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SUPPLY CHAIN ENHANCEMENTS FOR THE COASTAL RIVERINE FORCES DEPLOYED MARK VI PATROL BOATS

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SUPPLY CHAIN ENHANCEMENTS FOR THE COASTAL RIVERINE FORCES' DEPLOYED MARK VI PATROL BOATS

December 2018

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The Coastal Riverine Force currently has 12 Mark VI patrol boats in its inventory. The operational tempo for the Mark VI is demanding, with an expected operational availability of 300 days a year. Despite two annual Continuous Maintenance Availability periods for each vessel, the Coastal Riverine Force is experiencing readiness shortfalls during deployments due to a lack of replacement material, prompting the analysis of the Mark VI patrol boat deployment supply chain. This research reviews historical Mark VI demand data in order to develop a comprehensive understanding of the Coastal Riverine Force's supply chain methodology. The authors make recommendations to develop an enhanced deployed supply chain framework, which will improve replacement component availability, readiness rates, and operational availability, and potentially generate cost savings for the Navy Expeditionary Combat Command.

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ABSTRACT

The Coastal Riverine Force currently has 12 Mark VI patrol boats in its inventory. The operational tempo for the Mark VI is demanding, with an expected operational availability of 300 days a year. Despite two annual Continuous Maintenance Availability periods for each vessel, the Coastal Riverine Force is experiencing readiness shortfalls during deployments due to a lack of replacement material, prompting the analysis of the Mark VI patrol boat deployment supply chain. This research reviews historical Mark VI demand data in order to develop a comprehensive understanding of the Coastal Riverine Force's supply chain methodology. The authors make recommendations to develop an enhanced deployed supply chain framework, which will improve replacement component availability, readiness rates, and operational availability, and potentially generate cost savings for the Navy Expeditionary Combat Command.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Active Component
ALSA	Air Land Sea Application Center
AOR	Area of Responsibility
AVCAL	Aviation Consolidated Allowance List
C2	Command and Control
CI	Counter Intelligence
COCAM	Combat Camera
COG	Cognizance Code
CONUS	Continental United States
COSAL	Consolidated Shipboard Allowance List
COTS	Commercial Off-the-Shelf
CMAV	Continuous Maintenance Availability
CRF	Coastal Riverine Force
CRG-1	Coastal Riverine Group ONE
CRG-2	Coastal Riverine Group TWO
CRG	Coastal Riverine Group
CRS	Coastal Riverine Squadron
CTF	Combined Task Force
DLR	Depot Level Repairable
DoN	Department of the Navy
ECRC	Expeditionary Combat Readiness Center
EHR	Equipment History Record
EOD	Explosive Ordnance Disposal
EOQ	Economic Order Quantity
FLC	Fleet Logistics Center
FOL	Forward Operating Location
FSL	Forward Support Location
GPC	Government Purchase Card
HADR	Humanitarian Assistance and Disaster Relief
HVU	High Value Unit

IA	Individual Augment
IMEC	Item Mission Essentiality Code
ISR	Intelligence, Surveillance, and Reconnaissance
LICN	Local Item Control Number
MDT	Maintenance Down Time
NAVELSG	Navy Expeditionary Logistics Support Group
NAMP	Naval Aviation Maintenance Program
NAVSUP	Navy Supply
NC	Not Carried
NCF	Naval Construction Force
NCR	Naval Construction Regiments
NDI	Non-Destructive Inspection
NECC	Navy Expeditionary Combat Command
NEIC	Navy Expeditionary Intelligence Command
NIIN	National Item Identification Number
NSB	Naval Studies Board
OCO	Overseas Contingency Operations
OMFTS	Operational Maneuver from the Sea
OMMS-NG	Organizational Maintenance Management System-Next Generation
OTS	One Touch Support
PUK	Pack-Up-Kit
RC	Reserve Component
RFI	Ready for Issue
RO	Requisition Objective
SBI	Safe Boats, International
SFA	Security Force Assistance
SOF	Special Operations Forces
SRC	Scheduled Removal Component
TOC	Total Ownership Costs
TSC	Theater Security Cooperation
UCT	Underwater Construction Teams
USAF	United States Air Force

USN	United States Navy
VBSS	Visit, Board, Search, and Seizure
WCC	Work Center Code

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EXECUTIVE SUMMARY

The mission of the expeditionary community demands a flexible and rapid response from its forces. Such was the case when the Navy procured and rapidly employed the Mark VI patrol boat. Although the Mark VI is a very capable platform, its rapid acquisition and employment has resulted in a logistics and maintenance framework that is underdeveloped, creating challenges for the Costal Riverine Force (CRF).

The purpose of this report is to enhance the effectiveness of the Mark VI patrol boat Pack-Up-Kit (PUK) by conducting an in-depth analysis of the patrol boat's supply data. The enhanced performance of the PUK will have three positive effects throughout the life cycle of the Mark VI. The enhanced performance will increase patrol boat readiness, limit the occurrence of material shortfalls, and reduce the cost of expedited global shipping, which is a by-product of the shortfalls.

In addition to increasing readiness and reducing costs, the authors provide recommendations for improving operational record keeping and implementing controls for managing excessive order quantities. The authors draw on more than 40 years of combined naval aviation maintenance experience in both sea-based and expeditionary land-based deployments in assessing the challenges the CRF faces and in developing recommendations for Mark VI operational planners.

DATA PROCESSING

In assessing Mark VI patrol boat operations, the authors gathered and analyzed 34 months of raw demand data for the fleet of 12 Mark VI patrol boats. The data is comprehensive for the time period of November 2015 through July 2018, and includes 3,469 requisitions across all 12 Mark VI patrol boats. This raw demand data required pre-processing in order to make it useful for analysis to identify trends, failures, and usage rates. Pre-processing of the raw demand data was also necessary to establish time periods of usage for a more refined analysis of cyclical failure trends and recurring component requirements.

Engine operating hours were used to establish 100-hour time periods of operational use over the service life of each Mark VI patrol boat. Engine hours were chosen due to their alignment with a patrol boat's true operational use. The 100-hour time periods allowed detailed analysis of demand data for a specific time in each boat's service life, providing a unique dataset for each boat in each time period.

FINDINGS

The pre-processing and analysis of the raw supply data provided useful insights for developing recommendations for Mark VI operational planners at the group and squadron level. These findings are the foundation of the authors' recommendations to improve the effectiveness of the Mark VI PUK, which will enhance operational readiness, reduce material shortfalls, and limit the frequency of expedited shipping, which is very costly. The framework the authors developed will significantly increase the probability of having the required material on-hand when it is needed. The majority of the high demand items are relatively inexpensive, generally small, and non-perishable. Therefore, there is very little risk associated with keeping them on-hand.

Aggregating quantities demanded across all Mark VI patrol boats and assigning those demands to 100-hour time periods identified the top 15 readiness degraders by National Item Identification Number (NIIN) and quantity for each 100-hour time period across all 12 Mark VI boats. Additionally, the data provided the top 15 readiness degraders by NIIN and quantity for each 100-hour time period at the individual boat level.

This research also identified the top 50 demanded NIINs with associated price across all Mark VI patrol boats based on quantity demanded. Having each item's unit cost data was useful in determining these top 50 demanded NIINs are all low-cost consumable items.

Lastly, the data was processed to display items with an Item Mission Essentiality Code (IMEC) classified as severe primary mission degraders. This data showed that with the exception of one item, every severe mission degrader was a low-cost consumable component.

RECOMMENDATIONS

1. Pack-Up-Kit Standardization

Having a PUK prepositioned with the right material in it is critical to the success of a deployed Mark VI patrol boat squadron. As deployment planning for a CRS is conducted, the PUK can be developed based on the actual operational time for each Mark VI at the deployment location. Recommendations for PUK standardization are:

- Modify the PUK configuration to include the top 15 NIINs for each time period commensurate with the operational time on the Mark VI patrol boats to be utilized during a deployment.

- Estimate the operational hours a Mark VI patrol boat will accrue during an upcoming deployment using an average from the previous three deployments. Apply that estimate to the current operational time and include the top 15 NIINs from the projected time periods in the PUK's configuration.

- Modify the PUK configuration to include the top 50 NIINs demanded across all Mark VI patrol boats. PUK quantities for each of these 50 items should be reconciled between Coastal Riverine Group (CRG) and CRS maintenance and supply subject matter experts.

- Modify the PUK configuration to include components with an Item Mission Essentiality Code (IMEC) classification of "severe mission degrader," given their relatively low cost and consumable nature. PUK quantities for these critical items should be reconciled between CRG and CRS maintenance and supply subject matter experts.

- The CRG has constant oversight and is in the critical path for the requisition process. PUK management should be transparent to the CRSs, with the exception of the quantity reconciliation previously mentioned.

2. Operational Records

This recommendation uses principles from naval aviation's flight-hour program and aircraft logbook requirements. To improve and continue to refine the PUK analysis, the engine operating hours for the Mark VI need to be reported weekly by the CRS maintenance officer. The NECC and CRG should receive these reports and create a repository (or archive) of historical data. In addition, the traceability of the major DLRs needs to be improved. Naval aviation uses either an equipment history record (EHR) or a scheduled removal component card (SRC). These records are used to track the item from cradle to grave and provide exceptional oversight. They will enable the CRS and the CRG to quickly identify "bad actor" DLRs or inadequate component repairs.

3. Ordering for Demand

During the analysis, it was apparent that CRSs were ordering excess quantities to keep spare parts on-hand. This may be a common practice, but it must be managed and controlled. Ten items account for 90% of the total cost for the 50 highest demand NIINs. Any NIIN being ordered in excess of the requirement must to be justified by a technical manual. The CRS should provide the technical reference to the CRG before the order is approved. This is an everyday occurrence in naval aviation and easily implemented for the Mark VI.

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- Commander David Davis — CRG-1, N4
- Lieutenant Jolifer Fridge — CRG-1, Material Readiness Officer
- Lieutenant Pablo Suarez — CRG-2, Stock Control Officer
- LSCS Stephen Mustin — CRS-4, Supply Chief

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I. INTRODUCTION

> Logistic considerations belong not only in the highest echelons of military planning during the process of preparation for war and for specific wartime operations, but may well become the controlling element with relation to timing and successful operation.
>
> —Vice Admiral Oscar C. Badger
> (DocPlayer, 2018, p. 1)

The mission of the Navy Expeditionary Combat Command (NECC) is to organize, man, train, equip, and sustain naval expeditionary combat forces. These expeditionary forces conduct combat and combat support missions across the spectrum of naval warfare operations and primarily enable access from the sea, allowing freedom of action across sea-to-shore and inland operating environments (Department of the Navy [DON], 2018).

The Coastal Riverine Force (CRF) is one component command of the NECC and is comprised of two Coastal Riverine Groups (CRGs): Coastal Riverine Group 1 (CRG-1) and Coastal Riverine Group 2 (CRG-2), located in Imperial Beach, CA and Virginia Beach, VA respectively. The CRF supports the mission of the NECC by operating ashore; at sea; in harbors, rivers, and bays; and across the littoral waterways. It primarily conducts maritime security operations through port and harbor security patrols and also protects high-value assets adjacent to coastal waterways, such as major ports (DON, 2018).

To carry out its mission, the CRF relies upon the Mark VI patrol boat. The Mark VI is the Navy's latest acquisition in the NECC domain and is the first major redesign of a patrol boat since the 1980s. The Mark VI was engineered with a focus on decreasing total ownership cost (TOC) and manpower requirements. The major design elements of the Mark VI are an all-aluminum hull, enhanced performance, improved fuel efficiency, and armored plating protection for the engines and fuel systems. In addition, the Mark VI was designed with rapid transportability in mind, and its relatively compact size makes it possible to transport it on the U.S. Navy's L-class amphibious ships (Naval Technology, n.d.).

Currently, the Navy supply system is reactive in nature as a result of the short time span of operational use for the Mark VI patrol boat. This reactivity can result in material support shortfalls that present significant problems for a weapon system that is expected to have an operational availability of 300 days a year. These readiness challenges are highlighted when the Mark VI is forward deployed to locations where the CRF is expected to consistently provide critical security.

