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VERIFICATION AND VALIDATION OF NAVAL AIR WARFARE CENTER AIR DIVISION (NAWCAD) F/A-18 SUSTAINMENT MODEL

by

Denntrick A. Horton

March 2023

Thesis Advisor: Douglas L. Van Bossuyt
Co-Advisor: Ronald E. Giachetti

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This thesis addresses Verification and Validation (V&V) efforts for the Naval Air Warfare Center Air Division (NAWCAD) FA-18 sustainment model to ensure the model can make predictions regarding Tier One mission needs of the Air Division. For the development of the model, the Institute for Defense Analytics (IDA) used SIMLOX as the software tool and developed a data pre-processing pipeline using historical supply data as the inputs for the pipeline. Once the data is pre-processed, the data is used as inputs to the model. This thesis verified the model for correctness using a structured walkthrough. Model validation was performed to ensure the model can predict the number of expenditures using a t-test and percent error between historical and projected expenditures. Using a t-test, the model failed to produce a confidence level of 0.95 to use the model for sustainment decisions in the future. Additionally, the model under-predicted the total number of expenditures required by 66 percent and 70 percent for all depot-level repairable items. These findings will be used to improve the model for the purpose of receiving accreditation as a performance and pricing model.

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VERIFICATION AND VALIDATION OF NAVAL AIR WARFARE CENTER AIR DIVISION (NAWCAD) F/A-18 SUSTAINMENT MODEL

Denntrick A. Horton
Lieutenant, United States Navy
BS, Tuskegee University, 2016

Submitted in partial fulfillment of the
requirements for the degree of

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March 2023

Approved by: Douglas L. Van Bossuyt
Advisor

Ronald E. Giachetti
Co-Advisor

Oleg A. Yakimenko
Chair, Department of Systems Engineering

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This thesis addresses Verification and Validation (V&V) efforts for the Naval Air Warfare Center Air Division (NAWCAD) FA-18 sustainment model to ensure the model can make predictions regarding Tier One mission needs of the Air Division. For the development of the model, the Institute for Defense Analytics (IDA) used SIMLOX as the software tool and developed a data pre-processing pipeline using historical supply data as the inputs for the pipeline. Once the data is pre-processed, the data is used as inputs to the model. This thesis verified the model for correctness using a structured walkthrough. Model validation was performed to ensure the model can predict the number of expenditures using a t-test and percent error between historical and projected expenditures. Using a t-test, the model failed to produce a confidence level of 0.95 to use the model for sustainment decisions in the future. Additionally, the model under-predicted the total number of expenditures required by 66 percent and 70 percent for all depot-level repairable items. These findings will be used to improve the model for the purpose of receiving accreditation as a performance and pricing model.

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LIST OF ACRONYMS AND ABBREVIATIONS

CMC	Commandant of the Marine Corps
CNAF	Commander, Naval Air Forces
CRIM	Cost and Readiness Impact Model
DOD	Department of Defense
DON	Department of the Navy
IDA	the Institute for Defense Analytics
NAMP	Naval Aviation Maintenance Program
NAVAIRFOR	Naval Air Forces
NAVSUP	Naval Supply Systems Command
NAWCAD	Naval Air and Warfare Center for Air Defense
PRE	program-related engineering
PRL	program-related logistics
RCB	Reliability Control Board’s
USN	United States Navy
V&V	Verification and Validation

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EXECUTIVE SUMMARY

This thesis conducts verification and validation of an F/A-18 sustainment model for the Naval Air and Warfare Center for Air Defense (NAWCAD). The model is used to predict the number of expenditures during a period of time in the future. The model uses historical data as the input to the model and the outputs are used to determine the number of expenditures required in the future. For this task, the model was verified for correct implementation by conducting a structured walkthrough. Because the model developers used SIMLOX, which is a special purpose programming language for simulating sustainment that was unavailable to the author, detailed code review was not conducted.

As part of this process, an external systems diagram, input and output diagram, and flowchart were developed during this effort as required by the Office of the Chief of Naval Operations for models seeking accreditation. Using the F/A-18 sustainment model outputs, the model outputs were compared to the historical aviation requisitions purchased over the time interval of August 1, 2019, to April 30, 2022. To compare the model outputs to the historical aviation requisitions, the number of expenditures during this time period were compared to the projected using a t-test assuming unequal variances. As a result of this test, the model produced a p-value of .42, which showed the data was in favor of the alternative hypothesis stating that the model and projected number of expenditures are different. Once the model failed the t-test, the number of expenditures were grouped according to cognizance codes 1R or 7R with the 7R components receiving three different groupings according to low, medium, and high demands to determine the percent error between the historical and predicted expenditures. 1R components are Naval Supply Systems command managed consumable materials and 7R components are depot level repairable components.

As a result of this effort, the model's percent error decreases as the number of wholesale demands increases within the model and the model's predictions are highly dependent upon the price of the component.

In addition, the F/A-18 sustainment model consistently over-estimates the number of components needed compared to actuals in AFAST. Additionally, the average price for 7R components was higher for the AFAST Average Price in comparison to the SIMLOX Average Price which was attributed to the number of projected total demands in relation to the number of wholesale demands. The price of an item is highly contingent upon the source selection for the price comparisons.

With the model overpredicting the number of demands, this leads to an inaccurate depiction of the number of components required to maintain fully mission capable or mission capable within a system. Fully mission capable refers a platforms capability to perform all the associated missions of the platform without any major degradations whereas mission capable refers to the platforms capability to perform the associated missions with minor degradations. Given this information, the model's predicted expenditures are $268,968,118.50 under the historical AFAST expenditures which does not contribute to an improvement in NAVAIR's tier one mission readiness metrics. On average, the model under-predicts the number of expenditures by 66% and also under-predicts the number of demands by 70%.

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First, I want to thank God for guiding my footsteps and directing my steps to decide to exercise my Engineering Duty Officer option. Also, I want to give a huge thank you to my wife, Domanique Horton, for being my supporter, sounding board, and the rock of our family. I want to acknowledge my daughter for coming in the final stretch and being a huge blessing to our family and giving me a much-needed boost of enthusiasm to finish the journey strong. Thank you to my family and friends for your words of encouragement and support along the way throughout the process and the assistance of my professors and SE 580–23 cohort who were of tremendous assistance from start to finish.

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I. INTRODUCTION

This thesis focuses on the Verification and Validation (V&V) of the Naval Air Warfare Center Air Division's (NAWCAD's) F/A-18 sustainment model used to support F/A-18 sustainment decisions. The F/A-18 sustainment model uses historical aviation maintenance and supply data in conjunction with operational data to predict F/A-18 sustainment impacts in the future. The F/A-18 sustainment model produces sustainment impact predictions using SIMLOX, which is a discrete-event stochastic simulation software. This thesis's V&V of the F/A-18 sustainment model is to ensure the model can provide cost per flight hour, fully mission capable, or mission capable aircraft impact projections as outputs to the Cost and Readiness Impact Model (CRIM). These metrics will be used to support program-related engineering (PRE) and program-related logistics (PRL) 1A4N budget requests by linking the budget requests to an improvement in mission readiness (Naval Air Systems Command [NAVAIR] 2021).

To verify and validate the F/A-18 sustainment model, the model is verified by conducting a structured walkthrough of the model inputs and validating the predictive nature of the model by comparing model predictions to historical aviation maintenance records in a given period. To conduct the verification, the model structure is verified for correctness by ensuring the model was implemented correctly. Additionally, the Validation efforts involved in this thesis focus on using historical aviation maintenance records as inputs to the model for predicting the appropriate number of demands by comparing the predictions of the model to the number of demands generated in a previous year. For this thesis, the input data ranges from August 1, 2019, to April 30, 2022, with the model predictions being compared to historical maintenance records from August 1, 2019, to April 30, 2022.

The work accomplished in this thesis contributes to improving mission readiness by verifying the use of the F/A-18 sustainment model ability to predict impacts and link to costs. Upon V&V of this capability, the ability to use the F/A-18 sustainment model to link costs to mission readiness enables resources to be diverted or allocated to mission priorities vice the current process which has been deemed incapable of accomplishing this feat. The motivation for this improvement stems from the Office of the Chief of Naval Operations which mandates that Navy programs using operating appropriations with projected annual costs of $250 million or more will be justified using accredited models (Office of the Chief of Naval Operations [OPNAV] 2021).

With the mandate is required for programs more than $250 million, NAVAIR developed CRIM with the help of IBM and the Institute for Defense Analytics (IDA) to prioritize investments using high-fidelity modeling (NAVAIR 2021). With the verification and validation of the F/A-18 sustainment model, this effort allows the general format of the model to be used for modelling the sustainment of other platforms within the Navy's aviation fleet and assist with improving the Reliability Control Board's (RCB) priorities.

A. BACKGROUND

This section provides a baseline understanding of the F/A-18 platform and context for the modelling, simulation, verification, and validation efforts of this thesis. In the DOD and DON, both departments utilize modelling and simulation as a tool for budget requests and resource allocation. Additionally, the DOD and DON have specific mandates and requirements associated with the Verification, Validation, and Accreditation of models such as CRIM. In this section, CRIM is decomposed by identifying the underlying sub-models used to produce sustainment recommendations. Next, the simulation software tool used to simulate the F-18 sustainment model is provided to demonstrate the role of SIMLOX within the F-18 sustainment model.

1. F/A-18 Platform Overview

The F/A-18 is the platform of interest for this study. This section provides a baseline understanding of the technical specifications of the platform, purpose, locations, and countries using the platform in their services.

The F/A-18E and F Super Hornet came into existence as a redesign of the original F/A-18 Hornet. Initially, the F/A-18 Hornet consisted of both the F/A-18 C and D variants, which were single- and two-seat variants. In comparison to the F/A-18 C and D Hornet, the F/A-18E and F Super Hornet are greater in length, height, and wingspan.

Table 1. F/A-18 C/D/E/F Technical Specifications Comparison. Adapted from Boeing (n.d.a).

Technical Specifications	**F/A-18 C and D Hornet**	**F/A-18 E and F Super Hornet**
Length	56 Feet	60.03 Feet
Height	15.3 Feet	16 Feet
Wing Span	40 Feet	44.9 Feet

The Super Hornet entered fleet service with the United States Navy (USN) in 1999. It achieved initial operating capability (IOC) in September 2001 with the U.S. Navy's Strike Fighter Squadron 115 (VFA-115) at Naval Air Station Lemoore, California (Boeing n.d.b.). In the USN, the F/A-18 is used in a variety of different roles ranging from fleet defensive operations, close air support, fighter escort, reconnaissance, maritime strike, and tanker missions during the day or in night-time operations. The F/A-18 E and F variants are similar to the F/A-18 C and D in the fact that the E is a single seat platform and F is a two-seat platform (Boeing n.d.a.).

Currently, Boeing has three customers for the F/A-18 E and F/A-18F. They are the Royal Australian Air Force, which is holding 24 F/A-18 F in its arsenal at Base Amberley in Queensland; Kuwait Air Force, which signed a contract for 22 F/A-18Es and 6 F/A-18 Fs as of January 2021 (Janes 2021); and the United States, which is Boeing's primary customer for the E and F variants of the F/A-18, with both variants in use by the USN and the Marine Corps, in squadrons on the Pacific and Atlantic coasts. The F/A-18 C/D/E/F Technical Specifications Comparison (Boeing n.d.a.), shown in Table 2, depicts the list of all active United States Navy squadrons and their locations with over 608 in the USN and Marine Corps' armament in 2021 according to NAVAIR (2020).

Table 2. F/A-18 E and F Squadrons (Commander Naval Air Force Pacific and Atlantic. Adapted from NAVAIRFOR (2022).

PACIFIC SQUADRONS		ATLANTIC SQUADRONS	
VFA-2	Lemoore, CA	VFA-11	Oceana, VA
VFA-14	Lemoore, CA	VFA-31	Oceana, VA
VFA-22	Lemoore, CA	VFA-32	Oceana, VA
VFA-25	Lemoore, CA	VFA-34	Oceana, VA
VFA-27	Iwakuni, Japan	VFA-37	Oceana, VA
VFA-41	Lemoore, CA	VFA-81	Oceana, VA
VFA-86	Lemoore, CA	VFA-83	Oceana, VA
VFA-94	Lemoore, CA	VFA-87	Oceana, VA
VFA-97	Lemoore, CA	VFA-103	Oceana, VA
VFA-102	Lemoore, CA	VFA-105	Oceana, VA
VFA-113	Lemoore, CA	VFA-131	Oceana, VA
VFA-115	Iwakuni, Japan	VFA-143	Oceana, VA
VFA-122	Lemoore, CA	VFA-211	Oceana, VA
VFA-125	Lemoore, CA	VFA-213	Oceana, VA
VFA-136	Lemoore, CA	VFA-106 FRS	Oceana, VA
VFA-137	Lemoore, CA	Aviation Support Detachment Oceana (ASD)	Oceana, VA
VFA-146	Lemoore, CA	Strike Fighter Weapons School Atlantic	Oceana, VA
VFA-147	Lemoore, CA		
VFA-151	Lemoore, CA		
VFA-154	Lemoore, CA		
VFA-192	Lemoore, CA		
VFA-195	Iwakuni, Japan		
Strike Fighter Weapons School Pacific	Lemoore, CA		

When the F/A-18 is referenced in this thesis, the F/A-18 E and F variants will be the platforms referred to in the modelling and simulation efforts. In addition to providing a baseline of the F/A-18 variants, a baseline understanding of the maintenance construct utilized to maintain these platforms is imperative to understanding the F/A-18 sustainment system.

2. Naval Aviation Maintenance Program

As defined by Naval Supply Systems Command (NAVSUP), the objective of the Naval Aviation Maintenance Program (NAMP) is to achieve the aviation material readiness and safety standards established by the Chief of Naval Operations and Command Naval Air Forces in coordination with the Commandant of the Marine Corps (CMC) where the NAMP serves to direct maintenance policies, procedures, and responsibilities at every level of naval aviation (Commander Naval Air Forces [CNAF] 2022). For the execution of this guidance, naval aviation maintenance is overseen and administered by Commander, Naval Air Forces (CNAF) with assistance from NAVSUP and NAVAIR with NAVSUP being responsible for material support and NAVAIR providing life-cycle support of naval aviation aircraft (NAVAIRFOR 2022). While NAVAIR serves as the technical manager for aviation maintenance, the Aircraft Controlling Custodians (ACCs) are responsible for funding, training, manpower, material, and equipment to meet their operational responsibilities who consists of the Commander, Naval Air Force (COMNAVAIRFOR, Commander, Naval Air Force Reserve (COMNAVAIRFORES), and Chief of Naval Air Training (CNATRA).

To execute these responsibilities, the ACCs retain administrative and assignment of aircraft to reporting custodians where Navy Type Wings fulfill this role by being responsible for manpower, training, material readiness, and inspection of their activities. Navy Type Wings maintain and monitor material readiness using Decision Knowledge Programming for Logistics Analysis and Technical Evaluation (DECKPLATE) and Organizational Maintenance Activity (OMA) data by aircraft and squadron (NAVAIRFOR 2022).

Aviation maintenance is conducted at three different echelons according to organizational, intermediate, and depot level maintenance. Organizational maintenance consists of maintenance that can be accomplished by squadron personnel with the intent of restoring the aircraft’s operational readiness as quickly as possible. In comparison, intermediate maintenance is performed by Intermediate Maintenance Activities (IMA) specializing in ready-for-issue parts and ready-for-use support equipment to support aircraft operations (NAVAIRFOR 2022). In addition, intermediate level (I-level) maintenance activities are capable of inspecting, testing, and repairing aircraft components and support equipment. In stark comparison to organizational and intermediate maintenance, depot level maintenance and rework is more in-depth and requires

> designated depot activities on aircraft, equipment and material requiring overhaul, upgrading, or rebuilding of parts, assemblies, subassemblies, and end items, including manufacture, modification, testing, and reclamation of parts. Rework requires extensive diagnostic equipment and industrial-level manufacturing capabilities beyond the capability and resources of O-level and I-level maintenance activities. Rework typically occurs in depot facilities managed by Commander, Naval Air Systems Command (COMNAVAIRSYSCOM) or at original equipment manufacturer (OEM) sites.

The costs to maintain aviation platforms are used in the development of the Program Objective Memorandum to allocate materials and services to the NAMP from the CNO (COMNAVAIRFOR 2022).

3. OM&N Funding

To allocate resources to DOD, DOD adheres to a process called the Planning, Programming, Budgeting, and Execution process among the armed services used to prioritize which programs and force requirements to fund based on strategic objectives. (Congressional Research Service [CRS] 2018). The planning phase is used for the purpose of developing the resource allocation strategy to be implemented by the DOD in the coming years based upon National Security Strategy, Defense Strategy Guidance, and National Military Strategy to develop the Defense Planning Guidance (RAND 2016). During the programming phase of the PPBE, the programming phase consists of developing the list of objectives seeking to be met based upon Department of Defense objectives over a five-year time interval (DAU 2022). As a result of the formation of the programs, each of the DOD components is required to submit a program objective memorandum (POM) and budget estimate. The POM is reviewed and accepted by the Office of the Secretary of Defense (OSD) which leads to the submission of the Budget Estimate shortly thereafter. Both documents are used in support of resource allocation and phased execution of the program budget (DOD 2017). During the execution phase, OSD and the DOD components use the previously approved program funding in comparison to current expenditures to assess whether the program is performing as anticipated (CRS 2022).

