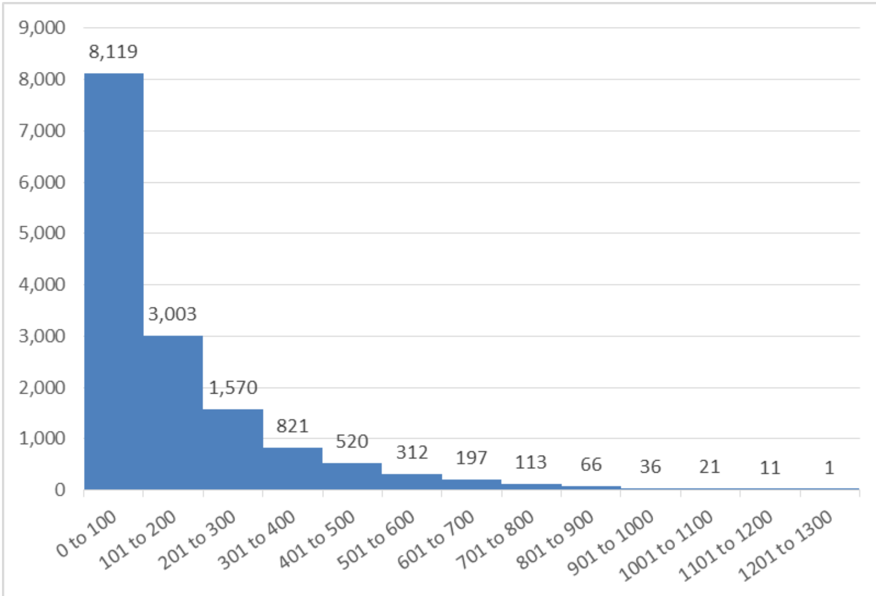
- Changes in item disposition. Excess includes any item that is obsolete or defective. Price changes also influence the amount of excess. Units usually may carry very cheap items in excess without penalty. However, if the price increases above a certain threshold, the unit must report the previously exempted items as excess.

- Level settings. The unit-level supply databases have a function, commonly called a level setting, which can update some allowance quantities based on demand during a specified period.

- Improper unit-level inventory management. This category encompasses all the bad habits that lead to inventory discrepancies. One common problem is poor receipt and issue practices, which can result in gains by inventory (e.g., discovery of an item previously written off).

As of July 2016, the average age of the FRC backorders provided by DLA is 149 days with a median of 87 days. The minimum age of backorders is one day with a maximum age of 1,248 days representing a total wait time of 2,205,512 days over 14,790 requisitions. Figure 1 shows the distribution of average backorder age.

Figure 1. Age Distribution of July 2016 NAVSUP AVDLR Backorders



A. LITERATURE REVIEW

For our study, a review of previous studies, policies, and GAO reports provide a starting point to orient our research. We found that the highly variable demand experienced by the DOD results in substantial number of backorders. Additionally, poor inventory practices result in a significant amount of excess material. The Navy may be able to use the problem of excess material to alleviate the problem of backordered requisitions.

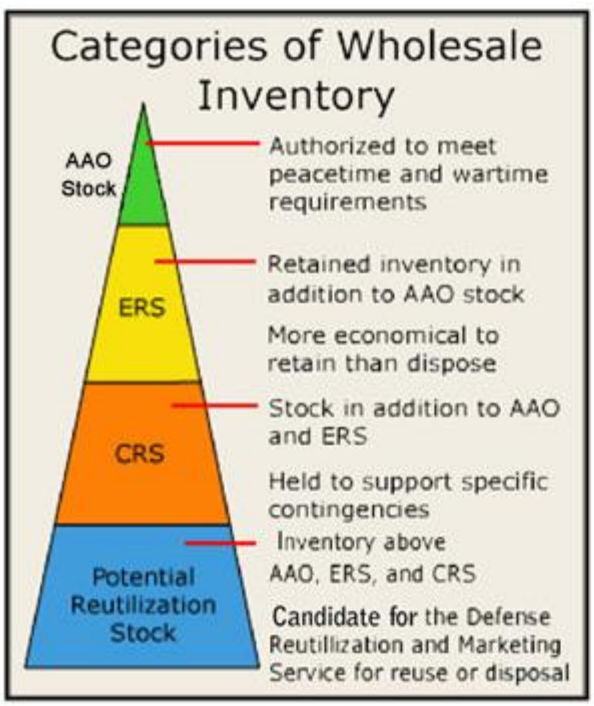
1. Inaccurate Forecasting

Inaccurate forecasting is a possible cause for supportability issues. It is historically known that the DOD and its component services' demand forecasts are repeatedly inaccurate, as recently highlighted in Rigoni and Souza (2016). Inaccurate demand forecasts cause shortfalls in inventory (by under-forecasting), which can lead to backorders, or cause excess inventory (by over-forecasting) because the demand is not there for use.

The DOD implemented the Comprehensive Inventory Management Improvement Plan (CIMIP) in 2010 due to the inaccurate demand levels. The CIMIP aimed to reduce excess DOD secondary inventory, which are the parts that FRCs rely on. Secondary inventory, by DOD definition are “minor end items; replacement, spare, and repair components; personnel support and consumable items” (Rigoni & Souza, 2016, p. 1).

Figure 2 shows the inventory categories in an easy-to-read pyramid. The tip of the pyramid, Approved Acquisition Objective (AAO) Stock, is essentially the base stock to support requirements. As one descends toward the lower levels of the pyramid, the stock is more than the level needed to support routine operational requirements. Briefly, the lower levels (Economic Retention Stock (ERS), Contingency Retention Stock (CRS), and Potential Reutilization Stock (PRS)) are held as safeguards for allowing more stock for unforeseen demands (Defense Acquisition University Log 102, Section 9.5). Due to the ongoing limited fiscal environment, pressure has been placed on DLA and the components’ logistics services to reduce inventories, which could explain why stockout, and subsequent high customer wait time (CWT), is occurring.

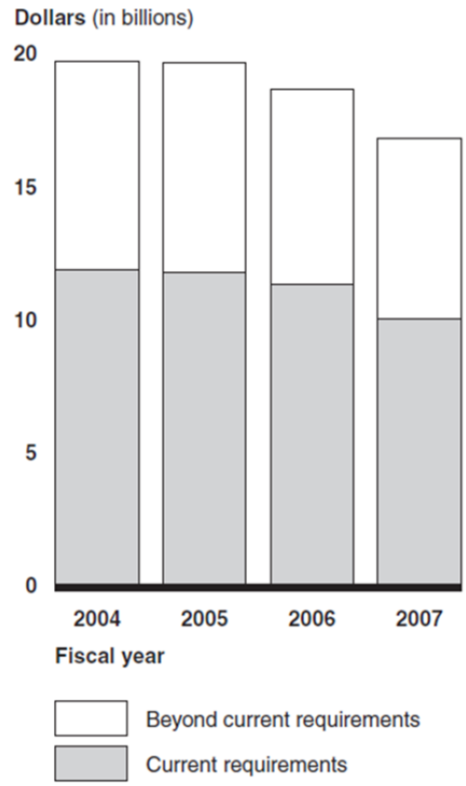
Figure 2. Categories of Inventory. Source: DAU (2016).



The CIMIP emerged after the past three decades' various reports criticizing the DOD's fiscal responsibility, namely in inventory management. A 1988 GAO report found that the stock of secondary items from 1980 to 1987 grew $50.6 billion, of which DLA accounted for $4.1 billion growth (57 percent increase) and the Navy increased to $19 billion (167 percent increase) (GAO Defense Inventory, 1988, p. 8). Although total value of required stock grew $27 billion during that same timeframe, $19 billion was considered excess material; and the 186 percent increase in unrequired stocks far surpassed the 84 percent increase in required stocks (p. 1), implying excess stock is growing faster than the required stock. Following this report, in 1989, the GAO identified 14 special-interest target areas, including special review of DOD's inventory management systems, which continues to this day as part of the now 32 special interest areas on GAO's 2015 list (Rigoni & Souza, 2016, p. 2).

GAO also published a multi-year series where it reviewed the secondary inventory of the Air Force (2007), Navy (2008), Army (2009), and DLA (2010). As shown in Figure 3, GAO's report on Navy's spare parts inventory explained that yet again, "inventory that exceeded current requirements or had inventory deficits resulted from inaccurate demand forecasts" (Rigoni & Souza, 2016, pp. 2–3). Furthermore, GAO found that from 2004 to 2007, Navy's "secondary inventory in excess of current requirements" averaged $7.5 billion, or about 40 percent, of Navy's total inventory (Rigoni & Souza, 2016. p. 3). As expected based on the findings, "GAO concluded that 'inaccurate demand forecasting is the leading reason for the accumulation of excess inventory' throughout the services and DLA" (Rigoni & Souza, 2016, p. 3).

Figure 3. Navy Secondary Inventory Meeting and Exceeding Requirements (Fiscal Year 2004–2007). Source: Rigoni & Souza (2016).



The FY2010 National Defense Authorization Act (NDAA) tasked "the inventory management systems of the military departments and the DLA with the objective of reducing the acquisition and storage of secondary inventory that is excess to requirements," (Rigoni & Souza, 2016, p. 4). This inspired a few DOD inventory management practices. It "required the 'development of metrics to identify bias toward over-forecasting and adjust forecasting methods accordingly,'" which "would eventually result in the DOD developing a common metric for forecast accuracy and forecast bias that would measure the performance of each military service and DLA" (Rigoni & Souza, 2016, p. 4). A forecasting bias in terms of inventory management refers to a consistent difference between what quantity was forecasted for a given item and the actual inventory needed for that item. Bias can refer to either over-forecasting (ordering too much of an item) or under-forecasting (ordering too few of an item).

In response, CIMIP was published in October 2010, with the objective of "a prudent reduction in current inventory excesses as well as a reduction in the potential for future excesses without degrading materiel support to the customer" (Rigoni & Souza, 2016, p. 4). GAO, in turn, published its response to DOD, concluding that although the plan did address Congress's intentions in the NDAA, there were possible challenges in implementation, including (emphasis added) "*a standard accuracy metric and performance targets.*" As Rigoni & Souza describe, "GAO felt that this level of standardization could be difficult to reach given the fact that the services and DLA had different approaches to measuring demand forecast accuracy" (2016, pp. 5–6).

Furthermore, DOD Instruction 4140.01, released in December 2011, stated that DOD "shall operate as a high-performing and agile supply chain responsive to customer requirements during peacetime and war while balancing risk and total cost." It led to *DOD Supply Chain Material Management Procedures* Volume 2, *Demand and Supply Planning*, which "provided guidance on how DOD components should forecast customer demand" (Rigoni & Souza, 2016, p. 6).

It can be inferred that Congress expects the DOD and components to stop stockpiling, which ties up funds in the new fiscal environment. One of the reactions to this was DLA's Big Ideas Initiative, implemented in March 2012 in support of DOD's national defense strategy. The Big Ideas Initiative relied on five focus areas, which originally would save $10 billion over five years. The five focus areas were "improved customer service, decreased material costs, decreased operating costs, improved inventory management, and achieving audit readiness" (DLA, Annual Financial Report: Fiscal Year 2012 {Unaudited}, p. iii). Stated in the FY2012 annual report:

> Reductions in operating costs will be achieved by consolidating inventories, leveraging industry ability to store and deliver high-demand items and rightsizing out distribution footprint. DLA will improve its inventory management through faster procurement processes, better demand planning and collaborating with customers (p. iii).

Most importantly, dealing with excess inventory partly would be accomplished by attacking "War Reserves and Operational Inventory through better leverage of commercial infrastructure and agreements" (DLA, Annual Financial Report: Fiscal Year 2012 {Unaudited}, p. 4).