A standard Navy supply chain will provide consumable items for routine maintenance and a stock pool of repairable components that are ready-for-issue (RFI). These components facilitate rapid fault isolation and the replacement of the defective component. The purpose of this method is to minimize maintenance down time (MDT). The relatively young age of the Mark VI patrol boat platform necessitates contractual agreements with parts manufacturers and procurement through commercial off-the-shelf (COTS) purchases in some cases until the Navy supply system has a chance to catch up to demand and meet these requirements organically. These agreements are made after the requirement for material support arises, so a Mark VI may be inoperable until the material is received. Inherently, this supply chain is reactive and results in long lead times and delays in repairs. This fosters an environment for a cyclical readiness problem. To meet its mission requirements, the CRF over-utilizes the remaining Mark VIs, increasing the probability that the boats will require a repair and perpetuating cyclical readiness issues.

As previously mentioned, the Mark VI routinely deploys to isolated and austere environments. Even under a traditional Navy supply chain, these types of locations would present a challenge; however, the challenge is exacerbated under the current Mark VI manufacturer supply chain. The primary strategy the CRF employs to minimize material shortfalls during deployments is to pre-position a pack-up-kit (PUK) at or near the deployment location. The PUK consists of what the deploying unit determines to be the necessary replacement components that will be needed for the duration of the deployment. This PUK composition is based on the maintenance technicians' experience and CRF leadership's recommendations. The PUKs are not standardized and each squadron deploys with a PUK that contains different materials and components.

The Mark VI design has made significant advancements in capability, technology, and weapons systems from its predecessors; however, because of readiness shortfalls, the Navy is hesitant to purchase an additional 36 Mark VI patrol boats. When deployed, Mark VI patrol boat operational availability depends heavily upon the PUK's contents, creating the opportunity for a single point of failure. The critical nature of the PUK mandates an in-depth analysis of historical data to identify trends and component failure rates in order to achieve near-optimized levels of support in remote regions of the world for deployed units. This level of analysis requires a strong working knowledge of Navy supply processes and the relationships between maintenance and supply personnel. The authors draw on more than 40 years of combined naval aviation maintenance experience in both sea-based and expeditionary land based deployments in their assessment of the challenges faced by the CRF.

The research objective of this MBA project is to provide analysis for the composition of deployment PUKs for the CRF's Mark VI patrol boat. To achieve this objective, the authors applied, at a high level, the define, measure, analyze, improve, and control (DMAIC) framework of Lean Six Sigma to produce recommendations focused on improving readiness and operational availability, and potentially generate cost savings for the NECC.

The DMAIC construct consists of *defining* the problem in order to identify opportunities for improvement, *measuring* available data, *analyzing* that data to determine the root cause of deficiencies, and offering recommendations for *improving* and *controlling* processes for future success.

A. THE MARK VI PATROL BOAT BACKGROUND

The Mark VI was designed and built by American boat builder Safe Boats, International (SBI) for the CRF as a replacement for an aging fleet of patrol craft. In May 2012, the Navy awarded a $36 million contract to SBI to produce the first six boats. In July 2014, the Navy ordered an additional four Mark VI units, followed by an additional two boats one year later. By July 2015, the Navy had ordered 12 Mark VI boats (Naval Technology, n.d.). The 12th Mark VI was delivered to the Navy in January 2018 (Navy Recognition, 2018). The first two Mark VI boats were accepted by CRG-2 in September

2015 (United States Navy [USN], 2015). The first Mark VI boats arrived in Manama, Bahrain, which is located in the U.S. Navy's Fifth Fleet Area of Responsibility (AOR), in March 2016 and were first used operationally in April 2016 (Mustafa, 2016, para. 2). As of October 2018, the U.S. Navy had the option to acquire 36 additional Mark VI boats (Naval Technology, n.d.).

B. MARK VI PATROL BOAT GENERAL CHARACTERISTICS

The Mark VI is a multi-mission-capable platform that can be configured to conduct visit, board, search, and seizure (VBSS) operations, explosive ordnance disposal (EOD) personnel transport, and Special Operations Forces (SOF) personnel transport. Additionally, the Mark VI can serve as a Command and Control (C2) center and perform counterintelligence (CI) missions, security force assistance (SFA), high value unit (HVU) shipping escort services, and Theater Security Cooperation (TSC) type operations (DON, n.d.).

The Mark VI has the capability to conduct operations in brown, green, or blue water environments (Naval Technology, n.d.). These are the river, coastal, and open ocean environments, respectively. The Mark VI's primary purpose is to conduct security patrols of harbors and bays to provide protection to the U.S. Navy and allied assets, interests, and critical infrastructures (DON, n.d.).

The Mark VI is 84 feet in length, has a draft of less than five feet, and can displace up to 85 tons. It is propelled by two Rolls-Royce MTU 16V 2000 M94 diesel engines, which combined produce 5,200 horsepower. The published speed and endurance are a cruising speed of over 25 knots, the ability to sprint at over 35 knots, and a range of 600 nautical miles (DON, n.d.).

The Mark VI can carry as many as 18 passengers and is armed with four MK 50 .50 caliber gun systems, two MK 38 Mod 2 25mm gun systems, a MK 44 machine gun system, and various other crew-served weapons (DON, n.d.). Figure 1 shows the Mark VI patrol boat.

Figure 1. Mark VI Patrol Boat. Source: Navy Recognition (2018).

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II. NAVY EXPEDITIONARY COMBAT COMMAND

The NECC was established in 2006 in response to global security threats and the emerging need for a new maritime strategy. The command's headquarters are located at the Naval Amphibious Base in Little Creek, VA, and is the command element for all of the Navy's expeditionary forces. It is responsible for providing the requisite manpower, training, and equipment to the expeditionary forces (DON, 2006).

The NECC aligns the efforts and fosters the integration of all the expeditionary capabilities within the Navy, thus creating a unique enterprise. The Navy needed a force capable of transitioning from traditional sea-based blue water operations to a force capable of delivering combat power to the inland coastal waterways. The expeditionary forces are capable of operating at sea and on land, with the ability to deploy deeper inland as required. With the NECC at the helm, the standard operating procedures will remain consistent and efficient. Additionally, the enterprise approach will yield benefits from economies of scale and common practices (DON, 2006). As explained by Admiral John B. Nathan, USN (DON, 2006):

> The term "expeditionary" captures the essence of U.S. national security strategy and takes on added importance in view of the ongoing war on terrorism countering military threats overseas rather than on American shores. Additionally, it extends from traditional blue water roles into green and brown water and pushes the maritime domain into an inland battle space. (p.1)

A. NECC MISSION AND OBJECTIVES

In order for the NECC to execute its mission, its forces need to be prepared to conduct maritime security operations and joint contingency operations. The NECC was created to be a scalable expeditionary force, capable of rapidly deploying and being self-sustainable; however, as a newly established command, the NECC had three important elements to incorporate to bring its concept of operations to fruition. The elements are realignment, redistribution, and recognition (DON, 2006).

Realignment would require the Navy to take its existing expeditionary forces and change their structure. The structural changes would provide flexibility for the forces to conduct enhanced maritime security operations and improve the forces' combat effectiveness. As previously discussed, the realignment and consolidation of forces would also provide benefits from economies of scale and common capabilities (DON, 2006).

The redistribution element specifically addressed the physical location of the forces and was a result of the realignment effort. Once the forces were realigned under their new commanders, it became apparent that the global distribution was not efficiently supporting the joint operations around the world. In order to contribute more effectively and relieve stress on the joint forces conducting global operations, the Navy redistributed its expeditionary forces' responsibilities among the various joint AORs (DON, 2006).

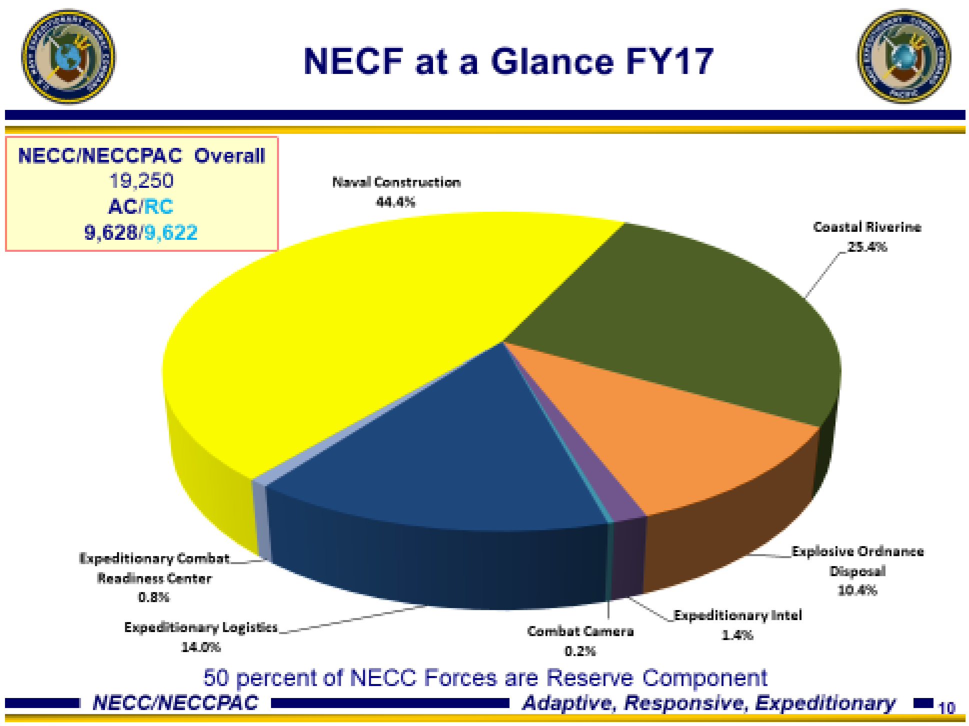
The NECC knew that in order to remain effective and provide long-term capabilities to the Navy and AOR joint commanders, it would need to develop the abilities to counter threats. The NECC invested heavily in identifying and assessing potential threats and developing capabilities to defend against or neutralize them (DON, 2006). As stated by Admiral Mike Mullen, USN:

> Today's uncertainty and today's threats are of an entirely unique sort, caused by new challenges. We therefore need a new maritime strategy for this era and this war for our time and the incredible growing challenges that we face. (DON, 2006, p. 1)

Even with the development of robust expeditionary capabilities, the NECC is not a standalone combat force. It primarily operates as a protection force that fits in the seams and bridges the gap between conventional forces in the joint battle space, or AOR. It enhances the capabilities available to the joint commanders and easily integrates with other services and U.S. coalition partners. The NECC provides a unique skill set for maritime security operations. In addition to unique capabilities, the NECC's manpower composition differs significantly from the general Navy forces (DON, 2006).

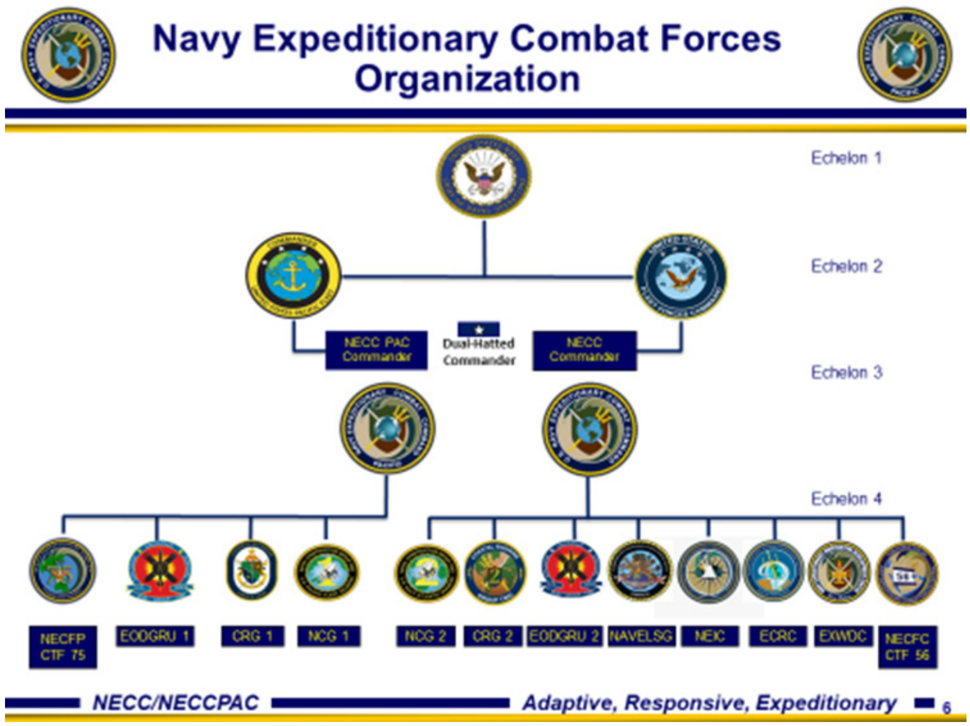
B. NECC COMPOSITION

The Navy has an Active Component (AC) and Reserve Component (RC). The AC is comprised of personnel who serve every day; the military is their full-time position. The RC, on the other hand, is composed of personnel who serve the military one weekend each month and one annual two-week period. Nearly half of the NECC's manpower comes from the Navy's RC, which is very high compared to the rest of the Navy. Figure 2 provides the manning composition across subcomponents of the NECC. The NECC enterprise has eight subordinate component commands, each of which provide a specialized capability (DON, 2018). Figure 3 shows the command structure for the NECC.