In analyzing the different types of funding required by DOD, the DOD receives many appropriations, most of which can be grouped into the five major categories: Research, Development, Test and Evaluation (RDT&E); Procurement; Operation and Maintenance (O&M); Military Personnel (MILPERS); and Military Construction (MILCON) (DAU 2022). Specifically related to Naval Aviation maintenance, the focus is on the allocation of Operation and Maintenance funding. According to the DON’s Operation and Maintenance, Navy FY 2022 President’s Budget, Operation and Maintenance appropriation finances the day-to-day costs of operating naval forces, specifically focusing on the resources required to man, train, and equip the operational forces (DON 2022). Within the budget estimate is a detailed breakdown of all the funding allocations. The estimate provides specific nomenclature for each funding allocation with 1A1A funding Mission and Flight Operations and 1A4N funding Air Systems Support (DON 2022). 1A1A funding is used for the purpose of Navy and Marine Corps forces maintaining a Fully Mission Capable or Mission Capable readiness status in support of national security (DON 2022). Additionally, 1A4N funding provides Air Systems Support funding for engineering and logistics analysis necessary to sustain aircraft systems and equipment. (DON 2022).

In support of the objectives of this thesis, the 1A4N funding source is critical due to the applicability of this V&V effort where the model is used in support of projecting the costs associated with F/A-18 sustainment in the future. This effort is in line with the Department of the Navy’s guidance which specifies Navy programs using operating (i.e., operations and maintenance, Navy) appropriations with projected annual costs of $250 million or more will be justified using accredited models (OPNAV 2022).

4. DOD and DON Modelling and Simulation Directives

For this thesis, it is imperative to draw a clear distinction between the topics of modeling and simulation (M&S). Within this thesis, a model is identified according to the definition outlined by International Council of Systems Engineering (INCOSE) where a model can be a prototype, conceptual abstraction, physical representation, or representation of a process or system (INCOSE 2015). Additionally, the definition outlined by INCOSE for a simulation is defined as: "the implementation of a model (or models) in a specific environment that allows the model's execution (or use) over time. In general, simulations provide a means for analyzing complex dynamic behavior of systems, software, hardware, people, and physical phenomena" (INCOSE 2015).

Using both definitions provided by INCOSE regarding M&S, both topics are explored further in this thesis with NAWCAD's F/A-18 sustainment model being a simulation model. The model is intended to be used to improve NAWCAD's operations by mimicking the behavior of an F/A-18 sustainment system and simulating operations in advance of execution for planning and budgeting (DON 2020).

NAWCAD is one of three commands within NAVAIR. NAWCAD is a command primarily focused on delivering solutions to the operational warfighters in the form of innovation, readiness, and speed to the fleet (NAWCAD 2022). With NAWCAD's focus on innovation and providing solutions to warfighters, NAWCAD uses M&S as a means of producing operationally and technically feasible solutions to warfighters.

According to the DOD, M&S is used for the purpose of aiding process improvement, decision-making, and acquisitions (DOD 2018). The Under Secretary of Defense outlines the appropriate guidance for the use of modelling and simulation among the various departments within the DOD and DOD components as follows: "Each DOD Component shall be the final authority for validation of representations of its forces and capabilities in models, simulations, and associated data, and shall be responsive to other DOD Components to ensure those forces and capabilities are appropriately represented" (DOD 2018).

Using this guidance, the DON generated and drafted the DON's Modeling, Simulation, Verification, and Accreditation Management, which outlines specific processes and procedures applicable to the DON regarding model usage and development. In reference to the DOD's stipulations, the CNO required that all Navy programs operating with projected annual costs of $250 million or more will be justified using accredited models. The models should be used in support of budget formation (OPNAV 2021). In reference to M&S from the DOD, DOD defines a modelling and simulation in the same manner as INCOSE.

In conjunction with the DON's definition of M&S, the DON stipulated that the Navy and Marine Corps are responsible for drafting and implementing instructions in support of service-specific activities. In line with the service specific activities, the CNO drafted the Performance and Pricing Model Policies and Procedures which utilized M&S as a means of justifying budget requests. In the Office of the Chief of Naval Operations (2021) instruction, the instruction is focused upon providing information to stakeholders who are seeking to use models for Planning, Programming, Budgeting, and Execution (PPBE). NAWCAD is responsible for maintaining and providing a justification for budget requests by aligning resource allocation to Tier One Mission readiness which consists of fully mission capable or mission capable platforms.

5. Cost and Readiness Impact Model

NAWCAD created CRIM which is comprised of several models to provide readiness outputs in support of resource allocation identification (NAVAIR 2021).

To develop CRIM, NAWCAD received the assistance of the Institute for Defense Analytics (IDA) and International Business Machines (IBM). Within CRIM, IDA is responsible for the inputs provided to IBM's optimization model. As depicted in Figure 1, CRIM consists of a set of stakeholder derived requirements, the automated degrader tracking system, and a data processing pipeline which interfaces with the automated degrader tracking system (ADTS) to tie stakeholder derived requirements to identify quantifiable outcomes that provide a positive impact on Cost per Flight Hour/Tail, Fully Mission Capable, and Mission Capable aircraft.

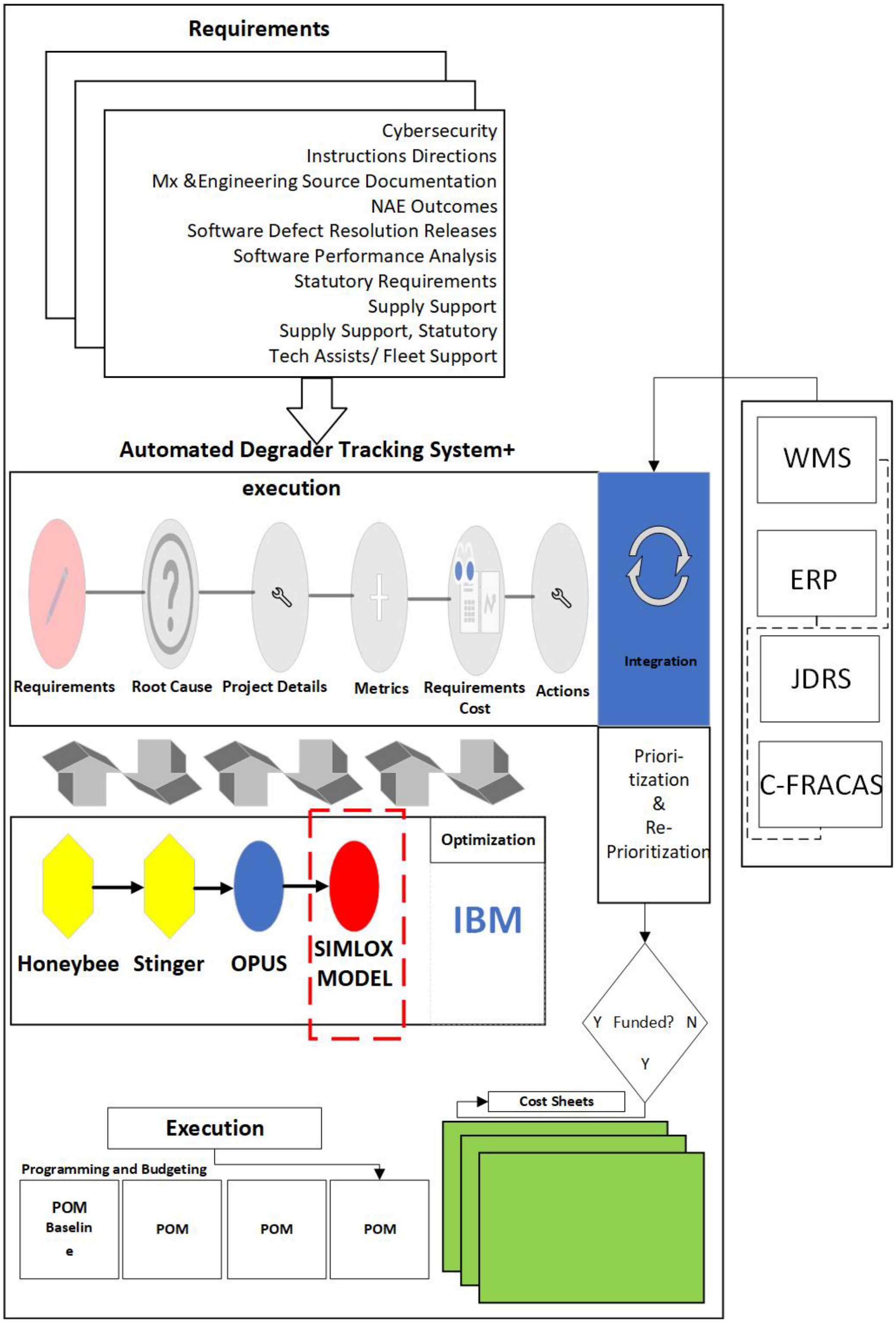

Figure 1. Cost and Readiness Impact Model. Source: NAWCAD (2022).

The ADTS is a web-based requirements capture model where programs enter data elements to capture a degraded system. Within ADTS, a root cause analysis of the system is conducted which is used to develop several different courses of action to address the degraders. From ADTS, the information developed is exported manually via an Excel file to be distributed to the modelling team where the information regarding the degrader is extracted is incorporated into IDA's data processing pipeline to input the data into SIMLOX. From there, SIMLOX produces a set of projections which can be used to decide on resource allocation or incorporated into the IBM decision optimization tool when multiple decisions are required to facilitate a reduction in Cost per Flight Hour/Tail, Fully Mission Capable, or Mission Capable aircraft metrics. If a decision is made to fund the request, the request will be added to a cost sheet to be incorporated into a Program Objective Memorandum. From there, the approved request will be updated into one of the external systems to track the performance of the request. For this thesis, this work will be bound to the data processing pipeline developed by IDA.

6. IDA's Data Processing Pipeline

Honeybee and Stinger are both R-based computer programs used for processing of raw manually entered data which are used by IDA to develop input tables to develop a SIMLOX simulation model. Figure 2 shows the relationship between manual data entry, Honeybee and Stinger, and SIMLOX.

Honeybee is used for the purpose of interpreting raw data generated from Flight Operations, Maintenance, and Supply databases, and generates A/C component metrics tables as an output. Next, Stinger receives inputs from Honeybee and translates them into tables capable of being interpreted by OPUS or SIMLOX. After Stinger translates the tables, the F/A-18 sustainment is implemented in SIMLOX, and upon completion produces a projection of the aircraft's sustainment over a period of time.

Providing further detail of each individual subset of the processing pipeline, Honeybee collects Raw Data from sources such as the Aviation Financial Analyst Tool (AFAST) (DON 2018), sailor-generated parts request entries, and organizational and depot stock levels. Once the data is retrieved from these databases, Honeybee computes the aircraft metrics for each of the individual components associated with the F/A-18. Once data processing in Honeybee is completed, metrics such as the component data, System Configuration Management, Stock levels, and Component deliveries are computed while incorporating station mapping of the associated maintenance repair facilities as well. Once the metrics are computed, each of the tables (discussed later) are produced as Excel .csv files to be loaded into the Stinger database.

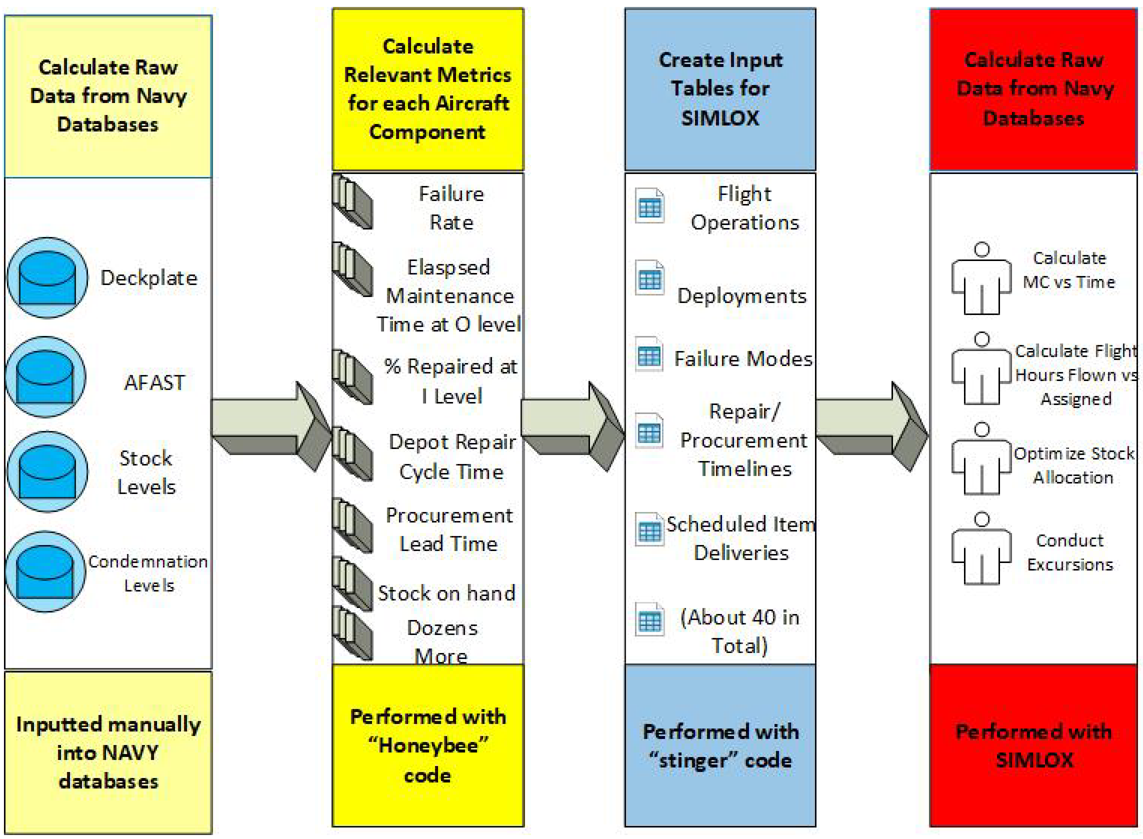

Figure 2. IDA's Data Processing Pipeline. Source: IDA (2022).

Once the .csv files are loaded into Stinger, the files are converted into tables capable of being used by the SIMLOX model. In conjunction with the files received from Honeybee, the individual aircraft units, scheduling data, mission data, and station data are used to create a table capable of being understood by the SIMLOX model. Once Stinger has completed its execution, there are more than forty tables capable of being inputted into SIMLOX with some of the key metrics for this thesis being flight operations, deployments, failure modes, repair timelines, and scheduled item deliveries. Using these output tables, a model abstraction and simulation of an F/A-18 in flight, undergoing maintenance, and sustainment during a given period of time is created.

Using these outputs from Stinger, the tables are used as inputs into the SIMLOX FA-18 sustainment model. SIMLOX is a simulation software tool used for the purpose of simulating and analyzing the performance of technical systems and providing sustainment related impacts to the software user (SYSTECON 2022). Given NAWCAD's intended use is related to Tier One Mission readiness, the outputs from SIMLOX are used in CRIM for decision support by government personnel or inputted into IBM's decision optimization tool in support of improving the Cost per Flight Hour/Tail, Fully Mission Capable, or Mission Capable metrics. Before the model can be used in operation for NAWCAD, NAWCAD is responsible for conducting V&V on its model on at least an annual basis. Within the OPNAV construct, OPNAV N81 holds the responsibility of monitoring the accreditation or re-accreditation of all models being submitted (OPNAV 2022).

B. VERIFICATION AND VALIDATION

V&V can be approached in several different manners dependent on the objective of the model. For the purpose of this thesis, V&V will be conducted on a simulation-based model which requires a different approach than a physical mock-up of a physical system. First, the directives and guidance on the conduct of V&V within the DOD and DON is considered since NAVAIR is a government entity. Next, the works of Sargent, Kleinjnen, and Thomsen are considered since each of these authors presents a unique approach to conducting V&V of simulation models.

1. DOD Verification and Validation

In reference to V&V from the DOD's perspective, the DOD defines Validation as the degree to which the model performs as intended by the user (DOD 2009). Additionally, the DOD defines Verification as the process of determining a model, simulation, and associated data are designed as intended according to technical parameters (DOD 2009). Thirdly, the DOD defines Accreditation as "the official certification that a model or simulation and its associated data are acceptable for use for a specific purpose" (DOD 2009). In providing a framework for the execution of Verification, Validation, and Accreditation (VV&A) within the DOD, the DOD modeling and simulation Verification, Validation, and Accreditation (VV&A) (2009) instruction outlines the procedures for the responsibilities and documentation of VV&A within the DOD. Within the instruction by the under-secretary of defense, the director for research and engineering is designated as the principal entity responsible for generating the appropriate policies, procedures, and documentation practices for VV&A (DOD 2018). Given the guidance on VV&A documentation, the information provided on documentation outlines that the intended use, intended user, and appropriate references should be provided as documentation for the model being used. Using the INCOSE methodology as a means of managing results, this guidance outlines the DOD's methodology for managing the results of V&V considering both the results and the managers responsible for the results (DOD 2018).