GAO released another defense inventory management report in April 2015, which concluded that the services "had generally been able to reduce their excess inventory" (Rigoni & Souza, 2016, p. 7). As seen in Figure 4, Army significantly improved in forecast accuracy, while Navy improved less than one percent. Air Force's accuracy declined. United States Marine Corps (USMC) and DLA were not included in this particular study. In Figure 5, the graph shows that the bias for over-forecasting was more likely, particularly in the Army (Rigoni & Souza, 2016, p. 8).

Figure 4. Demand Forecast Accuracy Performance by Service
Source: Rigoni & Souza (2016).

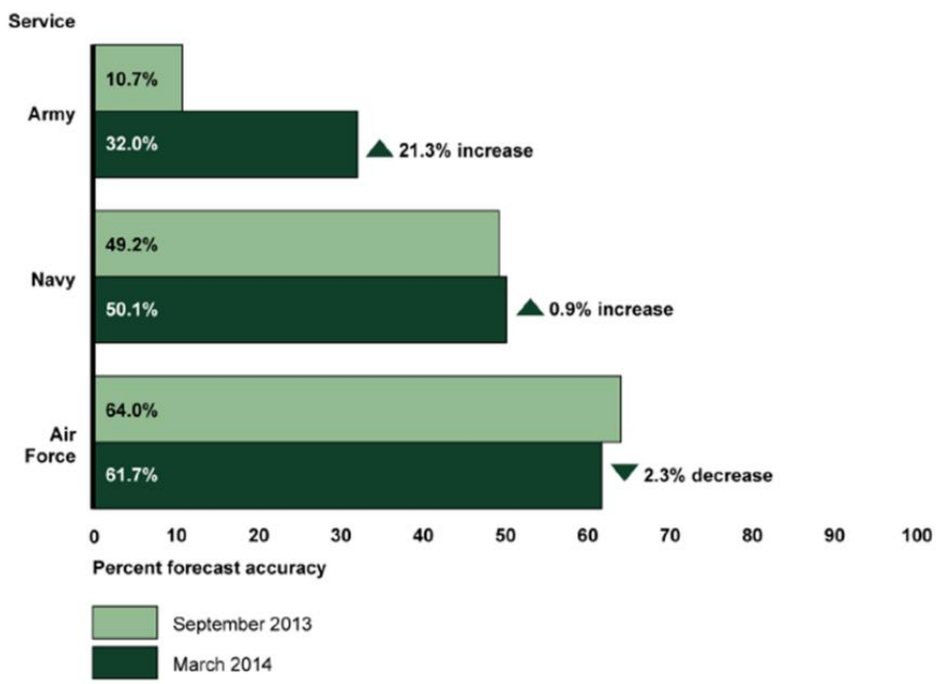
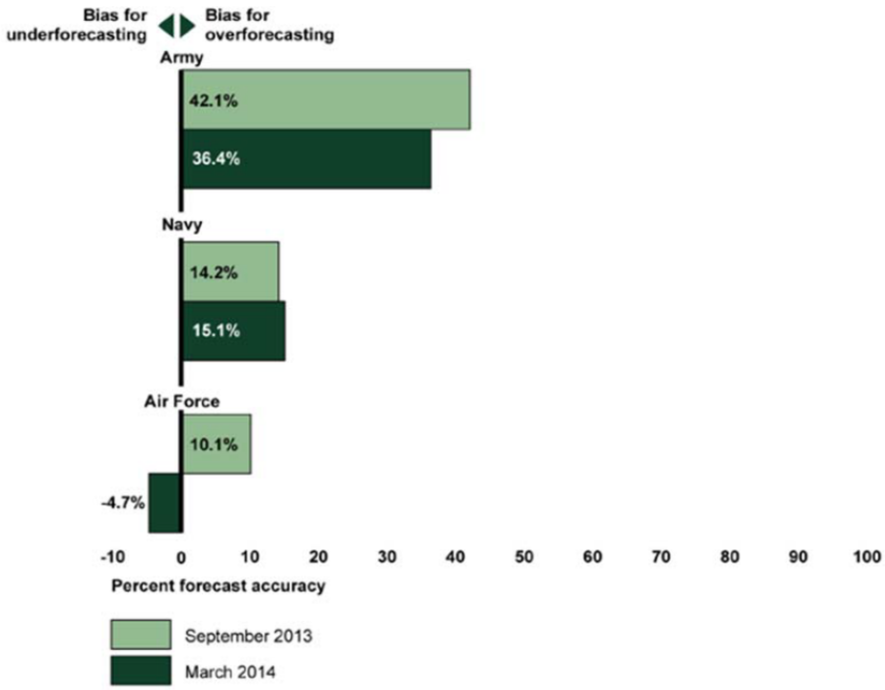


Figure 5. Demand Forecast Bias by Service. Source: Rigoni & Souza (2016).

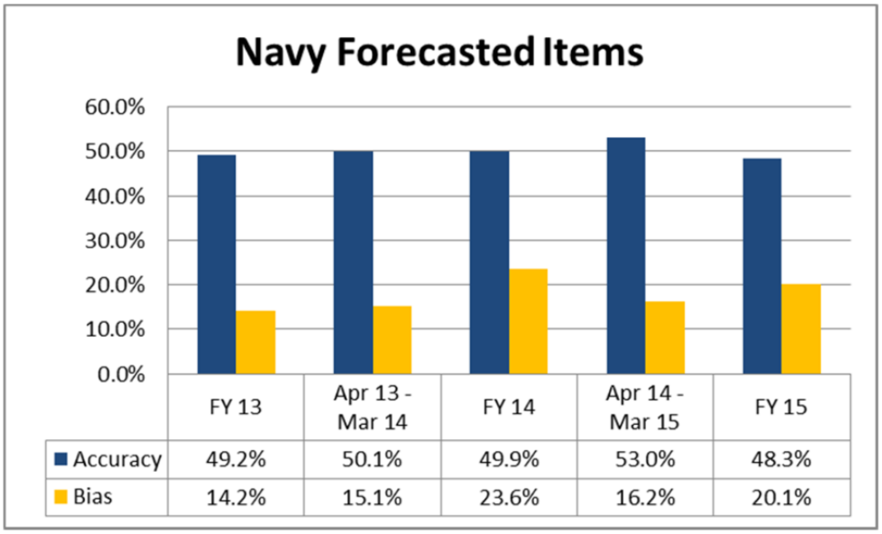


Due to Navy's inaccurate forecasts, NAVSUP was "reviewing and analyzing their demand forecasting processes and planning factors to improve performance on DOD's forecast accuracy and bias metrics tracked across the department" (Rigoni & Souza, 2016, p. 9). An analysis of NAVSUP WSS's raw data covering FYs 2013–2015 showed that accuracy was still low. As seen in Figure 6, forecasts still show low accuracy and bias despite actively working on methods to increase accuracy of demand forecasting (Rigoni & Souza, 2016, p. 10). Such was the case in 2013, where the DOD

> implemented an accuracy metric to monitor how well the services and Defense Logistics Agency were forecasting demand for inventory items. After three years, results were poor. DOD uses a metric derived from the Mean of Absolute Percentage Error. … We found the DOD metric produced non-intuitive results and was adversely affected by unit cost and demand volume (Rigoni & Souza, 2016, p. v).

Until forecasts are accurate, evidence suggests excess may be a solution.

Figure 6. Navy CIMIP Forecast Metric Results FY13-FYF15. Source: Rigoni & Souza (2016).



2. Excess Material Literature

According to reports from the GAO (2005; 2006) and a DOD Inspector General (DODIG, 2011) audit, significant opportunity exists for the DOD to use excess material as a source of supply. Leon and Paulson (2011), referencing the 2005 GAO report, noted:

> $2.2 billion dollars in 'substantial waste and inefficiency' because 'new, unused, and excellent condition items were being transferred or donated outside of DOD, sold on the Internet for pennies on the dollar, or destroyed rather than being reutilized.'… DOD purchased at least $400 million of identical commodities in fiscal years 2002 and 2003 instead of reutilizing available A-condition excess items (p. 20).

Leon and Paulson (2011) also found supporting evidence in their study of USMC acquisition indicative of a DOD-wide failure to utilize excess material as an alternative method of satisfying demand for repair parts. By comparing several periods of historical demand over a two-year period to corresponding inventory of excess material at DDS, they found that the USMC could have saved as much as $28.5 million dollars by screening excess material prior to ordering new stock. Additionally, McNulty, Dillion, and Mourning (2012) concluded that in April 2012, excess material available within the supply system could fill as much as $171 million in system-wide inventory deficiencies.

3. Redistributing Excess Material

Individual units designate material as excess when they process Global Level Settings on a quarterly basis. When a unit's demand history no longer supports the amount of inventory carried on-hand, the system designates the excess as ATC-6. Previous studies (Oswald 2013; McNulty, Dillion, and Mourning 2012) suggest that the Navy should proactively transship excess material from the unit holding it to a requesting unit when the requesting unit's stock level drops below a given item's reorder point. However, Oswald (2013) found evidence suggesting while such rebalancing does decrease the overall level of excess material, it does not markedly improve inventory management costs or fill rates.

Rather than proactively redistributing excess material, our proposal is to source all initial orders originating at an FRC through Navy ERP to screen excess material. While Oswald (2013) found that transshipment cost generally accounted for less than one percent of total inventory management cost when proactively redistributing excess inventory, this study focuses on utilizing excess material once an order has been placed. In these cases, the supply system would incur transportation cost whether the requisition is filled through excess or through the DLA acquisition process.

4. Summary of Literature Review

Backordered AVDLRs have been a problem for many years. Many studies have focused on various methods of reducing backorders, i.e., improving forecasting methods, increasing customer fill rate through the Navy or DOD supply chain, whether through improvements of demand forecasts to develop improved inventory policies, or more efficient transportation and distribution networks. Additionally, significant effort revolved around the growing abundance of excess material managed by the Navy. This study attempts to use the problem of excess material to reduce the problem of backordered AVDLRs. While this study does not investigate the sources or possible solutions to either problem, it evaluates possible methods of utilizing excess material to satisfy backordered aviation requirements, ultimately increasing aviation readiness. Cost savings occur because excess material ships as "free-issue." There would be reduced cost due to higher aviation readiness, but quantifying both figures is outside the scope of this project. Referencing the work of previous studies, this project aims to determine if Navy excess material can satisfy a significant portion of existing backorders.

THIS PAGE INTENTIONALLY LEFT BLANK

III. METHODOLOGY

This chapter describes the data collected, the sources of the data, and the analysis of the data to provide information relevant to future decisions. The data collection section details what data was gathered and from whom. The data organization section describes how the data was systematized for comparison. The comparison methodology section specifies the methods used to compare the data sets and provide the outputs used in the analysis. Finally, the expectations section discusses the expected results of the comparison, prior to running the comparisons.

A. DATA COLLECTION

Two sets of data are needed in order to determine if excess material can satisfy backordered requirements: material in Navy inventory currently designated as excess and DLA requisitions for NAVSUP identified as backordered. Comparing both data sets by the common part identifiers—the National Item Identification Numbers (NIIN)—would identify what, if any, requisitions can be fulfilled by excess stock. While a comparison of the current excess list and DLA backorders will determine what backordered requisitions can be fulfilled presently, it will not provide any indication if such a process will provide continual yields in backorder reduction in the future. Ascertaining future efficacy requires an analysis of past data.

NAVSUP provided our research team with 24 months of excess material listings, organized by individual month, beginning August 2014 and ending July 2016. The data was drawn from Navy ERP and provided in Microsoft Excel (.xls) format. DLA contributed 24 months of backordered NAVSUP requisitions, also organized by individual month, beginning August 2014 and ending July 2016. The DLA data was also in Microsoft Excel (.xls) format and sourced from the DLA information warehouse.