Source: B. Garbert, personal communication, September 26, 2018.

Figure 2. NECC Manning Composition



Source: B. Garbert, personal communication, September 26, 2018.

Figure 3. NECC Command Structure

1. Coastal Riverine Force

The primary mission of the CRF is to conduct maritime security operations during all phases of military operations, 24 hours a day, and in all weather conditions (USN, n.d.-b). The basic phases of military operations are deter, defend, counter-attack, and stability operations. The CRF is capable of operating ashore or at sea. It can operate effectively across littoral waterways, harbors, bays, and all river environments. In addition to providing maritime security for ports and harbors, the CRF also provides high-value target security inland. Providing security for a hydroelectric power plant to protect the infrastructure of a region is an example of inland security. The CRF also conducts infiltration and exfiltration for small military units such as SOF and can provide C2 for those units. C2 provides communication suites for the embarked units and enables direct communication with national military authorities (USN, n.d.-b).

2. Explosive Ordnance Disposal

EOD personnel are some of the most highly trained and skilled personnel outside of the SOF. These personnel are recognized experts in the fields of explosives, diving, and parachuting. Because of their unique training, EOD personnel can parachute in from aircraft to reach distant targets and can also neutralize underwater explosives and mines. Their primary missions include counter-improvised explosive device operations. They routinely liaison with the U.S. Secret Service and the U.S. State Department to protect the president, other officials, and foreign dignitaries (USN, n.d.-c). The EOD has even provided security for international events such as the Olympics (USN, n.d.-c).

3. Naval Construction Force

The Naval Construction Force (NCF), or Seabees, is capable of conducting numerous types of construction to operating forces in most AORs. Specifically, the Seabees are capable of constructing roadways, bridges, temporary airfields, and logistics bases, and providing direct support to any human assistance and disaster relief (HADR) operations. In addition, the NCF can perform underwater construction to repair infrastructure in ports and harbors as well as provide limited force protection efforts. The NCF is comprised of four naval construction regiments (NCR), which include 11 battalions and two underwater construction teams (UCT) (USN, n.d.-d).

4. Navy Expeditionary Intelligence Command

The Navy Expeditionary Intelligence Command (NEIC) brings a unique capability to the NECC. Its mission is to provide relevant and actionable intelligence to the joint commanders. NEIC capabilities give the expeditionary, maritime, joint and combined forces intelligence to deny the enemy sanctuary, provide freedom of movement for coalition forces and effectively attack enemy forces if necessary (USN, 2010). The NEIC's unique capability is its intelligence, surveillance and reconnaissance (ISR) collection methodology. The NEIC operates in the coastal waterways, rivers, littorals, and inland environments, which means that it conducts ISR from a much closer proximity than traditional methods and is more effective (USN, 2010).

5. Navy Expeditionary Logistics Support Group

The Navy Expeditionary Logistics Support Group (NAVELSG) is responsible for providing worldwide logistics support to the expeditionary elements. The group specializes in freight terminal and warehousing operations, air cargo handling, postal services, ordnance reporting and handling, customs inspections, fuel distribution, and contingency contracting. Additionally, like the brethren Seabees, the NAVELSG supports HADR operations and can effectively integrate with host nations to provide support. The NAVELSG is headquartered in Williamsburg, VA, and is composed of five regional regiments and 11 battalions, all located in the United States (USN, n.d.-e).

6. Combat Camera

The mission of Combat Camera (COCAM) is to provide to the Joint Forces commander imagery that is collected during military operations. COCAM personnel receive specialized combat training, which enables them to operate in hostile environments (Air Land Sea Application Center [ALSA], 2007).

C. NECC ENABLERS

In addition to its subordinate forces, the NECC has two entities that directly support its expeditionary mission. The Expeditionary Combat Readiness Center (ECRC) and the various Combined Task Forces (CTFs) provide this support.

1. Expeditionary Combat Readiness Center

The ECRC is responsible for processing every Sailor preparing to serve in an individual augmentee (IA) capacity to support Overseas Contingency Operations (OCO). The ECRC is responsible for the Sailors' training, deployment, and redeployment. In addition, the ECRC provides Navy liaison officers to support the Sailor. The ECRC's mission does not end until each Sailor returns home (USN, n.d.-a).

2. Combined Task Force

There are three CTFs in different fleets around the globe, and these commanders are focused on the unique war requirements in their theaters of operations. These CTFs serve as the primary delivery method for the Navy's Expeditionary Forces within their respective AORs (DON, 2018).

Generally, the Mark VI patrol boats operate out of San Diego, CA; Little Creek, VA; Bahrain and Guam. As an example, when the CRS deploys to Bahrain, it falls under the operational command of CTF-56. The CRS is still a component of the NECC, but it operates to support the mission and vision of the CTF-56 commander. Additionally, the Mark VI patrol boats remain at the deployment AOR. So, when a CRS deploys, it relieves the previous CRS personnel, but the boats remain at the location. This deployment strategy is much more efficient than transporting the patrol boats each time a CRS deploys and redeploys.

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III. LITERATURE REVIEW

In this chapter, the authors discuss relevant literature on expeditionary logistics, overseas combat support basing, CRF patrol boat and naval aviation management policies and procedures, and inventory management practices.

A. NAVAL EXPEDITIONARY LOGISTICS

The research in the study conducted by the Naval Studies Board (NSB) focuses on the concept of Operational Maneuver from the Sea (OMFTS). While this concept does not specifically relate to this thesis, the tenets and overarching theme of the study is very relevant to how naval expeditionary forces are sustained during periods of deployment. OMFTS centers on the idea of logistics operations delivering tailored support packages from a sea-based platform to highly mobile combat forces, similar to the CRF deploying a tailored PUK with each unit operating the Mark VI patrol boat (NSB, 1999).

As stated by the Naval Studies Board, "Naval expeditionary logistics, which is about moving naval forces and sustaining their operations in a broad array of environments" (NSB, 1999, p.1) and "Logistics needs derive from combat capability, which, in turn, derives from the forces and concepts employed to attain that capability" (NSB, 1999, p.4). The ability to rapidly deploy forces to any area of the world, whether from the continental United States (CONUS) or an overseas base, is critical for the U.S. military's immediate response capability. Overseas basing of assets to support future contingencies is a means of achieving the readiness desired once forces are rapidly deployed to a particular theater.

The NSB acknowledges that, "Designing the support concept or concepts that best fit the needs of future logistics operations is not a trivial task" (NSB, 1999, p.10). One of the greatest challenges faced in expeditionary logistics today is balancing the needs of the warfighter with the budgetary constraints the U. S. military faces in a fiscally uncertain environment. The future state of expeditionary logistics is an incremental process of determining required operational capabilities and the requisite logistic support to meet those operations and regulating both to strike a balance between cost and risk (NSB, 1999).

The expeditionary nature of the CRF drives the requirement for self-sufficiency. While deployed to the remote and austere environments its mission routinely dictates, the CRF lacks the benefit of shore-based logistical sustainment. Its ability to deploy worldwide poses logistical challenges that are unique to its particular theater of operation. Decisions regarding reliance on overseas supply channels must be made. Their current logistics sustainment model incorporates a PUK as a substitute to traditional CONUS supply chain utilization. Regardless of its theater of operation, a standardized, well-engineered logistics sustainment approach is required in order to maximize the operational availability of mission-critical assets.

B. OVERSEAS COMBAT SUPPORT BASING

According to Lang, "Based on the unpredictability of the nature and location of recent conflicts, it is growing more apparent that U.S. defense policymakers can no longer just plan for one particular deployment in a specific region of the world" (Lang, 2009, p. 3).

Pre-positioning of materiel in support of future contingencies is key to the success of the U.S. military's rapid deployment of troops. In order for selected pre-positioning sites to remain effective, access to them must remain unfettered. The political climate of the world today introduces risk in the form of uncertainty and instability, which must be taken into consideration. This uncertainty led the United States Air Force (USAF) to take an academic approach in determining the most appropriate locations for pre-positioning equipment to support the rapid deployment of military forces. The fundamental intent of this research was to answer the question, "How should the USAF structure and locate war reserve materiel in order to cover a broad set of potential missions around the globe?" (Lang, 2009, p.1).

The network of a forward-operating supply chain can be broken down into its most fundamental components of demand nodes, supply nodes, and a transportation network linking the two nodes. The demand nodes, or forward operating locations (FOLs), are where the mission of a military is conducted and where the demand for resources will originate (Lang, 2009).

The demand for resources will not always be known in advance and can fluctuate based on mission requirements or unforeseen changes in the nature or scope of the mission. The supply nodes, or forward support locations (FSLs), are sites in close proximity to the demand nodes for which they provide service. In addition to providing logistics support, FSLs may, in some cases, be equipped to perform maintenance on equipment utilized by their supported FOLs. In order to be effective, the FSLs must be designed with the agility to support dynamic demand signals from the FOLs they support (Lang, 2009).

The transportation network provides the link between FOLs and FSLs. The transportation network is a vital component of the combat support network construct. It must be robust enough to respond to changing logistics requirements that FOLs place on the FSLs (Lang, 2009).

Risk should be considered a component of any military operation, but it is especially inherent in the realm of forward-deployed logistics networks. Specifically, the chance of FSL node degradation or complete loss of access to an FSL introduces unreliability into a combat support network. Events such as an enemy attack on an FSL, the loss of a critical service from a host nation like the closing of an airfield, or a natural disaster can render an FSL ineffective. The susceptibility of an FSL has a direct correlation to its reliability.

Reliability of a forward-deployed logistics network is measured by the network's capability to absorb the loss of an FSL. Lang asserts, "A reliable solution is one where even if one or more facilities become unavailable, the remaining system is still adequate to meet demand" (Lang, 2009, p. 9).

The ability to design a desired or acceptable level of reliability into a forward-operating logistics network comes at a cost that must be considered by planners. In today's fiscally constrained environment, striking the optimal balance between budget limitations and warfighter demands is an ongoing issue that requires careful consideration of resources, which must be allocated at the right time, location, and quantity.

C. COASTAL RIVERINE FORCE PATROL BOAT MANAGEMENT

The CRF patrol boat management program is divided into 10 areas. Specifically, the areas are requirements for patrol boat management, boat maintenance administration and logistics, boat equipment, boat maintenance and repair, turnover of patrol boats between deployed squadrons, engineering operation casualty control, engineering casualty control and procedures, reporting for ancillary equipment, inspections, and crew rest and utilization. Each element of the management program supports the next; thus, every element needs to be performed for the overall program to be effective. Patrol boat management is governed by CRF Instruction 4590.1C (CRF, 2018). The instruction outlines the responsibilities and organizational requirements for the CRG and the CRF squadrons for all of the patrol boat types, including the Mark VI. In addition, it lists all the collateral equipment on each type of vessel and sample PUKs for each patrol boat. This instruction lays the foundation for the management, maintenance, and personnel requirements and identifies the limitations of each. The reporting requirements established in this instruction are significant to this research. Each squadron is required to submit a monthly boat report, which includes the mission capability status and the active operational time for each Mark VI. This data enabled the authors to identify any potential component failure patterns throughout the operational life of the Mark VI (CRF, 2018).

