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An Analysis of Aviation Maintenance Operations and Supporting Costs, and Cost Capturing Systems

4 December 2012

by

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ABSTRACT

The United States Navy has a number of entities that work together to ensure that aircraft in the Navy are supplied with the parts and materials required to maintain mission readiness. An analysis of the operating and support system costs characterizes cost variance across organizational-, intermediate-, and depot-level maintenance. In this report, we examine both labor and material cost for both repairable and consumable items and categorize those costs by type of maintenance action. This analysis is intended to help in the development of a cost model that could aid in both budget planning and execution.

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ACKNOWLEDGMENTS

Let us start by saying that our time at the Naval Postgraduate School (NPS) has been a time of personal growth, overcoming doubt within ourselves, and gaining confidence in an area of our personal and professional knowledge where it had been lacking. NPS is truly one of the most rewarding and enhancing training tours that the Navy has to offer.

We extend a sincere thank you to Professor Doerr and Professor Kang. We are grateful to have had the experience of working with experts in the field. As our advisors, you have provided us with the support, direction, and encouragement that enabled us to produce a product that we are proud of and that will hopefully benefit the Navy as well.

Thank you to CAPT Kelly, CAPT Munning, and the rest of the COMNAVAIRFOR team for recognizing the best use and direction of our initial MBA project proposal and for allowing us the opportunity to take on a project that is truly meaningful—not only to the NPS curriculum and the Navy but to the aviation community as well. The knowledge gained during this process has truly shaped how we will approach logistics and management throughout our careers.

Thank you to Mr. Kevin Doyle for answering questions and for your tremendous help with bridging gaps and merging data from multiple systems. You truly helped make sense of the data.

Lastly, all of this would not have been possible without the unwavering love and support of our families. Our wives, Cheryl and Amy, and our children, Gabriela, Sofia, Cameron, and Preston, have been a source of motivation and strength every second of every day, encouraging us to achieve more in our lives than we thought capable. It is with our utmost gratitude that we say thank you to them for all of this and so much more. The words on this page can never do justice to the amount of love, respect, and appreciation we have for you all. You are forever, and always will be, the pillars of our strength, life, and world. From Alex: to God, to whom I give Glory through my work and who gives me strength, thank you, Lord, for putting all who made this possible in each other's paths.

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ABOUT THE AUTHORS

LT Alejandro Palomino is an aerospace maintenance duty officer (AMDO). He was commissioned through the Legacy Seaman to Admiral Program upon completion of his Bachelor of Science in Business Administration and Management Information Systems in 2004 from Norfolk State University. After graduating from the Naval Postgraduate School, he will report to the Sun Kings VAW-116 to assume the duties as the assistant maintenance officer (AMO).

LT Palomino was born in Bogota, Colombia, S.A., and grew up in Venezuela. After immigrating to the U.S., he entered the Navy in June 1996 as an undesignated airman. He was assigned to Strike Fighter Squadron 87, NAS Cecil Field, FL. In 2004, he received his commission as a naval officer. After serving at the Naval Dive and Salvage Center, Panama City, FL, in 2004, he was selected to re-designate to AMDO. Shortly after selection, he was assigned to serve as part of the Wildcat team by the commanding officer of Strike Fighter Squadron 131, NAS Oceana, VA, in 2005. While there, he was the material control branch officer and the maintenance material control officer for the F/A 18C Squadron. In 2008, between duty stations, LT Palomino completed a successful GSA assignment as a watch officer at European Command Deployment and Distribution Operations Center (ECJ4 EDDOC), Stuttgart, Germany. After returning stateside, he was assigned to the USS *Enterprise* (CVN 65) as the General Aircraft Division (IM-2) and the Avionics Armament Division (IM-3) division officer.

LT Palomino is happily married to Cheryl and has two children, Gabriela (15) and Sofia (11). They reside in Monterey, CA. In his free time, LT Palomino is a dedicated husband and father, and is active in the community chapel where he served as a volunteer for different ministry events.

LT Jesse Epp is an aerospace maintenance duty officer (AMDO). He was commissioned through the Officer Candidate School (OCS) program at Naval Station Newport, and he received a Bachelor of Science from Embry-Riddle Aeronautical University.

After graduating from the Naval Postgraduate School, he will report to USS *John C Stennis* (CVN 74) to assume the duties of quality assurance officer (QAO).

LT Epp was assigned to the Sun Kings VAW-116 as an aviation structural mechanic (AM), which deployed on board the USS *Constellation* (CV 64). On board, he completed a general associate's degree from Central Texas University and started classes with Embry-Riddle Aeronautical University. Shortly after his assignment to VAW-116, he married his wife, Amy, in September 2001. They currently have two sons, Cameron and Preston. During his second tour with the Center for Naval Aviation Technical Training Unit (CNATTU) Norfolk, he completed his degree in professional aeronautics. After the completion of his bachelor's degree, Epp was selected for OCS and assigned to his third tour with the Wall-bangers of VAW-117. As an AMDO, he excelled at duties such as material control officer (MCO), assistant maintenance officer (AMO), and maintenance material control officer (MMCO). In his free time, LT Epp is a dedicated husband and father, is highly active in the community as a volunteer coach for youth sports, and is an active member of the La Mesa Parent Teacher Association.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACES	Aviation Cost Evaluation System
AESA	Active Electronically Scanned Array
AFAST	Aviation Financial Analysis Support Tool
AIMD	Aircraft Intermediate Maintenance Department
APN	Aircraft Procurement, Navy
ASKIT	Aviation Store Keeper Information Tracking
AT	Action Taken
ATMSR	Aircraft Type/Model/Series Report
AVDLR	Aviation Depot-Level Repairable
AWM	Awaiting Maintenance
BCM	Beyond Capability of Maintenance
BOR	Budget Operating Target Report
CAGE	Commercial and Government Entity
CAIG	Cost Analysis Improvement Group
CAPE	Cost Assessment and Program Evaluation
CEO	Chief Executive Officer
CFO	Chief Financial Officer
COMNAVAIRPAC	Commander, Naval Air Forces Pacific
COMNAVAIRFOR	Commander, Naval Air Forces
CPFH	Cost Per Flight Hour
CRS	Congressional Research Service
DECKPLATE	Decision Knowledge Programming for Logistics Analysis and Technical Evaluation
DLR	Depot Level Repairable
DoD	Department of Defense
DoDI	Department of Defense Instruction
DoN	Department of the Navy
EMD	Engineering and Manufacturing Development
EMT	Elapsed Maintenance Time
ESC	Executive Steering Committee
EXTPRICE	Extended Price

F/A	Fighter/Attack
FHP	Flying Hour Program
FRC	Fleet Readiness Center
GAO	Government Accountability Office
GCU	Generator Converter Unit
I-Level	Intermediate Level
IMA	Intermediate Maintenance Activity
JCN	Job Control Number
JSF	Joint Strike Fighter
LCC	Life-Cycle Cost
LORA	Level of Repair Analysis
MAF	Maintenance Action Form
MAL	Malfunction Description Code
MDR	Master Data Record
MDS	Maintenance Data System
MOS	Military Occupational Specialty
MTBF	Mean Time Between Failure
NACA	NALCOMIS AIMD Cost Accounting
NAE	Naval Aviation Enterprise
NALCOMIS	Naval Aviation Logistics Command Management Information System
NALDA	Naval Aviation Logistics Data Analysis
NAMP	Naval Aviation Maintenance Program
NAMSR	Naval Aviation Maintenance Subsystem Report
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVPERS	Naval Personnel Command
NCTS	Naval Computer and Telecommunications Station
NCCA	Naval Center for Cost Analysis
NEC	Navy-Enlisted Classification
NIIN	National (or NATO) Item Identification Number
NMCI	Navy/Marine Corps Intranet
O&I	Organizational and Intermediate

O&MN	Operation and Maintenance, Navy
O&S	Operating and Support
O-Level	Organizational Level
OPN	Other Procurement, Navy
OPTEMPO	Operating Tempo
OSD	Office of the Secretary of Defense
SAF/FM	Secretary of the Air Force, Financial Management
SUF	Suffix
TEC	Type Equipment Code
TD	Technical Directive
TOC	Total Ownership Cost
TMS	Type/Model/Series
VAMOSC	Visibility and Management of Operating and Support Cost
WP	Waiting Parts
WUC	Work Unit Code

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I. INTRODUCTION

A. MOTIVATION

As professional aviation maintenance officers, we wanted to pursue a topic that would benefit our entire community. Supporting aviation maintenance involves a balance of funding, manpower, and logistics. Parts and materials directly affect all three. Understanding how parts and materials influence our supply systems, troops, and drive cost is the key to identifying weaknesses and the first step to process improvements, which, in turn, can reduce labor hours and lead-times and save money. By analyzing the data of a component with a high failure rate, and in turn, a high utilization rate, we hoped a large amount of statistically significant data would be available that could be used to answer the following questions.

B. RESEARCH QUESTIONS

By analyzing the current data-collecting systems utilized by the Department of Defense (DoD), can naval aviation accurately predict proper inventories, safety stocks, and costs associated with organizational- and intermediate-level maintenance?

Are the current data systems capturing the necessary data to make cost-effective maintenance decisions at the organizational and intermediate (O&I) levels?

If not, what data fields should be added?

What can be done to improve data collection?

C. EXAMINING ORGANIZATIONAL-, INTERMEDIATE-, AND DEPOT-LEVEL MAINTENANACE COSTS

1. Organizational-Level Maintenance

Organizational-level (O-level) maintenance is performed by the maintenance personnel assigned to the operational unit or squadron. A squadron is a mix of officer and enlisted personnel, each assigned to a specific assignment or billet. A Service member is required to have the appropriate level of training and/or the Navy-enlisted classification (NEC)/designator/military occupational specialty (MOS). The NECs and training standards are required to ensure mission readiness and are governed by Naval Personnel Command (NAVPERS). NAVPERS determines the required levels of training, qualifications, and the number of personnel for assignment. This is calculated utilizing the documented number of work hours performed, and the mission of the squadron or unit determines the manning levels and training requirements. The mission of O-level maintenance at a squadron is to maintain all assigned aircraft and associated aeronautical equipment in a full mission-capable status. Other duties associated with this process are improving the local maintenance process, standing watches, and performing other required duties. All of these tasks feed the manning requirements for size and determining costs (Department of the Navy [DoN], 2012).

O-level maintenance can be grouped into three main categories: scheduled, unscheduled, and technical directive compliance. Scheduled maintenance is the primary form of maintenance performed at the O-level. Scheduled maintenance is designed to prolong and improve the life and performance of the system being serviced. Engineers with intimate knowledge of these systems determine the design and schedule of this type of maintenance. Some tasks are established at the birth of the system, while others are implemented as they are identified. Unscheduled maintenance occurs when systems unexpectedly fail and require repair and/or replacement of good components. Technical directives (TDs) are implemented when trends occur and/or safe-for-flight concerns are raised. Most TDs are inspection based, but some require the removal and replacement of suspected faulty components. TDs are a preemptive approach to preventing catastrophic failure (DoN, 2012).

2. Intermediate-Level Maintenance

Intermediate-level (I-level) maintenance is the next level of support. I-level maintenance personnel are assigned to a ship-based aircraft intermediate maintenance department (AIMD) or a shore-based fleet readiness center (FRC). I-level maintenance is designed to provide a higher level of maintenance support, with improved capabilities to repair and test components. AIMDs and FRCs are capable of providing support to multiple type/model/series (TMS) of aircraft. Pooling these resources allows the Navy to save money and improve the readiness of O-level maintenances. I-level commands are responsible for receiving parts, assessing the condition of the components, and determining the necessary action. Depending on priority and availability, parts are repaired and returned to the squadron for installation and use on the aircraft or for induction into the supply system. Parts that are beyond capability of maintenance (BCM) are shipped to the appropriate depot-level maintenance activity or to the manufacturer. Among the Sailors and Marines that work in I-level facilities, civilian artisans are contracted to provide expert support and technical expertise, not only to repair components but also to train personnel. These artisans improve the capabilities of the I-level command and contribute to the professional development of Service members. Just as the O-level duties of the Service members vary, the work performed determines the manning of the AIMD or FRC and contributes to the cost of supporting a system. Artisans in AIMDs and FRCs also represent a cost of support (DoN, 2012).

O- and I-level activity Service members share O- and I-level maintenance duties. This provides rotational assignments for Service members to complete sea/shore rotations, as well as to gain valuable O- and I-level maintenance experience (DoN, 2012).

3. Depot-Level Maintenance

Depot-level maintenance includes naval aviation industrial establishments and commercial facilities. Depot repair consists of aircraft overhauls, rebuilding and repairing of parts, assemblies, subassemblies, and any other system that falls outside of the capabilities of the O- and I-level maintenance departments. Depot-level maintenance represents another level of costs associated with the operations and support of systems. These costs usually fall under the category aviation depot-level repairable (AVDLR; DoN, 2012).