B. DATA ORGANIZATION

The data as provided is raw output from organizational databases and contains a great deal of information that is not necessary for the effort at hand. Streamlining the data is necessary to ensure an accurate comparison of the data sets. A portfolio of information categories is established based on what is needed for the comparisons and analysis and what categories are common to both sets. The list of categories is then ordered identically for each of the respective data sets to establish uniformity within the backorder data, as well as the excess data. The categories and display order are summarized in Tables 1 and 2.

Table 1. Information Categories Used for Backorder Data

Category	Description
Req Number	Requisition Number; the unique alpha numeric identifier for each backordered requisition (order)
IPG	Issue Priority Group
DODAAC	Department of Defense Activity Address Code
Status	Current Supply Status of the requisition, i.e., Backordered, etc.
Quantity	The quantity of the item required to satisfy the requisition.
FSC	Federal Supply Class
NIIN	National Item Identification Number; the numeric identifier for each item in the federal supply system, comparable to a SKU
Price	Value in U.S. dollars of the item
Plant	Stock Inventory Point
Age	Amount of time, in days, the requisition has been backordered
Nomenclature	A brief description of the item
UOI	Unit of Issue; the order quantity of the item
WSDC	Weapon System Designator Code
COG	Cognizance code

Table 2. Information Categories used for Excess Data

Category	Description
COG	Cognizance Code
FSC	Federal Supply Class
Material	National Item Identification Number; the numeric identifier for each item in the federal supply system, comparable to a SKU
Description	Nomenclature
UOI	Unit of Issue; the order quantity of the item
UOI Total Qty to UOI MSL Qty	Unit of issue compared to the maximum stock level allowance
UOI Price	Unit Price

When ERP produces reports, it lists every stock number with any quantity of excess above its maximum stock level (MSL). The quantity reported is the total quantity and includes both the allowable inventory and excess. To ensure capture of only the quantity of excess available, an adjustment to each quantity is required to separate the available quantity from the total quantity. An Excel IF logical function is used to quickly identify the excess quantities of each NIIN. The IF function compares the total quantity of each NIIN to the associated MSL quantity. In each instance where the total quantity exceeds the MSL quantity, the MSL quantity is subtracted from the total quantity to obtain the excess quantity. The IF function, provided by NAVSUP WSS, is as follows:

=IF(UOI Valuated Stock Unrstrctd > UOI MSL Qty, UOI Valuated Stock Unrstrctd - UOI MSL Qty, 0)

C. COMPARISON METHODOLOGY

The nature of the available data imposes multiple considerations for timely and accurate comparisons. The first concern is the volume of data. The excess material lists averaged over 32,000 unique NIINs per month, while the backorder lists averaged over 4,300 unique NIINs across an average of 18,000 requisitions per month. It was impractical and inefficient to compare the hundreds of thousands of requisitions and excess line items by hand, so an automated comparison method was required.

To answer our research question regarding how many backorders could be satisfied by occasionally screening excess material on an ad hoc basis, we compared the July 2016 backorder list to the July 2016 Navy excess material list. We found that out of 14,790 requisitions backordered, we could have issued 68 unique NIINs partially filling 13 requisitions and completely filling and additional 75 requisitions. The total dollar value of these successfully filled requisitions was just over $100,000. Often, individual units perform this type of analysis on their biggest "head-hurters" one requisition at a time. Reactive screening is time consuming and not efficient for either the FRC or the local unit expeditors to complete. Unfortunately, in the event that a unit or expeditor finds a match on the excess list, it is necessary to exert a significant effort to reroute their requisition to the excess supply source. Additionally, there is no guarantee that the supply of excess stock could sustain the continuous demand of backorders. However, this method would be useful on a periodic basis to alleviate the numbers of backorders. Occasionally assigning this duty to temporary employees such as reservists or contracted labor may yield success in lowering outstanding backorders, ultimately allowing more focus on harder to fill items.

The recorded backorders and excess listings are also highly dynamic. Backordered requisitions carry forward in the record until satisfied, resulting in a month-to-month fluctuation of new line items being added and old line items either enduring or being removed from the record. A similar paradigm exists in the excess stock listing. Periodic adjustments to allowable inventory, requisition of stock, and disposal contribute to constant changes in the excess material available. Such variability necessitates a recursive capability in the comparative method used.

Python programming language is used to develop and run the comparison of the backorders and excess stock records. Python is chosen because of its ease of learning and use (especially for those without prior programming experience) and its capability to run recursion on association lists. A copy of the script in use for the comparisons is in

Appendix A. The Excel files for both backorders and excess are converted to comma separated value (.csv) format for compatibility with Python.

For the backorder data, the program uses a dictionary data structure, assigning the NIINs as keys and the quantities as values. It does the same for the excess data, using the material as keys and the quantities as values. Each month of backordered data is compared to its equivalent month of excess data. The program matches keys—NIINs—with any match representing an excess stock item available to satisfy a backordered requisition. The backordered quantity is subtracted from the excess quantity and the changes are carried forward as the updated states of the respective quantities. When there is sufficient excess quantity to satisfy the total matched backordered quantity of any given requisition, the requisition is considered closed and is removed from the active pool of keys. When there is not sufficient excess quantity to satisfy the matched backordered requisition, the backordered quantity is changed to reflect a partial fill and the adjusted balance is carried forward. The program then repeats the matching for all subsequent months, covering a total of 24 months ending July 2016. Utilization of excess stock by NIIN, and fulfillment of backorder requisition by document number, is tracked across the entire 24 months so that each new month's excess and backorder files can be updated to reflect actions conducted in prior months. Outputs are segregated by month and include number of backordered requisitions filled, number of requisitions partially filled, and quantities of backorder items filled.

To determine if the level of Navy excess material can satisfy enough backordered requisitions to warrant a permanent change in ordering procedures, this study uses 24 months of historical data of all FRC requisitions backordered with DLA as well as data of excess stock owned by the Navy. Using a unique program coded in Python (see Appendix A), we directly compare 24 months of historical data of FRC requisitions backordered with DLA, with 24 months of NAVSUP aviation excess stock listings. The comparison is performed with monthly data, while ensuring that we remove successful matches from the excess inventory and backlog to not inflate our success. This study quantifies how many backorders the excess inventories could have filled over the preceding two-year period. We start with the August 2014 excess inventory listing downloaded from Navy ERP, provided by NAVSUP WSS, and treated this as our "beginning inventory." Next, using our program in Python, we directly compare the August 2014 backorder list from Fleet Readiness Center Southeast (FRCSE) in Jacksonville, Florida, FRCSW in San Diego, California, and FRC East in Cherry Point, North Carolina, to the inventory of excess material. DLA Aviation in San Diego, California, provided data for all three FRCs. We subtract any matches and count these as successful "fills." Since we use historical data, we then account for any difference between the August 2014 and September 2014 excess lists' quantities to recognize that "fill" in the previous month (subtracting a set quantity for the subsequent month dependent on requisitions filled in the previous month). Additionally, the Python coding ensured that requisitions filled in the prior month would be eliminated in subsequent months of the backorder listings. We also coded Python to allow for partial-quantity fills. At the end of the 24-month comparison, the requisitions filled from excess would allow us to quantify the impact of the long-term policy change.

At this point, there was concern that there would be inaccurate inventory levels. Since the excess listings are snapshots in time, we assumed that nothing shipped from excess during that period. Additionally, since the average age of backorders is approximately 149 days, we understood that because our listings are merely a snapshot in time, we had to ensure that after each successful fill we removed that requisition from our future snapshots to avoid double-counting successful matches.

We made an additional adjustment to the data. The Navy runs Global Level Settings on a quarterly basis. As previously discussed, we carefully examined the data and removed any duplicates from our sample to provide the most accurate analysis.

D. WHAT WE EXPECTED TO FIND

We expected NAVSUP excess stock would fill a substantial number of backorders. While FRCs might see a marginal increase in wait time for those items filled by Navy excess stock that is not co-located (instead of normal inventories available in stock at co-located DLA warehouses), the increase would be low due to modern commercial transportation capabilities. Additionally, Navy ERP would automatically refer any item not filled by NAVSUP excess to DLA for sourcing, adding just a few hours to the process. With an average age of the current backorder list of 149 days, an additional few hours of screening time would have minimal impact to readiness. This automatic process would use "free-issue" excess material to save time and thousands of dollars. It also significantly cut down on the average number of backorders and average age of all orders.

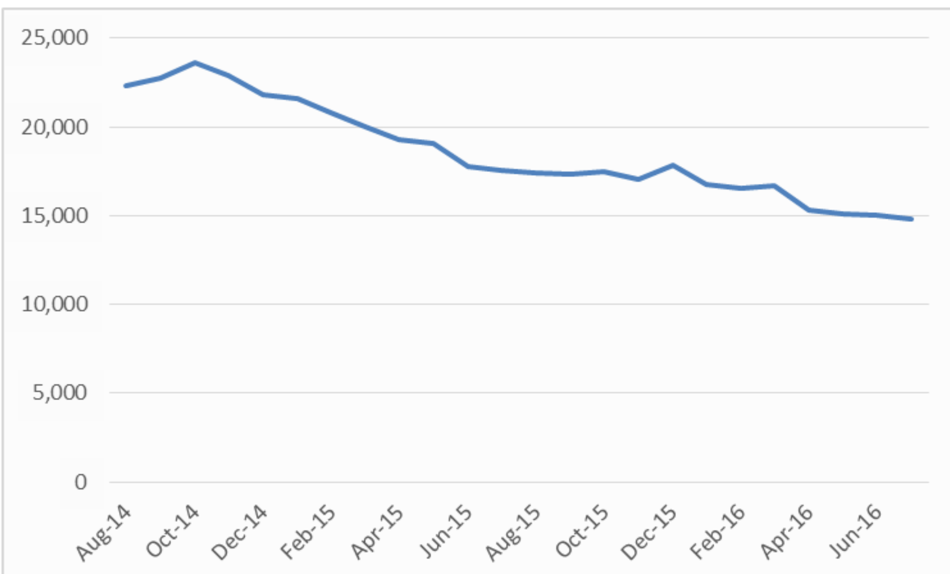
At a minimum, we expected to show, through a trade-off analysis, that even if a full-scale policy change is not implemented, the use of 1–2 Full Time Equivalent employees or perhaps Navy Reservists on Active Duty for Special Work orders to screen the excess stock would result in significant reduction in aged backorders.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. ANALYSIS AND RESULTS

After sorting the 24 months of data we found that the number of backordered requisitions ranged from 14,790 to 23,609. Figure 7 shows that the historical trend was down after a slight uptick in October 2014. In August 2014, there were a total of 22,340 backorders. However, by July 2016, the number had dropped to the lowest total observed of 14,790, with a running average of 18,615 requisitions. The cause of this downward trend was unclear, and its determination is outside the scope of our research. The trend existed prior to running our comparison program and this chart is meant to show the natural baseline.

Figure 7. Backordered Requisitions



Multiple backordered requisitions exist for the same NIIN both from different Navy commands and from multiple orders for the same Navy command. After removing duplicate NIINs we found that the total number of backordered requisitions consisted of between 3,751 and 4,978 unique NIINs, also in a downward trend as shown in Figure 8.