D. NAVAL AVIATION MAINTENANCE PROGRAM

Every aspect of naval aviation is governed by the Naval Aviation Maintenance Program (NAMP). The NAMP is directed by the Chief of Naval Operations, but it is managed by the Commander Naval Air Forces, who is a vice admiral. The NAMP governs policies, procedures, and responsibilities for every level of aviation maintenance. It is based on four core principles, one of which is at the focal point of the authors' research. This is the principle of consistent and accurate data collection and analysis, combined with a continuous effort to improve the effectiveness, efficiency, quality, and safety of naval aviation maintenance (USN, 2017).

The three levels of maintenance are organizational, intermediate, and depot. The majority of organizational maintenance is performed by the unit, or squadron, that operates the aircraft on a daily basis. This level of maintenance includes general servicing, lubrication, routine inspections, and defective component replacements. Intermediate level maintenance activities provide support for the organizational level activities. This support comes in the form of aircraft component repair, calibration of test equipment, and aircraft inspections, such as non-destructive inspections (NDIs). NDIs are used to identify structural defects that cannot be detected visually. Depot-level maintenance is the most in-depth type of maintenance. It consists of major overhauls, major modifications, and rebuilding of aircraft components. Additionally, the depot provides engineering support to the organizational- and intermediate-level maintenance activities for more complex repairs (USN, 2017).

The requirements and methodology of collecting data and keeping records in naval aviation provide the ability to conduct recurring analysis and continually improve each maintenance activity's performance. These concepts are useful in developing recommendations for the NECC to improve the material support for the Mark VI patrol boat.

E. INVENTORY MANAGEMENT

Managing inventories is important for several reasons. It costs money to manufacture items, store (or hold) the inventory, and transport the inventory. Therefore, it is important to have the appropriate amount of material available to meet demand. As a result, many private companies have invested heavily in recent years to improve their logistics and inventory performance (Peterson, Pyke, & Silver, 1998).

Two of the techniques used to improve inventory management are the multi-echelon inventory approach and the economic order quantity (EOQ). Multi-echelon inventory is effective in situations where inventory is needed in multiple locations across an entire logistics supply chain. It is a method used to determine the appropriate types of inventory that should be stocked at each echelon (or level) based on demand and cost. EOQ is a method used to determine the size of the order that should be placed for each individual item. This is done using the cost of the item, the demand, and the item's holding cost. This enables decision-makers to set the appropriate reorder point for various materials (Peterson, et al., 1998).

These two concepts are relevant to this research because the Mark VI supply chain has inventory that is held in multiple geographical locations, material shortages cause decreased mission readiness and operationally availability for the Mark VI patrol boats, and excess inventory is an inefficient use of resources.

IV. MARK VI SUPPLY PROCESS

The Mark VI patrol boat supply process is triggered by a demand, or pull, on the supply chain. Specifically, the demand is triggered when the custodial Coastal Riverine Squadron (CRS) orders material for the boat. The process begins when personnel perform maintenance on the boat and determine that material is required for the repair. The material requirement is then passed through the CRS chain of command for endorsement and is ultimately approved by the cognizant CRG. The CRG determines how to procure the material depending on the type and availability of the material. There are certainly nuances in the system, which is continuously developing, and the current CRS procedures provide additional context to the challenges the CRF faces while supporting the Mark VI (S. Mustin, personal communication, September 27, 2018).

Prior to a technician beginning maintenance on a boat, there is a "job" documented in the Organizational Maintenance Management System-Next Generation (OMMS-NG), which is the system used to track maintenance and order required materials. When a technician determines a material or item is required to repair a malfunction or material condition deficiency, the technician orders the material in OMMS-NG. The order is then passed through the CRS chain of command for validation. It requires the endorsement of the work center supervisor, division officer and department head. Once the CRS chain of command has endorsed the material request, it is forwarded to the cognizant CRG for review and final approval. If the item ordered is in-stock, the CRG issues the material to CRS supply personnel. The CRS supply personnel provide the material to the maintenance technicians, who perform the repair (S. Mustin, personal communication, September 27, 2018). Figure 4 shows the typical material requisition process flow for a CRS.

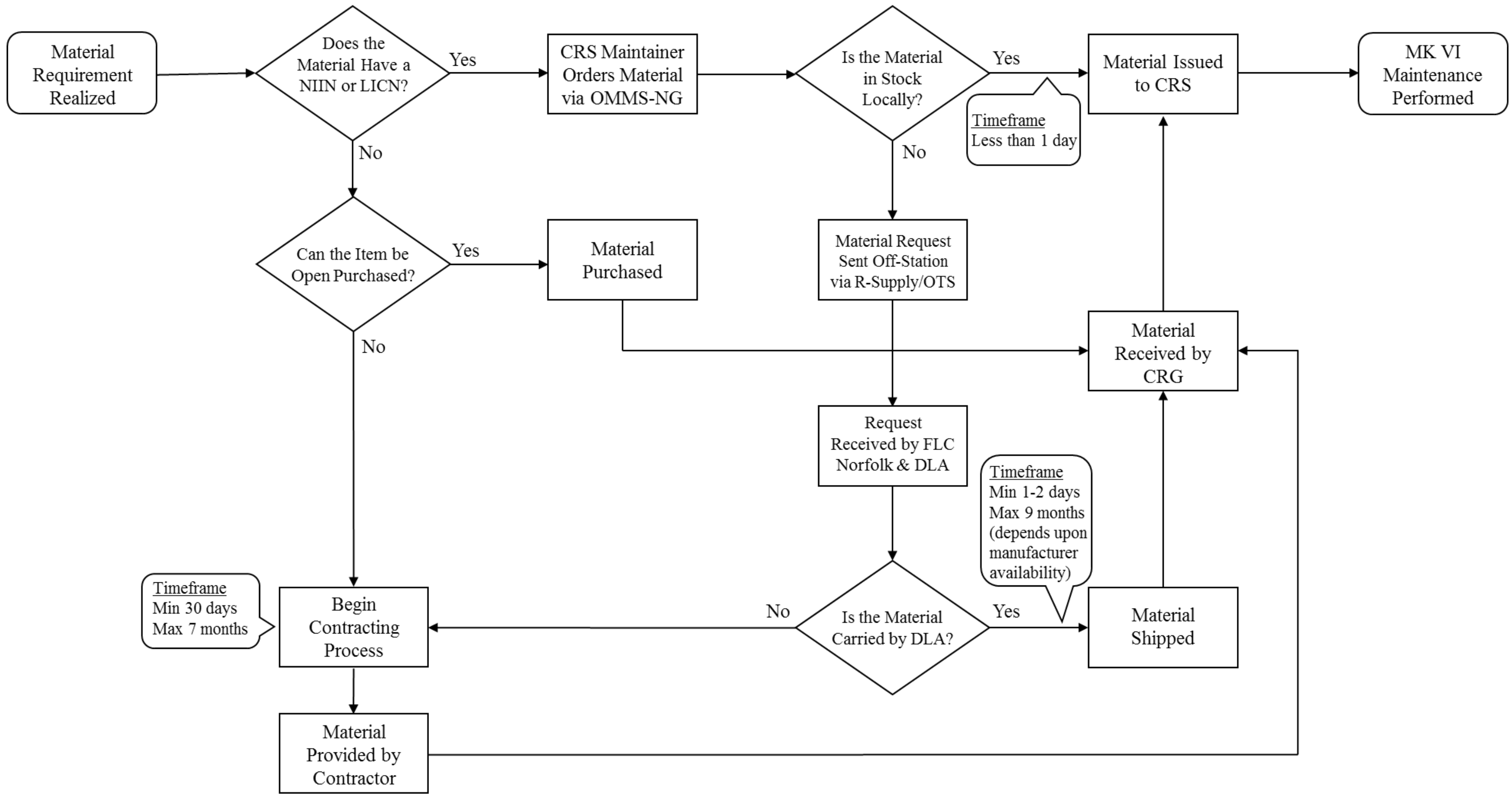

Figure 4. Coastal Riverine Squadron Material Requisition Process Flow

A. STANDARD MATERIAL REQUISITION PROCESS

The CRG determines if the item has a national item identification number (NIIN) and what its cognizance code (COG) is to determine how to procure the item. The methods to procure the item vary depending on whether or not the item being requested has a NIIN. The NIIN is a universal numerical identifier for the material, but because the Mark VI is a small and specialized platform, not all of its components have a NIIN. The COG code is used to determine whether an item is considered a consumable or a depot-level repairable (DLR) and from where the material is sourced. Consumable materials are items that are only used or installed on the boat once and then discarded (USN, 1997). DLR components are generally more expensive items that are repaired and returned to service. For the CRS to receive a replacement DLR, the maintenance technicians are required to give the defective DLR to the CRG. This ensures that the repair of the defective DLR occurs as soon as possible, so it may be returned to service and available for requisition by another CRS.

If the item has a NIIN, it is sourced through the normal supply system. Specifically, the CRG creates a stock record card in R-Supply, which is the system used to order items at the CRG level. The CRG does maintain a stock of some items from the Mark VI patrol boat. If the item is in stock at the CRG or the local supply depot, the requisition is provided by that organization and given to the respective CRS. If the item that is ordered is considered not carried (NC), meaning it is not stocked locally, then the CRG sends the requisition off-station to an outside source. To send a requisition off-station means the requirement cannot be supported locally and an outside supplier must fulfill the need. The requisition is sent off-station via a web-based system called One Touch Support (OTS) that interfaces with R-Supply (P. Suarez, personal communication, October 5, 2018).

OTS is a system that provides a single point of entry for inquiries into the naval supply system. OTS is capable of providing the status on military requisitions and has the ability to cross-reference a part number to a NIIN. Additionally, OTS provides customers with real-time availability of material from multiple government inventories worldwide (USN, 2003).

Once the requisition has been transmitted to OTS, it is sourced to the appropriate supplier. The supplier is identified and linked to the item in OTS through the COG of the item being requisitioned. Once the supplier receives the requisition, it provides the material to the CRG, which then in turn sends it to the CRS where the material was originally placed on order (P. Suarez, personal communication, October 5, 2018). The lead time for the material depends on suppliers' locations and whether or not the item is readily available, but the process for materials with a NIIN remains the same.

B. NON-NATIONAL ITEM IDENTIFICATION NUMBER MATERIAL PROCUREMENT

There are two primary methods for procuring an item that does not have a NIIN: commercial-off-the-shelf (COTS) and ordering the item through OMMS-NG. In addition to the primary methods, the CRS can also request that a contract be written to provide a specific material requirement or service; however, contracting is a lengthier and more involved process.

1. Commercial-off-the-Shelf Purchasing

The COTS method is used if the item is not available through the Navy supply system but is available from a commercial source, as long as the item meets certain criteria. Ordering the item through OMMS-NG is slightly different than ordering it with a NIIN.

Each CRS has a government purchase card (GPC) program, which mean that CRSs have personnel who are authorized to use an official government credit card to make authorized purchases. The GPC can be used to purchase required materials as long as it follows the existing purchase policies and does not exceed the micro-purchase limit, which is $5,000. If the purchase meets these guidelines, the CRS can purchase the item directly from the commercial source. This practice is commonly referred to as an open purchase. If the item does not meet the open purchase requirements, it can be ordered in OMMS-NG (P. Suarez, personal communication, October 5, 2018).

2. Ordering in Organizational Maintenance Management System-Next Generation

Items without a NIIN in OMMS-NG are designated as parts not listed. Once this designation is attached to the item, a local item control number (LICN) is generated. The item does not have a NIIN or COG, so this means the Navy does not have a source for the item. At this point, the CRG and CRS have exhausted their capabilities to source the item, and the order is sent to higher echelons of Navy supply to identify a source for the item. However, if the item exceeds the $5,000 threshold, the CRG executes the contracting option for procurement (P. Suarez, personal communication, October 5, 2018).

3. Contracting for Materials or Services

As previously mentioned, procuring material or services by contract is the least desirable option for the CRS and CRG. Contracting is a challenging and lengthy process, which usually leads to longer-than-normal lead times and is contrary to the operational culture of the CRF. Therefore, the CRG and the CRF avoid contracting as a source of procurement if at all possible (P. Suarez, personal communication, October 5, 2018).