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II. BACKGROUND AND LITERATURE REVIEW

A. BACKGROUND

1. F/A-18 Hornet and Super Hornet

Developed in the 1970s as a multi-role, all-weather, supersonic, twin-engine, carrier-based aircraft, the F/A-18 (Fighter/Attack) Hornet is a product of the combined efforts from McDonnell Douglas and Northrop Grumman. Its multi-role capability made it a versatile weapons system and set the stage for the F/A-18 Super Hornet. Flying its first flight in 1995, the F/A-18 Super Hornet was designed to replace the F-14 Tomcat. The F/A-18 family consisted of A, B, C, D, E, F, and G series, all of which were variations of the same aircraft, with the major differences being single- or double-seated cockpits and variations in fuel capacity. Each new series of aircraft incorporated upgraded radar systems, avionics, and weapon-carrying capability. These variations helped tailor each series to a specific set of mission capabilities. The F/A-18 family of aircraft eventually replaced the F-14 Tomcat, A-6 Intruder, S-3 Viking, and EA-6B Prowler. With a single platform performing multiple roles, the F/A-18 provided an opportunity to drastically improve logistics support. For example, imagine seven TMS of aircraft on an aircraft carrier with each aircraft consisting of two types of tiers. To support these aircraft, the aircraft carrier must maintain an adequate number of tiers to ensure the full mission capability of its fleet of aircraft. Now, imagine if there were only three TMS of aircraft. The number and variety of parts and materials required to sustain carrier-based flight operations is drastically reduced (United States Navy, 2009).

2. Generator Converter Unit

The F/A-18 Super Hornet's generator converter unit (GCU) has experienced increased demand; changing system utilization is a common theme for many system components operated by the fighting forces in the DoD. Estimating the ever-changing utilization rates associated with a component and determining the strain and wear imposed is a challenge that the DoD faces. This information is critical when determining the mean time between failure (MTBF) and, in turn, the reliability of the weapon system.

The GCU is similar to the alternator in a vehicle. It takes mechanical energy produced by the jet engines of the F/A-18 and converts that into electrical energy for the appropriate systems of the aircraft to operate. Without a properly operating GCU, the F/A-18 cannot complete its mission. Currently, the GCU is the number one AVDLR and readiness degrader for the F/A-18 community. As subsystems of larger weapon systems are upgraded, changed, and integrated, the effects of these changes are felt on other components that operate together to make the entire system function. The GCU is a great example of this: higher electrical loads and higher demands on the aircraft's electrical systems are a result of components being removed and replaced by new ones to support the avionics that the aircraft utilizes, and failures of the GCU can be attributed to the change in its utilization. Figure 1 illustrates a time stamp when the new radar system, Active Electronically Scanned Array (AESA), was installed and its demand placed on the GCU in 2005 compared to the current utilization. The utilization change is illustrated by the volts and currents that the system handles; the white strip represents the old radar system; and the gray strip represents the new demands after the new AESA was installed.

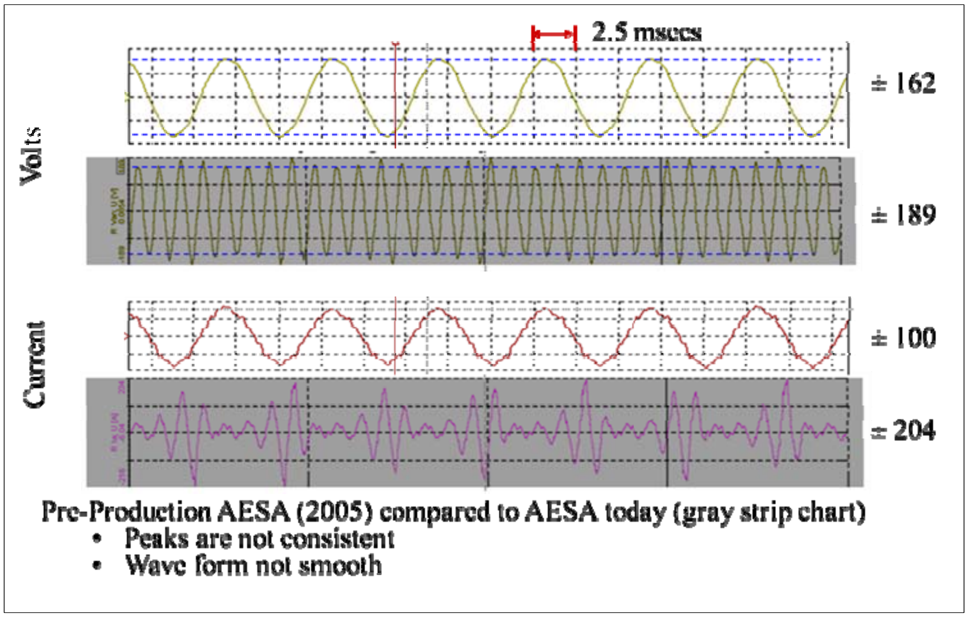

Figure 1. Generator Converter Unit's Current Utilization
(Commander, NAVAIR, 2010)

Strains applied to the current system have caused the MTBF of the GCU to decrease. The new demand placed on the GCU is much higher than the original demand. Failure to correctly estimate the reliability and life of a system is extremely costly and, in some cases, dangerous to the operators of the system (Naval Air Systems Command [NAVAIR], 2010).

3. Level of Repair Analysis

Level of repair analysis (LORA) is an analytical method to be used in determining the appropriate level of maintenance. LORA follows a series of steps that takes inputs, such as reliability of the system, maintainability, physical dimensions, weight, and so forth. Those inputs are then used to determine the optimal provisions of repair and maintenance facilities in order to reduce life-cycle cost and increase operational readiness. LORA helps solve problems as simple as how to avoid paying hundreds of dollars on transportation charges for a single $20 part or how to organize and staff an I-level facility. LORA is also responsible for determining the appropriate level to repair and/or to dispose of high-cost, repairable items by creating cost benefit analyses at each level, starting at the O-level and working its way up (DoN, 2003).

4. Maintenance Data Systems

The maintenance data systems (MDSs) were created to enhance naval aviation by tracking different maintenance actions and their effects on diverse elements of naval aviation. *The Naval Aviation Maintenance Program* (*NAMP*; DoN, 2012) describes *MDS* as a system that “furnishes data products that provide management tools for the efficient and economical management of maintenance organizations” (p. 14.1.1). Maintenance organizations, such as I-level and O-level, are responsible for the proper incorporation of data that is uploaded into the Naval Aviation Enterprise (NAE) on databases such as Aviation Financial Analysis Support Tool (AFAST) and Decision Knowledge Programming for Logistics Analysis and Technical Evaluation (DECKPLATE) via MDS. The final data should be usable as a management information system data source tool for all levels of management in questions related to

- equipment reliability and maintainability,

- material usage, and
- maintenance material cost expenditure.

MDS is the beginning of a series of building blocks that presents the big picture of maintenance, how much it really costs, and where the manager can find areas of interest in order to implement change or make an educated decision in order to better the system (DoN, 2012). Currently, AFAST is widely utilized by the fleet as the preferred method to track and monitor spending throughout different operational commands.

B. LITERATURE REVIEW

Every year, the DoN has to make decisions about the annual budget. These decisions are heavily based on readiness and modernization, two of the four pillars of military capabilities. According to the Congressional Research Service (CRS), *readiness* is "the ability of each unit to deliver the outputs for which it was designed," while *modernization* is "technical sophistication of all the elements of the force" (Tyszkiewicz & Daggett, 1998, p. 265).

To put it in simple terms, the DoD budget takes into account the factors of sustaining current capabilities and supporting the incorporation of new capabilities. The link between those two pillars, our research, and the way the DoD budgets in the present economic situation is operating and support (O&S). The goal of this project is to identify the cost of O&S throughout the maintenance cycle, and focusing on a component, such as the GCU, will help capture the data. We believe that by identifying more, if not all, of the costs associated with O&S, better maintenance decisions can be made and the DoD can improve the way it budgets in order to better sustain readiness throughout the fleet and also plan for the future.

1. Current Cost/Expenditure System Used by the Navy

Unger (2009) depicted the relationship between multiple systems' expenditure patterns, flying hours, and fleet sizes. In his work, Unger recognized the complexity of the system and acknowledged that there are different costs; some are affected by flying hours, some by fleet sizes, and others by a complicated mix of the two or sometimes one and not the other. Additionally, Unger (2009) explained that the mixed cases appeared to be a manifestation of fixed-plus-variable cost structure, which is not constantly compatible with the traditional Air Force cost per flight hour (CPFH) program. Unger (2009) addressed the current categories by which costs are separated and presented to higher echelons for review during budgetary processes. Table 1 shows the expenditure category elements as described by the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG).

Table 1. CAIG Costs
(Unger, 2009, p. 2)

CAIG Cost Element Descriptions

CAIG Element	Description
1.0 Mission personnel	Cost of pay and allowances of officer, enlisted, and civilian personnel required to operate, maintain, and support operational systems
2.0 Unit-level consumption	Includes the cost of fuel and energy resources; operations, maintenance, and support materials consumed at the unit level; stock fund reimbursements for depot-level reparables; operational munitions expended in training; transportation in support of deployed-unit training; temporary duty pay; and other unit-level consumption costs
3.0 Intermediate maintenance	Intermediate maintenance performed external to a unit, including the cost of labor and materials and other costs expended by designated activities/units in support of a primary system and associated support equipment. Includes calibration, repair, and replacement of parts, components, or assemblies and technical assistance
4.0 Depot maintenance	Includes the cost of labor, material, and overhead incurred in performing major overhauls or maintenance on a defense system, its components, and associated support equipment at centralized repair facilities, or on site by depot teams
5.0 Contractor logistical support	Includes the cost of contractor labor, materials, and overhead incurred in providing all or part of the logistics support to a weapon system, subsystem, or associated support equipment. The maintenance is performed by commercial organizations using contractor or government material, equipment, and facilities
6.0 Sustaining support	Includes the cost of replacement support equipment, modification kits, sustaining engineering, software maintenance support, and simulator operations provided for a defense system
7.0 Indirect support	Includes the cost of personnel support for specialty training, permanent changes of station, and medical care. Also includes the costs of relevant host installation services, such as base operating support and real property maintenance

The Secretary of the Air Force, Financial Management (SAF/FM) directorate developed a category cost element different from the CAIG's. The intention is to account for "the variable with flying hour," "variable with tails," and "fixed" costs (Unger, 2009).

The original concept was later changed after the report analysis yielded new, unexpected results between variations in different levels or stages, especially at the depot level. Table 2 is the Air Force expenditure category scheme that resulted from the analysis.

Table 2. Alternative Air Force Expenditure Categorization Scheme
(Unger, 2009, p. 26)

Variable cost per flying hour
- 2.1 POL/energy consumption

Variable cost per TAI
- 1.2 Maintenance personnel
- 2.2 Consumables/repair parts
- 2.5 Other unit-level consumption
- 5.2 Contractor logistics support
- 6.1 Support equipment
- 7.1 Personnel support

Partially variable cost per flying hour
- 1.1 Operations personnel

Partially variable cost per TAI
- 1.3 Other mission personnel

Fixed costs
- 7.2 Installation support

NOTE: We cannot determine 2.3 + 4.0 (depot maintenance), 2.4 (training munitions), 3.0 (intermediate maintenance), 5.3 (other contract support), 6.3 (other recurring investment), 6.4 (sustaining equipment support), 6.5 (software maintenance), and 6.6 (simulator operations).

Unger (2009) provided us with a platform from which efforts could be oriented by following some of the work conducted by the Air Force and comparing it to the current cost/expenditure system utilized by the Navy. Because our current research was designed to identify factors that affect O&S, we usefully applied a methodology similar to that used by Unger, which also made cost comparisons across Services easier.

2. Making Accurate Cost Decisions

According to a Government Accountability Office (GAO) report dated July 20, 2010, the DoD cannot effectively manage and reduce O&S costs for most of the weapon systems that the GAO reviews. The GAO analyzed and compared life-cycle O&S cost estimates and historical data on actual O&S costs. The GAO found that five of the seven aviation systems reviewed did not have the life-cycle O&S cost estimates developed at production milestones and that the data used to calculate costs was incomplete. Incomplete and insufficient data forced the DoD to make inaccurate calculations when determining O&S costs. Providing accurate data, the ability to analyze the rate of O&S cost growth, identifying cost drivers, and developing plans for managing and controlling costs are essential for the successful calculation of O&S costs. Updating methods, identifying life-cycle O&S costs, and identifying cost drivers will aid in the accuracy of estimates. These measures need to be reevaluated periodically throughout the life of the system (GAO, 2010). By using the GCU's historical data, we hoped to highlight the factors affecting the GCU as well as use the lessons we learned from the GCU's data to build a model that will aid in the accuracy of future calculations for other systems and their components.

Our research and findings are not intended to design a new activity-based cost system. However, there are lessons and approaches that activity-based costing uses that help provide a good product and information that leads to the formulation of a good, competitive strategy. In "Measure Costs Right: Make the Right Decisions," Cooper and Kaplan (1988b) explained that costs are categorized and separated so that they can be traced back to their origins and show the true cost of the individual component to the company. This is extremely important when calculating the O&S costs of a weapon system. Understanding and identifying the fully burdened costs associated with the weapon system is the only way to identify the support ability of the system and its value-adding capabilities to the organization. Cooper and Kaplan (1988b) covered the important aspect of the cause of distorted data. They explained that current cost systems typically overstate costs of high-volume items and understate costs of low-volume items, thus providing misleading information and leading to inaccurate decisions (Cooper & Kaplan, 1988b). A central goal of our thesis is to demonstrate an approach to gathering and categorizing costs to facilitate decision-making. We also raise questions about the accuracy, or at least the completeness, of that data.