Figure 8. Total Unique Backordered NIINs, across all Requisitions

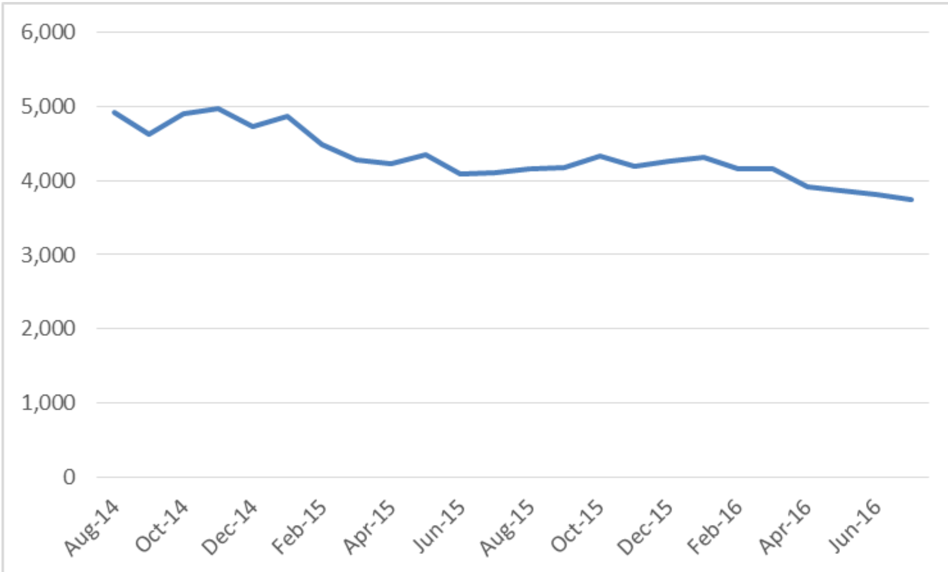
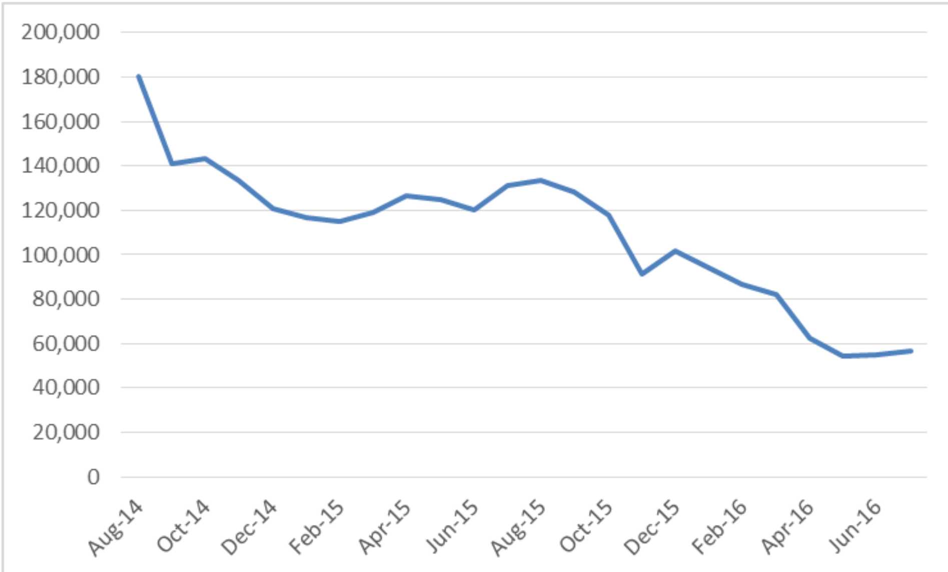


Figure 9 shows the total quantity of units across all NIINs in all requisitions. Again our 24 months of data demonstrated an overall downward trend ranging from 54,456 to 180,510, consistent with the downward trend in the number of backordered requisitions and the decrease in unique NIINs backordered. Dividing the total monthly quantity by the monthly backordered requisitions provides a rough approximation of the average quantity per requisition. The average drops by one-half, from a high of 8.08 units per order to 3.83 units per requisition, indicating a clear reduction over time in the number of units ordered during the 24 months observed.

Figure 9. Quantity of Backorder Units



Next we identified the number of unique NIINs in our excess material. Figure 10 shows an upward trend in the number of NIINs in excess material ranging from 24,383 NIINs to 39,742 NIINs. Such a trend corroborates the GAO's findings that Navy excess material is growing (GAO 2008).

Figure 10. Number of Unique NIINs in Excess Material

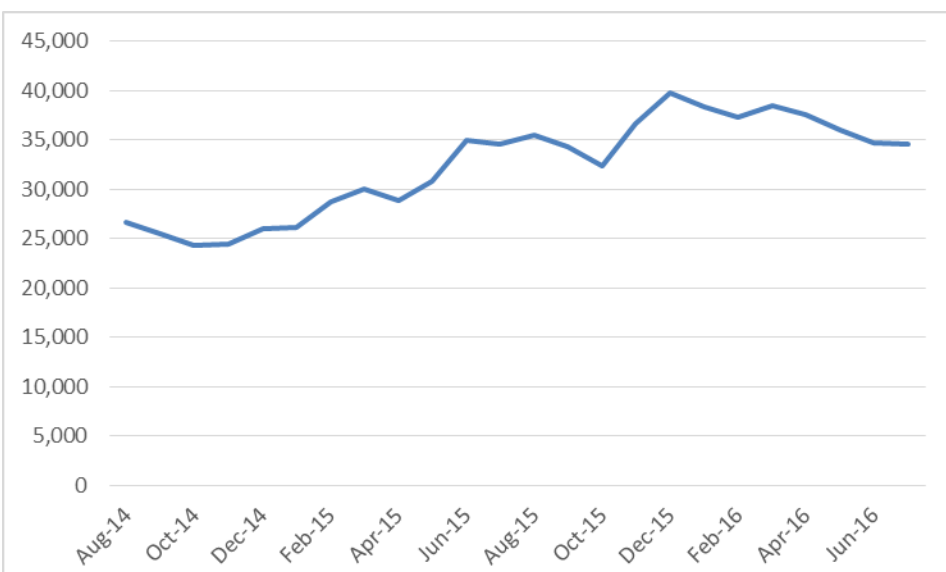
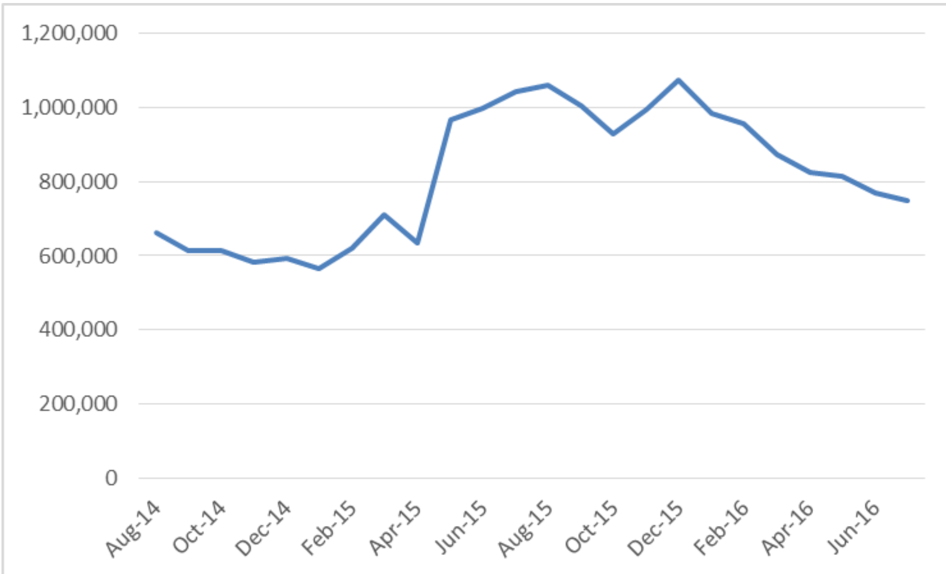


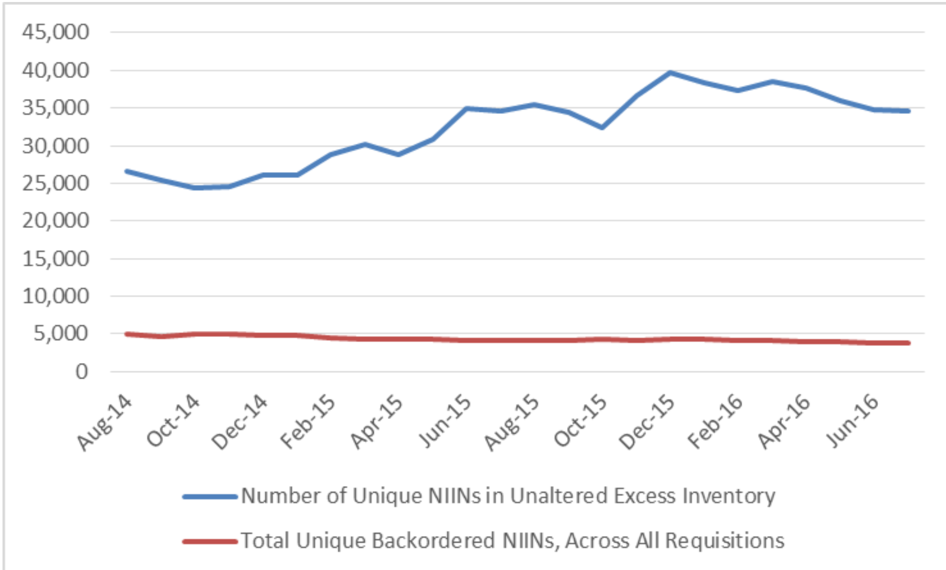
Figure 11 shows that as the number of NIINs trended upward the quantities of units also trended upward ranging from 563,722 total units to 1,074,755 units. Again, this corroborates the GAO's findings (GAO 2008).

Figure 11. Quantities for all NIINs in Excess Material



As the number of NIINs available in excess increase, it stands to reason the opportunities for matching backordered requisitions increases as well. Conversely, as the number of NIINs required in backordered requisitions decrease, the opportunities for matching excess material decreases due to the shrinking candidate pool. When examined relative to each other, as in Figure 12, the increase in available NIINs in excess is comparatively larger than the decrease in required NIINs backordered. An overall increase in the number of matched requisitions is a reasonable conclusion. It is analogous to shopping at a large retail store with a small shopping list; the sheer volume of options on the shelf should guarantee more matches than a comparatively smaller store.

Figure 12. Comparisons of NIINs, Backordered and Excess

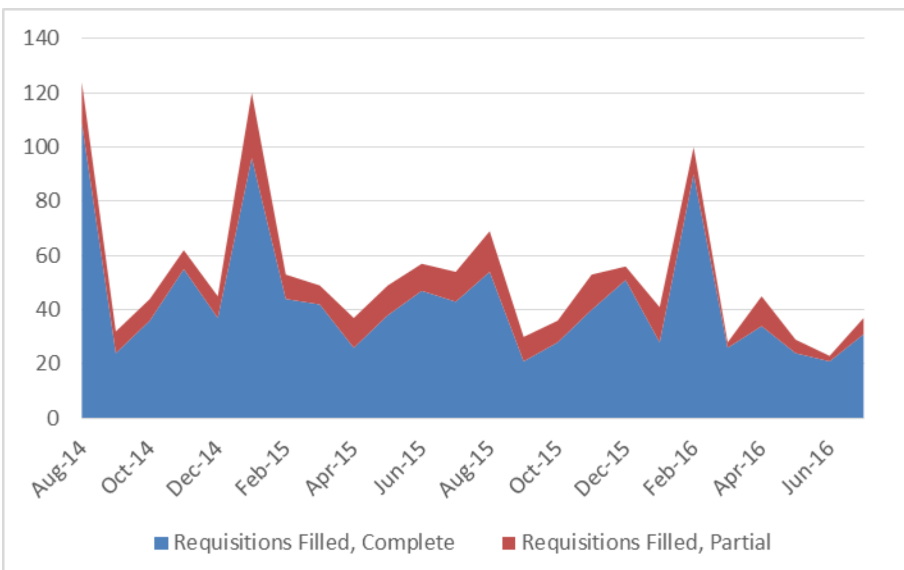


After running the matching process, we found that excess material filled 3,312 units from 1,083 requisitions at a dollar value of $1,048,560.54. As expected, after Month One our success rate significantly dropped from filling 124 requisitions to 32 requisitions in Month Two. Despite two anomalies in January 2015 and February 2016, our successful fill rate trended downward. Overall we found an average of 43.5 requisitions filled per month. This comparison only counted a successful fill if the excess material inventory could completely satisfy a backordered requisition's total quantity. If not, then the requisition was not filled at all.