A material requirement or service being put up for contract both have the same requirements. A minimum of three quotes from different sources are needed to satisfy the requirement. Once the CRG has this information, the supply personnel send the request to the Fleet Logistics Center (FLC) in Norfolk, VA. The FLC generates a statement of work, which includes the specific requirements of the material or service, and then it solicits industry partners to bid on the contract. Once the bids have been accepted and reviewed, the FLC selects a vendor and presents that vendor to the CRG. As long as the CRG accepts the selected vendor, the contract is awarded and a contract delivery date is determined. This date is when the service or material will be provided to the CRS (P. Suarez, personal communication, October 5, 2018).

In rare cases, it is impossible to provide multiple quotes for a contract; this is called sole-source contracting. Sole-source contracting normally results from there only being one manufacturer of a component or service provider for the boat. In this instance, an additional justification for the sole-source contract is required and reviewed by the FLC

(P. Suarez, personal communication, October 5, 2018). As a specific example of sole-source, the port and starboard running lights on the Mark VI are produced by a German manufacturer and can only be purchased through this company. Thus, each time the lights are ordered, the sole-source justification is submitted (S. Mustin, personal communication, September 27, 2018).

C. CONSOLIDATED SHIPBOARD ALLOWANCE LIST ADJUSTMENTS

The CRS can request to have NC items stocked to prevent the delay of having items sent off-station. To have these items stocked, they have to be added to the Consolidated Shipboard Allowance List (COSAL). The COSAL is a list of equipment that is required to support a particular ship or boat and is stocked by the Navy supply system. To have an NC item added to the COSAL, the CRS must submit a fleet COSAL feedback report and request permission to add the item to the COSAL (P. Suarez, personal communication, October 5, 2018).

An additional method for stocking an item is through the aforementioned stock record card that is created when ordering an item with a NIIN. If the stock record card designates the item as a demand history item, the demand for that specific item is tracked in R-Supply. If the demand for the NIIN is two or more orders in a six-month period, then the CRG creates a Requisition Objective (RO) for that NIIN. Once the RO is created, the NIIN becomes a recognized and consistent demand, and is kept as a part of the inventory. A subsequent reorder point for the NIIN is set, and when the inventory level reaches the reorder point, it triggers an order to replenish the stock. However, the process is different for items that do not have a NIIN (P. Suarez, personal communication, October 5, 2018).

V. DATA COLLECTION AND ANALYSIS

Records collected for this research consisted of 34 months of raw demand data with approximately 3,500 line items for all 12 Mark VI boats in the NECC inventory. Table 1 displays an abbreviated sample of the raw demand data analyzed. Each line item represents an order placed (referred to as a requisition going forward) for a particular NIIN. A unique identifier code known as a request number is assigned to each requisition. Embedded in the request number is the Julian date showing when the requisition was initiated. A single requisition is often not a fixed quantity. Instead, any number of a particular component can be ordered under a single requisition. For example, a technician may place an order for a component with a quantity of one to repair a specific failure, but may also order a commonly replaced consumable component, such as an O-ring, in a quantity of eight. Each requisition is identified by a work center code (WCC), which corresponds to a particular boat. For example, a WCC of MK02 ties a requisition to patrol boat hull number 1202, while a WCC of MK03 ties a requisition to patrol boat hull number 1203, and so on.

Table 1. Raw Mark VI Demand Data Example

Cog	NIIN	NIIN Nomenclature	Qty	UI	Unit Price	Total Price	Request Nr	IMEC Definition	WC
9B	123846034	GASKET	12	EA	9.48	113.76	4365A7230MV31	No IMEC Code Assigned	MK42
9B	008423044	PIN,COTTER	1	HD	0.82	0.82	4365A70655D66	Safety	MK03
1H	015661914	SHOULDERS ASSY	1	EA	31,375.00	31,375.00	4365A8198MR68	Minor Mission Impact	MK41
1H	015661915	MANUAL FIRING PANEL	1	EA	2,657.00	2,657.00	4365A8025MR73	Minor Mission Impact	MK41
9B	982073993	ANODE,CORROSION PRE	7	EA	61.81	432.67	4365A7297MK74	No IMEC Code Assigned	MKO1
3B	012272335	PUMP	1	EA	290.90	290.90	4365A7319MB58	Loss of a Secondary Mission Capability	MK04
1H	LLH0D4174	FILTER ELEMENT,AIR	1	EA	27.62	27.62	570927284M045	No IMEC Code Assigned	MK02
3B	012232980	OHMMETER	1	EA	1,091.49	1,091.49	4365A8124MR12	Loss Of a Primary Mission Capability	MK41
1H	LLH0D4174	FILTER ELEMENT,AIR	1	EA	27.62	27.62	570927284M043	No IMEC Code Assigned	MK02
9B	016211866	ANODE,CORROSION PRE	3	EA	54.61	163.83	4365A70365D04	No IMEC Code Assigned	MK03
7G	015264783	NAVIGATION SET,SATE	1	EA	3,297.00	3,297.00	570928072M378	Severe Degradation of a Primary Mission Capability	MK05
9B	121786269	O-RING	3	EA	3.82	11.46	4365A63135D58	No IMEC Code Assigned	MK04
9B	013517612	O-RING	3	EA	10.74	32.22	4365A7318MK54	No IMEC Code Assigned	MKO1
9B	011747588	PACKING,PREFORMED	3	EA	1.40	4.20	4365A7311MB59	Minor Mission Impact	MK04
0G	123509774	FILTER ELEMENT,FLUI	1	EA	44.17	44.17	4365A71845D81	No IMEC Code Assigned	MK04
0G	123509774	FILTER ELEMENT,FLUI	1	EA	44.17	44.17	4365A71845D80	No IMEC Code Assigned	MK04
0G	123509774	FILTER ELEMENT,FLUI	1	EA	44.17	44.17	4365A71935D93	No IMEC Code Assigned	MK04
9B	016263789	FILTER,FLUID	1	EA	220.49	220.49	4365A71845D73	No IMEC Code Assigned	MK04

During collection and analysis of the data, it was clear the CRF was working through a learning curve in the collection methods of the Mark VI operational usage data. The operational usage data acquired was sporadic, and the method of tracking engine operating hours changed several times since its acceptance of the Mark VI patrol boats.

Making the operational usage data provided for this research useful required the authors to make assumptions about the number of operational months a patrol boat experienced since its initial acceptance by the CRF. The assumption was made that every month from its acceptance date would be considered operational for the purposes of determining average monthly operating hours.

A. METHODOLOGY

Pre-processing of the raw data was required in order to pare it down to a useful level to identify trends, failures, and usage rates. Since maintenance and component failures are driven by operating hours, it was necessary to pre-process the raw demand data in order to establish time periods of usage for more refined analysis of cyclical failure trends and recurring component requirements.

1. Data Sorting

The data was segregated by WCC to identify all requisitions placed for a particular patrol boat hull number. Each individual boat's data set was subsequently sorted by NIIN and aggregate quantities for each distinct NIIN were established. This data represents the total demand at the individual component level for each patrol boat over its entire in-service time.

Once aggregate usage data was established at the individual boat level, the next step was to determine the date of each requisition. The data was placed in chronological order based on the requisition's Julian date contained within the request number.

In order to determine monthly operational hours for each patrol boat, the engine operating hours for each boat over its lifetime were divided by the months from its in-service date to present. Figure 5 shows the formula used to determine the average monthly operating hours for each patrol boat.

$$\text{Monthly Average Operating Hours} = \frac{\text{Total Boat Operating Hours}}{\text{Total Months Boat in Service}}$$

Figure 5. Average Operating Hour Formula

2. Determining Usage Periods

The decision was made to analyze the data in periods of 100 hours. To determine the number of months in each 100-hour period, 100 hours was divided by the monthly average operating hours. Figure 6 shows the formula used to determine the number of months in each period. This created the time periods needed to assign the requisitions and determine at what point in the boat's service life a NIIN was ordered. In essence, this identifies the point in time at which each item failed and needed to be replaced.

$$\text{Number of Months per 100 Hours} = \frac{\text{100 Hours}}{\text{Monthly Average Operating Hours}}$$

Figure 6. Months in One-Hundred-Hour Period Formula

To assign the requisitions to the correct time period, the date the requisition was placed had to be identified. As previously mentioned, the Julian date is embedded in each request number. To determine how many days elapsed during each 100-hour period, the average number of months per 100 hours was multiplied by 30 days. Figure 7 shows the formula used to determine the number of days elapsed.

$$\text{Number of Days per 100 Hours} = \text{Number of Months per 100 Hours X 30 Days}$$

Figure 7. Elapsed Days in One Hundred Operating Hours

The authors applied 100-hour operating periods to each boat individually based on the demand data available for analysis. Due to variations in the length of the acceptance process from boat to boat and the length of demand history available, it was necessary to display each boat's demand data beginning at different points in its service life. For instance, hull number 1201 was the first boat accepted by the NECC. Hull number 1201's first demand showed up in the 500-600-hour time period. In contrast, a newer boat, such as hull number 1404, showed demand starting in the 0-100-hour time period. Table 2 shows a sample of a patrol boat's demand data by time period.

Table 2. Excerpt of Patrol Boat Demand Data by Time Period

Hull Number	0-100 Hours		100-200 Hours		200-300 Hours		300-400 Hours		400-500 Hours		500-600 Hours	
	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty
1205	No Data Available		No Data Available		000222518	3	002405851	10	015329840	2	002452040	2
					002745713	6	002687868	20	015719999	2	008077968	2
					008423044	3	004038897	4	015834521	1	008392325	2
					009002139	3	009857845	6	015835367	2	008423044	1
					009650288	3	010137384	12	016190644	1	010744229	10
					013363372	3	011959752	20	016211922	8	011563765	1
					015210987	6	013093680	30	016211935	7	011785559	10
					016198100	6	013489724	12	016299846	2	012621812	1
					016211866	6	015214244	2	016433380	2	015213198	1
					123990977	1	015336147	2	016440902	2	015329840	3
					982071567	2	015346963	6	016440907	2	015834521	1
					982073989	2	015827622	1	123861596	6	015835367	2
					982073993	14	015832787	40			015843277	1
					982076264	4	015843277	1			016190644	1
					982076323	2	016194067	1			016243827	2
					982077070	1	016484225	10			016299846	2
					982079020	1	123509774	4			016300284	1

B. LIMITATIONS

The mission of the expeditionary community demands a flexible and rapid response from its forces. Such was the case when the Navy procured and rapidly employed the Mark VI patrol boat. Although this is a very capable platform, the rapid employment resulted in a logistics and maintenance framework that was under-developed, creating challenges and limitations for this research.

There are only 12 Mark VI patrol boats in the Navy's inventory. As a result of the platform being rapidly acquired and relatively new, detailed historical operational reports were not available. The oldest Mark VI has been in operation for four years, and the newest has been in operation for six months. Individual boat operational usage ranged from 500 to more than 1,800 hours. To enable the legitimate comparison of aggregate and then individual demands over time, the data was normalized. An average monthly operational time was applied to each boat. The average was determined individually for each boat by dividing the total operating hours by the number of months the boat was in service.

The supply data that focused the authors' analysis was for a period of 34 months. There were a few periods on several of the boats that the data was unavailable. Additionally, it was apparent in the data that at some points the individual CRSs were trying build a stock of low-cost consumable items.

Determining the exact date a boat started operating regularly was difficult to ascertain. The date a boat was placed in service is not necessarily the date it was utilized operationally on a regular basis. The earlier hull numbers were accepted by the Navy but sat at the pier awaiting the installation of additional systems before the boat began operating regularly. The operational hours for the life cycle of each Mark VI were available in the form of engine operating hours, which were only recorded in aggregate for each hull number. For example, as of September 20, 2018, boat 1502 accrued 491 engine hours since its in-service date of March 2018. However, the monthly operational hours for boat 1502 are unavailable.

Additionally, the engine hour record-keeping practices have changed throughout the lifecycle of the Mark VI and are not consistent after engines are replaced in a boat. As a result, the operating hours for hull number 1206 could not be reconciled, and it was excluded from this research.