3. Identifying the Relevant Data

As a result of the Secretary of Defense's policy on usage of specifications and standards, MIL-PRF-49506 (Logistics Management Information) was developed to replace MILSTD-1388–2B. It is not a revision of MIL-STD-1388–2B; rather, it represents a fundamental change in the way data requirements are levied on contracts. MIL-PRF-49506 does not contain any "how to" requirements. The new specification is designed to minimize oversight and government-unique requirements (p. 7-2).[1] Although this manual has been canceled, the DoD's Military Standard (MIL-STD-1388–1A; 1983), a military standard logistic support analysis, is a publication that covered many aspects of logistics support. The MIL-STD (DoD, 1983) Task Section 400, Determination of Logistics Support Resource Requirements, provided detailed guidance regarding the process of assessing the O&S costs that must be considered before a system can be adopted and when a new system's production line is about to be closed. Upon examination of the Super Hornets, the DoD utilized the GCU to determine its effective service life and the Navy's measures and processes for changing and adapting a weapon system to best combat constantly changing global threats. The MIL-STD (DoD, 1983) Section 403 provided guidance for weapon systems reaching the end of their life cycle. It identified key areas to assess regarding the system/equipment, such as

- expected useful life,
- support requirements,
- problems associated with inadequate supply after termination of product line, and
- the ability to predict and solve support inadequacies.

The overall purpose of this instruction is to ensure that all aspects of a weapon system are considered before it is implemented, extended, or changed and that the appropriate data is collected during the life of the system so that the appropriate decisions can be made. We considered many of the same metrics outlined in Section 400 (DoD, 1983), such as identifying

[1] This is copied from the *Department of Defense Handbook Acquisition Logistics,* MIL-PRF-49506 (p. 7-2).

- logistics support resource requirements for each task,
- new or critical logistics support resource requirements,
- participants in the support process and their required resources,
- effects of new strains on weapon systems,
- estimations of the life of aging components, and
- reductions in O&S costs.

Utilizing the data provided, we hoped to classify areas that can be identified as key causal factors or metrics that can be better used to identify and explain O&S costs associated with the system. The MIL-STD (DoD, 1983) provided us with a good starting point and guidance regarding the current system used.

Accurate forecasting of the demand for spare parts is vitally important for maintenance, but the sporadic nature of demand makes accurate forecasting difficult (Hua, Zhang, Yang, & Tan, 2007). Hua et al.'s (2007) study centered on how excess inventory of spare parts increases costs and how important it is to manage these costs that come from holding inventory and from inadequate inventory controls. They described the case of a Chinese company that held spare inventory of approximately $12 million out of $21 million total inventory with a turnover of 0.58 times per year. While we did not attempt to develop a forecasting model for spare parts, the Hua et al. (2007) study showed how spare parts affect O&S estimations and demonstrated that effective sparing levels are necessary for cost-effective management of maintenance processes. To have effective sparing levels, the Navy must capture accurate and relevant maintenance data at the O&I levels.

4. Establishing Measures

The United States Marine Corps is growing increasingly concerned about expenditures generated from the O&I levels; moreover, Romero and Elliott (2009) believed efforts to reduce budgetary impact on O&S must be taken before it is to late. Romero and Elliott (2009) began their thesis, *Developing a United States Marine Corps Organizational and Intermediate Level Maintenance Performance Cost Model,* by noting a multitude of O&S cost drivers, such as inventory, operating tempo (OPTEMPO), and equipment age, procurement costs that are not within the scope of decision-makers.

Furthermore, Romero and Elliott (2009) suggested that by developing a method to understand and analyze the relationship between cost variations and the continued increases in spending, the DoD could support sustainment budgetary requirements in the annual funding process. In this manner, budgetary planners could have a more reliable way to forecast future budgets, especially during times of monetary uncertainty. Romero and Elliott (2009) presented an example about how overestimating inventory has created extra spending within the Marine Corps. With the end of operations in Iraq and a drawdown over the horizon at Afghanistan, a question must be asked: What is going to happen to the inventory built to sustain the wars? The DoD has created inventories to sustain operations, so the question is this: When is the right time to take the foot off the gas, particularly when war itself is so unpredictable and may not present an exact final day? Questions like these are extremely important to our project because the costs associated with the sustainment of operations can be vastly complex and variable. Romero and Elliott (2009) covered the importance of identifying the very aspects that can be affected by the lowest level of maintenance.

According to Dixon (2006) in *The Maintenance Costs of Aging Aircraft: Insights From Commercial Aviation*, a close study of how commercial aircrafts age could help military decision-makers understand how “aging effects” affect cost estimation over time. In the cost study, Dixon (2006) covered three separate linear regressions by computing age effects on (1) aircraft ages zero to six years old, (2) aircraft ages six to 12, and (3) aircraft ages 12 and older. Dixon (2006) displayed the results of the RAND study as follows: Group 1 shows a maintenance increase cost rate of 17.6% per year; Group 2 displays an annual increase rate of 3.5% per year; and Group 3 yields a surprising 0.7% increase per year. Dixon (2006) also explained that organizations must assume a rapid constant increase in cost with age; however, other studies showed that such assumptions are incorrect. Furthermore, the reason that the younger aircraft result is higher than the rest is due to a cost shift from manufacturer-provided maintenance to owner-provided maintenance after the warranties have expired (Dixon, 2006). Dixon’s point was that leadership in the military must spot such changes while projecting future budgets not as a linearly increasing cost but as a midway point at which costs need to be reevaluated.

Utilizing flight hours to calculate the life of an airframe and its components is the most widely used and accepted method of measurement. A linear relationship is assumed to exist, along with the assumption that all parts on the aircraft have constant failure rates. These assumptions do not factor into the age of the weapon system or components or into the change in mission or utilization of the weapon system and its components. In our analysis of the GCU's data, we hoped to identify trends in the failure rates and make correlations to the age and/or utilization of systems that the GCUs support. In *A Method for Forecasting Repair and Replacement Needs for Naval Aircraft: Phase II,* DeLozier and Wilkinson (1986) defined the variables that could be used in a method for forecasting repair and replacement needs for naval aircraft Phase II. These variables include the replacement rate, fraction recycled, failure rate, and repair rate.

Delozier and Wilkinson (1986) provided valuable insight to aid our interpretation of the current maintenance data. Models such as this need accurate data to predict replacement rates. Our analysis examined the data used to determine failure rates and the fraction replaced that impact replacement rates and costs.

Understanding how to identify which costs are fixed and which costs are variable is important. This process is complicated further by the mix of funds that the DoD uses to cover expenses. Cooper and Kaplan (1988) discussed costing systems that can cloud the waters and make it difficult to see what the true expenses are, or how making changes to a process or system will affect the costs associated with the program or system a mix of funds are intended to support. Understanding the impact of changes and the importance of identifying costs, as well as understanding errors in the way that data is recorded and interpreted, makes it difficult to form a plan of attack. Data collection systems that are easy to use and understand, not only by management but also by the frontline user, greatly enhance the accuracy and volume of data collected. The DoD has many systems collecting data to form an array of measures. We used multiple sources of data to examine how costs that may seem fixed at a high level actually vary across categories at the O-level.

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III. METHODOLOGY AND DATA SOURCES

A. METHODOLOGY

Our results were derived from using Microsoft Excel ("Excel") to manipulate data collected and stored in AFAST and DECKPLATE databases. Excel and our data sources are tools available to today's naval officers. By using tools and data that are available to aviation maintenance officers, we hope that our methods can benefit the aviation maintenance community by identifying strengths and weaknesses in the data, as well as by describing and using methods to make better use of the data collected.

The data used to calculate the following results was derived from a merging of AFAST and DECKPLATE data, starting March 23, 2009, and ending September 30, 2010. This data range was selected because it represented the current consecutive fiscal years that have been completed. By selecting the last two fiscal years, we hoped to identify any new trends or tease out information that had not been discovered yet.

Data from DECKPLATE, a system that NAVAIR maintains in Patuxent River, and AFAST, a system which is maintained in San Diego at Commander, Naval Air Forces Pacific (COMNAVAIRPAC), requisition and cost data were merged to create a single, more detailed database. These separate inputs created the combined product that was utilized. The data field DECKPLATE Work Order Info (all) was matched with the requisition information in DECKPLATE, then the AFAST cost data was added to match the requisition information. The merging of DECKPLATE and AFAST data was completed by Mr. Kevin Doyle, a data analyst at Commander Naval Air Forces (COMNAVAIRFOR), based on our request.

Organization of the data was accomplished by extensive use of Excel pivot tables. Pivot tables automatically sort, count, total, or give the averages of the data field selected; for example, by selecting the merged DECKPLATE and AFAST data, we can easily and quickly manipulate the data. Pivot tables make sorting and organizing this large volume of information easier and more accurate by removing a majority of the manual data manipulation, thus removing the chance for human error in the data entry. Pivot tables can be filtered and re organized until only the data you desire is displayed, for example the initial pivot table displays additional filtered data results in a second table (also called a pivot table) showing a summary of the selected data. Changes can be made to the summary's structure by dragging and dropping fields graphically. The "rotation," or pivoting, of the summary table gives the concept its name.

A snapshot of the GCU's maintenance history is represented by the 5,579 line items, each with 80 data fields of information. Seventeen pivot tables were created and utilized to filter, organize, and analyze this data. Manually grouping the job control numbers (JCN) was completed in order to build our correlation tables. The 5,579 individual JCNs could be tied to 186 mother JCNs.

Pivot tables provided the core descriptive statistics that are the central part of our analyses. In addition, correlation tools were also used to demonstrate the sorts of post hoc, or "what if," analysis that could be performed by naval aviation professionals if the sorts of tables we built in this thesis were made available to them. We utilized Excel to create a Phi correlation to see how often items are ordered together (Cramer, 1946). Phi correlations are appropriate for measuring the strength of the association between binary (or dichotomous) variables. The Phi correlation coefficient is defined as

$$\boxed{\Phi = \frac{(\mathrm{a} \cdot \mathrm{d}) - (\mathrm{b} \cdot c)}{\sqrt{(a+b) \cdot (c+d) \cdot (a+c) \cdot (b+d)}}} \tag{1}$$

where *a* is the number of observations in which both variables are coded 1; *b* is the number of observations in which the first variable is coded 1 but the second is coded 0; *c* is the number of observations in which the first variable is coded 0 but the second is coded 1; and *d* is the number of observations in which both variables are coded 0.

The data used in these correlations is converted from quantities ordered to items ordered or not—a binary repression of the data. The correlation is intended to show if there was an interaction between parts; for example, if there was a part used to repair the GCU, were there any other parts used in conjunction with that part as well. For this reason, we changed the data to binary where 1 represents a part that is used to repair the GCU and 0 represents the absence of a part being utilized. Excel's CORREL tool provides an output table with values illustrating the strength of their correlation: +1 representing items that are perfectly positively correlated and -1 representing items that are negatively correlated. Phi correlation tools are not available in Excel so we coded them manually using Excel. Phi correlation results were formatted to find the result in the same visual representation as Excel's CORREL tool output table, making it easier to read and compare to our results.

In this project, we took a close look at the costs of aviation, the costs of aviation maintenance, and the systems that capture that data. Utilizing the same data sources used by the Navy to track and store maintenance information, we tracked parts through the maintenance and supply system capturing O-, I-, and depot-level maintenance actions, failure rates, and costs. Data sources used by the Navy already capture a large portion of the maintenance transaction; by using this data, we identified the strengths and weaknesses of the current data system as well as painted a picture of costs associated with naval aviation maintenance for a single item. After exploring accessible online database tools such as AFAST, DECKPLATE, and VAMOSC that track historical cost data throughout the fiscal year, we used these tools to identify costs and changes that contribute to significant cost variations for that item.

The item we selected was the GCU. By examining the GCU, we focused our data collection and analysis. With the GCU's current high utilization rate and its impact on the F/A-18 weapon system, data analysis on the GCU is important for the fleet. Also, because there is a great deal of data related to the GCU in our source data sets, we ensured that we could extract enough data to demonstrate the usefulness of our methodology.

B. DATA SOURCES

Aviation maintenance involves a lot of data collection in order to ensure that maintenance actions are properly performed and documented. This process is intended to provide vital information that is critical to the safety of the aircrew and personnel performing maintenance on the aircraft; ensuring accountability, the tracking of parts and materials are also functions of this data collecting. By combining the data collected from aircraft that are of the same TMS or that utilize the same parts and materials, the DoD can quickly identify trends, anticipate demands, and ensure proper stocking levels. Using a combination of data sources utilized by the DoD, we identified the cost of repairable components on the Navy across O-, I-, and depot-level maintenance. Section 1 of this chapter is a description and reason for the use of the following data systems.

1. The Navy Visibility and Management of Operating and Support Costs

The DoD utilizes information from all Services to make budgetary decisions. The Services provide information from a database source called Visibility and Management of Operating and Support Cost (VAMOSC). VAMOSC is a management information system that collects and reports U.S. Navy and Marine Corps historical O&S costs. In 1975, the Deputy Secretary of Defense directed all Services to collect actual weapon system O&S costs. In 1992, management of the Naval VAMOSC to provide executive oversight was assigned to the Naval Center for Cost Analysis (NCCA) and to the OSD CAIG. Today, VAMOSC provides data of direct and indirect O&S costs of weapon systems; it also provides non-cost information, such as flying hour metrics, age of aircraft, and so forth. VAMOSC also contains military personnel databases composed of personnel costs and has recently added databases covering DoN civilian personnel and Navy facilities physical characteristics and operating costs (VAMOSC, 2012).