Initially, surprised by the low rate of successful fills, we alternatively researched whether filling partial quantities would increase the likelihood of finding matching NIINs between excess and backorders. We modified the matching process to count partial fills and separately kept track of when the remaining balance of a previous partially filled requisition was completely filled in a subsequent month. This resulted in excess material filling 7,831 units from 1,294 requisitions covering 1,005 unique NIINs at a dollar value of $1,123,002.74 with an average of 54 requisitions per month. Figure 13 shows the total successful fill rate of backorders once we allowed partial requisitions to be filled, with complete fills in blue and partial fills in red. The trend line of combined complete and partial fills mirrors the initial trend that only allows completely filled-quantity requisitions, but allows us to fill an additional 4,519 units covering an additional 211 requisitions.

The results clearly run contrary to the assessment indicated by the raw data. An explanation of the possible reason necessitates a revision of the previous shopping analogy. Instead of shopping at a large retail store with a small shopping list, imagine shopping at a large retail store with a small shopping list of only automotive parts. The volume of automotive parts available on the shelf is only a fraction of the overall store inventory, and the specific nature of the shopping list renders the non-automotive inventory moot. The pool of candidate matches is in actuality much smaller than originally indicated, therefore fewer matches should be expected.

Figure 13. Total Filled Backordered Requisitions Including Partial Fills

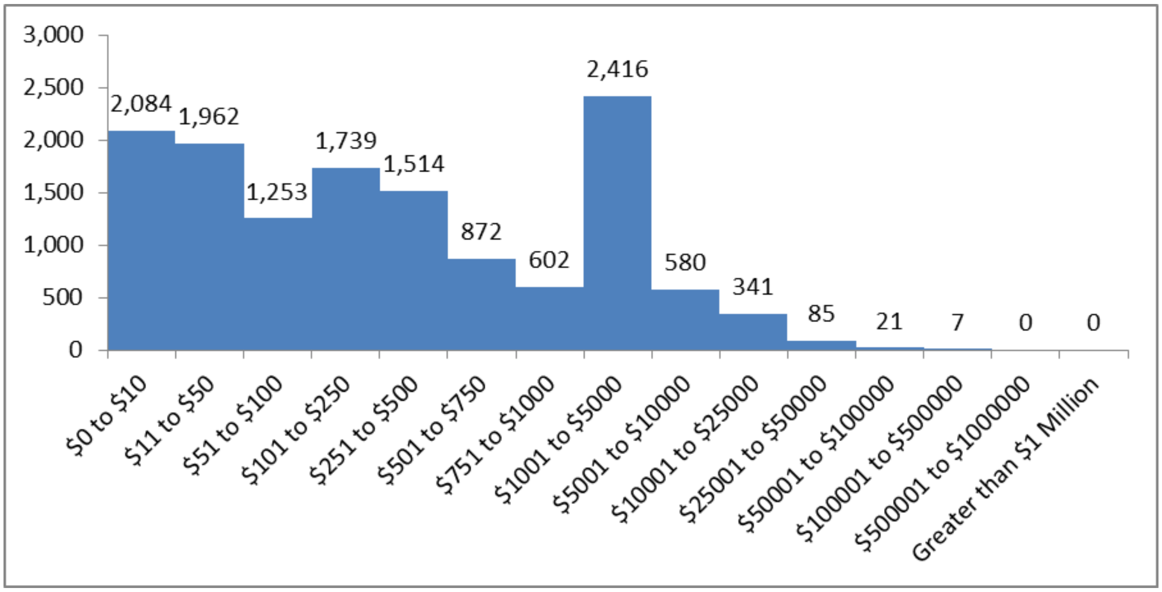


There were 13,476 unique NIINs backordered during the 24 months studied. Thirty percent of the NIINs had a unit price of $50 or less. Sixty-three percent of the NIINs' unit price was $500 or less. Interestingly, 18 percent of the backordered NIINs had a unit price above $1,000 and below $5,000. Barring this anomaly, this analysis shows that the majority of backordered NIINs were at a low price point. Table 3 shows the ranges of a NIIN unit price, the frequency that a NIIN had that unit price value, and the percentage that the unit price value was of the total NIIN population. Figure 14 shows the ranges of a NIIN unit price and the frequency of a NIIN having that unit price value.

Table 3. NIIN's Unit Price Frequency and Percentage of Backordered Population

Price	*Frequency*	*Percentage of NIINs*
$0 to $10	2,084	15
$11 to $50	1,962	15
$51 to $100	1,253	9
$101 to $250	1,739	13
$251 to $500	1,514	11
$501 to $750	872	6
$750 to $1,000	602	4
$1,001 to $5,000	2,416	18
$5,001 to $10,000	580	4
$10,001 to $25,000	341	3
$25,001 to $50,000	85	1
$50,001 to $100,000	21	0
$100,001 to $500,000	7	0
$500,001 to $1,000,000	0	0
Greater than $1 Million	0	0

Figure 14. NIIN's Unit Price Frequency of Backordered Population

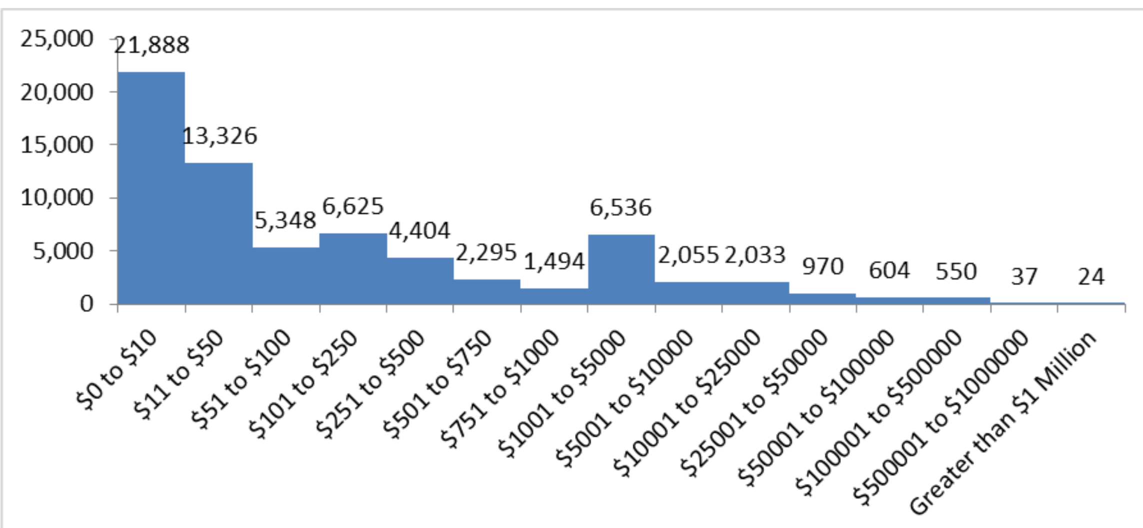


During the 24 months of data, there were 68,189 unique NIINs in the excess population. Table 4 shows the ranges of a NIIN unit price, the frequency of a NIIN having that unit price value, and the percentage that the unit price value was of the total NIIN population. Figure 15 shows the ranges of a NIIN unit price and the frequency of an excess NIIN having that unit price value. As seen in Table 4 below, 52 percent of the excess NIINs have a unit price value of $50 or less. Seventy-six percent of excess NIINs have a unit price value of $500 or less. We see a similar spike in available excess NIINs that have a unit price above $1,000 and below $5,000 at ten percent.

Table 4. NIIN's Unit Price Frequency and Percentage of Excess Population

Price	*Frequency*	*Percentage of NIINs*
$0 to $10	21,888	32
$11 to $50	13,326	20
$51 to $100	5,348	8
$101 to $250	6,625	10
$251 to $500	4,404	6
$501 to $750	2,295	3
$751 to $1,000	1,494	2
$1,001 to $5,000	6,536	10
$5,001 to $10,000	2,055	3
$10,001 to $25,000	2,033	3
$25,001 to $50,000	970	1
$50,001 to $100,000	604	1
$100,001 to $500,000	550	1
$500,001 to $1,000,000	37	0
Greater than $1 Million	24	0

Figure 15. NIIN's Unit Price Frequency of Excess Population

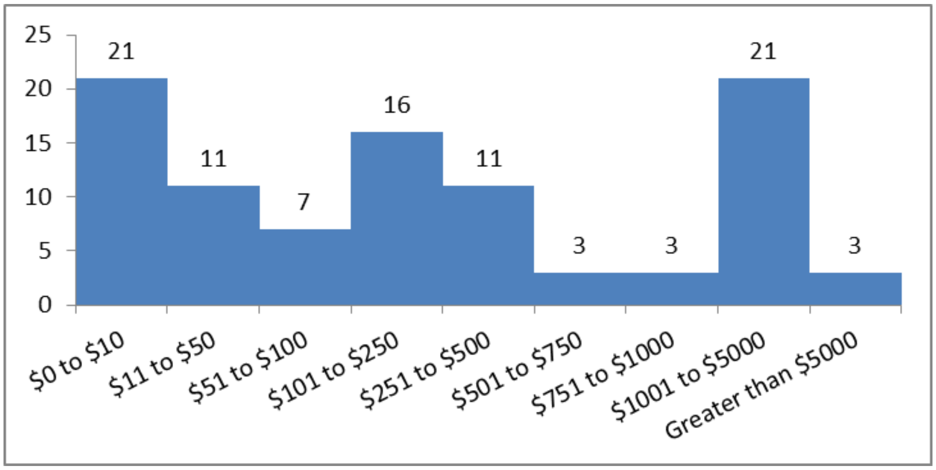


When comparing the backordered list to the excess list for the first month of data, August 2014, one could assume that there would be a high probability of filled requisitions due to the price similarities available in excess. On the contrary, we found that out of the 17,756 backordered requisitions, excluding Local Stock Numbers, only 124 requisitions were filled, accounting for 441 units and covering a total of 96 unique NIINs. Thirty-three percent of applicable NIINs had a unit price of $50 or less. Interestingly, again there was a spike for the unit price above $1,000 and below $5,000, with 21 NIINs or 22 percent of the total. Table 5 shows the ranges of a NIIN unit price, the frequency of a NIIN having that unit price value, and the percentage that the unit price value was of the total NIIN population for filled requisitions (both completely and partially). Figure 16 shows the ranges of a NIIN unit price and the frequency of a filled NIIN having that unit price value.