C. DATA NORMALIZATION

Normalization of the data was required due to the variations in which each boat's demand signal picks up in its service life. It is also a critical step to providing accurate recommendations to NECC operational planners for deployed spare parts inventories. Normalizing involved aggregating demand across the 11 boats analyzed to display all requisitions contained within each 100-hour period. This required applying the number of boats that showed demand in a particular 100-hour period to the aggregated quantity demanded for each specific NIIN in that time band. For example, if the aggregate quantity demanded for a particular NIIN was 48 units in the 500-600-hour time period, and the number of boats with demand during this same time period was six, then the normalized demand for that NIIN is a quantity of eight during that period.

D. FINDINGS

Aggregating quantities demanded across the 11 boats analyzed provided the means to identify each time period's top 15 readiness degraders in terms of quantity demanded for each NIIN. This information is useful to operational planners as it gives visibility to trends during specific periods of a boat's operational service and will be useful in forecasting for required maintenance based on these trends.

Each boat was unique in its failure rates and failure modes. By segregating data into time periods for a specific boat, requirements for that particular boat were able to be ascertained. Analysis at the single boat level provides operational planners with relevant data in order to plan for a deployment with that boat. This enables informed forecasting of likely failures throughout the patrol boat's lifecycle.

Analysis of the Item Mission Essentiality Code (IMEC) showed that, with the exception of one item, every NIIN classified as a severe mission degrader was a low-price consumable component. With the critical nature and relatively low cost of these items, recommendations are made for their inclusion in every PUK.

The research identified the top 50 demanded NIINs based on the aggregate quantity requisitioned for 11 Mark VI patrol boats; all are low-cost consumable items. Recommendations are made in the next chapter for designated supply and maintenance personnel to review these 50 items to determine the appropriate quantities based on Mark VI maintenance publications.

VI. RECOMMENDATIONS

Operating complex weapon platforms is challenging, no matter what the environment. However, it becomes even more difficult when the platform is deployed to remote locations. A longer supply chain inherently results in longer lead times, which precipitates into lower readiness levels. The authors' three recommendations to improve Mark VI logistics include PUK standardization, operational records management, and ordering for demand. Additionally, there are four opportunities to conduct future research on the Mark VI: PUK performance evaluation, Mark VI patrol boat regional analysis, inventory management practices, and maintenance training improvements.

The Mark VI deploys to remote locations, so it needs a refined logistics support strategy to maintain readiness levels and meet the operational tempo as required in its AOR. In order to develop a support plan, accurate supply-demand data and the operational time accrued on each Mark VI is needed. This data enables the development of a framework to forecast material failures as the Mark VI progresses through its life cycle. Additionally, the framework can be used to determine what materials should be kept at the deployment location. These concepts have been used in the naval aviation community for decades.

The authors have over 40 years of naval aviation maintenance management experience in carrier-based operations and expeditionary F/A-18, MH-60S, and E-2C squadrons. To plan effectively for these deployments, aviation maintenance managers have to be very familiar with the interface between the Navy supply system and the maintenance domain. This familiarity enables accurately forecasted maintenance and material requirements. The recommendations that follow are based on these aviation concepts and the experience of the authors.

A. PACK-UP-KIT STANDARDIZATION

PUK standardization based on the actual material requirements of the Mark VI as it progresses through its life cycle will improve the availability of required materials, enable planners to forecast material requirements throughout deployments, reduce the administrative burden on the squadron, reduce shipping costs, and improve readiness rates for the Mark VI. Having a PUK stocked and pre-positioned based on the demand data from the Mark VI boat in various stages of its life cycle will build upon the current PUK composition.

The aviation method of determining the quantity of on-hand inventory is called the aviation consolidated allowance list (AVCAL) conference. The AVCAL conference is attended by the stakeholders in the maintenance and supply organizations who support the deploying aviation squadron. Typically, it includes personnel from the squadron, carrier air wing, carrier supply, carrier aircraft intermediate maintenance department, Commander, Naval Air Forces Atlantic, and the Navy Supply Weapons System Support Command. This concept needs to be implemented between the CRS, cognizant CRG, and NECC supply and maintenance leadership while CRSs are preparing for a deployment.

The current methodology results in PUK compositions changing for each squadron's deployment. This occurs because the squadron is allowed to modify the contents. There is value added by this process because the CRS maintenance and supply personnel do have valuable experience; however, the contents of the PUK should always include the top 15 degraders by time period and quantity that were identified in this research.

1. Standardization Framework

Tables 3 and 4 display the top 15 degraders by time period. Quantities displayed in these tables were normalized for a single Mark VI patrol boat. Tables 3 and 4 provide a framework that enable the CRF to forecast material requirements based on the operational hours of each individual Mark VI. Tables 3 and 4 also show the top 15 demanded NIINs during every 100-operational-hour period. This enables planners to incorporate those NIINs into each PUK. For example, a CRG designing a PUK for a patrol boat with 1,100 hours would use the corresponding column in tables 3 and 4 to determine the specific NIINs and quantities to have built into the PUK.

The framework provides another unique planning capability. In addition to designing the PUK with the NIINs based on the boat's current operational time, the CRG can forecast the requirements for the duration of the deployment. Using the previous example of a patrol boat with 1,100 hours, the CRG would incorporate the NIINs in the column labeled “1100-1200” hours.

To *predict* requirements, the CRG will apply a moving average of the operational hours accrued by the boat for the last three deployments. For example, assume the average time accrued is 350 hours. Thus, the CRG will also include the NIINs and quantities in columns “1200-1300,” “1300-1400,” and “1400-1500” hours. The use of the moving average keeps the operational average current and close to the actual operational tempo of the patrol boat. This approach should be applied to each boat as the PUK is being designed.

Table 3. Top 15 Degraders: 0-1000 Hours

0-100 Hours		100-200 Hours		200-300 Hours		300-400 Hours		400-500 Hours		500-600 Hours		600-700 Hours		700-800 Hours		800-900 Hours		900-1000 Hours	
NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty
123757304	32	123757304	7	200103224	11	LLNC41082	11	982073993	9	016243048	7	016239928	10	982073993	12	016243048	9	016243048	12
123757301	16	123757301	4	982073993	8	LLNC41083	6	123756378	8	123143476	7	121634234	8	016243048	10	123143476	8	LLNT32248	10
123757302	12	123757302	3	982076264	3	LLNC41084	6	123143476	7	016239928	4	123367307	8	016239928	10	123757304	7	016239928	8
123748191	4	016596637	2	016198100	3	LLNC41085	6	016239928	6	123367307	4	123756378	8	123367307	10	015026919	5	123143476	8
123757297	4	123861596	2	016211866	3	982073993	6	123367307	6	123756378	4	123845073	6	123756378	10	016198685	5	123367307	8
015336147	2	982076264	2	982071567	2	013093680	5	016243048	5	016484225	4	016243048	5	016211935	7	982066176	5	123756378	8
015834521	1	016198100	2	016211935	2	015832787	5	016194240	4	982073993	3	016244532	4	123757304	7	016484225	4	016676603	6
015843277	1	123748191	2	016254583	2	016239928	5	016211935	4	200103224	2	123861596	4	123757301	6	123757301	4	016484225	5
		016254583	1	016263801	2	123367307	4	016211866	3	123757304	2	982073993	3	016211922	6	123757302	3	013093680	3
		016263801	1	123861596	2	123756378	4	016211922	3	123509774	2	001806165	3	016211866	5	008077968	3	008077968	3
		016302124	1	002745713	1	123757304	4	016440155	2	123861596	2	016299846	3	123757302	4	016437057	2	013702599	3
		016307971	1	015210987	1	016211922	3	123845073	2	LLNC41270	2	016211922	2	123509774	4	123844743	2	015206833	3
		123169209	1	016198042	1	016211935	3	016198042	2	016299846	2	123844743	2	011563765	3	016194240	2	015254060	3
		123509774	1	123844691	1	002687868	3	982074687	2	010744229	2	123861053	2	982073989	3	016239928	2	016028756	3
		123757297	1	982073989	1	011959752	3	982076323	2	011785559	2	123861070	2	982076323	3	016440155	2	123861596	3

Table 4. Top 15 Degraders: 1100-1900 Hours

1000-1100 Hours		1100-1200 Hours		1200-1300 Hours		1300-1400 Hours		1400-1500 Hours		1500-1600 Hours		1600-1700 Hours		1700-1800 Hours		1800-1900 Hours	
NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	Qty	NIIN	QTY	NIIN	Qty	NIIN	Qty
016239928	8	016239928	12	LLNC41568	21	123143476	17	016440155	5	016243048	48	No Data Available		002452040	5	016596637	5
016243048	8	LLNT32354	8	LLNC41569	21	016239928	16	123737493	2	123143476	34			016192504	4	000800259	4
123143476	8	123757304	7	123845073	12	123367307	16	002921102	1	016239928	32			123990602	4	016437519	3
123367307	8	016243048	4	LLNC41566	11	123756378	16	015478773	1	123367307	32			014637915	3	001060906	2
123756378	8	015334850	4	LLNC41567	11	016239962	13	016220432	1	123756378	32			014808784	2	007836519	1
002050565	4	000800259	3	LLNC41570	11	016243048	11	016438147	1	982073993	21			015317844	2	015211775	1
982073993	4	016025452	3	016243048	8	LLNC41669	10	016441335	1	123845073	16			016301375	2	015806472	1
015210987	3	016484225	3	123143476	5	LLNC41674	8	123990977	1	016211866	12			016436812	2	016220432	1
016025452	3	123861596	3	016239928	4	LLNC41680	7			121564531	9			007836519	1	016439973	1
015676028	3	016301375	3	016244532	4	123845073	6			016211922	8			014630718	1		
014769941	3	016311316	3	123367307	4	123789394	6			016211935	8			015518400	1		
013093680	2	123757301	3	123756378	4	LLNC41672	6			016676598	7			015547002	1		
016211935	2	016596637	2	123789394	4	LLNC41671	5			016298351	6			015674451	1		
123844691	2	123509774	2	123844743	4	123529432	5			016596637	6			015827617	1		
251508918	2	011354563	2	123845065	4	016596637	4			123164696	5			016192460	1		

2. Responsibilities

The CRG should be responsible for the design of each PUK using this framework. The CRG is aptly positioned to provide the continuity that will keep this PUK standardization framework in place and accurate. The administrative burden should not fall on the squadrons because they need to focus on the mission. A squadron is privy to the operational tempo and material requirements of boats while the CRS is on deployment. Once the deployment ends, the CRS personnel return to their homeport and the Mark VI remains at the deployment location. However, the squadron needs to be responsible for reporting PUK usage weekly to the CRG. This can easily be accomplished using an Excel database accessible on the NECC SharePoint website. This will provide the required visibility to enable the CRG to replenish PUK stock as necessary and prevent an unnecessary material shortfall. This is important from a logistics cost perspective as well since it can cost hundreds of dollars to expedite the shipping of a critical component that only costs $100. Properly managed resupply of PUK items has the potential to result in thousands of dollars in cost avoidance due to the lower frequency of expedited shipments required.

The majority of high demand items are relatively inexpensive, non-perishable, small, and fast-moving consumables. This means they can be held in inventory with very little risk or expense. They are small, fast-moving consumables, so the inventory turnover rate will be relatively high. Holding costs for these small components are negligible. Even if some of these items are not consumed during a deployment, they will be readily available for the next CRS without incurring additional cost. Table 5 lists the top 50 demanded NIINs, and Figure 8 illustrates that *10 of those items account for 60% of the demand.*

Table 6 lists NIINs identified by an IMEC classification of severe primary mission degrader and displays each NIIN's availability. Given their relatively low cost, and because all of the items with the exception of one are consumable, it is recommended that PUKs include these items. The appropriate quantities of these severe primary mission degraders should be reconciled between CRG and CRS maintenance and supply subject matter experts.

The CRG is the appropriate command to provide the oversight and management required to implement and maintain the process. Executed properly, this process will increase the Mark VI's readiness rates, ensure accurate PUK composition based on demand and operational data, enable planners to forecast material requirements, and reduce shipping costs.