In comparison to the DOD's guidance on managing the handling and submission of the VV&A results, the DOD's standard practice instruction is used to establish a consistent standard for planning and reporting VV&A efforts within the DOD. In the DOD, consistent documentation and standardized reporting is critical to maintaining standardization and uniform reporting among the DOD components. Upon completion of the VV&A efforts related to this project, the appendices will be used as a means of reporting the results of the V&V efforts performed within this thesis. Given the fact that a SIMLOX model is being used as a tool for predicting expenditures, research on proven use cases is essential to V&Ving the utility within the DOD.

2. Verification and Validation of Simulation Models by Sargent

In Sargent's (2010) Verification and Validation of Simulation models, the author presented a detailed description and methodology for conducting V&V on simulation models by comparing the phases of simulation model development and the applicable V&V effort associated with the model development phase. First, conceptual model validation is executed by validating the theories or assumptions to ensure the model is capable of being used in a simulation using a special purpose simulation language. Once the conceptual model is developed, the computerized model verification phase of verification is executed, which is centered upon verifying that the theories and assumptions have been translated into the appropriate variables for the study. With a face validation, the problem entity is checked for correctness by ensuring the flow paths within the model are aligned with a graphical representation via the use of subject matter experts (Sargent 2010). Once the computer verification process is completed, operational validation is conducted which is focused on ensuring the model can provide information relative to the study being conducted. During this step of V&V, the first objective is determining whether the system is observable or not observable with observable meaning it is possible to collect data on the operational behavior of the problem entity (SARGENT 2010). Since the F/A-18 sustainment model uses historical F/A-18 maintenance and supply records, the system is observable which allows the validation effort to be approached objectively.

For this study, the system of interest is observable thus the objective approach will be expounded on further. For the objective-observable approach, there are three recommended approaches used in comparing the simulation model output behavior to either the system output behavior or another model output behavior. First, the use of graphs is an acceptable subjective method of comparing output behavior to system behavior. Second, the use of confidence intervals is an objective based approach. Third, the use of hypothesis testing in conjunction with a t-test as the means of rejecting or accepting the null hypothesis is an effective method of comparing the system to the model (SARGENT 2010). For these three different approaches, graphs are the most common means of validating the model due to the statistical assumptions being difficult to verify or an inadequate amount of data available. Within the graphical approach, there are three different types of graphs which are commonly used: histogram, box plot, and scatter plots (Sargent 2010). During the use of Hypothesis testing, Hypothesis testing will be accomplished using a t-test. For this thesis, all three methods are applicable to the study of interest.

3. Verification and Validation of Simulation Models by Kleijnen

In Kleijnen's (1993) Verification and Validation of Simulation Models, the author begins by providing a definition of V&V with the following definition: Verification is the process of determining that a simulation software tool was designed and implemented according to technical parameters (Kleijnen 1993). After the code verification is completed, an analyst may test the distributions provided by the model using a goodness-of-fit test or chi-square test to test the whole distribution of the random variables within the model (Kleijnen 1993). In addition to verifying the distributions, the final simulation outputs are essential for verifying the correctness of the model where a comparison between the final simulation outputs are compared to historical results (Kleijnen 1993). Using the historical data and the outputs from the model, the data can be plotted with time on the horizontal axis and the real and simulated values on the vertical axis (Kleinjnen 1993). After the data has been plotted, the data is observed visually to determine if the depiction is a valid representation of reality. In the event that reality and simulation data correlation have to be validated, the use of a plot with both the real and simulated data on a graph which allows the OLS method to be used where the slope is determined to analyze the fit of the data. In addition, a one-sided hypothesis test is conducted in conjunction with a t-test as the method of conducting hypothesis testing.

In comparison to Sargent's method of conducting operational validation, Kleijnen's work recommends the use of hypothesis testing and a t-test, but Kleijnen's method suggests setting the expected value equal to the simulation output mean. Using this method, the data must be normally and independently distributed which requires independence testing prior to execution.

4. A Trajectory for Validating Computational Emulation Models of Organization

Within A Trajectory for Validating Computational Emulation Models of Organizations, the central focus of the article is validating the utility of emulation simulation models for the purpose of aiding decision-making within organizations (Thomsen et al. 1999). In the article, an emulation-based simulation model is a model which seeks to emulate a particular behavior of the organization which can be macro or micro theories or experiences. With the model being an emulation-based simulation model, the underlying assumptions developed are critical to ensuring the model is as close to reality as possible. With the underlying assumptions accuracy being paramount, the next step in the validation process is validation of representation followed by validation of usefulness (Thomsen et al. 1999).

> Validation of representation is defined as how well the simulation system can capture and simulate the important features being studied. Validation of usefulness is determined by the value of an emulation-based simulation system is in the advice that it can give, and the ability of the simulation to take axiomatic micro-behaviors and generate useful macro-level descriptions to guide organizational design.

With the model being verified as authentic for reasoning and representation, the model is validated for generality by ensuring the model is not overly specific to one situation where the model cannot be used to answer multiple questions. Once the model has been validated for generality, the model will be evaluated for reproducibility where the model is checked for biased input data and maintaining consistent procedures for model development to ensure that when a model is simulated by separate individuals' results will not vary substantially. During the validation of the Reasoning, Representation, and Usefulness of the Computational Organization Model, the model is validated by conducting four different sub-experiments: Retrospective, Gedanken, natural history, and prospective experiments (Thomsen et al. 1999). Each of the different experiments listed will provide different outputs subject to answering different validation questions related to the model. First, a retrospective experiment duplicates past performance, using a simulation model, and calibrates the model as needed to reproduce previous experiences (Thomsen et al. 1999). With the use of a retrospective experiment, the validation effort should be cautioned toward potential data biases since data is being used to replicate a pre-determined outcome. In comparison to the Retrospective method, the Gedanken method is concerned with answering whether the simulation system, Computational Organization theory, and predictions made by managers within the organization are valid. The simulation system is run using the retrospective method and serves as the comparison for the predictions and theory where t-tests are used to compare the results of the simulation system predictions and the manager's predictions.

5. Verification and Validation Approach Summary

Using the works of prominent figures within the field of V&V of Simulation models, each of the different authors outlined the significance of ensuring the model was correctly modelled and implemented as an appropriate verification method. In order to conduct the verification, the use of a flow chart to correlate the data flows within the model is used. In addition, the use of a structured walkthrough with the model design team proves to be useful since the software used to implement the model is special purpose simulation software specifically designed to provide reliability and sustainment projections.

Additionally, each of the authors presented hypothesis testing with t-tests as a means of conducting validation of simulation models. To conduct the hypothesis and t-test of the historical data, the historical data will be used as input to the model and the outputs of the model will be compared to historical data to determine if the projections are accurate. However, the use of a hypothesis and t-test possesses the possibility of committing a type I or type II error which will be accounted for by providing a visual means of comparing the historical and simulated results via a side-by-side comparison in the form of a histogram. Additionally, the historical and simulated data will be plotted on a scatter plot to visually depict the amount of variability between the two sets of data.

II. F/A-18 SUSTAINMENT V&V PLAN

Before beginning V&V of the model, an appropriate V&V plan is developed. The purpose of developing a V&V plan is to ensure the V&V team has a specified and consistent method of conducting V&V to ensure that the actions taken to V&V the model can be documented as evidence for model accreditation. For this thesis, the V&V of the model was conducted in multiple phases with the first phase entailing conceptual model verification. Next, the phase entailed V&V of the analytical model. The last phase consisted of verifying the model was implemented correctly and validating the model can predict the number of expenditures required in the future in relation to tier one mission readiness, as depicted in Table 3.

Table 3. Tier one mission readiness metrics.
Adapted from NAVAIR (2022).

Cost per Flight Hour	Cost per Tail
Fully Mission Capable	Mission Capable

In order to accomplish the V&V efforts for this work, the methodology outlined in Figure 3. Subsequent subsections in this chapter detail the steps of the methodology and actions taken as part of this thesis.

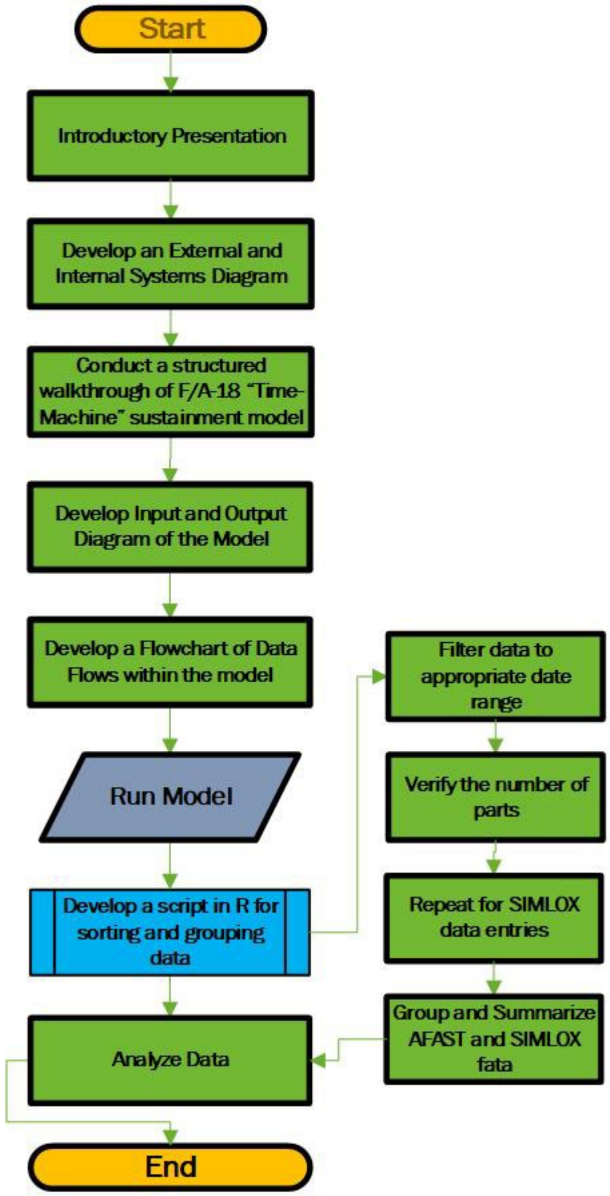

Figure 3. F/A-18 Sustainment Model V&V Plan

A. F/A-18 SUSTAINMENT CONCEPTUAL MODEL V&V

1. Step One: Introductory Presentation

Receive an introductory presentation from the stakeholder on the CRIM Modelling process and the efforts by the modelling team in creating CRIM. The purpose of the in-brief is to allow the Naval Postgraduate School (NPS) Independent Verification and Validation (IV&V) team an opportunity to gain an understanding of the problem seeking to be solved and the efforts accomplished thus far. Upon conclusion of the initial introductory presentation, the NPS IV&V transitioned to bounding and scoping the problem which is accomplished in step two.

2. Step Two: Develop an External and Internal Systems Diagram

Upon completion of the introductory briefing, the development of an external and internal systems diagram capturing all the sub-models within CRIM and the external systems interacting with CRIM was completed. The purpose of the external systems diagram is to make the boundaries between the system and external systems clear (Buede 2009). After identifying all the associated sub-models within CRIM, the problem was bounded in the next two steps.

3. Step Three: Identify Boundaries of F/A-18 Sustainment Model

Once the external systems diagram is developed, the boundaries of the model are identified for the purpose of understanding all the interfaces and interactions within CRIM. The boundaries of the problem are identified based upon the problem to be studied by specifying its limits or boundaries. In addition, everything that remains outside the boundaries of the system is part of the environment (Blanchard and Fabrycky 1981). For this thesis, the V&V efforts are narrowed to the F/A-18 sustainment model which is developed using IDA's data-processing pipeline and implemented in SIMLOX. The boundaries of this thesis are limited to addressing the data flowing into and out of SIMLOX to answer whether the F/A-18 sustainment model can provide sustainment predictions. To V&V IDA's F/A-18 sustainment model, the V&V efforts will be centered on Verifying the correct implementation and predictive nature of the model's ability to predict impacts to Cost per Flight Hour and Cost Per Tail.

B. F/A-18 SUSTAINMENT SIMLOX MODEL V&V

1. Step Four: Conduct Structured Walkthrough

To verify the model, a structured walkthrough of the model is conducted with the modelling team and NPS IV&V team to identify any potential errors since the model was implemented using a using SIMLOX a special purpose simulation language.

2. Step Five: Develop I/O Diagram

After the structured walkthrough, an input and output (I/O) diagram of the model is developed to identify all the data inputted to the model and outputted from the model.

C. F/A-18 SUSTAINMENT MODEL IMPLEMENTATION V&V

1. Step Six: Generate Flowchart

With the input and output data identified, the next step is to generate a Flowchart. The flowchart is developed by the NPS IV&V team to capture data flows within the model.

D. F/A-18 SUSTAINMENT MODEL PREDICTION VALIDATION

1. Step Seven: Receive Historical Data

To verify the predictive nature of the model, historical AFAST requisitions from August 1, 2019, to April 30, 2022, will be provided to the IV&V team as inputs to the F/A-18 sustainment model.

2. Step Eight: Conduct Simulation

The model will use historical data from August 1, 2019, to April 30, 2022, as the input data and the model will run starting on August 1, 2019, with an initial start time of zero and the model will be run for six years consisting of twelve 30-day months. Each month is considered one event and each event is completed a total of 25 replications with the events being averaged over this period. For the model, a random seed for the number generator will be set to: 987654321.

3. Step Nine: Develop Script in R

Develop a script in R to sort and filter the output .csv files from SIMLOX and AFAST cost sheets into columns to compute the total expenditures. To sort and filter the data into columns to compute the total expenditures, several sub-steps were executed to accomplish this feat as follows:

1. First, the data was loaded into R using a read.csv command to load the file into R studio from the working directory.

2. After the data was loaded into the working directory, the data was filtered down to the August 1, 2019, to April 30, 2022, date range leaving on the requisitions to serve as the baseline comparison.
3. After the data was filtered to the appropriate date range, the number of parts were checked which reduced the number of unique items to 496.
4. Next, the process was repeated for the SIMLOX data where the data was reduced to the appropriate date range by changing the SIMLOX values into dates.
5. Once the data was reduced to the appropriate date range and converted into dates, the data was separated into groups and summarized according to the number of demands for each part. This process was repeated for both the historical data and SIMLOX outputs.
6. For this thesis, the historical requisitions did not contain any components repaired locally, but the SIMLOX projections contained items repaired locally which were separated from the components repaired at wholesale due to the associated cost difference per repair.
7. Once both historical and SIMLOX outputs were grouped and summarized, the total number of expenditures was computed by using the number of demands generated at wholesale and the fraction of repairs conducted locally to get the total number of expenditures.

4. Step Ten: Conduct Historical Comparison

Upon completion of the model run, the simulation outputs for the years August 1, 2019, to April 30, 2022, will be compared to the historical number of demands provided for those years with the following equation.

$$Total\ Expenditure = Number\ of\ Demands * (1 - Fraction\ Repaired\ Locally) * Unit\ Cost$$

5. Step Eleven: Conduct t-Test

After generating the expenditures from both sets of data using the total expenditure equation, the hypothesis that the simulation mean and historical mean are equal will be tested.

$$t_{n-1} = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

After determining the t statistic, a level of risk of .05 is used.

6. Step Twelve: Compute Percent Error

To determine the amount of variability within the two data sets, the percent error between AFAST Expenditures and SIMLOX Expenditures will be determined for the model and computed according to cognizance code as well. Afterwards, the data will be plotted to determine the trend and strength of the data.

III. ANALYSIS

A. STEP TWO: DEVELOP AN EXTERNAL AND INTERNAL SYSTEMS DIAGRAM

During the execution of the verification efforts, the first step encompassed understanding all the external models associated with CRIM. To bound the Verification efforts to the F/A-18 sustainment simulation model, the development of an external systems diagram serves the purpose of identifying the external systems interfacing with the F/A-18 sustainment simulation model to identify the inputs and outputs going to and from the F/A-18 sustainment simulation model.

B. STEP THREE: IDENTIFY BOUNDARIES OF F/A-18 SUSTAINMENT MODEL

The development of an external systems diagram led to the development of the Cost and Readiness Impact Model (NAWCAD 2022), which encompasses all the systems which interface with the F/A-18 simulation model as depicted in red dashed lines in the Cost and Readiness Impact model.

C. STEP FIVE: DEVELOP I/O DIAGRAM

After identifying the boundaries within CRIM, the next step entailed Verifying the model was developed and properly implemented. In doing so, the modelers developed the F/A-18 sustainment simulation model by modelling and simulating the: F/A-18 platform, Naval Supply System, Maintenance System, and Operational characteristics of the F/A-18 sustainment system. To facilitate modelling of the sustainment system, the F/A-18 sustainment system was modelled using data from historical Supply Requisitions whereas the Operational data were procured from PMA-265.

According to Megan Gelsinger (email to author, October 26, 2022), the decomposition of the F/A-18 into its associated components was accomplished using DECKPLATE and AFAST to identify requisitions conducted against the platform's Type Equipment Code (TEC) (Naval Supply Systems Command [NAVSUP] 1998) and bill of materials. For model development, only items with a previous requisition are included in the model since the model is focused on F/A-18 sustainment over a period of time. Although there are components on the F/A-18 which have not failed, these components are assumed to be reliable and thus not included in the model based upon the purpose of the model.