Table 5. NIIN's Unit Price Frequency and Percentage of Filled Requisitions

Price	*Frequency*	*Percentage of NIIN Range*
$0 to $10	21	22
$11 to $50	11	11
$51 to $100	7	7
$101 to $250	16	17
$251 to $500	11	11
$501 to $750	3	3
$751 to $1,000	3	3
$1,001 to $5,000	21	22
Greater than $5,000	3	3

Figure 16. NIIN's Unit Price Frequency of Filled Requisitions

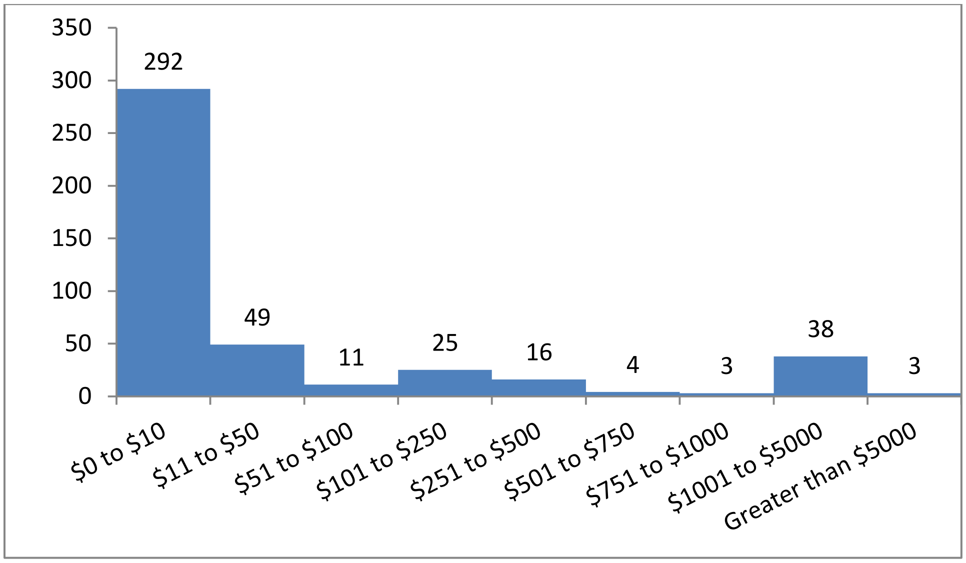


We also found that overwhelmingly the majority of successfully filled units (292) were at the lowest unit price. Sixty-six percent of filled units were $10 or less per unit. This is understandable, as the requisitions at this price point would be for items typically requisitioned in multiple quantities such as screws, seals, etc. Table 6 shows the ranges of a NIIN unit price, the frequency of an individual unit being filled at that price value, the number of NIINs encompassing the individual units filled, and the percentage that the filled individual unit at that unit price was of the total filled individual units. Figure 17 shows the ranges of a NIIN unit price and the frequency of an individual unit being filled at that unit price value.

Table 6. NIIN's Unit Price Frequency, Quantity of Units Filled, Number of NIINs, and Percentage of Filled Requisitions

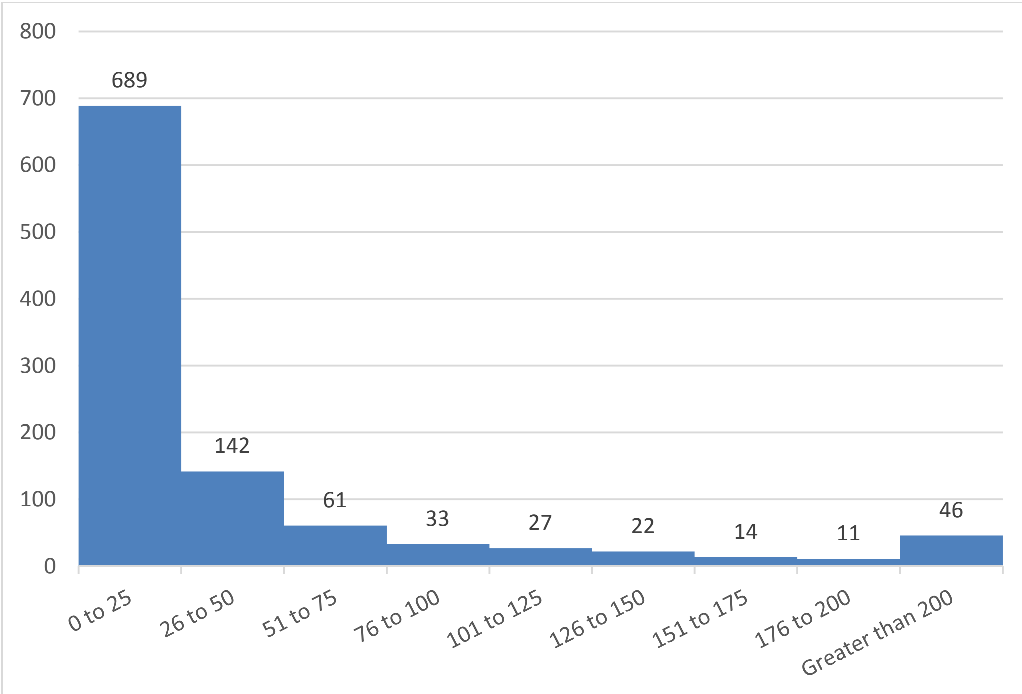
Price	*Qty*	*NIINs*	*Percentage of Filled Units*
$0 to $10	292	21	66
$11 to $50	49	11	11
$51 to $100	11	7	2
$101 to $250	25	16	6
$251 to $500	16	11	4
$501 to $750	4	3	1
$751 to $1,000	3	3	1
$1,001 to $5,000	38	21	9
Greater than $5,000	3	3	1

Figure 17. NIIN's Unit Price Frequency, Quantity of Units Filled, and Number of NIINs of Filled Requisitions



Since the number of successfully matched requisitions only represented an average of .05 percent of the total backordered requisitions over the 24 month period, we decided to look at the average age of our filled requisitions. Figure 18 shows the age distribution of completed requisitions. The age of our successful matches ranged from a minimum of zero to a maximum of 772 days with a median age of 17 and an average age of 42 days. The total number of waiting days saved was 43,647 days. This distribution does not include the age of those requisitions partially filled, which represented an additional 239 requisitions covering approximately 4,500 units with an additional waiting day age of approximately 9,800 days. Only 46 requisitions had an age over 200 days with half of those falling between 300–400 days.

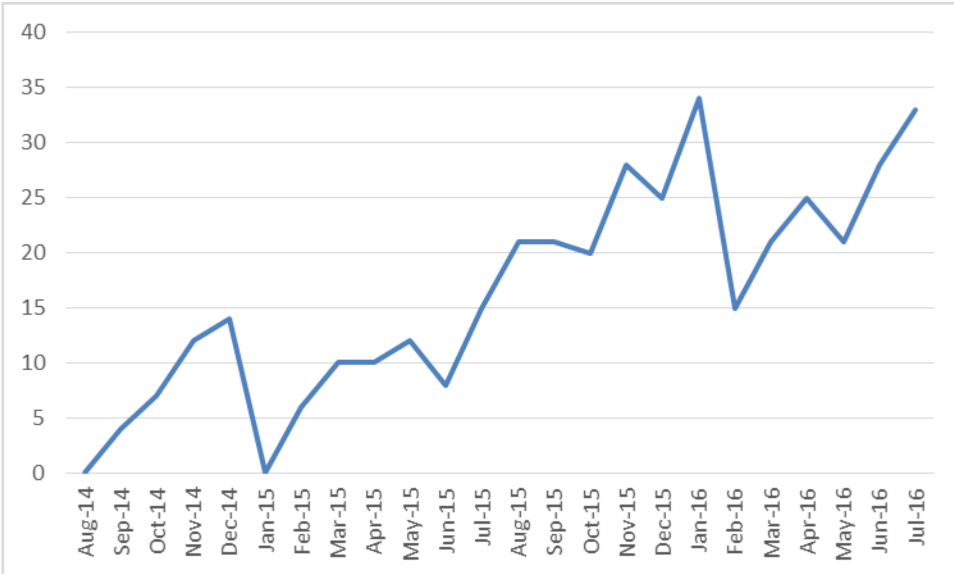
Figure 18. Age Distribution of Completed Requisitions



Since we are looking at historical snapshots of excess inventory data, our model does not take into account real life transactions occurring with historical inventory. In our data there were 479 instances where for a given month and NIIN, the NIIN's excess inventory quantity, once updated to account for issues we had made against backorders in a prior month, was calculated as a negative value. We hereafter refer to this situation as a "negative balance" instance. For example, NIIN 00–823-6329, MOTOR, CONTROL, had an excess quantity of four in Month One, August 2014. During Month One, our model subtracted three units from the excess inventory to satisfy backordered requisitions leaving its inventory at one. However, in Month Two, the MOTOR, CONTROL excess inventory was given as two in the unaltered excess inventory spreadsheet, so once the Python script decremented the excess inventory by the three units we issued in Month One, the balance became negative. This indicates an actual naval unit had drawn that inventory from excess, offloaded the material to DDS, or experienced a change in allowance levels due to running Global level settings. Two of the requisitions for MOTOR, CONTROL that our model theoretically filled in Month One, N6592342410662 and N6592342410675, remained active in Month Two, demonstrating that they were not actually filled by excess material and therefore did not account for the new lower quantity of excess inventory for the MOTOR, CONTROL. Our data does not show the source of supply for the third backordered requisition, N6592342410650, which was filled in reality and therefore no longer present in our Month Two backorder data. Additionally, our data does not show what occurred to the two units of MOTOR, CONTROL that had been designated excess in Month One of our data set but were no longer present in Month Two. Finally, our data shows that the MOTOR, CONTROL only became negative for one month (Month Two). In Month Three our "beginning inventory" had MOTOR, CONTROL remaining negative; however, additional inventory would have to have been designated as excess during Month Three to bring our "running inventory" back to at least zero, where it remained for the rest of our data comparison.

In total, our comparison found 142 unique NIINS from the excess material became negative due to the artificial demand signal imposed by our comparison. As shown in Figure 19, items in a negative inventory condition did not necessarily stay negative for the remainder of the 24-month period. Changes in excess stock such as new items entering an excess condition occasionally brought negative inventories back positive or at least to zero. Additionally, two anomalies occurred in Months 6 and 19, January 2015 and January 2016, respectively. In Month 6, the number of NIINS with negative inventory dropped by 14 to zero. In Month 19, the number of negative NIINs dropped by 19 units from 34 to 15. However, in general the list of negative inventory NIINs created by our artificial demand trended upward with our final month, July 2016, showing a total of 46 NIINs negative.

Figure 19. Quantity of Negative NIINs by Month.



We found that very few NIINs remained in a negative inventory status more than four months with an average time spent negative of 3.4 months. Only 38 of the 142 negative NIINS stayed negative more than five months with only eight NIINs remaining negative longer than eight months. The highest number of months a NIIN stayed negative was NIIN 01–229-0315, STUD ASSEMBLY, TURNL, which stayed negative for 16 months, during Months 5, 7–17, and 21–24, indicating some actual movement in and out of excess material. This indicates that the excess material inventory routinely turns over with the same or similar items. With STUD ASSEMBLY, TURNL showing negative a total of 16 months over three separate periods, our data shows that it was constantly replenished while simultaneously being backordered several times. This leaves a question of why some units continually face backordered requisitions while others are designating their material as excess. This is partially explained because different units run their allowance settings at different times. Until this variance in inventory management can be solved, the situation seems to support the merit of an ERP system capable of screening excess as a possible source of supply.

THIS PAGE INTENTIONALLY LEFT BLANK

V. SUMMARY

Historically, GAO has continually criticized the DOD for inadequate forecasting leading to poor inventory management practices and backordered requisitions. Additionally, GAO criticizes the DOD's high amount of excess inventory. While this study did not investigate the causes of backorders, it proposes one method of satisfying current and future backordered requirements by using the pool of excess material as a source of supply.

A. DISCUSSION

Our model completely or partially filled 7,831 units from 1,294 requisitions covering 1,005 unique NIINs at a dollar value of $1,123,002.74 with an average of 54 requisitions per month. While this is not a significant amount compared to the total number of backorders or dollar amount, it does represent a total reduction in wait time of approximately 43,485 days.