VAMOSC databases are intended as information files to be used in appropriations and cost analyses. These data are used to develop the O&S portion of life-cycle cost (LCC) and estimate indirect costs for future weapon systems. They also contribute to the Navy's efforts to reduce the total ownership cost (TOC) of legacy and future weapon systems. VAMOSC is used to identify significant cost drivers that represent cost reduction opportunities (VAMOSC, 2012).

The VAMOSC (2012) appropriation accounts applicable to the current project are as follows:

- Aircraft Procurement, Navy (APN*)*: procurement of new aircraft, modifications to existing aircraft, and spare parts;
- Other Procurement, Navy (OPN): procurement of ship and aviation support equipment, communication and electronic equipment, ordnance

support equipment, civil engineer support equipment, supply and personnel/command support equipment, and spare and repair parts; and

- Operation and Maintenance, Navy (O&MN): expenses necessary for support of the fleet, civilian employee pay, travel and transportation, training, consumable supplies, recruiting and advertising, base operations, and base communications and subsistence.

2. Cost Analysis Improvement Group

CAIG, now called the Cost Assessment and Program Evaluation (CAPE), was created as an independent standard cost-estimation parameter utilized by the DoD during acquisitions and any cost tracking or estimation event. The CAPE is also consistent with DoD regulations and is under administrative control by an appointed DoD official.

Table 3 was extracted from the VAMOSC website, and it shows the CAPE cost elements utilized by cost estimators. The data is historical and is collected from several different reliable sources such as military personnel, NAVAIR, and so forth.

Table 3. ATMSR TMS Query CAIG Format Fiscal Year 1997 to Present (VAMOSC, 2012)

F/A-18F

			2010	
			Constant FY11 Dollars	Count
1.0 Unit-Level Manpower	1.1 Operations Manpower		$ 64,716,338.00	
	1.2 Unit-Level Maintenance Manpower		$ 162,591,916.00	
	1.3 Other Unit-Level Manpower		$ 33,682,446.00	
2.0 Unit Operations	2.1 Operating Material	2.1.1 Energy (POL, Electricity)	$ 297,914,264.00	
		2.1.2 Training Munitions and Expendable Stores	$ 10,150,936.00	
	2.2 Support Services	2.2.1 Transportation of Things	$ 3,941,126.00	
	2.3 Temporary Duty		$ 6,948,334.00	
3.0 Maintenance	3.1 Organizational Maintenance and Support	3.1.1 Organization-Level Consumables	$ 72,613,444.00	
		3.1.3 Organization-Level DLRs	$ 136,440,499.00	
		3.1.4 Contract Maintenance Services	$ 19,317,686.00	
	3.2 Intermediate Maintenance	3.2.4 Government Labor	$ 49,474,146.00	
		3.2.5 Contractor Maintenance		
	3.3 Depot Maintenance	3.3.1 Government Depot Repair	$ 107,804,069.00	
		3.3.2 Contractor Depot Repair	$ 1,159,562.00	
		3.3.3 Other Depot Maintenance	$ 2,567,930.00	
4.0 Sustaining Support	4.1 System Specific Training	4.1.1 System Specific Operator Training	$ 2,424,307.00	
		4.1.2 System Specific Non-Operator Training	$ 2,345,326.00	
	4.4 Sustaining Engineering and Program Management		$ 14,047,932.00	
	4.5 Other Sustaining Support		$ 846,207.00	
5.0 Continuing System Improvements	5.1 Hardware Modifications or Modernization		$ 154,551,948.00	
A1.0 Total Aircraft Number	A1.1 Regular Aircraft Number	A1.1.1 Regular Aircraft Number - Navy		133
	A1.2 FRS Aircraft Number	A1.2.1 FRS Aircraft Number - Navy		72
A2.0 Total Annual Flying Hours	A2.1 Regular Total Annual Flying Hours	A2.1.1 Regular Annual Flying Hours - Navy		50,875
	A2.2 FRS Total Annual Flying Hours	A2.2.1 FRS Annual Flying Hours - Navy		19,185
A5.0 Total Barrels of Fuel Consumed	A5.1 Barrels of Fuel Consumed - Regular	A5.1.1 Barrels of Fuel Consumed - Regular - Navy		1,538,101
	A5.2 Barrels of Fuel Consumed - FRS	A5.2.1 Barrels of Fuel Consumed - FRS - Navy		569,318
P1.0 Unit-Level Total Personnel Count	P1.1 Operations Personnel Count			475
	P1.2 Maintenance Manpower Count			2,461
	P1.3 Other Personnel Count			495
P2.0 Total Intermediate Personnel Count	P2.1 Intermediate Personnel Count - Maintenance			577
	P2.2 Intermediate Personnel Count - Other			20
		Sum:	$ 1,143,538,416.00	

The following are level elements as defined by CAIG (2007):[2]

1.0 *Unit*[3]*-level manpower* includes the costs of all operators, maintenance, and other support manpower at operating units. Unit-level manpower costs are intended to capture direct costs (i.e., costs of unit-level individuals that can be clearly associated with the system performing its intended defense mission). It includes MilPers costs (e.g., basic pay, allowances, entitlements, etc.).

1.2 *Unit-level maintenance manpower* is the cost of all military, civilian, and contractor manpower that performs unit–level maintenance on a primary system, associated support equipment, and unit-level training devices.

1.3 *Other unit-level manpower* is the cost of all military, civilian, and contractor manpower that performs administrative, security, logistics, safety, engineering, and other mission support functions at the unit level.

3.0 *Maintenance* includes the costs of labor (outside of the scope of the unit level) and materials at all levels of maintenance in support of the primary system, simulators, training devices, and associated support equipment.[4]

3.1 *Organizational maintenance and support* includes the cost of materials and other costs used to maintain a primary system, training devices, simulators, and support equipment.

3.1.1 *Organization-level consumables* include the costs of materials consumed in the maintenance and support of a primary system and their associated support and training equipment at the unit level. Illustrative types of maintenance consumables are coolants and deicing fluids.

3.1.3 *Organization-level* Depot Level Repairable (DLR) includes the net cost the operating unit incurs for DLR spares (also referred to as exchangeable items) used to maintain equipment at the unit level.

3.1.4 *Contract maintenance services* includes the separate costs of contract labor, materials, and assets used in providing maintenance

[2] The CAPE level elements were taken directly from the VAMOSC user manual and are in accordance with DoDI 5000.02 and DoD 5000.4M. The elements display costs that are followed by the DoD while describing money estimates for various programs because they bring essential understanding to the true cost of a system as a whole.

[3] *Unit*, in the purpose of this MBA project, can be defined as a squadron- or organizational-level command.

[4] This cost is tracked by Numbers JCNs and order documents generated at the O-level.

services to a weapon system, subsystem, support equipment, training device, or simulator at the unit level.

3.2 *Intermediate maintenance* includes the cost of labor and materials and other costs expended by I-level maintenance organization in support of a primary system, simulators, training devices, and associated support equipment. Where I-level maintenance activities cannot be separately identified from O-level maintenance, the costs are often combined as either organizational or intermediate maintenance.

3.2.4 *Government labor* includes the costs (using DoD standard composite rates, or hourly equivalent) of military and government civilian manpower that performs intermediate maintenance on a primary system, simulators, training devices, or associated support equipment at I-level maintenance activities.

3.3 *Depot maintenance* includes the fully burdened cost of labor, material, and overhead incurred in performing major overhauls or other depot-level maintenance on a system, its components, or other associated equipment at centralized repair depots, contractor repair facilities, or on site by depot teams.

3.3.1 *Government depot repair* includes government labor, material, and support service costs for depot repair.

3.3.2 *Contractor depot repair* includes the separate costs of burdened contract labor, material, and assets used in providing maintenance services to a primary system, subsystem, or associated support equipment. If possible, labor, material and other costs should be displayed separately.

3.3.3 *Other depot maintenance* costs not otherwise included. For example, this could include second-destination transportation costs for weapons systems or subsystems requiring major overhaul or rework, special testing, environmental costs, transportation of field repair teams, and technical assistance that is unique to the system and not included elsewhere in the estimate.

4.0 *Sustaining support* includes support services provided by centrally managed support activities external to the units that own the operating systems.

4.1.2 *System-specific non-operator training* includes the costs of advanced system-specific training associated with maintenance and other support functions in units designated as primary training facilities. (VAMOSC, 2012)

3. Decision Knowledge Programming for Logistics Analysis and Technical Evaluation

DECKPLATE is a new reporting system based on the Cognos incorporated analysis, query, and reporting tools. It provides report and query capabilities content-equivalent with the current Naval Aviation Logistics Data Analysis (NALDA) systems and allows reporting and analysis capability not available with the current systems. The new web-based reporting system provides a sound basis for future implementation of emerging DoN architectural requirements. DECKPLATE is the next generation data warehouse for aircraft maintenance, flight, and usage data. The system provides a web-based interface to a single source of the information currently being stored in multiple NALDA systems. Through the use of Cognos analysis, query, and reporting tools, the user has the capabilities to effectively obtain readiness data in a near real-time environment, as well as history data for trend analysis and records reconstruction (NAVAIR, 2012).

Figure 2 displays data flow and how DECKPLATE serves as a centralized data warehouse of all current aviation systems under the NAE.

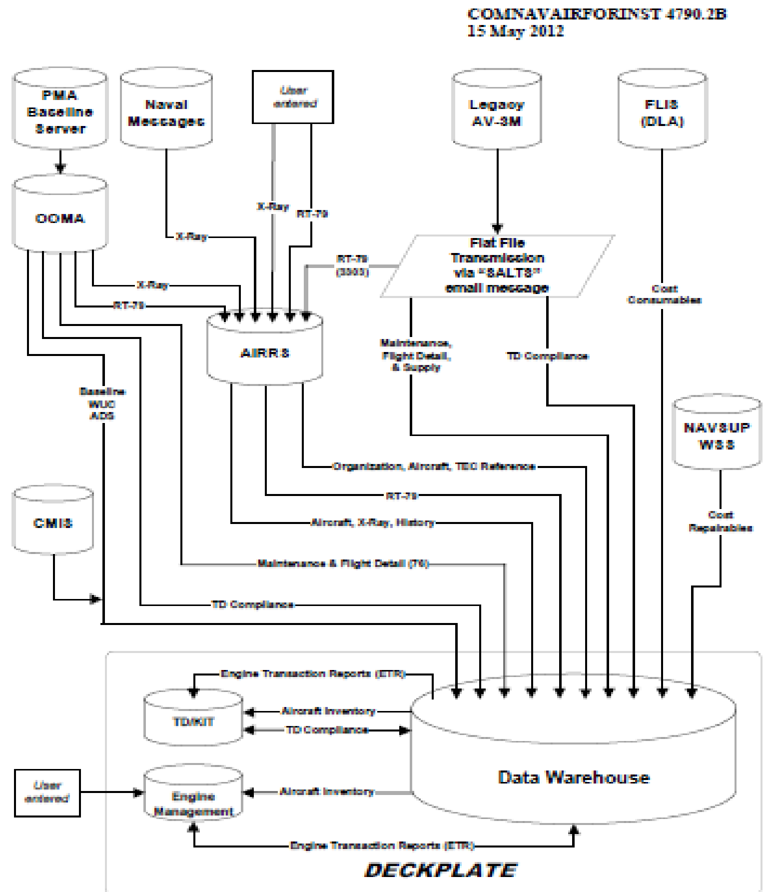

Figure 2. DECKPLATE Data Flow
(DoN, 2012)

4. Aviation Financial Analysis Tool

AFAST was developed as a result of a study conducted at COMNAVAIRPAC in 1994 by 23 reserve officers who were chief executive officers (CEOs) or chief financial officers (CFOs) in their civilian capacity. They were tasked by Vice Admiral Spane to advise him on how better to run COMNAVAIRFOR and COMNAVAIRPAC like a business. One of the study group's conclusions was that while COMNAVAIRPAC's financial tracking and analysis were up to industry standards, there was no cost management applied to the flying hour program (FHP). Their study had identified two tools already in existence in the fleet that could be used as a source of data to build a cost management system at COMNAVAIRPAC. Their recommendation was to develop AFAST using those systems as data sources. The two systems identified were the

Aviation Store Keeper Information Tracking (ASKIT) system and Naval Aviation Logistics Command Management Information System (NALCOMIS) AIMD Cost Accounting (NACA) system. ASKIT was selected to provide flight hours and fuel costs accumulated monthly by squadron and reported via the budget operating target report (BOR). NACA input files, extracted from the NALCOMIS, were selected as a source of squadron and AIMD costs via the requisition and maintenance action form (MAF) data. The reserve group was tasked to develop a prototype at Naval Air Station North Island. The prototype evaluation was completed in October 1995, and the decision was made to implement the system in all COMNAVAIRPAC activities that were supported by the NALCOMIS within the AIMD. The implementation was completed in 1996, and training was provided by the reserve group to the COMNAVAIRPAC staff. The original AFAST software was developed by the reserve group and supported by a contract with the Naval Computer and Telecommunications Station (NCTS) in San Diego, CA. This contract ended at the close of fiscal year 1996, and subsequent support and development has been provided via a commercial contractor (NAVAIR, 2012).