After identifying the source of the F/A-18 decomposition, the next step entailed verifying the modelling and appropriate implementation of the intermediate and depot level repair facilities and stock levels. For the intermediate maintenance activity, the intermediate maintenance data was procured using DLA and intermediate activity stock levels at the time of the model run being conducted. In addition, the intermediate level facility locations were identified using DECKPLATE by using the locations of previous submitted requisitions. To verify the depot repairable level activities, the depot level repairable sources were labeled as wholesale in the model. According to Megan Gelsinger (phone call to author, October 26, 2022), the depot level repairable facilities were all labeled as wholesale in the model since the original equipment manufacturer (OEM) is proprietary information. Based upon this finding, the modelers labeled all depot level repair facilities as wholesale for modelling purposes. For the associated F/A-18 component metrics, the metrics inputted into the model were treated as valid inputs due to the associated pre-processing pipeline developing the components metrics and the Verification and Validation efforts are centered on the F/A-18 sustainment Simulation model.

After the structure and component metrics of the F/A-18 were identified, the next portion entailed verifying the operational data inputted into the model was valid. According to Megan Gelsinger (phone call to author, October 26, 2022), the scheduling, deployment, and squadron information were received from PMA-265 which is a program office focused on the F/A-18. Using the F/A-18 scheduling, deployment, and maintenance data, this serves the purpose of simulating aircraft flying and conducting corrective and routine maintenance repairs on the aircraft.

Prior to conducting the structured walkthrough, the model inputs are inputted into SIMLOX in the form Excel .csv file creating the static model used to conduct the simulation. Once the files are loaded in the SIMLOX software, the entities within the model are generated based upon the column and rows of each individual tab within the .csv file.

In the F/A-18 sustainment Model Inputs and Outputs figure (Figure 4), the inputs are depicted which contains the entities within the model. Within the model, all the entities are deterministic except for the "Time Distributions" and "Time Distributions-CM."

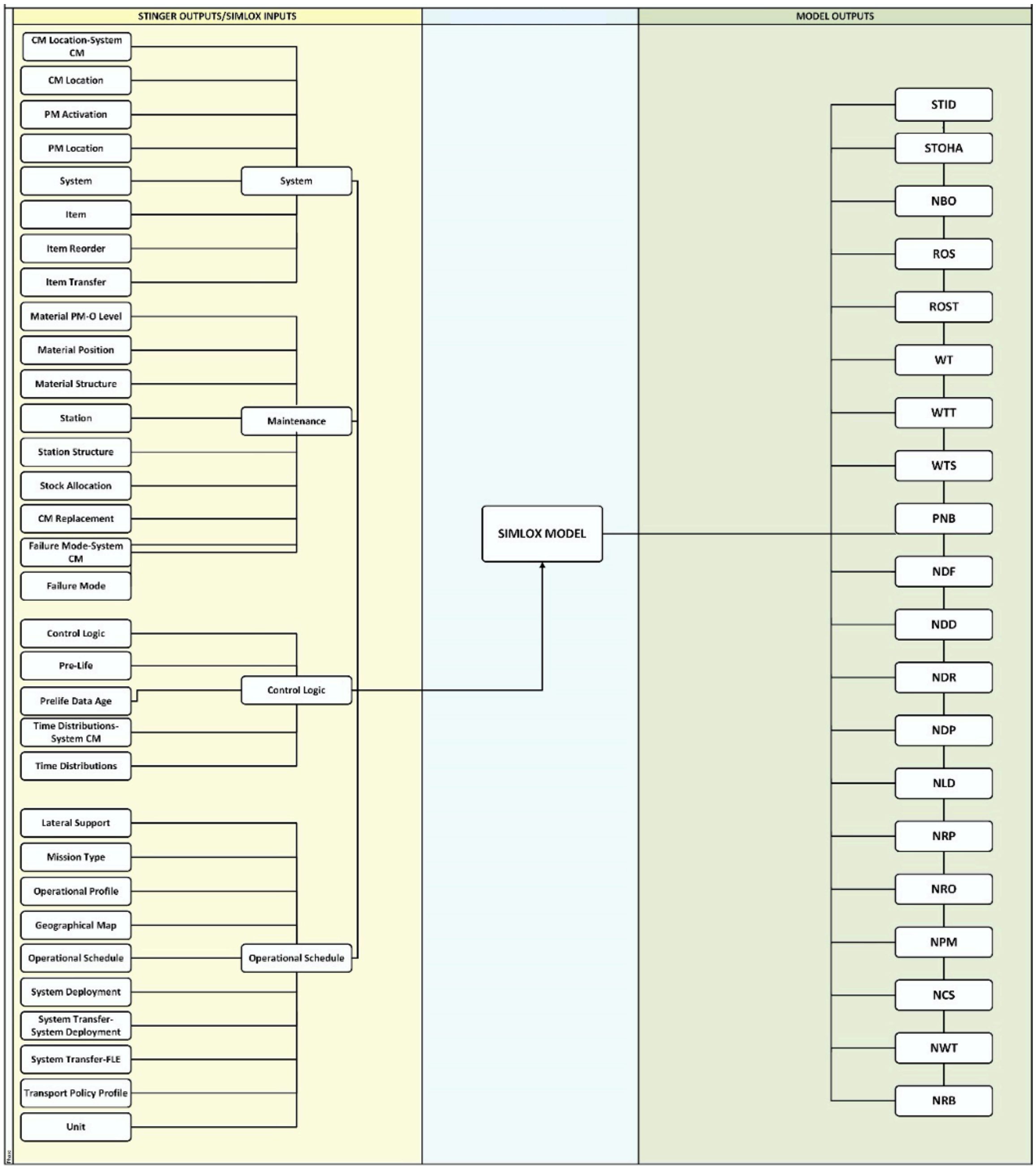

Figure 4. F/A-18 Sustainment Model Inputs and Outputs

In the model, “Time Distributions” and “Time Distributions-CM” are used in two different aspects within the model. In the “Time distribution” entity, the modelers used this entity for the purpose of modelling the procurement lead time or the depot repair cycle time. In the “Time Distribution” entity, the entity contains a column labeled DISTID, BASED, PARAM1, and PFAC. DISTID is a distribution identifier which in this model is the component NIIN (SIMLOX 2022). Additionally, PARAM1 is a mean repair completion or procurement lead time in hours. According to Megan Gelsinger (email to author, October 26, 2022), the mean repair or procurement lead time for each individual component in PARAM1 were developed using historical requisitions from DECKPLATE (I-Level Repairs) or NAVSUP contract data for Depot Level repairs and procurements. After identifying the process for PARAM1, all the procurement lead times (PCLT) were assigned a PFAC of one since there is only one option to select for that component’s replacement. Additionally, the Depot Cycle Repair Times (DCRT) and Procurement Lead Times (PCLT) were modelled using a discretized Weibull distribution with the associated value in Parameter one being the DCRT and PCLT completion or Procurement time at one point in the time distribution. Within the “Time Distribution” and “Time Distributions-CM,” the Discretized Weibull was assigned an associated PFAC based on the probability of that DCRT being selected from the time distribution when that CM event occurs.

In comparison to the “Time Distributions” entity, the “Time Distributions-CM” is used for on-aircraft maintenance events that do not require replacement using the Organization level as the repair entity. These events are included in the model since these events require time and are included in the model as non-critical since it does not generate a requisition. Within the model, the time distribution and time distributions serve the purpose of allowing the simulation to select random PCLT and DCRT throughout the simulation over the six-year duration. Specifically, the item re-order uses the “Time Distribution” PCLT as the procurement time for item re-order. In addition, the CM Location uses the “Time Distribution-CM” as the basis for the associated time of conducting the CM event.

D. STEP SIX: GENERATE FLOWCHART

As a result of the structured walkthrough, the walkthrough and modelling process implemented by the modelling team led to the development of a flowchart (Figure 5), which captures the overall process of the F/A-18 sustainment system. With the development of the flow-chart, the flow chart development adheres to the mandates for V&V in the DON which necessitates the development of model assumptions into a visual diagram (DON 2022).

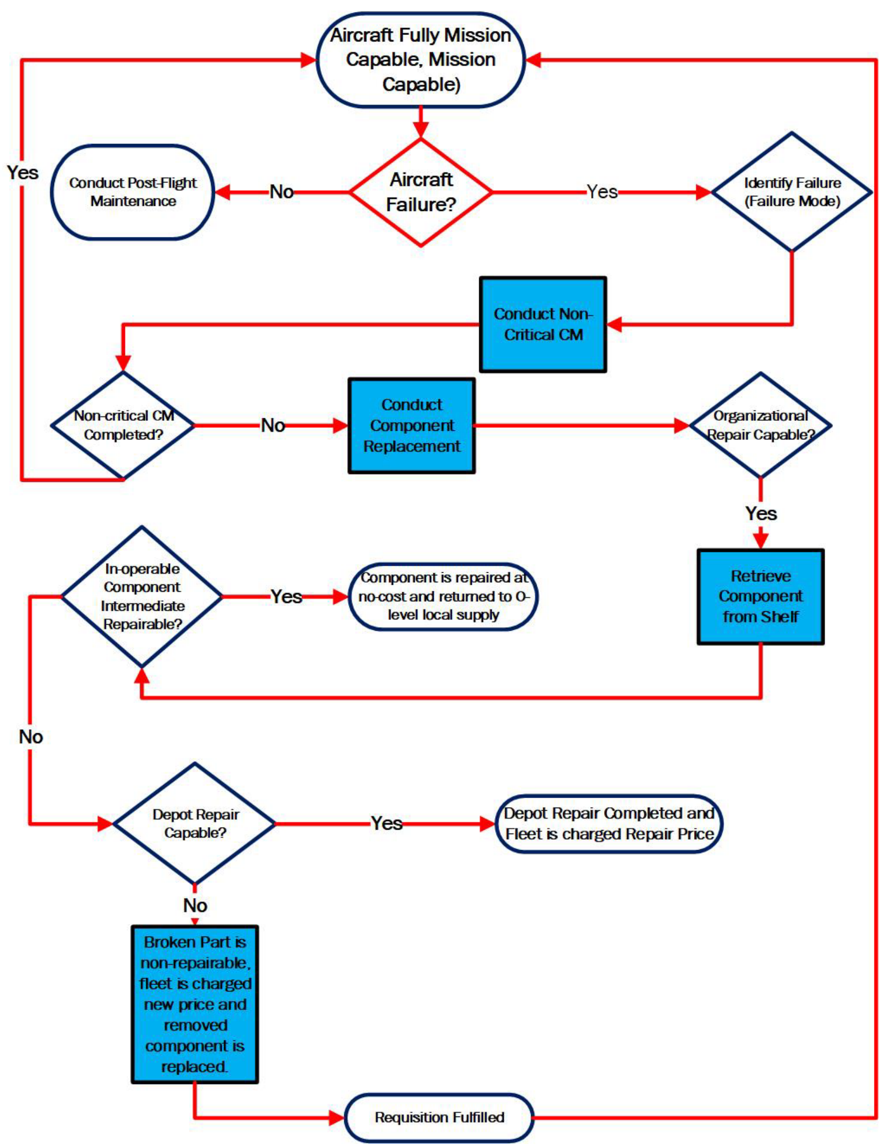

Figure 5. F/A-18 Sustainment Flowchart

Within the F/A-18 sustainment Flowchart, this figure depicts the high-level process of the F/A-18 sustainment process occurring within the model. First, the process begins with the aircraft beginning in an operational status with a failure occurring. Once the failure occurs, the failure will be corrected using either a maintenance procedure or an associated failure mode from the failure mode entity within the model will be selected. Based upon the associated failure mode, the failure mode will require maintenance or a component replacement. In the event a component is replaced, the component will be retrieved from the organizational level supply system. Once the item is removed from the local supply, the component will be transferred to an intermediate repair facility. In the event the component can be repaired by the Intermediate Facility, the component will be returned to the Organizational level supply system at no charge, but if the component cannot be repaired then the component will be elevated to a depot level repair. In the event the component cannot be repaired at the depot repair facility, the component will be discarded, and the supply system will be charged the new component price, but if the component can be repaired at the depot repair facility, then the supply system will be charged the component repair cost.

E. STEP EIGHT: CONDUCT SIMULATION AND STEP NINE: DEVELOP SCRIPT IN R

After verifying the model's implementation, the next portion of the effort entailed running the model to generate projected data to serve as a comparison to the AFAST historical data. Once the model run was completed, the historical data and projected data was grouped using R studio. Using R studio, the data was grouped and summarized according to the number of total and wholesale demands generated in the Appendix.

F. STEP TEN: CONDUCT HISTORICAL COMPARISON

After determining the number of total demands for the historical data, the next step entailed determining the average price for each individual NIINHOF. Using the average price, the expenditure was able to be calculated by the multiplying the total number of wholesale demands by the average price to determine the total number of expenditures for each individual NIINHOF. Once the total expenditure was determined for each individual

NIINHOF, the next step entailed determining the number of expenditures for the projected expenditures. According to Megan Gelsinger (phone call December 1, 2022), the average price for the uniqueNames within the F/A-18 sustainment model were determined using Derivation of Resource Price Database Planning which provides the current price of each individual component within the F/A-18 sustainment Model.

Using the same method executed for the historical data, the number of total and wholesale demands were determined within the model. Within the model, the differentiation between total and wholesale demands required a different pricing methodology. To determine the number of expenditures within the model, the number of wholesale demands was determined using equation one. Using equation one, the total number of expenditures was determined by multiplying NIINHOFs with a cognizance of 1R by the new price of an item and a component with a COG of 7R was multiplied by the repair or new price if the component could be salvaged and returned to the Navy Supply system.

G. STEP ELEVEN: CONDUCT T-TEST

As a result of the grouping and summarizing, the baseline comparison between the historical data and projected data yielded 347 NIINHOFs to compare the number of historical and projected expenditures. Using both expenditures, the next step entailed conducting a t-test in Excel. First, the determination between the appropriate t-test was determined which entailed determining whether a paired t-test could be conducted. As a result of this consideration, the paired t-test was not a feasible selection since the two sets of data were not conducted on the same independent variable. After determining the sample means pair t-test was not feasible, the next step entailed determining whether the two samples contained equal variances. As a result of this consideration, neither of the two sets of data contained equal variances which led to the selection of a t-test with un-equal variances in Table 4.

Table 4. AFAST and SIMLOX t-Test assuming Unequal Variance

t-Test: Two-Sample Assuming Unequal Variances	AFAST Expenditure	SIMLOX Expenditure
Mean	$4, 192, 011.674	$3, 416, 887.413
Variance	$244, 141, 459, 833, 006.00	$ 83, 450, 107, 240, 887.10
Observations	347	347
Hypothesized Mean Difference	0	
df	558	
t Stat	0.798	
P(T<=t) one-tail	0.213	
t Critical one-tail	1.648	
P(T<=t) two-tail	0.425	
t Critical two-tail	1.964	

After conducting the t-test, the null hypothesis assumed that both samples would be equal. As a result of the t-test, the null hypothesis specifies that the t-test is greater than or less than the one-tail or two critical factors. The t-test statistic does not exceed either of these two values which leads to the rejection of the null hypothesis in favor of the alternative hypothesis which states the AFAST and SIMLOX expenditures are not the same.

H. STEP TWELVE: COMPUTE PERCENT ERROR

As a result of this, the next step entailed determining the percentage error between the AFAST historical expenditures and the SIMLOX projected expenditures.

Within Figure 6, the percent difference from AFAST Baseline was created using a semi-log plot which consisted of the Y-axis being a log plot since the price difference was a variable of interest for the study and the specific component number was not of statistical significance. Using Figure 6 as a baseline, the price difference between the AFAST and SIMLOX expenditures yielded the determination that the price difference between the two sets of data was not linear and trending in a negative direction. In addition, the data was not densely populated which indicated that the data was not highly correlated. Of the 347 NIINHOFs, 306 of the 347 were deemed to have a percent difference of less than 100% of the historical baseline.