The following considerations were derived from our analysis of the 24 months of data:

- Sourcing backorders from the excess list saved an average of 42 days in CWT. The benefit to this is an improvement in operational readiness by filling the backorders potentially quicker than through DLA.
- It is unclear whether the cost savings of $1.2 million outweighs the cost of programming ERP to allow FRC to automatically screen for excess material by directly inputting requisitions into ERP.
- Sourcing backorders from the excess list would require changing current requisition policy and procedures and its associated costs such as retraining staff.
- There is an unknown impact to CWT for those requisitions that could have been filled by the co-located DLA warehouse but were filled by excess material potentially located at other sites.
- There is an unknown impact on the loss of surcharge income for DLA when requisitions are filled through excess material instead of through the DLA acquisition process.

Some limitations of our data analysis methods occur because we only had snapshots of data. For example, we did not have access to other transactions in and out of excess material or how these backorders were actually filled. Additionally, we looked at reducing only one metric, number of backorders, and did not calculate or quantify increased CWT as a time measure or as a cost measure (cost of a downed aircraft awaiting parts). For example, because we did not have DLA inventory data, if the backorder existed at FRCSW and was available at the co-located DLA warehouse in San Diego, the procedure of screening excess prior to ordering might lead to filling the order with excess material located in Atsugi, Japan, which would result in increased CWT. We also had to make assumptions as to what caused our running inventory to have negative inventories. Finally, we did not assess impact to transportation time and cost due to location of excess assigned to fill a backorder.

This study used only backorder data to determine if screening excess inventory could have reduced the number of requisitions entering backorder status. To truly test the impact of excess inventory on FRC orders, it would be necessary to compare all FRC requisitions to excess inventories available throughout the Navy. Potentially, this may result in much higher level of savings.

B. RECOMMENDATIONS

Based on our research and the limited number and limited dollar value of backorders filled by excess over the 24-month period studied, we recommend NAVSUP study the technical feasibility and associated cost of automating FRC requisition input to feed through ERP in an effort to screen this excess material. Depending on that cost benefit analysis, we recommend NAVSUP coordinate with DLA to explore a permanent policy change of FRCs submitting all initial requisitions into Navy ERP to screen excess material as a source of supply. Any requisitions unfilled by Navy ERP will automatically forward to DLA for fulfillment by existing WCF stock or through initiation of new contracts.

We also recommend that NAVSUP consider the possible limitations with the process of initially screening Navy ERP for excess stock. The first limitation is that although the excess stock population for NIINs is always revolving, in a sense, it is a finite pool and cannot be depended on for long-term fills for many part numbers. Consumable stock becomes available as excess stock for two reasons. The first reason is when unit-level allowances decrease, which causes DODAACs to turn in their excess. Another reason is when the existing part number is superseded by another NIIN, but the former NIIN is coded Acquisition Advice Code V and can still be technically used until exhausted. These two methods cause the pool for that NIIN to be finite because excess stock will not regenerate once these two methods are exhausted.

The second limitation with filling requisitions from excess stock is that the individual demands for these NIIN will not register in DLA's forecasting system. Over time, this hidden demand will delay or under-buy future DLA procurement orders. For example, although excess stock will fill a current FRC requisition through automatic Navy ERP review, a future requisition may remain unfilled because that demand did not register, which in turn did not generate a purchase requisition to order more stock for DLA warehouses. Requisitioning personnel must ensure that they are registering each filled requisition's demand with DLA in order to show demand data supporting future procurement planning for that NIIN. We believe that first automatically screening Navy ERP for excess stock is a great tool for preventing backorders, but we must be careful of the unintended consequence of creating inaccurate demand forecasts.

C. FUTURE RESEARCH

Through the course of our research, several additional questions arose. Many of them offer opportunities for future research to further refine our recommendations or to explore additional opportunities to improve management of Naval Aviation DLRs and ultimately increase aviation readiness.

1. Quantify the value (cost) of a downed aircraft. One of the counterarguments against changing policy to screen excess material first is that it will affect CWT. The argument is that shipping and transportation times lengthen the time it will take the FRC to receive their parts, if (and only if) that part would have been available from the co-located DLA warehouse anyway. A cost benefit analysis would determine if the savings from requisitioning items from "free issue" outweighs the cost of the minimal additional CWT.

2. A complete process map of the AVDLR requisitioning and repair process does not exist. Outdated publications have caused various organizations to create local procedures to best suit their operational realities. An up-to-date process map and analysis would provide an opportunity to identify bottlenecks or capacity deficiencies that potentially contribute to the growing backorder list.

3. In 2012, DLA shifted to a "lean inventory" posture resulting in the disposal of $6 billion of stock. A useful Cost Benefit Analysis would determine the true cost experienced since enactment of this policy, and determine if it contributes to the growing backorder problem. Additionally, the highly variable demand pattern of Naval Aviation may have led to an understated cost to readiness as lean inventory models typically show a higher success rate for steady state manufacturing processes.

4. Several components of this problem involve contracting considerations. For example, several of the backordered piece parts appear to be "low profit margin" items for the Original Equipment Manufacturer (OEM). Often, government bids for procurement go unanswered due to the OEMs unwillingness to initiate production for such low margin items. A useful study would determine the legalities of re-competing these items to other manufacturers for fulfillment. Future studies should explore additional production methods such as Additive Manufacturing, commonly known as three-dimensional (3D) printing, as an alternative solution to source hard to find items.