Table 5. Top 50 NIINs Ordered

Cog	NIIN	Nomencalture	UI	Unit Price	Part Number
0G	123509774	FILTER ELEMENT,FLUI	EA	44.17	0031845301
9B	016484225	HEADSET,ELECTRICAL	EA	1,032.83	
9B	013093680	ANODE,CORROSION PRE	EA	4.67	
9B	016596637	FILTER,AIR,ELECTROS	EA	60.00	235000924
9B	015210987	O-RING	EA	54.78	200-2470-010
9B	123143476	O-RING	EA	8.96	700429020000
9B	123861596	FILTER,FLUID	EA	39.23	X51108300001
9B	123748191	COVER,FLUID FILTER	EA	3.03	X00009628
9B	016299846	FILTER ELEMENT,FLUI	EA	48.07	59-01830
9B	016198100	O-RING	EA	53.07	204731
9B	016025452	LAMP,FLOOD,LED	EA	141.07	8001344
9B	016194240	RELAY,ELECTROMAGNET	EA	18.28	53595
9B	982076264	O-RING	EA	4.54	200977
9B	016437057	CABLE ASSEMBLY,SPEC	EA	183.30	11339AB
9B	015026919	INSERT,SCREW THREAD	EA	1.61	91732A746
9B	016211866	ANODE,CORROSION PRE	EA	45.53	203123
9B	123757302	CAP,PIPE	EA	47.00	735233000100
9B	016239962	BOLT,MACHINE	EA	18.10	933010074
9B	016211935	ANODE,CORROSION PRE	EA	141.60	203121
9B	123757301	CAP,PIPE	EA	123.93	735233000103
9B	016211922	ANODE,CORROSION PRE	EA	147.81	204232
9B	016440155	ANODE,CORROSION PRE	EA	46.10	HA3A-A
9B	123529432	O-RING	EA	11.24	700429115001
9B	982073993	ANODE,CORROSION PRE	EA	61.81	203127
9B	016239928	WASHER,SEAL	EA	6.12	X00023888
9B	016243048	GASKET	EA	13.82	X51204200003
9B	123367307	O-RING	EA	7.38	700429028004
9B	123756378	O-RING	EA	1.84	700429018007
9B	123757304	CAP,PIPE	EA	11.75	735233000101
9B	123845073	SEAL,NONMETALLIC SP	EA	9.57	5320160221
9B	016244532	NOZZLE,FUEL INJECTI	EA	2,306.59	RX51107500005
9B	123789394	GASKET	EA	7.93	X00014782
9B	123844743	SEAL,NONMETALLIC SP	EA	13.48	5320980080
9B	200103224	GASKET	FT	5.23	D1-0852
9B	016198685	NUT,SELF-LOCKING,HE	EA	6.18	201332
9B	982066176	NUT,SELF-LOCKING,HE	EA	3.63	201330
9B	121634234	WASHER,FLAT	EA	0.99	0019908240
9B	015832787	SNAP HOOK	EA	10.64	
	LLNC41669		EA	7.09	S8346KN006
	LLNT32354		EA	6.00	PS01954
	LLNT32248		EA	13.66	39695T34
	LLNC41566		EA	2.65	COTS
	LLNC41567		EA	0.40	COTS
	LLNC41570		EA	0.93	COTS
	LLNC41083		EA	0.31	114201
	LLNC41084		EA	1.65	396441
	LLNC41085		EA	0.55	310724
	LLNC41568		EA	0.80	COTS
	LLNC41569		EA	0.40	COTS
	LLNC41082		EA	0.36	114195

Table 6. Severe Primary Mission Degraders

COG	NIIN	COST	IMEC	AVAILABILITY
9Q	002674630	$ 529.13	Severe Degradation of a Primary Mission Capability	NC
9B	003168964	$ 2.06	Severe Degradation of a Primary Mission Capability	NC
9Q	009856911	$ 137.38	Severe Degradation of a Primary Mission Capability	NC
9B	010546453	$ 10.53	Severe Degradation of a Primary Mission Capability	ISS
9Q	013090794	$ 51.63	Severe Degradation of a Primary Mission Capability	NC
9B	013652910	$ 235.68	Severe Degradation of a Primary Mission Capability	NC
9B	013723076	$ 17.40	Severe Degradation of a Primary Mission Capability	NC
9B	013774161	$ 36.59	Severe Degradation of a Primary Mission Capability	NC
9B	014407389	$ 17.51	Severe Degradation of a Primary Mission Capability	NC
9B	014856573	$ 22.66	Severe Degradation of a Primary Mission Capability	ISS
9B	014993590	$ 1.87	Severe Degradation of a Primary Mission Capability	NC
7G	015264783	$ 3,297.00	Severe Degradation of a Primary Mission Capability	ISS
9B	015391084	$ 384.21	Severe Degradation of a Primary Mission Capability	ISS
9B	015672996	$ 83.75	Severe Degradation of a Primary Mission Capability	ISS
9B	013996806	$ 505.30	Severe Degradation of a Primary Mission Capability	ISS
9B	015317844	$ 43.08	Severe Degradation of a Primary Mission Capability	ISS
9B	001806383	$ 129.57	Severe Degradation of a Primary Mission Capability	NC
9B	015257690	$ 29.90	Severe Degradation of a Primary Mission Capability	ISS
9B	015004234	$ 13.36	Severe Degradation of a Primary Mission Capability	NC
9B	123043696	$ 19.15	Severe Degradation of a Primary Mission Capability	ISS
9Y	015249762	$ 11.22	Severe Degradation of a Primary Mission Capability	NIS
9B	008689847	$ 454.02	Severe Degradation of a Primary Mission Capability	NC
9B	014320331	$ 35.22	Severe Degradation of a Primary Mission Capability	NIS
9B	123043695	$ 1.95	Severe Degradation of a Primary Mission Capability	NIS
9B	010744229	$ 17.10	Severe Degradation of a Primary Mission Capability	NC
9B	000039193	$ 0.13	Severe Degradation of a Primary Mission Capability	ISS
9B	123169209	$ 125.74	Severe Degradation of a Primary Mission Capability	ISS
9B	009298730	$ 13.94	Severe Degradation of a Primary Mission Capability	ISS
9B	012103272	$ 1.84	Severe Degradation of a Primary Mission Capability	NIS
9B	012484020	$ 73.05	Severe Degradation of a Primary Mission Capability	ISS
9B	015329840	$ 41.88	Severe Degradation of a Primary Mission Capability	ISS
9B	000800259	$ 2.39	Severe Degradation of a Primary Mission Capability	NIS

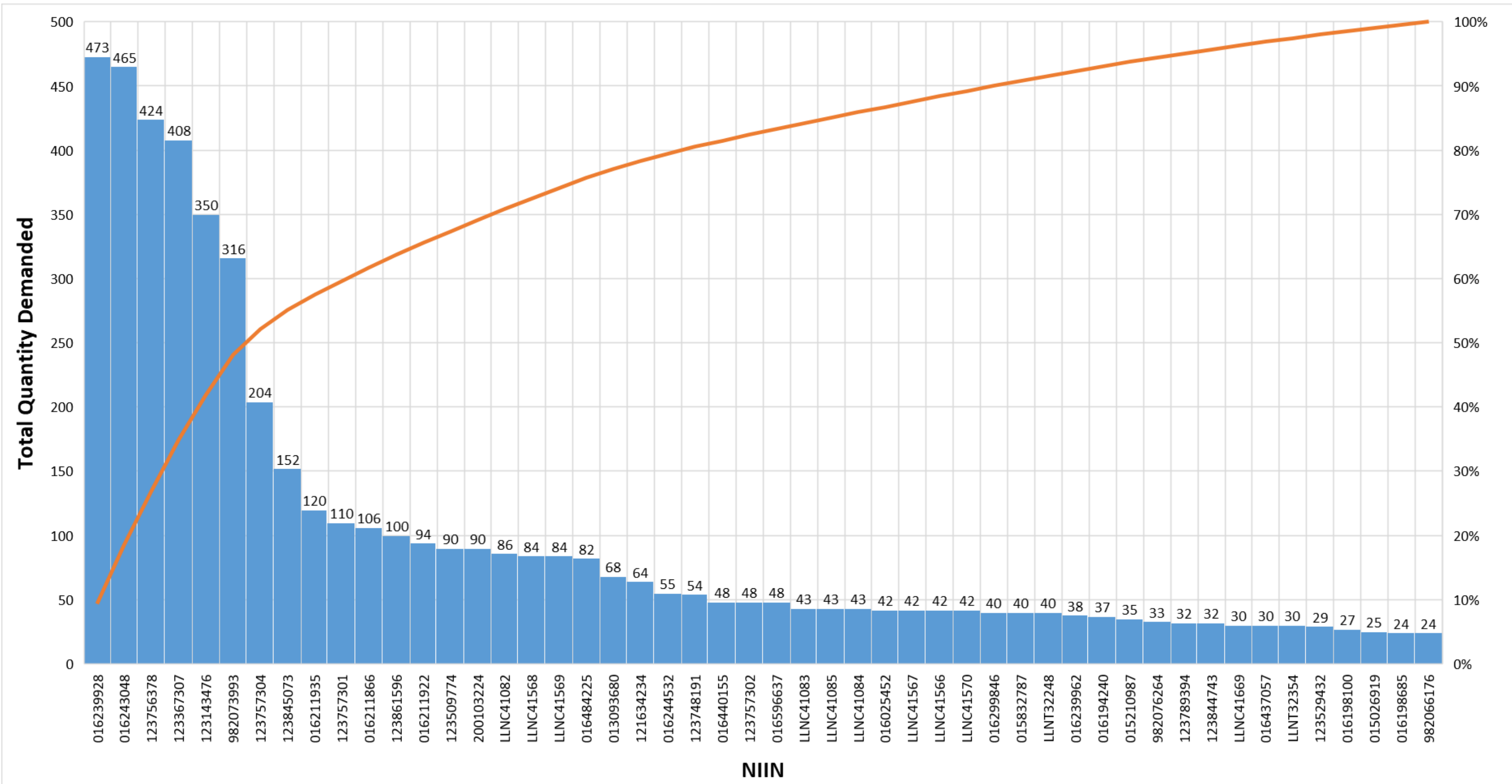

Figure 8. Top 50 Ordered NIINs by Quantity and Percentage

B. OPERATIONAL RECORDS

As previously mentioned, accuracy of the information being analyzed is of paramount importance. In aviation maintenance, one of the triggers for maintenance is flight hours. Flight hours are tracked, recorded, and applied immediately after each aircraft lands. The exact flight hours are reported by the pilot and are recorded to the 10th of an hour. For example, a one-hour and 30-minute flight is recorded as a 1.5 in the aircraft and maintenance records. This time is recorded and applied to the maintenance requirements that are driven by flight hours. This occurs before the aircraft is allowed to be flown again. The Mark VI does not need its operational time tracked in such detail; however, it must be tracked. Additionally, each aircraft has an electronic logbook that contains records for many items, but the relevant two for the Mark VI are the flight (operational) hours and the information for the major DLRs, which consist of the equipment history record (EHR) card and the scheduled removal component (SRC) card. In naval aviation, major DLRs are tracked from cradle to grave using an EHR card or an SRC card. Figures 9 and 10 are examples of the SRC and EHR card, respectively. Incorporating these concepts will enhance data collection, accuracy, and accountability for DLRs and enable a future analysis of the material support requirements for the Mark VI patrol boat throughout its life cycle. The following recommendations will improve data collection, accuracy, DLR accountability, and the material support of the Mark VI throughout its life cycle.

1. Operational Time Reporting and Responsibilities

The operational time for the Mark VI is based on engine operating time. As mentioned previously, engine operating time encompasses time underway and the time that systems on the Mark VI are operating. This is the foundation for the framework used to provide the recommendations in this research project. To facilitate accuracy in reporting, operational hours for each Mark VI should be reported weekly. This can easily be accomplished through a SharePoint established and maintained by the NECC. Additionally, the NECC should standardize when the report is due and ensure CRG and CRS leadership have appropriate access to review and submit reports.

The maintenance officer in each CRS should be responsible for submitting the weekly report. This responsibility should not be delegated because keeping the task with the maintenance officer will maintain oversight and reduce the likelihood of reporting errors. In naval aviation, the professional maintenance officers are responsible for the validity and accuracy of aircraft reports. This fosters oversight and places an emphasis on the importance of accurate reporting within the CRS. Additionally, the cognizant NECC should create a repository and update the operational hours of each Mark VI monthly based solely upon the reports from the CRS maintenance officer submitted through the SharePoint. Establishing a repository provides a back-up source of historical data in the event the SharePoint data becomes corrupted or is lost. Additionally, the timeliness and accuracy of operational hour reports should be reviewed during CRG inspections of CRSs.