The AFAST program was monitored by the COMNAVAIRPAC FHP Executive Steering Committee (ESC) to track the progress of cost reduction initiatives that were undertaken. The ESC decided in fiscal year 1999 to involve the type wings in monitoring the FHP costs in their respective type model aircraft. Training was provided to the type wings, and additional tools were developed to support the wing involvement. The original tool (AFAST User) was enhanced, and two new tools were developed. The two new tools were the Type Wing FHP Cockpit Chart and the TWING Detail Analysis tool. All exported tools have been developed as Excel spreadsheets or Microsoft Access databases to ensure Navy/Marine Corps Intranet (NMCI) compatibility and compliance. The master AFAST database is maintained at COMNAVAIRPAC on a dedicated file server. This database is updated and maintained by AFAST contractors and used to produce the other tools monthly. These tools are produced after the flight hours have been certified in the comptroller’s Aviation Cost Evaluation System (ACES), which is the official financial reporting system used to produce the Flying Hour Cost Report. AFAST draws the BOR data from ACES after certification. AFAST captures only direct maintenance costs as documented via Intermediate Maintenance Activity (IMA) NALCOMIS. These costs are the results of squadron and IMA requisitions generated in the NALCOMIS and MAF data used to identify BCM actions on repairable items. AFAST does not capture financial-only transactions. These transactions include contract costs, financial adjustments, carcass charges, and requisitions not submitted via the NALCOMIS. The business rule established at inception was that AFAST must capture 85% of costs to be an effective cost-management tool. Currently, AFAST captures approximately 90% of FHP costs (AFAST, 2009).

C. DESCRIPTION OF DATA FIELDS USED

1. Job Control Number

The JCN is a 9-to-11 alphanumeric character number utilized to identify different jobs conducted on the aircraft. The JCN is the main master data record (MDR) or document utilized to track maintenance procedures and material discrepancies and to order parts and materials. It contains information such as man-hours, order document numbers, and all other fields described in the data fields. It also provides a link between maintenance actions performed at I-level in support of the maintenance discrepancy initiated under a particular JCN. There is only one JCN per repairable item; conversely, there can be several consumable items ordered tracked under one JCN. An original JCN would follow a set format that is separated into four sections.

- First, a three-digit code that identifies the originating command. This code is known as the ORG code.
- Second, a three-digit Julian date to identify when the JCN was created.
- Third, a three-digit serial number to identify, in sequence, the actual job number.
- Fourth, the suffix, or SUF, to identify a subassembly or sub-subassembly repair actions performed independently of the major component repair and used only for I-level maintenance actions.

For example, a repairable component, such as the GCU, will have a JCN (e.g., AD6259018). If there is another repairable part needed to fix the GCU at the I-level, then a suffix would be added at the end of the original JCN (e.g., AD62590181**1A**). Therefore, by looking at the JCN, we can see whether there were other actions taken to repair the part; moreover, we can identify other repairable components utilized to fix the original subassembly (DoN, 2012).

Figure 3 is a visual example of how a JCN looks, starting with the original job and any other parts to support it.

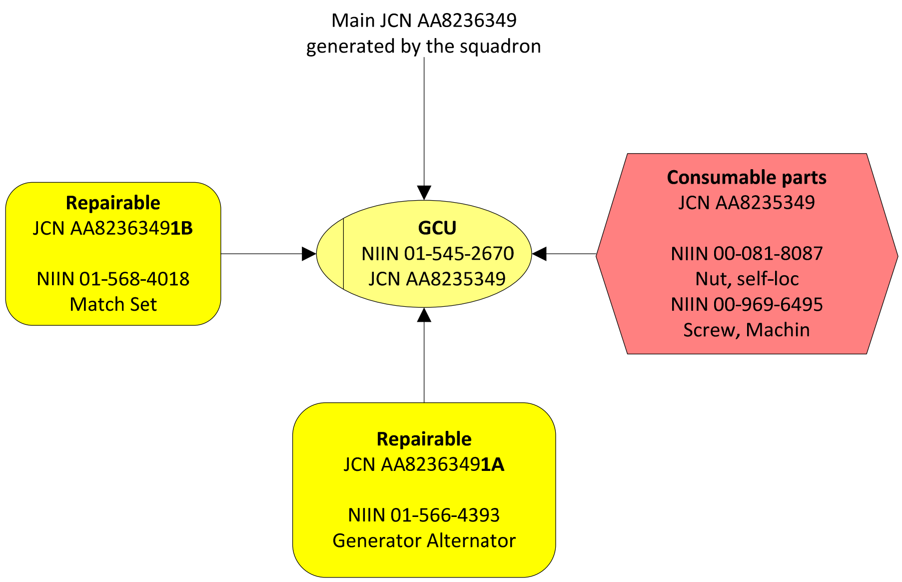

Figure 3. Job Control Number Representation

The JCN data was dispersed throughout DECKPLATE and AFAST. Each JCN was in its own individual row, as expected; nonetheless, it created a complication while trying to find and group main JCNs with its associated SUF. Therefore, we created a pivot table that displayed the JCNs as the "row label" and National (or North Atlantic Treaty Organization [NATO]) item identification number (NIIN), EXTPRICE in the values columns. Once the original pivot table was set, we had to organize the JCNs first in ascending order and finally group the SUF with the original JCN. For grouping, we utilized the group row function from Excel. At the end of the process, we had several rows of JCNs and their corresponding SUF. The new JCN pivot table was easier to read, and it showed the different charges against the original JCN, which also represents charges against the GCU. Another benefit of the JCN pivot table was that adding the NIIN field to the row label will display the NIINs ordered against the original JCN; in other words, it displays the parts required to fix the GCU.

Nevertheless, manually grouping the JCNs was a long and tedious task that is not practical to maintenance officers in the fleet. However, there is a great deal of information that can be gained by looking at this set.

2. Type Equipment Code

The type equipment code (TEC) is a four-digit character code used to identify the complete end item or category of equipment being worked on. This number is used to identify the TMS involved (DoN, 2012). Using the TEC code to filter the data, trends in specific systems common to a variety of aircraft can be found. For example, in our data, TEC codes were used to organize groups of aircraft with identical configurations. The GCUs found in the FA-18 are used in the following variants: F/A-18E, F/A-18F and F/A-18G. The F/A-18G is the electronic counter measure variant of the F/A-18, designed to replace the EA-6B. Once the data is grouped by TEC codes, it is easy to identify which group of aircraft, if any, is experiencing the highest number of failures per aircraft. In our data, we found that the F/A-18E is experiencing roughly 13 failures per aircraft over the time frame covered by our data. This is the highest number of failures per aircraft compared to the other TMSs involved.

3. Commercial and Government Entity

Commercial and Government Entity (CAGE) is a five-position code assigned to manufacturers and non-manufacturers, organizational entities, and contractors of items procured by agencies of the federal government. These codes help identify who manufactured the part (DoN, 2012).

4. Action Taken

Action Taken (AT) Code A is a one-character alphabetic or numeric code that describes what action has been accomplished on the item identified by a Work Unit Code (WUC). These codes include the multiple categories of BCMs as well as information regarding the repair (DoN, 2012). The AT code provides the ability to sort GCUs that were repaired from the GCUs that were BCM.

Using AT codes as the sorting data field in a pivot table and then pairing that information to the maintenance activity performing maintenance on the parts via the "action origination short name" (a data field used in DECKPLATE) will produce a consolidation of the data sorted by groups under each maintenance activity; this provides a summary of man-hours, parts ordered, and associated costs for each site. For example, we could instantly see that of the 1,388 "BCM1 – repair not authorized," four of them were issued by the AIMD onboard the USS *Ronald Regan*. By organizing the data this way, the total number of items processed for each AT code as well as the associated man-hours can also easily be identified.

5. Beyond Capable Maintenance

BCM is a term/code used by I-levels when repair is not authorized at that level or when an activity is not capable of accomplishing the repair because of a lack of equipment, facilities, technical skills, technical data, or parts (DoN, 2012). BCM is also used when shop backlog precludes repair within the time limits specified by existing directives. BCM codes are used to identify quantities and reasons for GCUs to be sent off for depot-level repair.

6. A National Item Identification Number

A NIIN is a nine-digit numeric code that uniquely identifies an item of supply in the NATO Codification System (DoN, 2012). NIINs allow us to filter and identify each component and the number of components used to repair the GCU. NIINs are extremely important while using pivot tables because the information associated with the individual NIIN represents quantitative factors such cost in dollars, man-hours, and items ordered. This information provided us with means to identify cost drivers, frequently ordered items, and also man-hours expended while repairing GCUs. Therefore, by using the NIIN, we could see which of the internal components was failing, how often, and how much it cost to repair.

7. Malfunction Description Code

A malfunction description code (MAL) is a three-character numeric or alphanumeric code used to describe the malfunction occurring on or in an item identified by a WUC (DoN, 2012). Filtering the data by MAL codes, counting the number of times a specific MAL code is used, then organizing the MAL codes by number of re-occurrences is a fast and easy way to see trends in specific types of failures. For example, 374 is the code representing an internal failure. This code appeared 1,043 times, far more times than any other code. This information can be used as the first step to identifying when the components are failing internally. These codes are utilized throughout the maintenance process and vary as new discrepancies are found and are documented against the part being repaired.

8. Measures of Maintenance Hours

a. Elapsed Maintenance Time

Elapsed maintenance time (EMT) measures the duration of an event from start to completion, regardless of the number of personnel performing the maintenance (DoN, 2012).

b. Man-Hours

Man-hours are used to measure the time that each individual spends to complete a single discrepancy (DoN, 2012).

9. Serial Numbers

Removed/installed equipment serial numbers are located on the part and are entered into maintenance data systems for record keeping. We used these numbers to keep track of how GCUs are moved through the maintenance and supply systems (DoN, 2012). Tracking these serial numbers could be useful to find individual component failures. For example, if there is an internal component that fails continuously, it demonstrates that the particular component has a high rate of failure; this also means that to maintain a desired level of readiness, an organization will require an increased availability of that component. Conversely, if the component is not identified as a high failure component by looking at different maintenance organizations, we could conclude that there is another factor creating the failure. Using serial numbers as the sorting data field in a pivot table could shed light on internal failures that are affecting other internal parts or high utilization components due to ordinary failure rates.

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IV. RESULTS

Our analysis focused on providing information associated with costs that are followed and used by the DoD to describe financial estimates for various programs. Our hope was to provide an essential understanding of the true cost associated with a system and its subsystems, as well as to increase the accuracy and detail of the data used by CAPE and other cost analysis groups during acquisition and budget estimation. The results obtained by our analysis were from AFAST and DECKPLATE data fields and relate and influence current level elements as defined by CAPE.

A. JOB CONTROL NUMBERS

A JCN is the main MDR; thus, it creates the means to track all maintenance actions back to the original job. A SUF JCN is added in order to accommodate an I-level action. These SUF JCNs represent additional actions, parts, and materials that are required to repair the system associated with the main JCN, such as ordering a repairable part to repair a GCU. Excel views the SUF JCNs as individual JCNs that are not part of a mother JCN; thus, manually grouping JCNs by the authors became a necessary evil. Table 4 displays an example of a pivot table that groups SUF JCNs into the original JCN. JCNs are extremely useful in this regard because the ability to track the parts and materials to the original discrepancy helps to tell the story; however, the tools in Excel do not automatically group JCNs together.