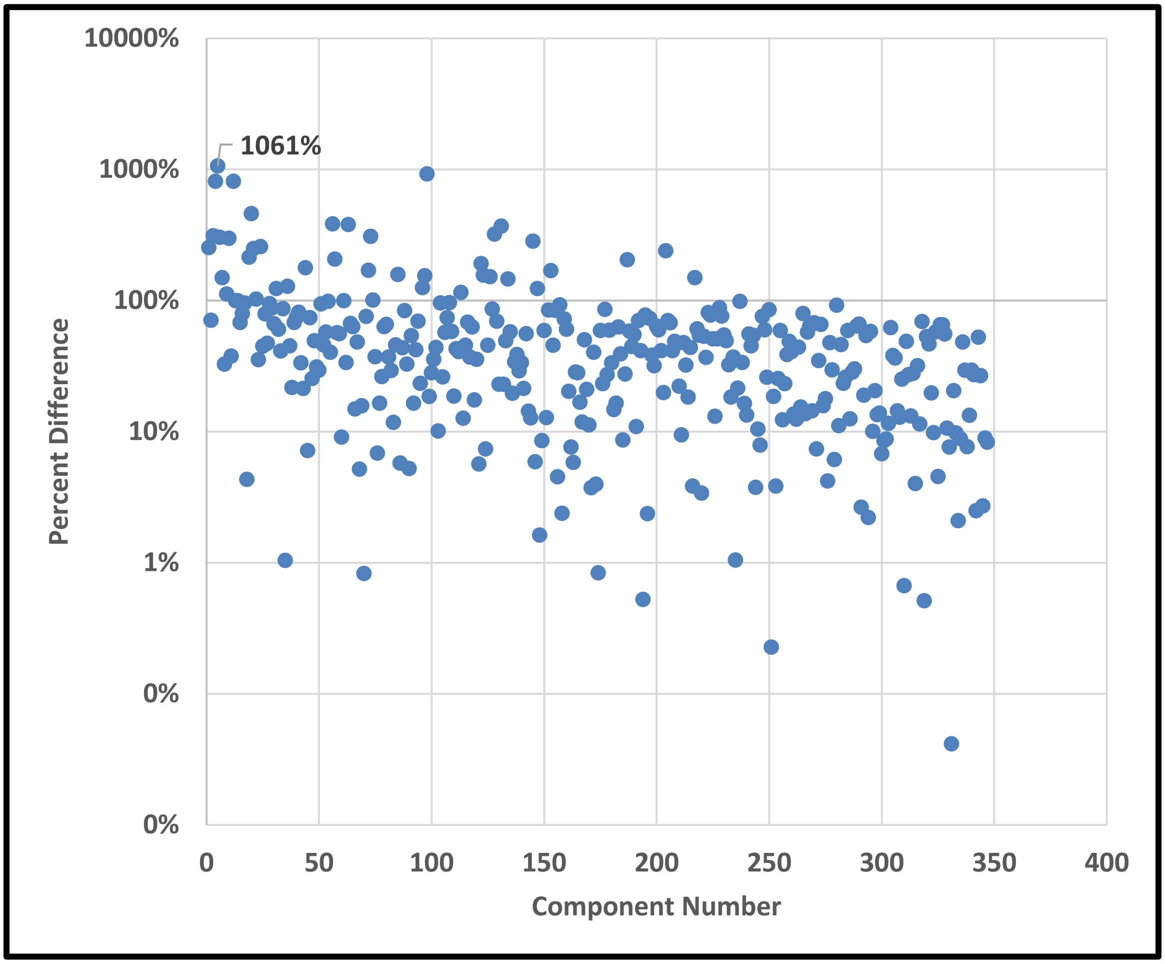

Figure 6. Percent Difference from AFAST Baseline

After identifying a significant outlier of 1061 percent, this significant outlier led to further exploration. Between the AFAST and SIMLOX number of wholesale demands for this data point, the historical number of AFAST wholesale demands was one and the number of SIMLOX demands was twelve. With the significant difference between the number of demands, the next step entailed determining the price difference between the two sets of data which yielded a price increase of 367 for the current price of the component in relation to the historical price of the component. As a result of the variability within the percent difference, this finding led to the decision to graph the number of expenditures and the number of wholesale demands to determine whether there is a relationship between the number of expenditures and total demands (Figure 7).

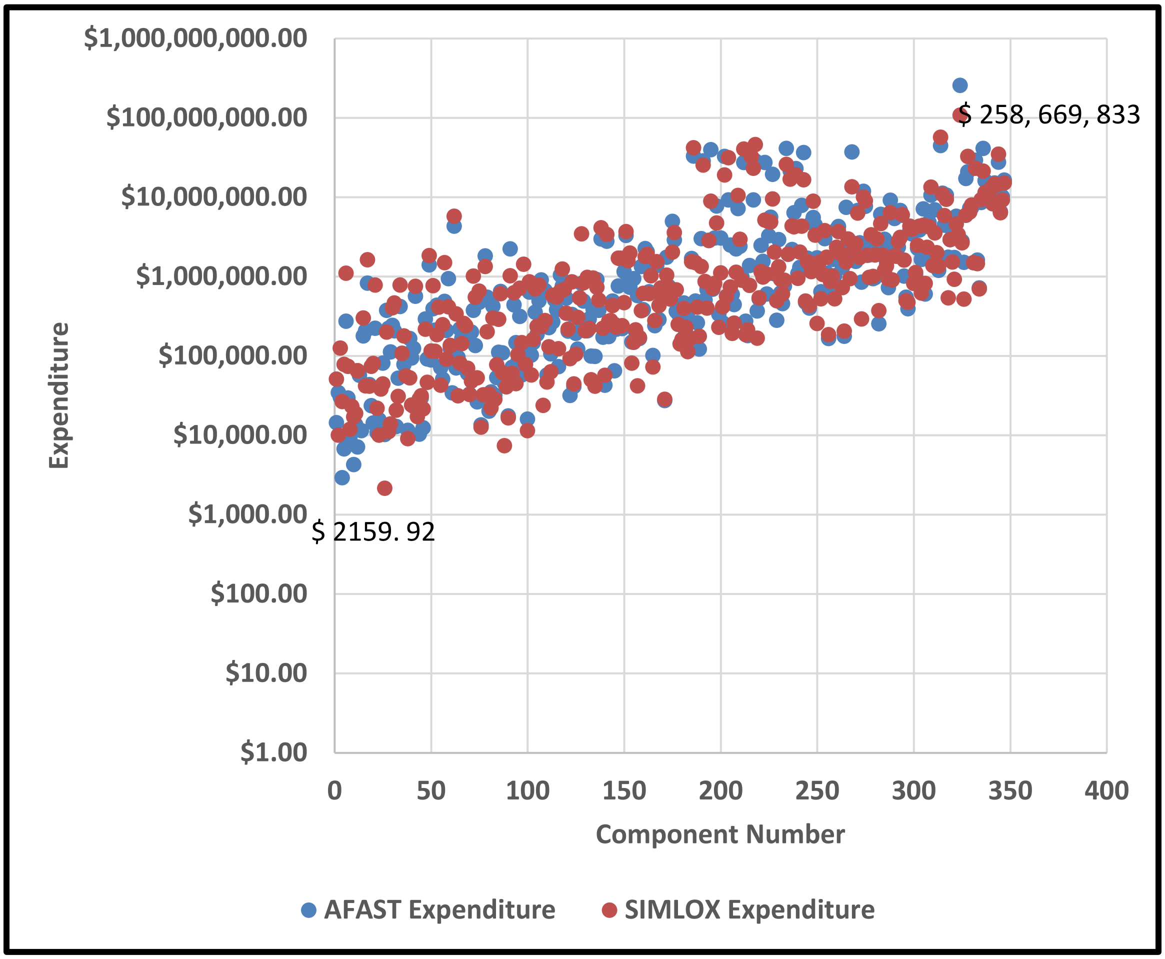

Figure 7. AFAST and SIMLOX Total Expenditures and Demands

Using a log normal plot, the number of expenditures and wholesale demands were grouped to ascertain the effect the number of demands had upon the number of expenditures. After grouping the number of AFAST and SIMLOX expenditures and wholesale demands, Figure 7 indicates an upward trend between the number expenditures and demands. With the graph showing a positive trend, the data indicates that as the number of demands increases then the number of expenditures increases which is expected since the number of expenditures is determined based on the price of the component and number of wholesale demands. Additionally, the data in figures 6 and 7 shows an increase in strength in the grouping of AFAST and SIMLOX expenditures and number of wholesale demands as the percent difference decreases. With the data showing an increase in strength, the significant outliers captured in the graph were further examined to determine the cause of the outliers within the model.

Within Figure 7, the historical expenditure of $258, 669, 833 is a significant outlier in relation to the predicted expenditure of $108, 915, 352.10, which led to an examination of the number of wholesale demands and expenditures in relation to the predicted number of wholesale demands and expenditures. As shown in the Appendix, component 325's AFAST number of wholesale demands was 271, whereas the projected number of wholesale demands was 261. Given the slight difference between the historical and predicted number of wholesale demands within the model, the next step entailed determining the appropriate price difference between the AFAST and SIMLOX price of the item with the AFAST price costing $954, 501.23 and the AFAST price of $764, 211. With both a decrease in the price and number of wholesale demands, the disparity between the number of expenditures and predicted expenditures is based upon this relationship.

With the data showing a positive upward trend as the number of expenditures and demands increased, this observation led to the examination of the number of AFAST and SIMLOX expenditures grouped according to the appropriate cognizance code, as shown in Table 5.

Table 5. NAVSUP Cognizance Code Description. Adapted from NAVSUP (1998).

COG	Description
1R	NAVSUP managed, aviation consumable
7R	NAVSUP managed, aviation depot-level repairable

For components containing a 1R cognizance, the component's expenditure was determined using the associated new price since the component was required to be replaced vice repaired. As a result of the grouping according to the cognizance, the examination entailed determining the strength of the correlation between the number of demands and expenditures in conjunction with the percent difference between the AFAST and SIMLOX expenditures. In Figure 8, the percent difference between the AFAST historical baseline and projected expenditures is captured.

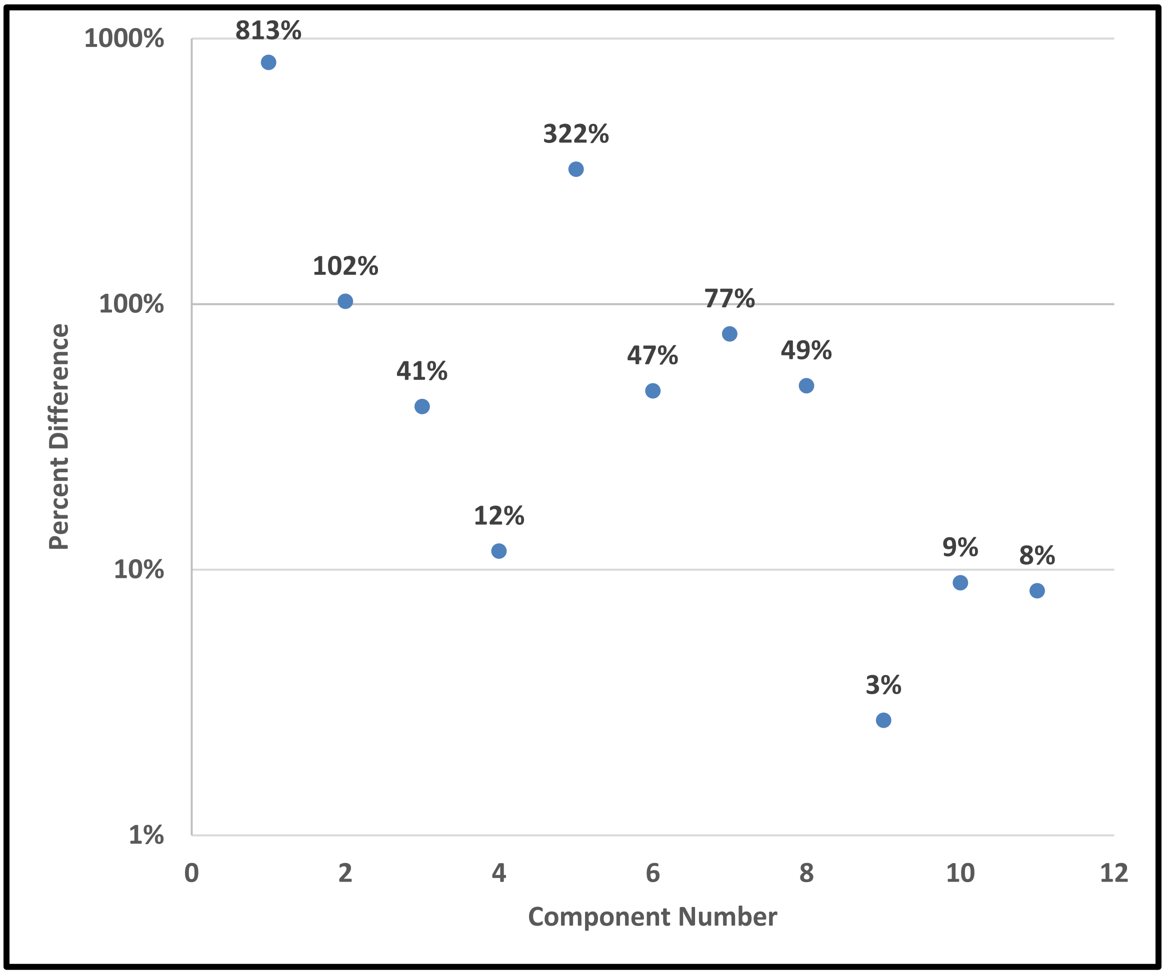

Figure 8. Percent Difference from AFAST 1R Components Baseline

Using a semi-log plot, the relationship between AFAST and projected baseline is explored where the graph has two significant outliers in relation to the remaining sets of data. Additionally, Figure 8 shows a steady decrease in the price difference as depicted in Figure 8 which showed a percent difference as the number of demands increased as well. To examine the 813% difference between component 15, the number of demands is explored and the associated price to determine if a trend continues between the disparity between the number of expenditures and wholesale demands. For component 15, the historical price was $7,179 and the number of wholesale demands was one in comparison to the number of projected wholesale demands of nine and a current price of $7,697 which is a difference of 518 between the historical price and current price. With an increase in the number of demands and an increase in price, the percent difference disparity is plausible based upon that disparity. As a result of the observed significant outlier, the next step entailed examining whether an upward trend and an increase in strength exists between the number of expenditures and total demands within 1R components.

Using a log normal plot, the relationship between the number of historical expenditures and demands was explored. Among 1R components, there exists a considerable increase in strength as the number of expenditures and demands increased. Additionally, Figure 9 displays an expected upward trend in the number of expenditures and number of demands as well. In the graph, the variability among the components containing a smaller number of demands was attributed to the disparity between the number of AFAST wholesale demands and the number of projected wholesale demands. Within the graph, seven out of the twelve components were over projected in comparison to the AFAST number of wholesale demands which led to the disparity between the number of AFAST and SIMLOX expenditures with the model showing a decrease in the amount of variability as the number of demands increased.

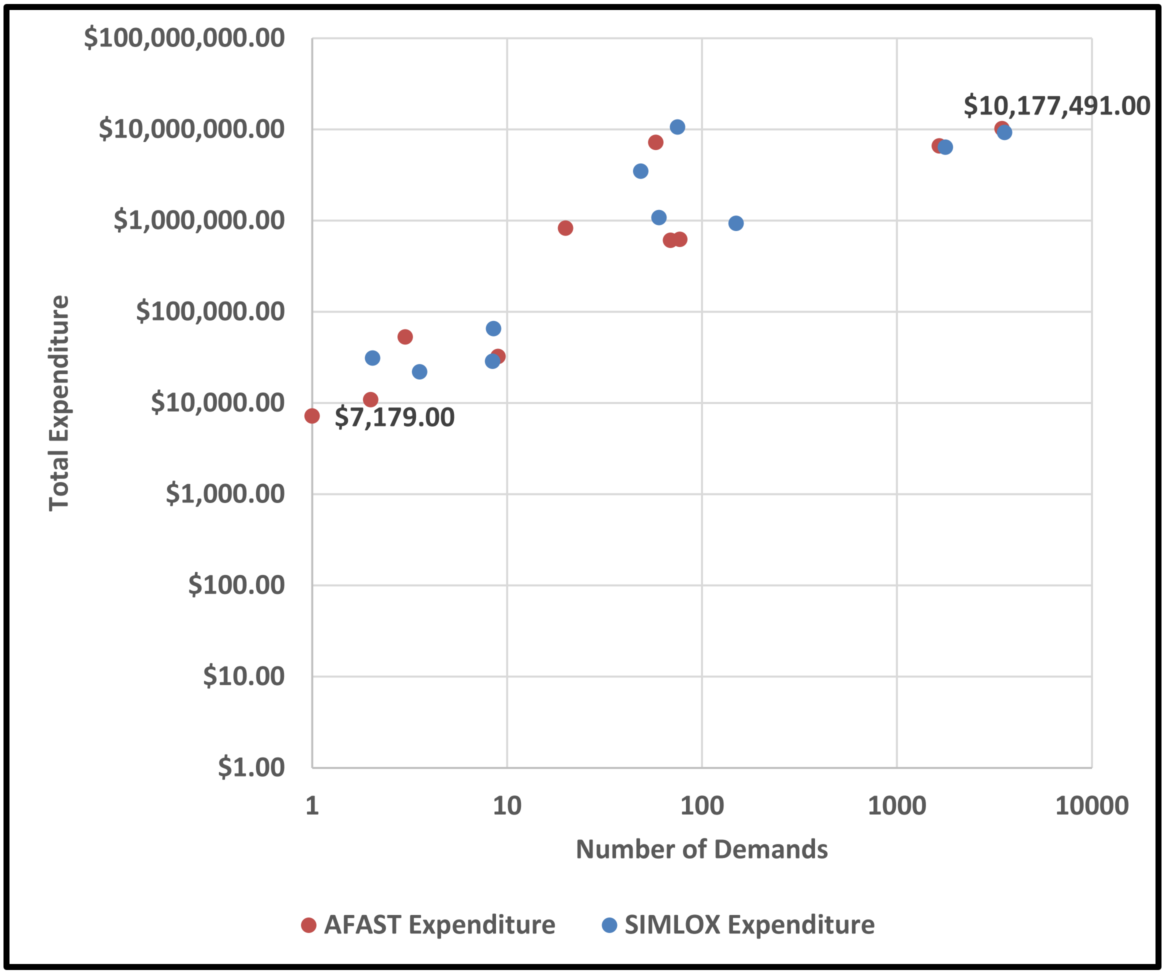

Figure 9. AFAST and SIMLOX 1R Total Demands and Expenditures

As a result of the observations within the 1R components, the next step entailed examining the relationship among 7R components according to low, medium, and high demands to examine whether the trend of number of expenditures and wholesale demands continues to increase and the percent difference from AFAST and SIMLOX expenditures continues to decrease with an increase in number of demands. In addition, the 7R components data set differs from the 1R components due to the 7R components containing 335 entries vice twelve 1R components resulting in a greater set of data to explore.