APPENDIX

```
#!/usr/bin/python3

# Supply Chain Management Project
# Students: LCDR Custard, LCDR Lease, LCDR Schotman
# Advisors: Dr. Ferrer, Dr. Dahel, CDR Ward
# Determine if excess material is a sustainable source of supply for DLA/FRC aviation backorders.

import csv
from operator import itemgetter

# List of monthly BACKORDER file names.
backorderFiles = [
‘BO_01_Aug14.csv’,
‘BO_02_Sep14.csv’,
‘BO_03_Oct14.csv’,
‘BO_04_Nov14.csv’,
‘BO_05_Dec14.csv’,
‘BO_06_Jan15.csv’,
‘BO_07_Feb15.csv’,
‘BO_08_Mar15.csv’,
‘BO_09_Apr15.csv’,
‘BO_10_May15.csv’,
‘BO_11_Jun15.csv’,
‘BO_12_Jul15.csv’,
‘BO_13_Aug15.csv’,
‘BO_14_Sep15.csv’,
‘BO_15_Oct15.csv’,
‘BO_16_Nov15.csv’,
‘BO_17_Dec15.csv’,
‘BO_18_Jan16.csv’,
‘BO_19_Feb16.csv’,
‘BO_20_Mar16.csv’,
‘BO_21_Apr16.csv’,
‘BO_22_May16.csv’,
‘BO_23_Jun16.csv’,
‘BO_24_Jul16.csv’
]

# List of monthly EXCESS file names.
excessFiles = [
‘EXCESS_01_AUG_14.csv’,
```

```
‘EXCESS_02_SEP_14.csv’,
‘EXCESS_03_OCT_14.csv’,
‘EXCESS_04_NOV_14.csv’,
‘EXCESS_05_DEC_14.csv’,
‘EXCESS_06_JAN_15.csv’,
‘EXCESS_07_FEB_15.csv’,
‘EXCESS_08_MAR_15.csv’,
‘EXCESS_09_APR_15.csv’,
‘EXCESS_10_MAY_15.csv’,
‘EXCESS_11_JUN_15.csv’,
‘EXCESS_12_JUL_15.csv’,
‘EXCESS_13_AUG_15.csv’,
‘EXCESS_14_SEP_15.csv’,
‘EXCESS_15_OCT_15.csv’,
‘EXCESS_16_NOV_15.csv’,
‘EXCESS_17_DEC_15.csv’,
‘EXCESS_18_JAN_16.csv’,
‘EXCESS_19_FEB_16.csv’,
‘EXCESS_20_MAR_16.csv’,
‘EXCESS_21_APR_16.csv’,
‘EXCESS_22_MAY_16.csv’,
‘EXCESS_23_JUN_16.csv’,
‘EXCESS_24_JUL_16.csv’
]

verbose = True
issuesDict = {} # Dictionary to keep track of all issues against a NIIN over time, used to decrement new month’s excess material by prior issues from excess.
filledReqs = [] # List of requisitions by document number that have been filled.
partialReqs = {} # Dictionary to keep track of partially filled requisitions by document number (key) and remaining unfilled quantity (value).
results = [] # List of lists containing the statistical data for each month, exportable to Excel.
monthlyNiinServiced = [“Requisitions Issued During, Partial and Complete”]
UniqueNiinInExcess = [“Number of Unique NIINs in Unaltered Excess Inventory”]
TotalUnitsInExcess = [“Sum of Quantities for all NIINs in Unaltered Excess Inventory”]
AdjustmentsToExcess = [“Number of Unique NIINs in This Month’s Excess That We Have Issued Some QTY of to Meet a Prior Backorder”]
AdjustmentsToZero = [“Number of Unique NIINs in This Month’s Excess That We Have Issued All of the Excess QTY of to Meet a Prior Backorder”]
AdjustmentsToNegative = [“Excess NIINs with Negative Balance”]
monthlySavings = [“Dollar Value of Backorders Filled”]
backorderUnits = [“QTY of Units in Initial Backorder”]
monthlyIssues = [“QTY of Units Issued from Excess”]
uniqueHitsPerMonth = [“Unique NIINs Issued”]
```

```
CompleteFills = [“Requisitions Filled, Complete”]
PartialFills = [“Requisitions Filled, Partial”]
dupReqs = 0
AgeListPartial = [] # List of ages of each completely filled requisition.
AgeListComplete = [] # List of ages of each partially filled requisition.
NIINRepeats = {} # Dictionary of NIINs and the number of times it is matched to excess
material.

for i in range(0,24): # Loop through the months.

   # Reset monthly statistics.
   saved = 0 # Dollar value of fills to backorder requisitions.
   issued = 0 # Number of units (quantity) filled to backorder requisitions.
   NIINhits = [] # List of NIINs issued to backorder requisitions.
   excess = {} # Dictionary to keep track of excess by NIIN and QTY for a given month.
   priorIssuedNiin = 0
   priorIssuedAllNiin = 0
   priorIssueExceedsQty = 0
   backorderQTY = 0

   with open(excessFiles[i],’r’) as f: # Read in the next excess .csv file.
         reader = csv.reader(f)

         for line in reader: # For each row in the file, create a dictionary entry where NIIN
         is key and qty is value.
            if line[3] in excess:
               combined = excess[line[3]] + int(line[6])
               excess[line[3]] = combined
            else:
               excess[line[3]] = int(line[6])
         UniqueNiinInExcess.append(len(excess))
         TotalUnitsInExcess.append(sum(excess.values()))

   for NIIN in excess: # Adjust quantities in current month’s excess by last month’s
issues.
      if NIIN in issuesDict:
         priorIssuedNiin += 1
         excess[NIIN] = excess[NIIN] - issuesDict[NIIN]
         if excess[NIIN] == 0:
            priorIssuedAllNiin += 1
            if verbose:
               print (“Zero inventory of “ + NIIN + “ in month “ + str(i+1) + .” Material has
               already been used.”)
         if excess[NIIN] < 0:
            priorIssueExceedsQty += 1
```

```
            if verbose:
               print ("Negative inventory of " + NIIN + " in month " + str(i+1) + ."
Material
               removed from excess outside of the simulation.")
   AdjustmentsToExcess.append(priorIssuedNiin)
   AdjustmentsToZero.append(priorIssuedAllNiin)
   AdjustmentsToNegative.append(priorIssueExceedsQty)

   # Read in the backorder .csv file
   with open(backorderFiles[i],'r') as g:
         reader = csv.reader(g)

         for row in reader: # For each backorder requisition in the new month, see if it has
         been 1) partially filled, 2) not filled at all, or 3) completed.
            try:
               backorderQTY += int(row[7]) # Count total backorder quantity for the
month.
            except (TypeError, ValueError):
               pass
            # 1) If document number (row[0]) was partially filled in a prior month, try to
fill
            the remaining quantity.
            if row[0] in partialReqs:
               neededNIIN = row[9]
               if neededNIIN in excess: # Check if the needed NIIN is in excess material
for
               this month.
                  neededQTY = partialReqs[row[0]] # Assign the quantity required to a
                  variable "neededQTY."
                  if neededQTY < 0:
                    print ("Less than zero.")
                  if excess[neededNIIN] >= neededQTY: # Verify if enough excess exists to
                  fill the order (no partial orders filled).
                     # Calculate how much excess quantity exists after filling backorder.
                     remaining = excess[neededNIIN] - neededQTY
                     # Update running total of issued units.
                     issued += neededQTY
                     NIINhits.append(neededNIIN) # Add NIIN to list of those issued this
                     month.
                     issuesDict[neededNIIN] = neededQTY
                     excess[neededNIIN] = remaining # Update excess material to reflect
                     amount issued.
                     unitPrice = float(row[10]) # Get unit price.
                     fillsavings = unitPrice * neededQTY # Calculate total savings for this
fill.
```

```
                saved += fillsavings # Update total amount saved.
                filledReqs.append(row[0])
                del partialReqs[row[0]] # Remove the requisition from “partialReqs”
                dictionary.
                AgeListComplete.append(row[12]) # Update “AgeListComplete” list to
                reflect monthly transactions.
                if verbose:
                    print(“Completely filled a prior partially filled backorder of” +
row[0]
                    + “ with “ + str(neededQTY) + “ of “ + neededNIIN + “ worth $” +
                    str(fillsavings) + “ from excess inventory leaving “ + str(remaining) +
                    “ on the shelf. Requisition age was “ +str(row[12]))

            elif excess[neededNIIN] > 0: # Verify if existing partial fill balances can
be
            met from excess material.
                partialFill = excess[neededNIIN]
                remaining = 0
                issued += partialFill
                NIINhits.append(neededNIIN) # Add NIIN to list of those issued this
                month.
                excess[neededNIIN] = remaining
                unitPrice = float(row[10]) # Get unit price.
                fillsavings = unitPrice * partialFill # Calculate total savings for this fill.
                saved += fillsavings # Update total amount saved.
                partialReqs[row[0]] = neededQTY - partialFill # Dictionary entry for
                remaining quantity needed for requisition after making partial fill.
                AgeListPartial.append(row[12]) # Update “AgeListPartial” list to
reflect
                monthly transactions.
                if verbose:
                    print(“Partially filled a prior partially filled backorder with “ +
                    str(partialFill) + “ of “ + neededNIIN + “ worth $” + str(fillsavings) +
                    “ from excess inventory leaving “ + str(remaining) + “ on the shelf.
                    Requisition age was “ +str(row[12]))

        # 2) If requisition has never been filled, attempt to fill completely or partially.
        elif row[0] not in filledReqs:
            neededNIIN = row[9] # Assign the NIIN to the variable “neededNIIN.”
            if neededNIIN in excess: # Verify if the needed NIIN is in the dictionary
                neededQTY = int(row[7]) # Assign the quantity required to variable
                “neededQTY.”

                if excess[neededNIIN] >= neededQTY: # Verify if there is enough excess
                to fill the entire requisition.
```

```
        remaining = excess[neededNIIN] - neededQTY # Calculate how much
        excess QTY exists after filling backorder.
        issued += neededQTY # Update running total of issued units.
        NIINhits.append(neededNIIN) # Add NIIN to list of those issued this
        month.
        if neededNIIN in issuesDict:
            issuesDict[neededNIIN] = issuesDict[neededNIIN] + neededQTY
        else:
            issuesDict[neededNIIN] = neededQTY # Update log of issues from
            excess needed later in order to update future month’s excess material.
        excess[neededNIIN] = remaining # Update excess material to reflect
        amount issued in the event there is additional demand this month.
        unitPrice = float(row[10]) # Get unit price.
        fillsavings = unitPrice * neededQTY # Calculate total savings for this
fill.
        saved += fillsavings # Update total amount saved.
        filledReqs.append(row[0]) # Add document number to list of filled
        requisitions.
        AgeListComplete.append(row[12]) # Update “AgeListComplete” list to
        reflect monthly transactions.
        if neededNIIN in NIINRepeats:
            NIINRepeats[neededNIIN] = NIINRepeats[neededNIIN] +1
        else:
            NIINRepeats[neededNIIN] = 1
        if verbose:
            print(“Completely filled a backorder, requisition # “ + str(row[0]) + “
            with “ + str(neededQTY) + “ of “ + neededNIIN + “ worth $” +
            str(fillsavings) + “ from excess inventory leaving “ + str(remaining) +
            “ on the shelf. Requisition age was “ +str(row[12]))

    elif excess[neededNIIN] > 0: # If a complete fill is not possible, verify if a
    partial fill is.
        partialFill = excess[neededNIIN] # Use all available excess to fill as
        much as possible of the required quantity.
        issued += partialFill # Update running total of issued units.
        NIINhits.append(neededNIIN) # Add NIIN to list of those issued this
        month.
        if neededNIIN in issuesDict:
            issuesDict[neededNIIN] = issuesDict[neededNIIN] + partialFill
        else:
            issuesDict[neededNIIN] = partialFill # Update log of issues from
            excess needed later in order to update future month’s excess material.
        excess[neededNIIN] = 0 # Nothing left in excess material after a partial
        fill.
        unitPrice = float(row[10]) # Get unit price
```

```
                fillsavings = unitPrice * partialFill # Calculate total savings for this fill.
                saved += fillsavings # Update total amount saved.
                partialReqs[row[0]] = neededQTY - partialFill # Dictionary entry for
                remaining quantity needed for requisition number after making partial
                fill.
                AgeListPartial.append(row[12]) # Update "AgeListPartial" list to
reflect
                monthly transactions.
                if neededNIIN in NIINRepeats:
                    NIINRepeats[neededNIIN] = NIINRepeats[neededNIIN] +1
                else:
                    NIINRepeats[neededNIIN] = 1
                if verbose:
                    print("Partially filled a backorder with " + str(partialFill) + " of " +
                    neededNIIN + " worth $" + str(fillsavings) + " from excess inventory
                    leaving " + str(remaining) + " on the shelf. Requisition age was "
                    +str(row[12]))

            # 3) Completed requisitions are blocked from additional matching to excess
            material.
            else:
                dupReqs += 1

    # Convert a list of NIINs issued to a set with no duplicates.
    hits = set(NIINhits)

    print ("\n For " + str(backorderFiles[i]) + " issued " + str(issued) + " units from " +
    str(len(NIINhits)) + " requisitions covering " + str(len(hits)) + " unique NIINs and
    saving $" + str(saved) + ."")
    monthlyNiinServiced.append(len(NIINhits))
    monthlySavings.append(saved)
    backorderUnits.append(backorderQTY)
    monthlyIssues.append(issued)
    uniqueHitsPerMonth.append(len(hits))
    CompleteFills.append(len(filledReqs))
    PartialFills.append(len(partialReqs))

labelrow = ["Month," 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24]
results.append(UniqueNiinInExcess)
results.append(TotalUnitsInExcess)
results.append(AdjustmentsToExcess)
results.append(AdjustmentsToZero)
results.append(AdjustmentsToNegative)
results.append(backorderUnits)
results.append(monthlyIssues)
```

```
results.append(monthlyNiinServiced)
results.append(monthlySavings)
results.append(uniqueHitsPerMonth)
results.append(CompleteFills)
results.append(PartialFills)

# Export monthly statistical data to an .xls file
with open (“results.csv,” “wb”) as csv_file:
    writer = csv.writer(csv_file, delimiter=‘,’)
    writer.writerow(labelrow)
    for line in results:
        writer.writerow(line)

# Display dictionary of NIINs and the number of times it is matched to excess material.
NIINRepeatsList = sorted(NIINRepeats.items(), key=itemgetter(1))
print (NIINRepeatsList)

# Display lists of ages for completed and partial fills.
print “Age List, Complete” ‘[%s]’ % ‘, ‘.join(map(str, AgeListComplete))
print “Age List, Partial” ‘[%s]’ % ‘, ‘.join(map(str, AgeListPartial))
```

LIST OF REFERENCES

Commander, Naval Air Forces. (2013). The Naval Aviation Maintenance Program. (Commander, Naval Air Forces Instruction No. COMNAVAIRFORINST 4790.2B). Washington, DC: U.S. Government Printing Office

Defense Acquisition University Log 102, 9.5 (n.d.). Retrieved October 24, 2016, from https://learn.dau.mil/Atlas2/html/scorm12/course/course_index.jsp?user_id=1504062&course_id=800840&course_prefix=LOG&version=11&scorm_version=3&roster_id=-0.7559445657969703_800840&course_name=Fundamentals%20of%20System%20Sustainment%20Management&course_number=102&mode_id=null&mode=browse&cid=20827.

Defense Logistics Agency. (2012). *Annual financial report: Fiscal year 2012 (Unaudited)*. Retrieved from http://www.dla.mil/Portals/104/Documents/J8Finance/DLAFY2012AnnualFinancialReport.pdf

Gilmore, J. M., Klemm, K. B., & Sweetser, J. J. (2011). *Analysis of aircraft carrier excess material offloaded to CARP facilities* (Master's thesis). Retrieved from Calhoun http://calhoun.nps.edu/handle/10945/10768

General Accounting Office. (1988). *Defense inventory: Growth in secondary items* (GAO/NSIAD-88-189BR). Washington, DC: Author. Retrieved from http://www.gao.gov/products/AFMD-90-10.

Government Accountability Office. (2008). Defense inventory: Management actions needed to improve the cost efficiency of the Navy's spare parts inventory. (GAO-09-103). Washington, DC: Author. Retrieved from http://www.gao.gov/products/GAO-09-103

Government Accountability Office (GAO). (2005a). DOD excess property: Management control breakdowns result in substantial waste and inefficiency (GAO-05-277). Washington, DC: Government Accountability Office.

Government Accountability Office (GAO). (2005b). DOD excess property: Management control breakdowns result in substantial waste and inefficiency (GAO-05-729T). Washington, DC: Government Accountability Office.

Government Accountability Office. (2006). DOD excess property: Control breakdowns present significant security risk and continuing waste and inefficiency (Report No. GAO-06-943). Washington, DC: Government Accountability Office.

Department of Defense Inspector General (DODIG). (2011). Changes are needed to the Army contract with Sikorsky to use existing DOD inventory and control costs at the Corpus Christi Army Depot (DODIG-2012-004). Washington, DC: Government Accountability Office.

McNulty, K. S., Dillion, A. J., & Mourning, M. H. (2012). *An enterprise-wide model for redistributing excess material* (Master's thesis). Retrieved from Calhoun http://calhoun.nps.edu/handle/10945/27868

Paulson, T. N., & Leon, E. N. (2011). *Analysis of the United States Marine Corps' utilization of Defense Logistics Agency disposition services as a source of supply* (Master's thesis). Retrieved from Calhoun http://calhoun.nps.edu/handle/10945/11063

Oswald, A. (2013). *Measuring the impact of business rules on inventory balancing* (Master's thesis). Retrieved from Calhoun http://calhoun.nps.edu/handle/10945/37689

Rigoni, M. P., & Souza, W. (2016). *Demand forecasting: An evaluation of DOD's accuracy metric and Navy's procedures* (Master's thesis). Retrieved from Calhoun http://calhoun.nps.edu/handle/10945/49370

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California