Table 4. Pivot Table for Job Control Numbers

Row Labels	Count of NIIN	Sum of Manhours	Sum of EXTPRICE
JCN PA2302369 (series)	14	3798	$82,888.68
AIMD NIMITZ	13	3795	$43,069.68
Oct 29, 2009			
Jan 22, 2010	11	3795	$33,068.68
001651942	1	345	$0.50
010050515	1	345	$3.00
012223502	1	345	$0.18
014793633	1	345	$1.00
014793739	2	690	$23,002.00
014793773	1	345	$1,363.00
014793776	1	345	$69.00
014793835	2	690	$7,524.00
014938822	1	345	$1,106.00
Nov 16, 2009	1	0	$5,495.00
Nov 16, 2009			
015313872	1	0	$5,495.00
Nov 5, 2009	1	0	$4,506.00
Nov 5, 2009			
014708683	1	0	$4,506.00
VFA-14	1	3	$39,819.00
Oct 29, 2009	1	3	$39,819.00
Oct 29, 2009			
014553692			

Totals

Sub totals

Row Labels	Count of NIIN	Sum of Manhours	Sum of EXTPRICE
JCN AG8003047 (series)	12	149.5	$96,360.00
AIMD EISENHOWER	11	148	$56,541.00
Feb 9, 2010	1	0	$20,919.00
Jan 4, 2010	3	0	$12,483.00
Jan 4, 2010	3	0	$12,483.00
014793745	1	0	$3,741.00
014951174	1	0	$5,001.00
014961068	1	0	$3,741.00
Feb 10, 2010	2	0	$8,742.00
Feb 13, 2010	2	0	$6,568.00
Feb 15, 2010	1	0	$5,001.00
Jan 5, 2010	1	0	$2,827.00
Jan 3, 2010	1	148	$1.00
Feb 14, 2010			
014793633	1	148	$1.00
VFA-143	1	1.5	$39,819.00
Jan 3, 2010	1	1.5	$39,819.00
Jan 3, 2010			
014553692			

Order Date
Order Received

Interesting contrasts were discovered by comparing different commands. During the analysis of the JCN tables, such as the comparison between Strike Fighter Squadrons VFA-143 deployed on the aircraft carrier USS *Dwight D. Eisenhower* and Strike Fighter Squadrons VFA-14 deployed on the aircraft carrier USS *Nimitz*, we found the following information while using pivot tables. The tables were showing marginal differences in cost, which was expected since parts cost the same; however, there was a large difference regarding total man-hours, especially at the I-level or AIMD. While both had ordered almost the same amount of parts for a relatively equal cost, they did not have the same amount of hours. Table 4 compares two different JCNs: the main JCN from the USS *Nimitz* AIMD accounted for 3,795 total man-hours, contrasted with 148 hours executed by the USS *Eisenhower* AIMD. As we know, man-hours add cost to the GCU or any other components because of the manpower requirements. We decided to add ordering dates and received dates to the tables so that we could see how long it took to repair the component. We found that only those parts that were not received the same date had man-hours. In accordance with the NAMP, man-hours measure the time that each individual spends to complete a single discrepancy, so we were surprised to see zero hours on parts that were received the same day. The example on Table 4 shows a time frame of 45 days. At the same time, there are exactly 345 man-hours for each part. We thought that the 345 hours represented the time that AIMD took to repair that particular subcomponent; for example, the time it took to fix a circuit card. However, when looking at a part common to both JCNs, NIIN 01–479–3633, we noticed that this part was a packing, which is a consumable part rather than a repairable item. We believe that these hours represent an awaiting time lapse rather than hours spent by maintenance personnel doing repairs. We came to that conclusion because the other parts that were received the same day have zero hours. Furthermore, the evidence of several consumable items with the same times as each other clearly indicates that those hours were not spent in repairing those individual components. Inaccurate representation of man-hours affects the accuracy of manning, over documentation of man-hours will inflate manning, and under documentation will reduce manning and drastically affect readiness. Getting these numbers correct is extremely important to personnel cost allocations and to the DoD financial and operational planning.

B. TYPE EQUIPMENT CODE

TECs were used to distinguish variants in weapon systems and the associated failure rates specific to that system. For example, the GCUs' high failure rate has become a problem for the F/A-18, and therefore, identifying the cause of the decreased MTBF is important to correcting the problem. Using the TECs and JCNs, we can determine the number of maintenance actions being performed to correct GCU discrepancies. Table 5 illustrates how we can determine which variant is experiencing the greatest rate of failure by comparing that variant's data to the number of aircraft associated with that TEC group.

Table 5. Type Equipment Code, Job Control Number, and Aircraft Count Used to Determine Percentage of Failures

TEC	Number of Discrepancies	Total Number in TEC	Variant	Discrepancies per aircraft
AMAH	2606	199	F/A-18E	13.10
AMAJ	2800	245	F/A-18F	11.43
AMAK	172	66	E/A-18G	2.61

The TECs can provide a starting point for determining the cause of increased failures. As seen in Table 5, the F/A-18E has the greatest percentage of failures, which makes it a good place to start examining the cause of GCU failures.

C. ACTION TAKEN CODES

AT codes provide an easy way to identify how discrepancies were corrected or whether the required repair was beyond the capabilities of the repairing activity. The AT code provides information regarding the reason that the receiving activity cannot repair the part. Similarly, BCM codes and cannibalization codes are particularly important to cost identification. The costs associated with BCMs are inorganic and typically high, whereas cannibalizations represent a failure in the supply system, causing unnecessary additional maintenance hours to be performed.

Table 6 provides a short definition of each AT code currently used as well as the number of times that each code was used in the data sample we analyzed. Table 6 also highlights the maintenance hours executed before a part was considered BCM, maintenance hours executed to repair GCUs, and maintenance hours executed on the cannibalization of GCUs caused by inadequate supply levels.

Table 6. Action Taken Codes Used to Illustrate Beyond Capability of Maintenance, Cannibalization, Repairs, and the Associated Maintenance Hours

AT Codes	Count of Action Taken		
1	1,388	BCM 1 - Repair Not Authorized	
2	6	BCM 2 - Lack of Equipment, Tools, or Facilities	
4	3	BCM 4 - Lack of Parts	
5	1	BCM 5 - Fails Check and Test	
7	94	BCM 7 - Beyond Authorized Repair Depth	
8	112	BCM 8 - Administrative	
A	106	Items of Repairable Material or Weapon/Support System Discrepancy Checked No Repair Required.	
B	1	Repair or replacement of items, such as attaching units, seals, gaskets, packing, tubing, hose, and fittings, that are not integral parts of work unit coded items or	
C	1,001	Repair	
D	270	Work Stoppage, Post and Redeployment, and Inter-Intermediate Maintenance Activity (IMA) Support	
F	1	Failure of Items Undergoing Check and Test	
P	137	Calibrated - No Adjustment Required	O-Level entry
R	1,582	Calibrated - Adjustment Required	O-Level entry
T	876	Removed and Replaced for Cannibalization	O-Level entry

Total OF BCM's	Total Repaired at I-level	Total Repaired at O-level
1,604	1,379	1,719
Documented Man-hours spent before BCM	Documented Man-hours spent on repairing GCU's	Documented Man-hours spent on Cannibalization
11,238	43,471	4,590

When analyzing AT codes, we can easily see how our ability to repair and/or maintain adequate inventory levels drastically affects time spent repairing weapon systems. Using AT codes, comparisons between maintenance activities can be made. For example, VFA-143 and VFA-103, aboard the aircraft carrier USS *Dwight D. Eisenhower*, and VFA-14 and VFA-41, aboard the aircraft carrier USS *Nimitz*, were deployed during roughly the same time frame and experienced very similar operational tempos. VFA-143, a squadron of F/A-18Es, cannibalized 46 GCUs, accounting for 298 maintenance hours, and VFA-103, a squadron of F/A-18Fs, cannibalized 23 GCUs, which accounted for 99 maintenance hours—totaling 69 cannibalized GCUs and 397 maintenance hours. These data allow you to compare maintenance practices, operations, flight hours flown, and other variables between the two commands. Similarly, VFA-14, a squadron of F/A-18Es, cannibalized 32 GCUs, accounting for 205 maintenance hours and VFA-41, a squadron of F/A-18Fs, cannibalized 22 GCUs, which accounted for 219 maintenance hours—

totaling 54 cannibalized GCUs and 424 maintenance hours. Not only can you compare squadrons assigned to a carrier or battle group but also across battle groups or theaters of operation. Comparisons are not limited to cannibalizations. For example, the AIMD onboard the USS *Dwight. D. Eisenhower* assigned a BCM1 status to 112 GCUs and its associated components. Meanwhile, the AIMD onboard the USS *Nimitz* assigned a BCM1 status to 32 GCUs and its associated components. These comparisons invoke further questions and form the basis for future research questions, such as what are AIMDs or squadrons doing differently, how are their operations affecting the system, and are the failures being caused by environmental factors or human error?

D. MALFUNCTION CODES

Malfunction codes can be used to identify trends in the types of failures. They are limited to the list of codes available and allow groups of similar malfunctions to be pooled together. The more specific or descriptive the code is, the more useful it becomes. Using the GCU’s data, we can easily see that internal failures are responsible for the greatest number of failures. This may not be enough to fix the problem, but it helps to narrow the search. This empowers the user to analyze subcomponents of the whole assembly and pinpoint the individual component that is failing. Thus, malfunction codes can guide future research and examination of supporting data needed to solve the problem.

E. NATIONAL ITEM IDENTIFICATION NUMBER

NIINs are extremely useful; while common names, nomenclatures, and even part numbers vary from organization to organization, the NIIN associated with that component does not. Organizing the data by NIINs allows us to see which components are being ordered to repair the weapon system. NIINs can be filtered in a number of ways. For example, by using the GCU’s data, we filtered NIINs to show the number of repairable and consumable components ordered. We then organized these lists into two groups: total number ordered and total cost.

Table 7 displays the top 10 consumable items. Table 8 displays the top 10 repairable parts used to repair the GCU. Items on each table are arranged by greatest to least number of units ordered and display their costs.

Table 7. Top 10 Consumable Parts Organized by Number Ordered

Nomen	NIIN	Number Ordered	Total Cost
O-RING	010050515	181	$ 276.25
O-RING	001651942	127	$ 42.71
O-RING	011192008	75	$ 246.69
TERMINAL	009507783	73	$2,312.17
PACKING	012223502	52	$ 27.90
O-RING	001660990	51	$ 26.37
O RING	000546940	38	$ 13.78
FILTERING DI	012217808	21	$ 162.45
GCU COVER	015526291	17	$ 808.94
F18 E/F G1 KI	LLPOZ5436	13	$ 0.13

Table 8. Top 10 Repairable Parts Organized by Number Ordered

Nomen	NIIN	Number Ordered	Cost
POWER SUPPLY	014793818	178	$ 308,084.00
CIRCUIT CARD	015452661	105	$ 488,784.00
ELECTRONIC CO	014708683	92	$ 405,540.00
MATCHED SET	015684018	88	$ 742,607.00
GENERATOR	014553692	78	$ 2,975,108.00
CIRCUIT, CARD	015664393	75	$ 1,416,483.00
GENERATOR	015452670	73	$ 2,879,190.00
ELECTRONIC CO	014951173	68	$ 329,223.00
ELECTRONIC CO	014708685	64	$ 124,679.00
GENERATOR,ALT	14708681	54	$ 1,025,031.00

From Tables 7 and 8, we can see how NIINs represent the frequency of items ordered during a selected period to sustain repairs on a GCU. This information is used to calculate future inventories and help maintenance professionals see trends in items that are being consumed at a higher rate than normal. More importantly, tracking the number of NIINs being ordered and understanding the failure rates of the individual components could point out the need to rework or repair the faulty components that are causing the larger, more expensive weapon systems to fail. By organizing the NIINs into ordering activities, pivot tables can help explore this data more precisely, thus helping to eliminate outliers in the reparable components ordered. For example, looking at Table 7, the number one consumable ordered is an O-ring. Deeper expansion of the pivot table shows that VFA-32 ordered 42 of the 181 O-rings—more than double the amount ordered by any other unit. By utilizing this information, some assumptions can be made; VFA-32 could be ordering more than the amount required to build up their inventory of consumable parts, or possibly, 41 O-rings failed before they were able to install a good one. Using the same data sample, the second highest consumable part ordered can be examined: once again, VFA-32 ordered 42 O-rings—over double the amount ordered by any other unit. Depending on the actual reasons for the quantities ordered, this information could be used to eliminate both sets of O-rings as a major cause of GCU failures across the fleet. Conversely, the top repairable components ordered from Table 8 were the power supplies. By further examining that NIIN, we see that FRC Oceana and FRC Lemoore ordered 77.52% of that NIIN. FRC Oceana and FRC Lemoore are the only two major shore-based repair facilities for the F/A-18. This information further supports examination of the power supply because of the total amount ordered.

Table 9 displays the top 10 consumables. Table 10 displays the top 10 repairable components, including GCUs. These tables are organized by the total dollar amount that each item represents within the data period used.

Table 9. Top 10 Consumable Parts Organized by Total Cost of Items Ordered

Nomen	NIIN	Number Ordered	Total Cost
SWITCH,PRESS	014938784	4	$2,690.28
TERMINAL	009507783	73	$2,312.17
CABLE ASSEMB	014080385	1	$2,233.66
SOLENOID,ELE	008681880	1	$1,796.20
COUPLING	011506744	10	$1,455.66
ADAPTER,SPLI	010330117	1	$1,187.22
RELAY,ELECTRO	011208774	1	$1,022.72
CONNECTOR,PLU	LLP234788	1	$1,000.00
GCU COVER	15526291	17	$ 808.94
CONNECTOR,R	011632549	1	$ 429.16

Table 10. **Top 10 Repairable Parts Organized by Total Cost of Items Ordered**

Nomen	NIIN	Number Ordered	Cost
GENERATOR	014553692	78	$ 2,975,108.00
GENERATOR	015452670	73	$ 2,879,190.00
CIRCUIT, CARD	015664393	75	$ 1,416,483.00
GENERATOR,ALT	014708681	54	$ 1,025,031.00
MATCHED SET	015684018	88	$ 742,607.00
CIRCUIT CARD	015452661	105	$ 488,784.00
ELECTRONIC CO	014708683	92	$ 405,540.00
ELECTRONIC CO	014951173	68	$ 329,223.00
POWER SUPPLY	014793818	178	$ 308,084.00
ELECTRONIC CO	014793620	43	$ 235,642.00

Determining cost drivers and the components that have the greatest impact on the budget was easy by utilizing NIINs to sort the data. This was also the same method we used to filter Tables 7 and 8. After examining the cost drivers shown on Table 10, additional data mining revealed that FRC Oceana and FRC Lemoore consumed 85.33% of the cost associated with the NIIN 015664393—the third highest cost driver to the DoD caused by GCU failures. (We started looking there because the top two NIINs represent the completed GCU assembly.) Again, because FRC Oceana and FRC Lemoore represent the major repair facilities for the F/A-18, this information supports further examination of circuit card costs.