Within the range of samples of low demands, the amount of variability among the 115 samples is non-linear and shows a decreasing percent difference as the number of demands increases which is consistent with the previous observations throughout the study thus far. Within the low demand group of 7R components of Figure 10, the sample set of AFAST wholesale demands ranged from one to 16 with an associated component price range of $1,237.86 to $723,515. In comparison, the number of projected wholesale demands ranged from zero to 92 with an associated price range of $765 as the lowest component cost and the highest component cost of $924,413. With the max number of historical demands being 16 and the maximum number of SIMLOX predicted wholesale demands being 92, the model overpredicts the number of wholesale demands on average by as much as 126%. As a result of the over projection between the number of wholesale demands and disparity between average component cost, the next step entailed determining whether a relationship exists between the number of expenditures and number of demands as depicted in Figure 11.

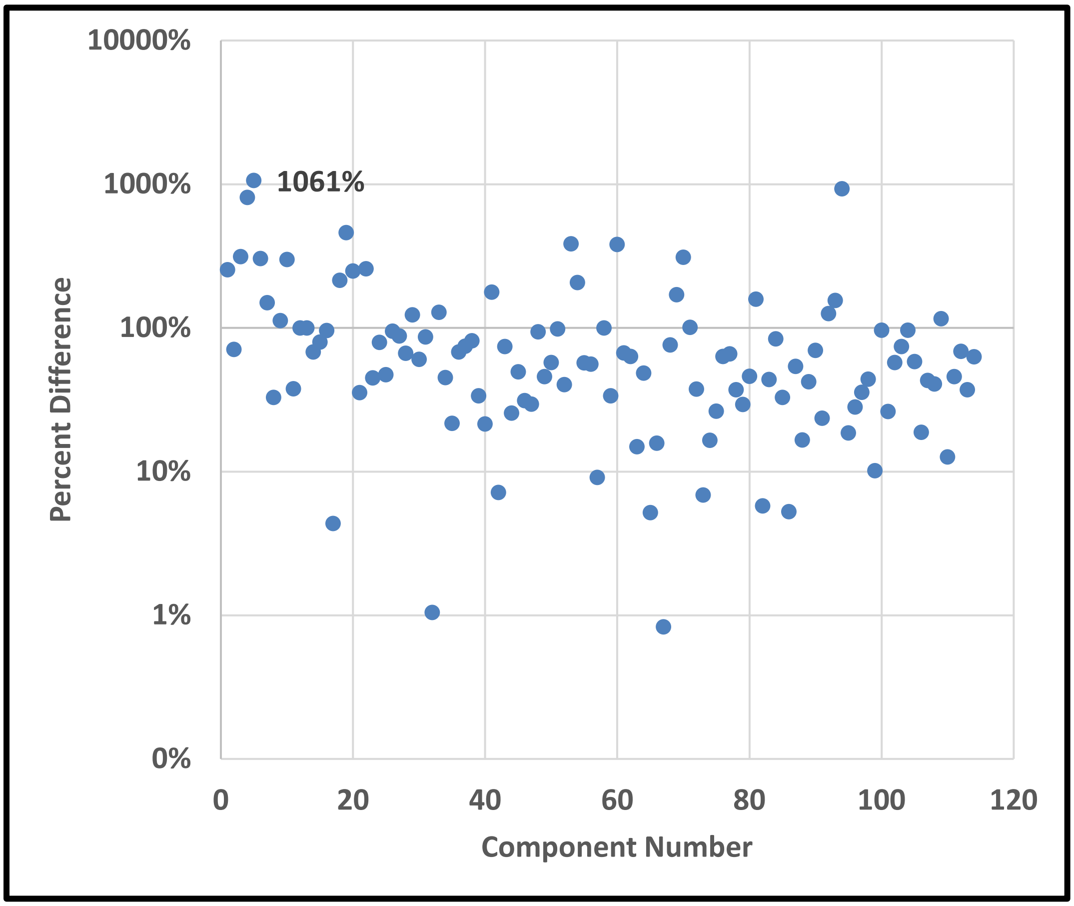

Figure 10. Percent Error from AFAST 7R Low Demand Components Baseline

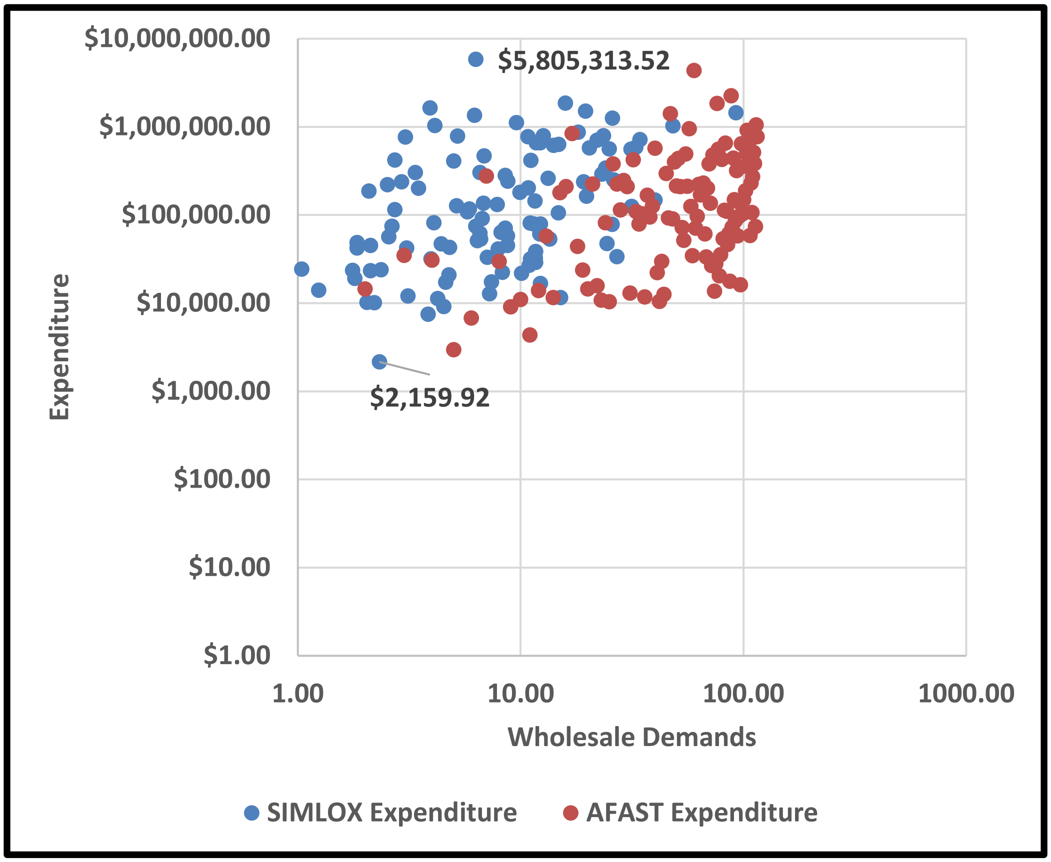

Figure 11. AFAST and SIMLOX 7R Low Demands and Expenditures

Within Figure 11, the graph shows a large concentration of historical and projected data within the middle the graphic and a substantial number of outliers within the SIMLOX Wholesale total demands which is directly attributed to the model over projecting the number of wholesale demands in relation to the number of historical demands. In addition, the number of expenditures and wholesale demands trends in an upward direction, but the number of expenditures is largely concentrated in one portion of the graph due to the associated range of the historical demands whereas the projected number of demands has more variability due to over-projection by the model. After identifying the strength of the data being largely concentrated in one area, the next step was to determine the impact that the associated range of the total number of wholesale demands in relation to the number of projected wholesales had upon the total number of AFAST Wholesale expenditures in comparison to the SIMLOX Wholesale expenditures. With the historical number of expenditures resulting in $32,025,075.04 and the number of SIMLOX projected expenditures being $38,024,905.50, the projected number of expenditures exceeded the historical number of expenditures by $5,999,830.46. Within the model, the model's number of expenditures exceeding the historical number of expenditures is attributed to the average component price of and the Using the data discovered in the low demand 7R components, the next step entailed examining the percent difference and number of expenditures for AFAST and SIMLOX medium demand 7R components.

In comparison to the number of low demands 7R components, Figure 12 indicates a substantial decrease in the percent difference from the historical AFAST baseline and the predicted number of expenditures for medium demands 7R components. In addition, the set of data is non-linear, but a steady decrease in percent difference with the set of data containing only eleven samples of the 115 containing percent differences greater than 100% in comparison to the low demands set of samples, which contained twenty three of the 115 samples exceeding a percent difference of greater than 100%. Within the medium group of 7R components, the sample set of AFAST wholesale demands ranged from 16 to 78 with a component price range of $743.51 to $815,919.75. In comparison, the number of projected wholesale demands ranged from zero to 244 with an associated component price range of $720 to $788,881. Similar to the low demands 7R components, the model overpredicts the number of wholesale demands by a percentage of 52% which is a 74% decrease in comparison to the number of wholesale 7R low demands. With the percentage difference decreasing between the AFAST and SIMLOX expenditures, the next step entailed determining whether the correlation between the AFAST and SIMLOX expenditures increases, and the variability decreases since the percent difference has decreased.

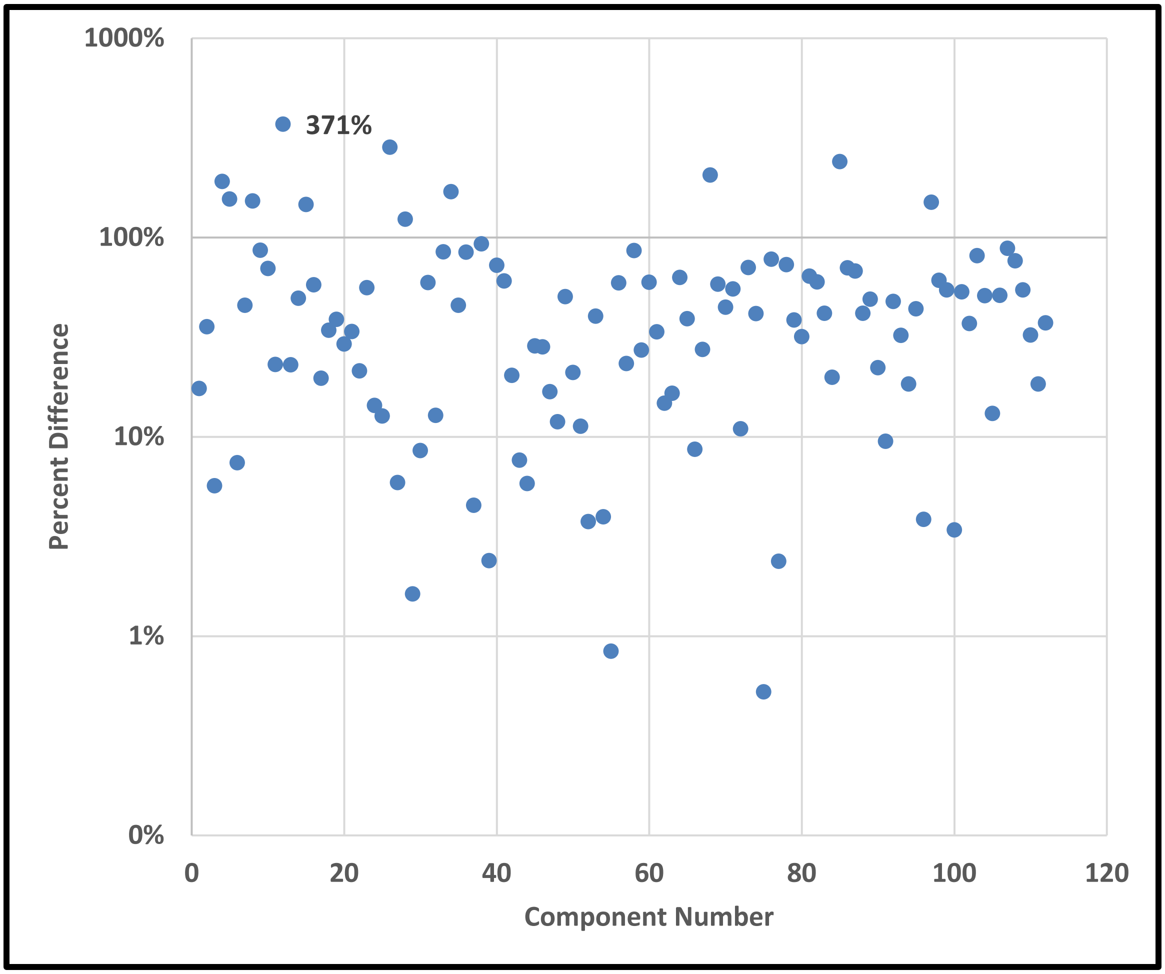

Figure 12. Percent Error from AFAST 7R Medium Demands Components

In comparison to Figure 11, the data is primarily grouped in the center of the graph which is due to the number of demands in the range of 16 to 78. The strength of the data has increased which is expected based upon the marginal decrease in the percent difference between the sets of data. Additionally, the outliers contained within the graph are all projected SIMLOX wholesale demands which is expected due to the SIMLOX Wholesale demands range starting at zero and extending up to 244. With the number of wholesale demands increasing, the graph indicates that an increase in the number of wholesale demands will attribute to an increase in the strength of the data and an upward trend in the number of expenditures as well.

With the historical number of expenditures resulting in $434,255,685 and the number of SIMLOX projected expenditures being $404,142,304.90, the projected number of SIMLOX expenditures in Figure 13 was under projected in comparison to the historical number of expenditures by $30,113,380.08. With the substantial decrease in AFAST and SIMLOX expenditures, the next step was to determine the average component price to ascertain whether a difference in price could lead to an explanation for the substantial decrease in the number of expenditures. For AFAST and SIMLOX components, the average AFAST component price was $74,426.40 and the average SIMLOX component price of $64,825.33.

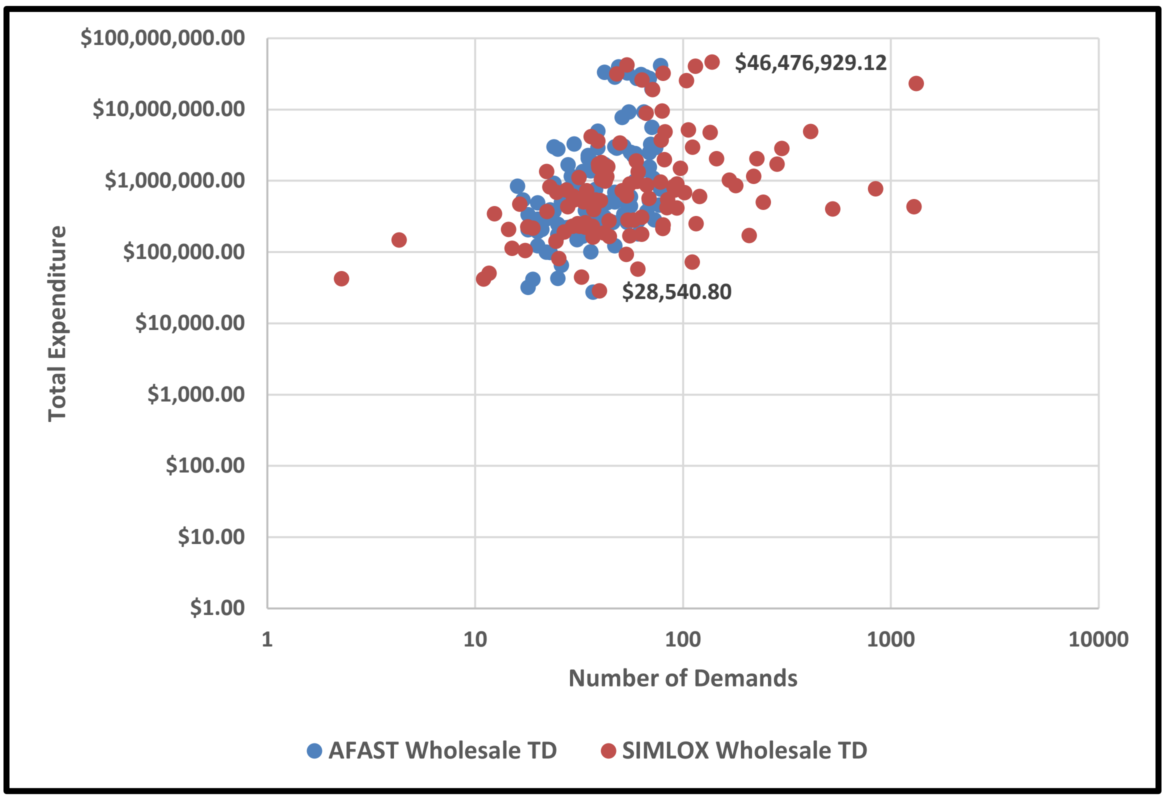

Figure 13. AFAST and SIMLOX 7R Medium Demands and Expenditures

As a result of the low and medium demands indicating an upward trend in the number of expenditures and an increase in strength and the number of demands increasing, the next step entailed determining whether that continues with the high demand 7R components.