2. Logbooks

The use of electronic logbooks in naval aviation has significantly reduced the administrative burden on operating units and drastically reduced the need for paper records, which can be easily lost or damaged. The NECC should use electronic logbooks to document the major DLR assemblies installed on the Mark VI and to record major maintenance performed on the patrol boats. For example, an electronic logbook could be used to record a brief description of major maintenance evolutions performed during each continuous maintenance availability period.

Each Mark VI should have a separate logbook that should maintained by the CRS performing the maintenance and replacing DLRs. In aviation, the SRC card and EHR cards are used to record pertinent information about DLRs. A component that is tracked with an EHR card is a component that is installed until it fails and needs to be replaced. The SRC card is used for an item that has a limited service life and needs to be replaced periodically. This record should follow the DLR through repair cycles as well so that when a new DLR is received, a detailed history of its use and maintenance can be reviewed before installation. This is useful for identifying potential bad actor DLRs. Bad actors are DLRs that are plagued with a history of repetitive malfunctions despite numerous repairs. The logbooks will be an important element of maintaining accountability of major DLRs and keeping an accurate history of major maintenance evolutions performed on each Mark VI for its entire life cycle. Implementing this recommendation for a fleet of 12 Mark VI patrol boats, which is controlled by the NECC, is completely manageable in a relatively short period of time.

SCHEDULED REMOVAL COMPONENT CARD

SECTION I - IDENTIFICATION DATA				
A. NOMENCLATURE	B. WORK UNIT CODE	C. FSCM	D. REPLACEMENT INTERVAL	E. REPLACEMENT DUE
F. PART NUMBER	G. SERIAL NUMBER	H. FST		

SECTION II - INSTALLATION DATA									
A. DATE	B. BUNO / SERNO INSTALLED ON	C. TOTAL AIRCRAFT / EQUIPMENT HOURS OR COUNTS				D. TOTAL HOURS OR COUNTS ON ITEM			

SECTION III - REMOVAL DATA									
A. DATE	B. TOTAL AIRCRAFT / EQUIPMENT HOURS OR COUNTS				C. TOTAL HOURS OR COUNTS ON ITEM				D. REASONS FOR REMOVAL AND JOB CONTROL NUMBER

CNAF 4790/28A (5-12) FRONT

PERMANENT RECORD

Figure 9. Sample Component Tracking Template. Source: USN (2017).

EQUIPMENT HISTORY RECORD (EHR) CARD

SECTION I - IDENTIFICATION DATA

A. NOMENCLATURE		B. WORK UNIT CODE	C. FSCM	D. REPLACEMENT INTERVAL	E. MAINTENANCE DUE
F. PART NUMBER	G. SERIAL NUMBER		H. FST	I. REFERENCE	

SECTION II - INSTALLATION DATA

A. DATE	B. BUNO / SERNO INSTALLED ON	C. TOTAL AIRCRAFT / EQUIPMENT HOURS OR COUNTS				D. TOTAL HOURS OR COUNTS ON ITEM			

SECTION III - REMOVAL DATA

A. DATE	B. TOTAL AIRCRAFT / EQUIPMENT HOURS OR COUNTS				C. TOTAL HOURS OR COUNTS ON ITEM				D. REASONS FOR REMOVAL AND JOB CONTROL NUMBER

SECTION IV - MAINTENANCE RECORD

A. DATE	B. ACTIVITY	C. REMARKS AND MAJOR PARTS REPLACED	D. SIGNATURE

CNAF 4790/113 (5-12) Front

PERMANENT RECORD

Figure 10. Sample Component History Template. Source: USN (2017).

C. ORDERING FOR DEMAND

Ordering the appropriate quantity of a consumable NIIN is important to the overall responsiveness of the supply system. Items ordered in excess to keep additional components on-hand at the operational level can have detrimental long-term effects. If the item is not ordered with frequency, there is a risk it will be dropped from the inventory. Inevitably, when the operational personnel order the item again, it is no longer carried because of a perceived lack of demand. This is a challenge faced in naval aviation, the surface Navy, and the expeditionary community. There is an easily implemented control used in aviation maintenance that can limit this practice. The aviation maintenance community requires that a technical reference be provided to order quantities above what is required by the assembly.

The analysis conducted during this research showed several instances of squadrons ordering excessive quantities of multiple NIINs. If a CRS orders a NIIN in multiple quantities, the individual ordering the NIINs should submit the maintenance document reference providing the need for the multiple quantities. The CRS maintenance leadership should ensure the reference is provided and is also accurate. Additionally, CRG supply personnel should verify the technical reference before approving the order.

This does not preclude ordering extra consumable components when it is necessary and makes sense. For example, if the CRS is performing maintenance that requires eight gaskets, but the maintenance evolution is difficult and several gaskets are normally damaged during the process, it makes sense to order additional gaskets. The CRS maintenance officer can coordinate with the CRG supply officer to work through these exceptions. However, it is important for leadership at all levels to monitor consumable material consumption. This is essential because just ***10 items account for 90% of the total cost for the 50 highest demand NIINs.*** Figure 11 illustrates the aggregate cost allocation for the top 50 NIINs.

1. Safety Stock

There is a well-established practice in inventory management known as safety stock, which is designed to address the need for having spare parts on hand. Safety stock is a form of protection from running out of a particular stock. It is a specific amount of inventory kept on-hand, based on an average, to account for the variability in demand over a short period of time. The level of protection of each safety stock can be increased or decreased as appropriate to meet the demand and satisfy critical material requirements. For example, a protection level of 95% can be assigned to a NIIN, which means that the NIIN will be available 95% of the time when it is ordered, and the safety stock level will adjust to meet it (Peterson et al., 1998).

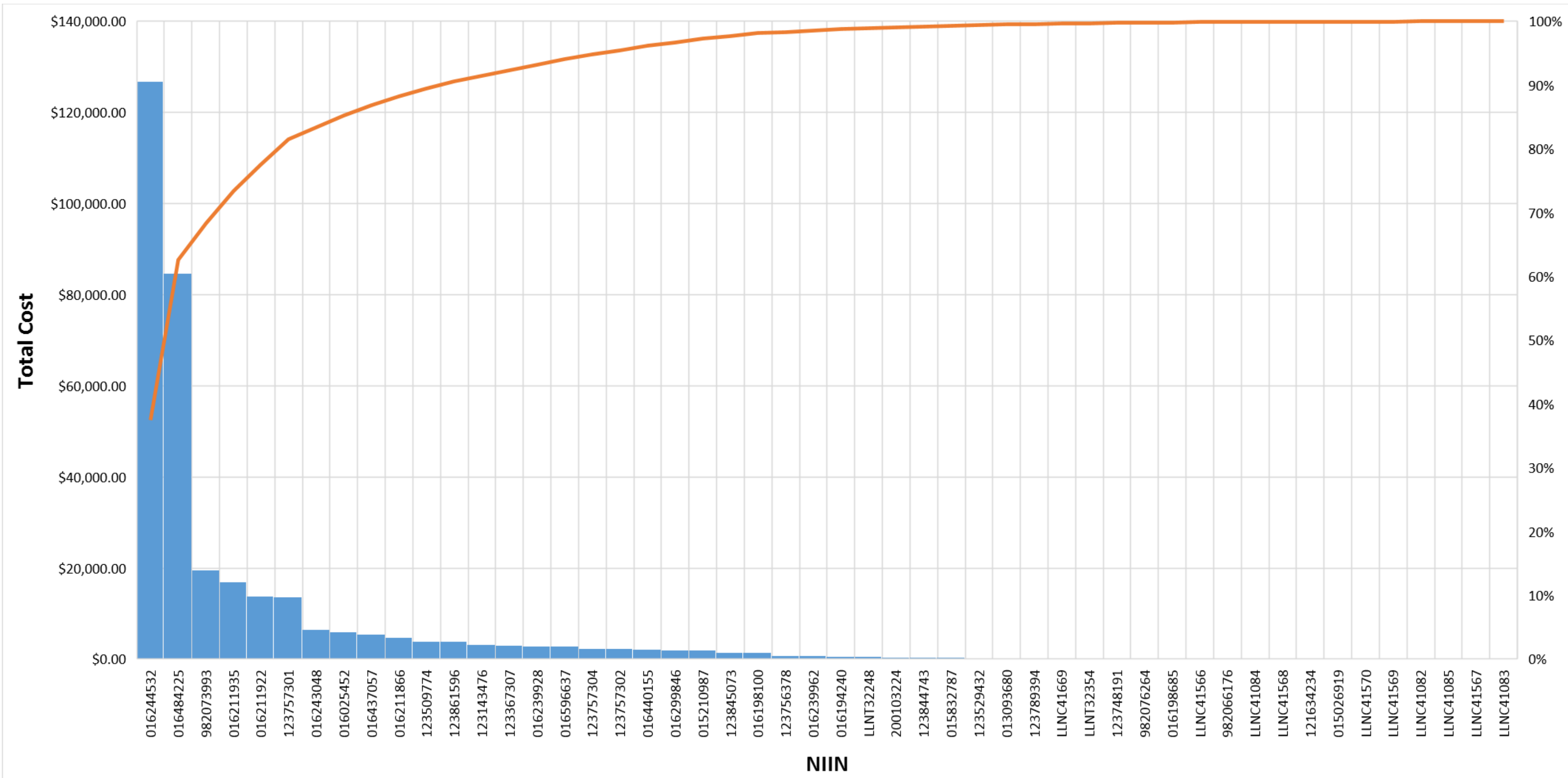

Figure 11. Top 50 Ordered NIINs by Total Cost and Percentage

D. FUTURE RESEARCH

During this research, the authors identified opportunities in the following areas for future research within the CRF.

1. Pack-Up-Kit Performance Evaluation

A review of the PUK is recommended after 18-24 months of deployment data has been collected following implementation of the recommendations provided in this research project. Additionally, due to the lack of complete and reliable data available for review at the time of this research, it is recommended that another similar analysis be performed after 18-24 months of consistent, accurate operational usage data has been collected by the NECC on the Mark VI patrol boats.

2. Mark VI Patrol Boat Regional Analysis

The Mark VI patrol boat operates in myriad environments, to include the arid, hot desert conditions in Bahrain and the humid, tropical rainforest conditions in Guam. At the time of this research, these are the two permanent detachments maintained by the CRF where Mark VI patrol boats remain deployed on a year-round basis. The boats assigned to each of these detachment sites remain on station, and personnel are rotated through in typical deployment cycles to maintain and operate the boats. With half of the current inventory of Mark VI patrol boats permanently deployed to these two sites, it is recommended that research be conducted to determine the impact these environmentally diverse locations have on the maintenance requirements of the Mark VI patrol boats. This will identify trends that may result in additional tailoring of pre-positioned parts inventories unique to the challenges faced in these areas of the world.

3. Inventory Management Practices

The data collected for this research project showed signs of ordering in bulk for high-use consumable components in what appeared to be stockpiling efforts by maintenance personnel. This leads to a phenomenon known as the bullwhip effect, where inconsistent quantities demanded result in disruptions across every level of the supply chain. Future research is recommended in order to establish the appropriate EOQ for these high-demand items based on the frequency of orders and the quantity required. This will ensure appropriate exercise of the supply chain and ultimately result in reducing variability in lead times and unavailability of critical components.

4. Maintenance Training

At the time of this research, training for maintenance personnel on major components of the Mark VI patrol boat such as engines and propulsion systems consisted of sending small groups of technicians to the manufacturers of these systems. The manufacturers are located in geographically dispersed locations from Mark VI patrol boats. As a result, training opportunities are limited, and costs in terms of dollars and time away from work are high.

This manufacturer-provided training is the only formal preparation these technicians receive in order to become proficient in maintaining the specific systems for which they receive training. This knowledge is then passed on to other technicians through on-the-job training. This leads to an underqualified work force and lack of technical proficiency continuity within the CRF. Performing a cost-benefit analysis to assess the viability of the Navy establishing a formalized training curriculum through the Naval Education and Training Command with a Navy enlisted classification code awarded upon completion is recommended.

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