This information about cost drivers supports and increases the accuracy of process improvement efforts. Maintenance professionals can also compare items for the same TMS by NIIN in order to identify common items utilized by each command or unit or to see if one item is less frequently used elsewhere. Identifying such trends can lead to the information we need to make good decisions regarding system support and improvements.

F. CORRELATIONS

Utilizing databases like DECKPLATE or AFAST and correlation analysis, maintenance professionals can identify positive or negative correlations among repairable components. Examining the correlation between components is a way to tease out a weak link in the system, bundle components together when considering safety stocks, and reduce the need for independent forecasting.

Figure 4 displays the top 10 repairable and consumable items ordered to repair GCUs. This figure was created using binary or dummy variables (1 if ordered, 0 if not ordered) instead of raw data utilized in Tables 7 through 10. Hence, it shows the most frequently ordered items, not the most heavily used items. The lightly shaded columns in Figure 4 represent consumable items.

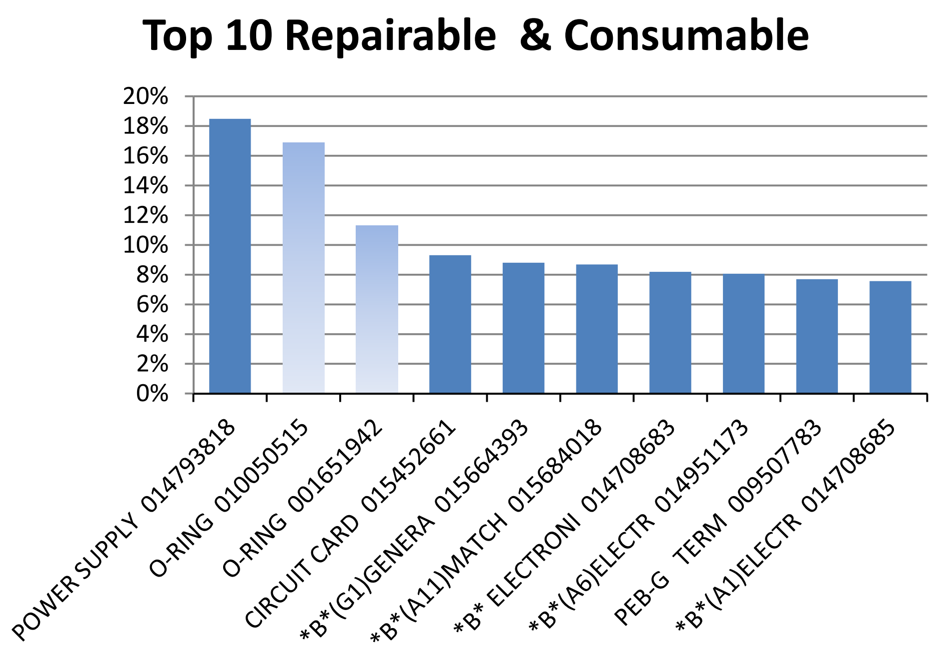

Figure 4. Percentages of Top 10 Items Ordered

With the data organized into dummy variables, we then used the tables to create another correlation analysis. This was done for several reasons. First, the correlations provide different sorts of information. In determining whether a certain kind of fault occurs frequently, knowing how frequently parts are ordered together (reported as follows) may be more important than knowing whether the amount used varies together (reported previously). Second, the high percentage of zeros (item not ordered) in the quantity ordered (the analysis reported previously) tends to distort the strength of the correlations. The correlations reported as follows will examine exactly (and only) the relative frequencies of the four cases that are possible with two parts: (1) Part A and B both used in an order, (2) Part A used but Part B not used, (3) Part B used but Part A not used, and (4) neither Part A nor Part B used.

Figure 4 illustrates the percentage of the time that a part was utilized while repairing a single GCU. These are different from the usage percentages. For example, 178 power supplies were ordered to repair 1,118 GCUs (representing 16%). When converting the dummy variables (frequency ordered) to percentages, we found that power supplies are on 18% of orders, as shown in Figure 4. This is because the raw data accounts for the quantity ordered while the dummy variables only track whether an item was used (not the quantity used). The percentage is also higher because some JCNs contained more than one generator. In accordance with the NAMP, there should be one repairable per JCN; therefore, finding this discrepancy shows a problem in data collection. Similarly, O-Ring 0100515 was 16% in the usage data and 17% in the dummy variable form (frequency ordered). But, not all of the items were different from the raw data; the majorities were exact matches and thus helped verify the accuracy of our data.

Based on this analysis, bundling of the repairable parts and the consumable parts might be considered. However, bundling repairable items must be based on a significant correlation; otherwise, it could prove costly and inefficient. The identification of these correlations is only the first step in the analysis required to determine which consumable parts might be intelligently bundled with repairable items.

Table 11 illustrates the top 10 items ordered from the data and also shows the Phi (ϕ) correlation between power supply, NIIN 01-479-3818, and electronic card, 01-470-8685. The equation shown in the same table is the initial step toward finding the significance of the correlation. This example shows that the closer the numbers are to 1, the higher their correlation to another component is. Nonetheless, numbers that are very small are not necessarily uncorrelated; the values can be small because of the sheer size of our sample. Table 11 also shows the 2x2 table utilized to explain the amount of times that an item is present (or not) in a JCN. For example, the power supply was present in 149 JCNs out of 2,425 total JCNs.

Once Phi is identified, it can be used to calculate the *p*-value, which will show the significance of this correlation.   Since Excel does not have a way to identify *p*-values for Phi, it is helpful to know that according to Cramer (1946), mathematically, Phi^2 is equal to Chi^2 divided by n (the sample size) or $\phi^2 = \chi^2/n$. Therefore, Phi^2 multiplied by n is equal to Chi^2 denoted $\chi^2 = \phi^2 * n$. This is useful because Excel has a Chi^2 distribution formula that shows the statistical significance of the correlation.

Utilizing the top 10 items ordered, Table 12 shows the *p*-values derived from Phi by using the Excel function "1-CHISQ.DIST (x, deg _ freedom, cumulative)," where *x* = Chi^2, deg _ freedom = 1 (1 is used for any similar 2 x 2 table) and cumulativ e = true. The *p*-value can be interpreted by looking at any intersection in which two parts meet. For example, on the top left corner, power supply and O-ring NIIN 01-005-0515 are not significantly correlated because there is a 42.7% chance that the times these parts were ordered together was just due to random variation, not due to any real relationship in usage of the two parts. Conversely, in the top right corner, there is less than a .001% chance that the frequency with which power supply and electrical card were ordered together was just due to random variation. Therefore, it is safe to say that the two have a significant correlation.

Table 11. Breakdown of Phi Correlation and How It Was Used in Excel

$$\Phi = \frac{(a \cdot d) - (b \cdot c)}{\sqrt{(a+b)\cdot(c+d)\cdot(a+c)\cdot(b+d)}}$$

2x2 table

POWER SUPPLY 014793818	ELECTRONIC C 014708685	
a	b	a+b
c	d	c+d
a+c	b+d	a+b+c+d = n

POWER SUPPLY 014793818	ELECTRONIC C 014708685	
149	61	210
2276	2364	4640
2425	2425	4850
0.089148499		

ϕ Table

	POWER SUPPLY 014793818	O-RING 010050515	O-RING 001651942	CIRCUIT CARD 015452661	GENERAL, ALTE 015664393	MATCHED, ELEC 015684018	ELECTRONIC C 014708683	ELECTRONIC CO 014951173	TERMINAL BOA 009507783	ELECTRONIC C 014708685
POWER SUPPLY 014793818	1	0.011397262	0.055140654	0.072695059	0.077284565	0.078445429	0.083144589	0.084333609	0.0[illegible]935824	0.089148499
O-RING 010050515		1	0.043927616	0.061656153	0.066302338	0.067478314	0.072241923	0.07355292	0.077104419	0.078336042
O-RING 001651942			1	0.018145022	0.022949788	0.024169421	0.029124931	0.030486579	0.034209128	0.035501194
CIRCUIT CARD 015452661				1	0.004826696	0.006053495	0.011045073	0.012417374	0.016178355	0.017484926
GENERAL, ALTE 015664393					1	0.00122723	0.006222444	0.007596123	0.011362758	0.012671676
MATCHED, ELEC 015684018						1	0.004995693	0.006369614	0.010137341	0.011446741
ELECTRONIC C 014708683							1	0.00137442	0.005145079	0.006455935
ELECTRONIC CO 014951173								1	0.003770996	0.005082083
TERMINAL BOA 009507783									1	0.001311459
ELECTRONIC C 014708685										1

Table 12. *P*-values Derived From Phi by Using 1-CHISQ.DIST

									P < .05	P < .10
P-Values	POWER SUPPLY 014793818	O-RING 010050515	O-RING 001651942	CIRCUIT CARD 015452661	GENERAL, ALTE 015664393	MATCHED, ELEC 015684018	ELECTRONIC C 014708683	ELECTRONIC CO 014951173	TERMINAL BOA 009507783	ELECTRONIC C 014708685
POWER SUPPLY 014793818		0.427354116	0.00012298	4.13523E-07	7.35617E-08	4.67912E-08	7.02396E-09	4.09018E-09	9.12426E-10	5.35014E-10
O-RING 010050515			0.00221926	1.75598E-05	3.88534E-06	2.61028E-06	4.87756E-07	3.01722E-07	7.88671E-08	4.88424E-08
O-RING 001651942				0.206354046	0.109983385	0.09233534	0.042527932	0.033741742	0.017200666	0.013421975
CIRCUIT CARD 015452661					0.736764957	0.673333691	0.441774378	0.387165035	0.259872718	0.223344013
GENERAL, ALTE 015664393						0.931890363	0.664765542	0.596799356	0.428754646	0.37751722
MATCHED, ELEC 015684018							0.727907952	0.657337404	0.480198023	0.425350393
ELECTRONIC C 014708683								0.923745124	0.720108893	0.652996097
ELECTRONIC CO 014951173									0.792843895	0.723394229
TERMINAL BOA 009507783										0.927228367
ELECTRONIC C 014708685										

The analysis of the correlation also reveals the following:

First, it is confirmed that O-rings are frequently used, which was also shown by Figure 4. Moreover, Figure 4 showed O-ring NIIN 01-005-0515 as the top consumable item ordered. Examining only usage data, we might conclude that a large safety stock of this item should be maintained. However, since previous analysis showed that a single squadron used this item heavily, increased safety stocks would not be warranted to support all squadrons, at least until the reasons that this squadron had excessive demand are determined. Also, the Phi correlations showed that the usage of this O-ring is significantly correlated to the usage of other O-rings, so any spike in demand at one squadron for this one O-ring in isolation is especially curious and would need further investigation before safety stocks were adjusted.

Second, Table 12 shows that by using Phi, the true picture emerges, although the correlation is small. It should be noted that there is still an indication of these parts being ordered together, hence the need to observe the failures in parts, such as the electrical card and the terminal board, since the correlation is stronger.

G. VAMOSC

The VAMOSC database is a great source of information but does not yield usable results for the purposes of this project. We tried using Naval Aviation Maintenance Subsystem Reports (NAMSRs) directly from the VAMOSC website by using a query data under WUC 4211800, 42A1E00, 42A1E90, and 42X1E40 but without success. When we contacted VAMOSC for assistance and provided our specific requirements, VAMOSC representatives provided the following fields of data: fiscal year, type/model/series-aircraft, NIIN, nomenclature, AVDLR cost, BCM count, I-level consumable cost, depot-level consumable cost, total consumable cost, O-level cannibalization count, I-level cannibalization count, O-level labor hours, I-level labor hours, and depot-level labor hours. However, the lack of subcomponent data at this level rendered this very useful database impractical and not worth analyzing for our purposes; With that said, it is hard to understand why a component such as the GCU, which is known to have a high failure rate and to drastically affect cost and readiness, is not well represented in the data. By selecting the GCU, we had hoped to find large and detailed amounts of data regarding the GCU and the components that it is comprised of because of their impact on the Navy and knowing the purpose of acquisition cost analysis systems, such as VAMOSC and the CAPE estimations is to project the O&S cost of future weapon systems. The lack of component and subcomponent data suggests these data fields did not include order-level data or man-hours utilized, which would have been essential to conduct a diagnostic analysis on cost drivers' estimation for future weapon systems. Furthermore, we are left with this question: Why is such data, collected by the Navy, missing from the VAMOSC database?

V. CONCLUSIONS

A. SUMMARY

The data systems used by the DoD have to be treated as an investment. These systems are tools that not only keep spending in the spotlight but also allow maintenance professionals to implement cost-avoidance methods. Those methods, which involve observing changes to man-hours, lead-times and cannibalization or consumption rates, are necessary to make smart maintenance and budgetary decisions. Although the MDS already provides information available to support a bird's eye view of combined unit operating cost for top tier commands' decision-making, it denies a comprehensive view of low-level commands' best practices, limiting the ability of the CAPE and other such entities to make accurate cost estimations.