Within Figure 14, the percentage error has decreased significantly in comparison to the low and medium demand 7R components with percent errors as high as 1061% in low demand and 371% in medium demand 7R components. With the percent error between the high components not exceeding 100% in the given set of samples, the graph indicates a greater concentration of data points within the 100% and 10% range of values which is expected due to the number of demands increasing. With the increase in number of demands, the data indicates a slight downward trend within the graph. Within the high demand group of 7R components, the sample set of AFAST wholesale demands ranged from 79 to 832 with a component price range of $1,555.01 to $954,501.22. In the sample set of SIMLOX wholesale demands, the sample set of data ranged from 17 to 1485 with a component price range of $1,268 to $764,211. In comparison to both the low and medium 7R demands, the high demand 7R component model overpredicted the number of wholesale demands by 28 percent which is 24% lower than the medium demands grouping and 98% decrease from the low demands grouping. As a result of the percent error decrease, the next step entailed determining whether there is an appropriate increase in strength and positive trend in the data as well.

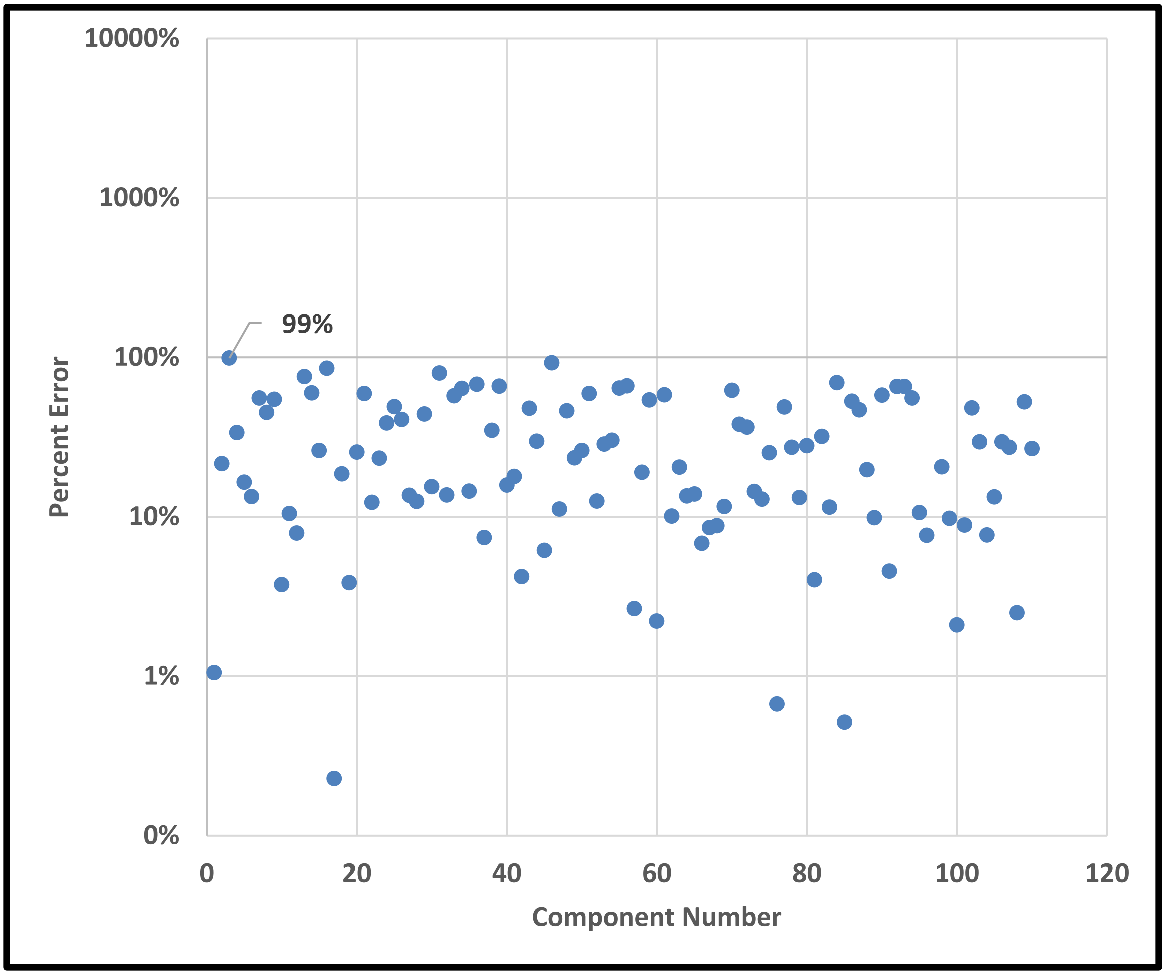

Figure 14. Percent Error from AFAST 7R High Demands Components

With the historical number of expenditures resulting in $945,682,267 and the number of SIMLOX projected expenditures being $696,418,303, the projected number of SIMLOX expenditures in Figure 15 was under projected in comparison to the historical number of expenditures by $249,263,964. With the significant disparity in the number of predicted expenditures, the next step entailed examining the effect that the average component price has upon the projection of expenditures. Within the sample set, the average component price of AFAST expenditures was $44,412.85 and the SIMLOX Expenditures average component price was $36,629.22. With a significant difference in the average price per component, the next plausible conclusion for the increase in expenditure can be attributed to the average number of historical wholesale demands being

221 and the average number of wholesale SIMLOX demands being 241.29, but the average component price is significantly for the AFAST components.

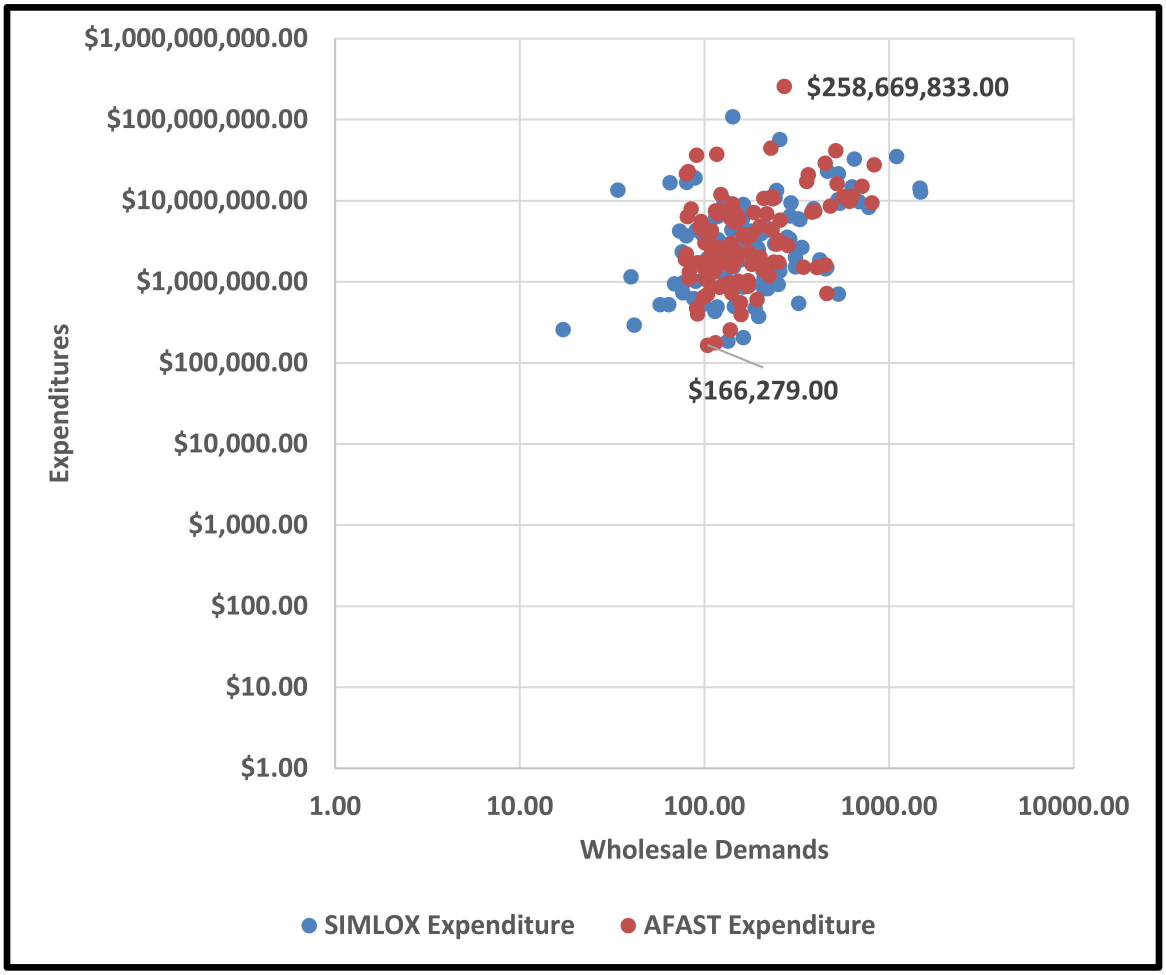

Figure 15. AFAST and SIMLOX 7R High Demands and Expenditures

In comparison to the low and medium demands, the strength of the correlation is the highest with the high demands set of data. This observation is expected due to the higher number of demands having a lower percent difference and a greater number of demands to decrease the variability within the data set.

IV. FINDINGS

A. CONCLUSION

For this thesis, the objective was to conduct V&V of the F/A-18 sustainment model to ascertain whether the model can predict expenditures on spare parts inventory for the F/A-18. Given this objective, the guidelines outlined in the Office of the Chief of Naval Operations Performance and Pricing Model Policies and Procedures helped to inform and the structure the methodology for executing this work.

Beginning with the initial introduction to the model, the requirements outlining the development and formation of the model were not provided as a baseline to conduct the Verification of the model. Given the lack of a conceptual model of the simulation, the structured walkthrough served as a means of developing a model description and background of the model. Using the background information and information from the model development team, this information led to the development of a conceptual model consisting of the model inputs and outputs while treating the SIMLOX software as a black box. With the SIMLOX software functioning as a black box, the next step of the model verification entailed creating a flowchart of the data flows within the model to serve as a conceptual representation of the model's data flow. With the inputs and outputs identified, this led to the examination of the model outputs and their intended use which readily became apparent that the number of demands due to failure within the model can be used to predict the number of expenditures required in the future. With the ability to predict the number of failures in the future, this measurement is directly capable of informing mission readiness by projecting Fully Mission Capable or Mission Capable and the associated costs to achieve peak readiness.

Using the number of demands due to failure (NDF) in the F/A-18 Sustainment model in Figure f4, the number of expenditures for both the AFAST and SIMLOX V&V efforts were not stipulated by the stakeholder which led to the implementation of a t-test to make the determination. Given this circumstance, the use of the t-test assuming un-equal variances and percent error from the AFAST historical expenditures and wholesale demands were used as validation findings. The F/A-18 sustainment model sought to predict the number of expenditures with a confidence level of 95%, but the model failed to achieve this with a p-value of 0.42 which led to a further examination of the data. With the model failing the t-test, the subsequent steps involved determining the percent error and graphically representing the data to make a subjective determination of whether the data is a good representation of the historical baseline.

In Table 6, the F/A-18 sustainment model consistently over-estimates the number of parts needed compared to actuals in AFAST. Additionally, the average price for 7R components was higher for the AFAST Average Price in comparison to the SIMLOX Average Price which was attributed to the number of projected total demands in relation to the number of wholesale demands. The price of an item is highly contingent upon the source selection for the price comparisons. For the AFAST price information, AFAST is the governing source whereas the SIMLOX projected prices are identified and selected from the Derivation of Resource Price Database Planning or AFAST if component price information is not available in the database.

In conclusion, the model does not perform as intended. With the model overpredicting the number of demands, this leads to an inaccurate depiction of the number of components required to maintain fully mission capable or mission capable. In addition, the model's predicted expenditures are $268,968,118.50 under the historical AFAST expenditures which does not contribute to an improvement in NAVAIR's tier one mission readiness metrics. On average, the model under-predicts the number of expenditures by a percent error of 66% error and the number of demands by 70%.

Table 6. Verification and Validation Findings

Demand Category	AFAST Wholesale Average Demands	AFAST Average Component Price ($)	AFAST Expenditure ($)	SIMLOX Wholesale Demands	SIMLOX Average Component Price ($)	SIMLOX Expenditure ($)	Percent Error from AFAST Expenditure	Percent Error from AFAST Wholesale Demands
All COGs	111	$54,391.13	$1,454,628,051	126.51	$47059.75	$1,185,659,932	66%	70%
1R	112	$20,627.60	$42,665,023.71	128	$25410.18	$47,074,419.17	135%	106%
7R Low Demand	7	$47,593.42	$32,025,075.04	11	$41653.16	$38,024,905.50	107%	126%
7R Medium Demands	42	$74,426.40	$434,255,685	51.09	$64825.33	$404,142,304.90	53%	52%
7R High Demands	212	$44,412.85	$945,682,267	241.29	$36629.22	$696,418,303	30%	28%

B. FUTURE WORK

The determination of whether to accept or reject the model should have an associated percent error with the number of expenditures which the model cannot exceed to prove the model can perform as the user intended. While conducting V&V of the model, the number of historical NIINHOFs were 558 and the number of uniqueNames within the model were 397 which led to a unique finding within the model. This finding is of significant interest because the historical and model projections are to be grouped and summarized according to the number of demands generated by each component. With the historical and projected model containing different sets of samples, the baseline and projected comparison was limited to 397 vice 558 due to the missing NIINHOFs. Without these additional NIINHOFs, it is unclear at the time whether the additional NIINHOFs would improve or degrade model performance, but to increase confidence within the model these NIINHOFs should be added to the model to ascertain the effect the additional 111 samples of data will have upon the model.

APPENDIX. F/A-18 SUSTAINMENT MODEL RESULTS

IID	Wd	td	AFAST Price	COG	AFAST Expenditure	SIMLOX Total Demands	SIMLOX Total Demands Wholesale	Repair Price	New Price	SIMLOX Expenditure	Percent Error from AFAST	Percent Error from AFAST Wholesale Demands
COMPONENT 1	1	1	7179	1R	7179	8.52	8.52		7697	65578.43865	813%	752%
COMPONENT 2	1	1	14477	7R	14477	6.40	6.40	7996	41961	51174.39892	253%	540%
COMPONENT 3	1	1	34648	7R	34648	2.20	2.20	4586	26376	10089.19977	71%	120%
COMPONENT 4	1	3	30636	7R	30636	5.16	5.16	24507	30636	126456.1175	313%	416%
COMPONENT 5	1	1	2953	7R	2953	10.92	10.92	2462	3079	26885.03951	810%	992%
COMPONENT 6	1	2	6761	7R	6761	12.28	12.28	6394	13634	78518.31858	1061%	1128%
COMPONENT 7	1	24	274964	7R	274964	30.76	9.56	116250	372475	1111350.001	304%	856%
COMPONENT 8	1	155	29724	7R	29724	98.16	2.64	28111	595562	74213.03876	150%	164%
COMPONENT 9	1	1	9045	7R	9045	3.12	3.12	3851	20038	12015.11973	33%	212%
COMPONENT 10	1	1	10976	7R	10976	2.12	2.12	10976	13723	23269.11948	112%	112%
COMPONENT 11	1	1	4328	7R	4328	4.60	4.60	3751	43350	17254.59967	299%	360%
COMPONENT 12	1	1	13815	7R	13815	1.80	1.80	10569	42663	19024.19957	38%	80%
COMPONENT 13	2	4	5440.5	1R	10881	10.12	3.56	4694	6187	22025.71965	102%	78%
COMPONENT 14	2	7	28742.5	7R	57485	5.96	0.00	5020	10239	0	100%	100%
COMPONENT 15	2	5	5788	7R	11576	19.88	0.00	5788	41059	0	100%	100%
COMPONENT 16	2	12	89649	7R	179298	8.08	3.36	89649	334010	301220.6339	68%	68%
COMPONENT 17	2	3	104309.5	7R	208619	6.96	3.08	13722	194490	42263.75957	80%	54%
COMPONENT 18	2	5	417414	7R	834828	3.92	3.92	417414	521769	1636262.847	96%	96%
COMPONENT 19	2	2	21944	7R	43888	1.84	1.84	22817	28524	41983.27906	4%	8%
COMPONENT 20	2	64	11872	7R	23744	88.00	6.28	11872	14843	74556.15957	214%	214%
COMPONENT 21	2	2	7201.5	7R	14403	11.04	11.04	7306	12792	80658.23874	460%	452%
COMPONENT 22	2	8	112316.5	7R	224633	65.72	5.20	150726	2237373	783775.1948	249%	160%
COMPONENT 23	2	2	7871	7R	15742	2.04	2.04	4980	16463	10159.19977	35%	2%
COMPONENT 24	3	3	17657.33333	1R	52972	2.04	2.04		15266	31142.6393	41%	32%
COMPONENT 25	3	3	3581.333333	7R	10744	11.68	11.68	3292	10444	38450.55941	258%	289%
COMPONENT 26	3	4	27165	7R	81495	2.12	2.12	21163	28683	44865.559	45%	29%
COMPONENT 27	3	3	3445.666667	7R	10337	2.32	2.32	931	8468	2159.919952	79%	23%