In this thesis, we constructed pivot tables to provide a view of cost and operations across the merging of AFAST and DECKPLATE data sets. We demonstrated the value of this multiple-data-set view of the data in several examples. Our ability to organize data from multiple sources into groups allowed identification of trends, establishing highs and lows in quantities ordered and other useful analyses. The pivot tables we created can isolate dates where noticeable changes occur, which can help pinpoint the cause of the change or, at the very least, narrow the search. For example, in a hypothetical scenario, we could assume that the AESA's system installation on the F/A 18, illustrated in Figure 1, represents the root cause of the sudden increase of GCU failures. The AESA's system was installed in 2005, and the data range used in our analysis did not cover this time period. However, we believe that the methods we used would support this assumption.

The answer to our primary research question is equivocal: based on our analysis, data systems do not appear to capture all the data necessary for decision-making at the O&I levels. While we were able to find useful information about the GCU at the O&I levels, we encountered limitations in the data. Data from two primary sources were merged; however, this merged view still produced an incomplete picture. The data lacked the necessary detail required to accurately predict proper inventories, safety stocks, and costs associated with O-, I-, and depot-level maintenance. Some data sources that we thought would prove useful lacked sufficient granularity to support our analysis.

Specifically, the consolidation of man-hours, the lack of data regarding awaiting maintenance (AWM) times, and the misleading representation of EMT made it difficult, if not impossible, to make accurate assumptions regarding safety stocks and inventory levels. In regard to the parts and materials being ordered, the data captured, combined with the ability to assign that part to a JCN, provided an opportunity to identify trends in failed parts and the ability to group them.

Given our experience in the fleet and knowledge of the data being collected, we believe current systems are capturing the necessary data to make cost-effective maintenance decisions at the O&I levels; however, as the data is consolidated and pushed upstream, critical data fields are left out and are not represented in a consolidated data system. We had hoped that the merging of AFAST and DECKPLATE data would provide the necessary information, but it did not; therefore, we cannot definitely say that current data systems capture the necessary data to make cost-effective maintenance decisions at the O&I levels.

B. RESEARCH LIMITATIONS

We were unable to obtain a DECKPLATE account in order to explore the capabilities of the database and verify the current data collected. However, pursuing a DECKPLATE account was not necessary because our sponsors at NAVAIR provided pre-filtered data containing a merging of databases utilized by the DoD. This data proved to be very useful. We would recommend that similar access be made available to all maintenance officers in the fleet. This access would provide aviation maintenance professionals with valuable information that could be used to improve decision-making and allow a more proactive approach to inventory control, logistics, and maintenance support.

VAMOSC, although a great tool for capturing the cost of major components such as the F/A-18 or the F-35, did not provide the same capabilities at the subcomponent level. For example, the F/A-18 TMS CAPE shows costs associated with the TMS at levels starting from personnel, labor hours, parts, and overhead, all the way down to the O-level cost of parts and materials. However, because a component or subcomponent, such as a mission computer or radar system that is part of the same TMS, would not have the same level of detail, it would be unclear what cost is applicable; thus, the possibility of seeing O&S costs at the basic component level was not available. VAMOSC is very useful at capturing detailed data at the weapon system level (e.g., the F/A-18 Super Hornet program), as Table 3 shows. However, the history of GCU failures cannot be tracked or analyzed with VAMOSC data.

AFAST's data is limited to spending, so pairing it with other data is time-consuming and difficult. AFAST did bring additional awareness, raising questions such as the following: Why doesn't your organizations' spending match other sister commands? Why has spending increased on particular items? and, most important, What are others doing right so that those better business practices can be implemented across the board?

AFAST did not contain the same level of detail as DECKPLATE, which is understandable because DECKPLATE incorporates more databases into its centralized warehouse. We encountered instances in which data was captured by DECKPLATE but was missing from AFAST, even though AFAST should have captured the data. For example, the JCN was located at both databases; however, AFAST had blank fields containing no data.

Our research could have benefited from more data fields, specifically AWM reason codes, which represent a reason for maintenance to stop and accounts for maintenance hours between worked maintenance hours. Table 13 is a list of AWM codes and their meaning.

Table 13. List of AWM Codes and Their Meaning

Awaiting Maintenance (AWM) Codes		
A1. Pre-induction Screening	M1. AWM Depot	M8. AWM Awaiting Other Shops
CC. MAF Canceled	M2. AWM SE/Hangar	WB. In Transit from AWP Locker
CM. Contractor Maintenance	M3. AWM Backlog	WD. Awaiting Disposition
CP. Contractor Parts	M4. AWM Off Shift	WP. AWP In Shop
DD. Analyst Delete	M5. AWM Other	WQ. AWP In AWP Locker
IW. In Work	M6. AWM Awaiting AIMD	WS. AWP Work Stoppage
JC. Job Complete	M7. AWM Flight/Operational	WT. In Transit to AWP Locker

Knowing the times associated with the AWM codes in Table 13 would dramatically improve the usefulness of this data. For example, knowing the waiting parts (WP) would define how long a system had to wait for parts or materials to arrive before maintenance could continue repairing the component. Having this data field and grouping components in this manner would provide better insight when calculating the quantities of materials needed to maintain readiness.

C. RECOMMENDATIONS

In conducting our analysis, we found that we needed data from multiple sources, and we found data integrity issues that seemed to revolve around data capture, which hampered our analysis. Hence, we recommend removing as much of the manual input to the system as possible, accompanied by the merging of data-collecting sources to tie information together. We believe that this is essential to maximizing the use of the vast amounts of data collected by the DoD.

Adopting a data system that works to consolidate collected data would increase the number of ways we can compare and measure data. Consolidating data views to facilitate the sort of analysis we report in this thesis is an approach that will empower aviation maintenance professionals to take a more proactive role instead of the reactive, budgetary role currently employed. Such a system would fill in the gaps we found in our analysis when we used AFAST data, and tried to use VAMOSC data.

Based on our analysis of the data we extracted, we have come to believe that maintenance systems in O- and I-level maintenance organizations should be merged and completely seamless, and these systems should interact with a single supply system that can match locations, dates, and times to materials. These data should be provided in real-time, or as close to real-time as possible, throughout a single maintenance and supply system used by the DoD. Maintenance hours should not be the only time that is tracked because in-work date and date completed do not provide enough information. A supply system that provides the time that a part spends in the supply system and all the other steps or stops along the way is extremely valuable. These times can be used to calculate wait times and identify bottlenecks. These time periods should match maintenance data system times entered for work being stopped and/or awaiting parts. Troubleshooting and logistics supporting times must be accurately factored in. These seamless systems should be able to provide current as well as historic logistics data.

Knowing when and where parts and materials are, and who is ordering or consuming them, can be used to determine whether the process, location, and installation could benefit from consolidation. Maintenance systems need to be designed to track installed components and flag their time in service by capturing the service life of components in their intended environment. Decision-makers would have the ability to see the MTBF of the components that make up the weapon system. This data, in conjunction with accurate lead-times and consumption rates, can be used to provide better estimates on safety stocks and improve the cost and accuracy of inventory management.

Naval aviation professionals are proud of the amount and richness of the data collected by the fleet. However, we occasionally encountered data that, in our opinion and experience as naval maintenance officers, was questionable. We believe that our databases are limited by human input errors and missing data fields, thus resulting in significant limitations regarding the data available for research. Incorporating more automation in our data-collecting system, while keeping no-value-added redundancy out, would reduce the chance of human error.

D. CONCLUSIONS

The DoD has access to all of the information described in this chapter and, for the most part, is actively collecting this information in multiple data systems that are not linked. It would require extensive amounts of time and money to filter and organize this information into useful data, but a data system that could consolidate this information has the potential to save time and money. A consolidated system would meet the needs of multiple entities in the DoD, from budgeting to manpower, contracting to troubleshooting weapon systems. This would be a worthwhile investment that should and can be based off of existing technology. This data collection and the interactive analysis tools are essential to all decision-makers while implementing cost-related decisions; moreover, these tools could bring the current reactive mind-set to a change that would add cost-avoidance techniques initially placed at the hands of the leaders at the lowest levels. Our hope is that we have furthered the discussion for the extensive use of automated data-collection systems and added to the momentum for improved implementations of standardized data-collection and organization processes throughout the DoD.

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LIST OF REFERENCES

AFAST. (2009). About AFAST. Retrieved from https://www.portal.navy.mil/comnavairfor/N42/N422/AFAST/Help/Training%20Aids/About%20AFAST.html

Birkler, J., Graser, J. C., Arena, M. V., Cook, C. R., Lee, G. T., Lorell, M. A., & Grossman, J. (2001). *Assessing competitive strategies for the joint strike fighter: Opportunities and options*. Santa Monica, CA: RAND.

Commander, Naval Air Systems Command (NAVAIR). (2010, June). *Air vehicle systems propulsion and power, E/F/G GCU reliability/availability/growth issues*. Naval Air Systems Command, MD: Author.

Commander, USAMC Logistics Support Activity. (1997, May 30). *Department of Defense handbook acquisition logistics.* USAMC Logistics Support Activity.

Cooper, R., & Kaplan, R. S. (1988a, April). *How cost accounting distorts product costs.* Retrieved from http://www.business.aau.dk/~hojen/indexfiler/4scm/CostAccountingDistortsProductCosts.pdf

Cooper, R., & Kaplan, R. S. (1988b, September–October). Measure costs right: Make the right decisions. *Harvard Business Review*. Retrieved from http://host.uniroma3.it/facolta/economia/db/materiali/insegnamenti/588_3930.pdf

Cost Analysis Improvement Group (CAIG). (2007). *Office of the Secretary of Defense Cost Analysis Improvement Group*. Retrieved from http://www.navair.navy.mil/air40/air42/toc_files/o_s_cost_estimating_guide_oct_2007.pdf

Cramer, H. (1946). *Mathematical methods of statistics.* Princeton, NJ: Princeton University Press.

DeLozier, R. C., & Wilkinson, V. K. (1986, September). *A method for forecasting repair and replacement needs for naval aircraft: Phase II*. Retrieved from http://www.ornl.gov/info/reports/1986/3445600709623.pdf

Department of Defense (DoD). (1983, April 11). *Logistic support analysis* (MIL-STD-1388–1A). Washington, DC: Author.

Department of the Navy (DoN). (2003, September 2). *Operational availability handbook: A practical guide for military systems, sub-systems and equipment* (OPNAV INSTRUCTION 3000.12A). Retrieved from http://doni.daps.dla.mil/Directives/03000%20Naval%20Operations%20and%20Readi ness/03–00%20General%20Operations%20and%20Readiness%20Support/3000.12A.pdf

Department of the Navy (DoN). (2012, May 15). *The naval aviation maintenance program (NAMP)* (COMNAVAIRFORINST 4790.2B). Washington, DC: Author.

Dixon, M. C. (2006). *The maintenance costs of aging aircraft: Insights from commercial aviation*. Santa Monica, CA: RAND.

Government Accountability Office (GAO). (2010, July 20). *DoD needs better information and guidance to more effectively manage and reduce operating and support cost of major weapon systems* (GAO-10–717). Washington, DC: Author.

Hua, Z. S., Zhang, B., Yang, J., & Tan, D. S. (2007). A new approach of forecasting intermittent demand for spare parts inventories in the process industries. *The Journal of the Operational Research Society, 58*(1), 52–62.

Naval Air Systems Command (NAVAIR). (2008, December 12). F/A-18 Hornet strike fighter. Retrieved from http://www.navy.mil/navydata/fact_display.asp?cid=1100&tid=1200&ct=1

Naval Air Systems Command (NAVAIR). (2010). E/F/G GCU reliability/availability/growth issues [PowerPoint presentation for CAPT Darrah]. Retrieved from Naval Air Systems Command.

Naval Air Systems Command (NAVAIR). (2012). Decision knowledge programming for logistics analysis and technical evaluation (DECKPLATE). Retrieved from http://www.navair.navy.mil/logistics/deckplate/

Office of the Assistant Secretary of Defense. (1992, December). *Cost analysis guidance and procedures* (DoD 5555.4M). Retrieved from http://www.dtic.mil/whs/directives/corres/pdf/500004m.pdf

Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]). (2008, December 8). *Operation of the defense acquisition system* (DoD Instruction 5000.02). Retrieved from http://www.dtic.mil/whs/directives/corres/pdf/500002p.pdf

Romero, A. T., II, & Elliott, D. B. (2009, December). *Developing a United States Marine Corps organizational and intermediate level maintenance performance cost model* (Master's thesis, Naval Postgraduate School). Retrieved from http://handle.dtic.mil/100.2/ADA514397

Tyszkiewicz, M. T., & Daggett, S. (1998, December 9). *A defense budget primer.* Retrieved from http://www.fas.org/sgp/crs/natsec/RL30002.pdf

Unger, E. J. (2009). *An examination of the relationship between usage and operating-and-*

support costs of U.S. Air Force aircraft. Santa Monica, CA: RAND.

United States Navy. (2009, May 26). F/A-18 Hornet strike fighter. Retrieved from http://www.navy.mil/navydata/fact_display.asp?cid=1100&tid=1200&ct=1

Visibility and Management of Operating and Support Costs (VAMOSC). (2012a). About VAMOSC. Retrieved from https://www.vamosc.navy.mil/

Visibility and Management of Operating and Support Costs (VAMOSC). (2012b). *Aviation type/model/series reporting user manual*. Retrieved from https://www.vamosc.navy.mil/

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