COMPONENT 28	3	11	126511	7R	379533	10.64	3.48	57636	261641	200573.2764	47%	16%
COMPONENT 29	3	3	74671	7R	224013	4.24	4.24	2655	47402	11257.19975	95%	41%
COMPONENT 30	3	4	37830.66667	7R	113492	4.28	1.24	11288	89777	13997.11969	88%	59%
COMPONENT 31	3	112	81681	7R	245043	257.64	5.00	81681	2183265	408404.9957	67%	67%
COMPONENT 32	3	6	69668.66667	7R	209006	6.84	6.84	68277	138598	467014.6711	123%	128%
COMPONENT 33	3	51	4321	7R	12963	65.44	4.76	4367	5461	20786.9198	60%	59%
COMPONENT 34	4	193	105580	7R	422320	250.00	12.64	62337	1054250	787939.6782	87%	216%
COMPONENT 35	4	5	27294	7R	109176	5.76	5.76	18756	1979989	108034.5576	1%	44%
COMPONENT 36	4	4	19690	7R	78760	9.92	9.92	18135	38722	179899.1973	128%	148%
COMPONENT 37	4	5	25620.75	7R	102483	2.56	2.56	21999	27503	56317.43874	45%	36%
COMPONENT 38	4	4	2922	7R	11688	4.52	4.52	2025	16423	9152.999811	22%	13%
COMPONENT 39	4	6	41821	7R	167284	21.00	6.60	8091	66708	53400.59971	68%	65%
COMPONENT 40	4	5	23708	7R	94832	6.72	1.04	23386	94803	24321.43946	74%	74%
COMPONENT 41	4	4	31429.5	7R	125718	1.76	1.76	13280	191903	23372.79948	81%	56%
COMPONENT 42	4	5	142405.5	7R	569622	3.04	3.04	250347	590214	761054.8667	34%	24%
COMPONENT 43	4	9	5530.25	7R	22121	7.40	7.40	2349	8524	17382.59963	21%	85%
COMPONENT 44	4	78	2602.75	7R	10411	143.44	11.68	2474	42422	28896.3202	178%	192%
COMPONENT 45	4	4	7410.75	7R	29643	3.96	3.96	8022	83170	31767.11929	7%	1%
COMPONENT 46	4	4	3125	7R	12500	10.08	10.08	2160	19682	21772.79963	74%	152%
COMPONENT 47	4	4	73545	7R	294180	2.52	2.52	86982	927446	219194.6364	25%	37%
COMPONENT 48	5	9	18503	7R	92515	4.40	4.40	10657	15816	46890.79895	49%	12%
COMPONENT 49	5	34	281550.744	7R	1407753.72	68.08	15.88	116250	365321	1846050.012	31%	218%
COMPONENT 50	5	47	17957	7R	89785	44.24	5.88	19755	106137	116159.3986	29%	18%
COMPONENT 51	5	5	79351.4	7R	396757	10.76	10.76	71559	1233189	769974.834	94%	115%
COMPONENT 52	5	5	42457.264	7R	212286.32	2.72	2.72	42287	234584	115020.6374	46%	46%
COMPONENT 53	5	108	87477	7R	437385	141.92	2.08	89701	976355	186578.0758	57%	58%
COMPONENT 54	5	5	41827.6	7R	209138	11.12	11.12	37314	46646	414931.6738	98%	122%
COMPONENT 55	6	6	11998.5	7R	71991	4.80	4.80	8952	11192	42969.59911	40%	20%
COMPONENT 56	6	45	8556.666667	7R	51340	123.52	26.12	9519	55575	248636.2789	384%	335%
COMPONENT 57	6	6	81733	7R	490398	19.56	19.56	76951	96190	1505161.549	207%	226%
COMPONENT 58	6	20	35247.16667	7R	211483	19.68	6.72	13550	63105	91055.99988	57%	12%
COMPONENT 59	6	18	158579.1667	7R	951475	22.40	2.72	154125	361942	419219.9975	56%	55%
COMPONENT 60	6	6	20721	7R	124326	6.80	6.80	19947	40626	135639.5973	9%	13%
COMPONENT 61	6	39	5750.5	7R	34503	36.40	0.00	5834	92275	0	100%	100%

COMPONENT 62	6	6	723515	7R	4341090	6.28	6.28	924413	1155520	5805313.517	34%	5%
COMPONENT 63	6	6	11817.33333	7R	70904	24.08	24.08	14128	21721	340202.2367	380%	301%
COMPONENT 64	6	6	16068	7R	96408	11.08	11.08	2869	70468	31788.51978	67%	85%
COMPONENT 65	7	7	31605	7R	221235	4.08	4.08	19942	24930	81363.35818	63%	42%
COMPONENT 66	7	7	24119.42857	7R	168836	11.60	11.60	12386	15484	143677.5972	15%	66%
COMPONENT 67	7	9	24952.85714	7R	174670	13.28	13.28	19518	24400	259199.036	48%	90%
COMPONENT 68	7	7	32865.14286	7R	230056	8.76	8.76	27622	49876	241968.715	5%	25%
COMPONENT 69	7	7	8686	7R	60802	8.52	8.52	8261	56157	70383.71966	16%	22%
COMPONENT 70	7	7	4750.571429	7R	33254	7.08	7.08	4658	19191	32978.63937	1%	1%
COMPONENT 71	7	117	28767.85714	7R	201375	83.44	1.84	26318	32899	48425.11892	76%	74%
COMPONENT 72	7	97	54117.42857	7R	378822	498.44	48.20	21224	208467	1022996.802	170%	589%
COMPONENT 73	7	83	19378.42857	7R	135649	423.96	31.28	17751	175639	555251.2848	309%	347%
COMPONENT 74	7	7	3800.714286	7R	26605	13.48	13.48	3961	4953	53394.2791	101%	93%
COMPONENT 75	8	26	59850.375	7R	478803	20.72	11.76	55939	147709	657842.6345	37%	47%
COMPONENT 76	8	8	1708.5	7R	13668	7.24	7.24	1758	5887	12727.91977	7%	10%
COMPONENT 77	8	8	3499	7R	27992	11.64	11.64	2802	37574	32615.27938	17%	46%
COMPONENT 78	8	8	229470.75	7R	1835766	6.20	6.20	218108	4120426	1352269.573	26%	23%
COMPONENT 79	9	9	3604.444444	1R	32440	8.44	8.44		3392	28628.47939	12%	6%
COMPONENT 80	9	9	61632.66667	7R	554694	10.80	10.80	18814	23520	203191.1964	63%	20%
COMPONENT 81	9	18	2252.555556	7R	20273	44.60	27.04	1243	6792	33610.72003	66%	200%
COMPONENT 82	9	9	3933.222222	7R	35399	8.28	8.28	2689	10816	22264.91958	37%	8%
COMPONENT 83	9	9	47412	7R	426708	6.56	6.56	46020	239127	301891.1933	29%	27%
COMPONENT 84	10	10	5367.7	7R	53677	25.76	25.76	3040	25924	78310.3992	46%	158%
COMPONENT 85	10	22	11247.2	7R	112472	23.16	23.16	12542	18814	290472.7181	158%	132%
COMPONENT 86	10	57	65192.5	7R	651925	51.04	14.04	43754	84418	614306.1642	6%	40%
COMPONENT 87	10	12	10963.7	7R	109637	6.56	6.56	9417	27787	61775.5189	44%	34%
COMPONENT 88	10	10	4618.3	7R	46183	3.84	3.84	1947	12054	7476.479833	84%	62%
COMPONENT 89	10	10	6117.3	7R	61173	7.92	7.92	5194	6495	41136.47916	33%	21%
COMPONENT 90	11	12	1604.636364	7R	17651	21.92	12.28	1362	4335	16725.35992	5%	12%
COMPONENT 91	11	12	204049.6364	7R	2244546	4.12	4.12	250347	586525	1031429.619	54%	63%
COMPONENT 92	11	11	6599.363636	7R	72593	12.16	12.16	4982	7370	60581.11894	17%	11%
COMPONENT 93	11	11	40131.72727	7R	441449	14.80	14.80	42423	53031	627860.3907	42%	35%
COMPONENT 94	12	12	12336.08333	7R	148033	8.72	8.72	5157	61043	44969.03911	70%	27%
COMPONENT 95	12	12	7120.5	7R	85446	14.76	14.76	7146	14546	105474.9584	23%	23%

COMPONENT 96	12	18	26404.33333	7R	316852	41.40	34.28	20844	59760	714532.32	126%	186%
COMPONENT 97	12	14	4823.833333	7R	57886	40.12	40.12	3677	10155	147521.2393	155%	234%
COMPONENT 98	12	13	11710.25	7R	140523	92.44	92.44	15608	19511	1442803.516	927%	670%
COMPONENT 99	12	14	8082.333333	7R	96988	17.56	11.48	6880	9733	78982.40018	19%	4%
COMPONENT 100	13	15	1237.846154	7R	16092	20.08	15.12	765	5110	11566.79996	28%	16%
COMPONENT 101	13	13	49218.76923	7R	639844	18.12	18.12	47875	103229	867494.9902	36%	39%
COMPONENT 102	13	13	7917.846154	7R	102932	8.72	8.72	6628	8287	57796.15891	44%	33%
COMPONENT 103	13	13	11390.30769	7R	148074	19.72	19.72	8268	68130	163044.958	10%	52%
COMPONENT 104	13	13	27553.07692	7R	358190	22.00	22.00	31934	65293	702547.9929	96%	69%
COMPONENT 105	14	14	13425.07143	7R	187951	19.16	19.16	12381	28128	237219.9569	26%	37%
COMPONENT 106	14	16	35800.85714	7R	501212	23.52	23.52	33507	43970	788084.6356	57%	68%
COMPONENT 107	14	24	65129.07143	7R	911807	11.52	2.92	80984	114482	236473.2753	74%	79%
COMPONENT 108	14	14	48409.71429	7R	677736	2.36	2.36	10135	49696	23918.59947	96%	83%
COMPONENT 109	14	24	48159.64286	7R	674235	18.48	8.52	33030	79711	281415.5996	58%	39%
COMPONENT 110	14	27	4153.357143	7R	58147	33.12	24.40	1937	19304	47262.80013	19%	74%
COMPONENT 111	14	15	16429.64286	7R	230015	7.84	7.84	16728	40259	131147.5172	43%	44%
COMPONENT 112	14	14	7629.785714	7R	106817	8.16	8.16	7761	21303	63329.75858	41%	42%
COMPONENT 113	15	15	18026.66667	7R	270400	32.88	32.88	17731	44858	582995.276	116%	119%
COMPONENT 114	15	15	34164.4	7R	512466	20.36	20.36	28358	56413	577368.8724	13%	36%
COMPONENT 115	15	19	25566.4	7R	383496	30.64	24.96	22392	31817	558904.3195	46%	66%
COMPONENT 116	16	16	4615.3125	7R	73845	31.48	31.48	3953	4944	124440.4391	69%	97%
COMPONENT 117	16	68	65480.625	7R	1047690	50.24	12.20	54079	118185	659763.7985	37%	24%
COMPONENT 118	16	16	48065	7R	769040	25.84	25.84	48490	105702	1252981.586	63%	62%
COMPONENT 119	16	32	52489.5625	7R	839833	24.68	16.68	41545	83293	692970.5991	17%	4%
COMPONENT 120	17	17	31716.52941	7R	539181	12.40	12.40	27985	39501	347013.9939	36%	27%
COMPONENT 121	18	18	11463.88889	7R	206350	19.00	19.00	11476	25767	218043.9971	6%	6%
COMPONENT 121	18	18	1779.444444	7R	32030	53.44	53.44	1745	8219	93252.7998	191%	197%
COMPONENT 122	18	118	18668.66667	7R	336036	179.48	50.36	17083	56499	860299.8721	156%	180%
COMPONENT 123	19	21	2182.157895	7R	41461	32.56	26.68	1669	7931	44528.92016	7%	40%
COMPONENT 124	20	25	41155.1	1R	823102	55.20	48.56	31829	71541	3474030.981	322%	143%
COMPONENT 125	20	20	9722.95	7R	194459	17.44	17.44	6051	9608	105529.4389	46%	13%
COMPONENT 126	20	20	6136.6	7R	122732	63.36	63.36	4886	21462	309576.9593	152%	217%
COMPONENT 127	20	20	14557.3	7R	291146	37.96	37.96	14273	27505	541803.0737	86%	90%
COMPONENT 128	20	79	24678.45	7R	493569	90.32	33.52	24991	295199	837698.3255	70%	68%

COMPONENT 129	20	20	13544.1	7R	270882	14.52	14.52	14360	17952	208507.1968	23%	27%
COMPONENT 130	21	21	9909.761905	7R	208105	60.16	60.16	16283	20355	979585.2785	371%	186%
COMPONENT 131	22	23	13328.77273	7R	293233	17.92	17.92	12602	27307	225827.8364	23%	19%
COMPONENT 132	22	22	4560.772727	7R	100337	11.68	11.68	4336	11571	50644.47913	50%	47%
COMPONENT 133	23	52	17061.3913	7R	392412	78.12	51.88	18640	204666	967043.1977	146%	126%
COMPONENT 134	23	23	4328.478261	7R	99555	11.00	11.00	3806	12727	41865.99915	58%	52%
COMPONENT 135	24	24	38422.08333	7R	922130	27.52	27.52	26919	130744	740810.8713	20%	15%
COMPONENT 136	24	24	15755.5	7R	378132	33.36	33.36	15207	23787	507305.5167	34%	39%
COMPONENT 137	24	24	125002.25	7R	3000054	36.24	36.24	114943	557600	4165534.299	39%	51%
COMPONENT 138	25	25	6963.16	7R	174079	33.96	33.96	6621	24732	224849.159	29%	36%
COMPONENT 139	25	54	1724.88	7R	43122	60.76	44.44	1297	2235	57638.68	34%	78%
COMPONENT 140	25	33	112238.68	7R	2805967	49.80	35.00	97347	280352	3407145.012	21%	40%
COMPONENT 141	25	25	7071.28	7R	176782	44.12	44.12	6250	7816	275749.9992	56%	76%
COMPONENT 142	25	25	9851.04	7R	246276	54.44	54.44	5173	70839	281618.1186	14%	118%
COMPONENT 143	26	26	19088	7R	496288	27.92	27.92	15515	86319	433178.7961	13%	7%
COMPONENT 144	26	72	2524	7R	65624	115.56	115.56	2177	4991	251574.1197	283%	344%
COMPONENT 145	27	27	8118.185185	7R	219191	29.44	29.44	7884	20503	232104.9584	6%	9%
COMPONENT 146	28	161	27429.42857	7R	768024	284.28	56.20	30518	38150	1715111.598	123%	101%
COMPONENT 147	28	28	60456.17857	7R	1692773	39.20	39.20	43886	65088	1720331.19	2%	40%
COMPONENT 148	28	40	7973.107143	7R	223247	80.20	47.92	5056	24186	242283.5198	9%	71%
COMPONENT 149	29	29	40020.44828	7R	1160593	16.40	16.40	28809	184442	472467.5922	59%	43%
COMPONENT 150	30	38	110126.4667	7R	3303794	78.64	38.28	97347	280352	3726443.14	13%	28%
COMPONENT 151	30	30	28739.76667	7R	862193	43.44	43.44	36633	288143	1591337.52	85%	45%
COMPONENT 152	31	31	23810.48387	7R	738125	81.56	81.56	24384	30481	1988759.035	169%	163%
COMPONENT 153	31	36	4848.064516	7R	150290	25.28	25.28	3234	83685	81755.51926	46%	18%
COMPONENT 154	31	31	30699.90323	7R	951697	4.32	4.32	34471	93648	148914.7167	84%	86%
COMPONENT 155	32	33	6414.9375	7R	205278	36.64	36.64	5856	19677	214563.8383	5%	15%
COMPONENT 156	32	32	18101.84375	7R	579259	2.28	2.28	18602	88611	42412.55905	93%	93%
COMPONENT 157	33	161	5076.090909	7R	167511	208.64	49.96	3433	86157	171512.6801	2%	51%
COMPONENT 158	33	33	40936.30303	7R	1350898	22.20	22.20	16809	238655	373159.7969	72%	33%
COMPONENT 159	34	34	11336.88235	7R	385454	53.64	53.64	11533	167637	618630.1142	60%	58%
COMPONENT 160	35	35	64666.77143	7R	2263337	40.48	40.48	44549	189880	1803343.512	20%	16%
COMPONENT 161	35	35	59253.6	7R	2073876	59.56	59.56	32164	246111	1915687.833	8%	70%
COMPONENT 162	35	35	18513	7R	647955	29.68	29.68	20560	29123	610220.7951	6%	15%

COMPONENT 163	36	103	39918.72222	7R	1437074	167.20	32.92	31190	400314	1026774.801	29%	9%
COMPONENT 164	36	75	2824.333333	7R	101676	110.96	50.44	1447	6393	72986.68043	28%	40%
COMPONENT 165	36	36	6711.333333	7R	241608	58.08	46.36	6087	15567	282193.3194	17%	29%
COMPONENT 166	36	36	38525.86111	7R	1386931	39.80	39.80	38985	132270	1551602.988	12%	11%
COMPONENT 167	36	1022	8011.277778	7R	288406	1295.92	57.16	7587	71676	433672.9179	50%	59%
COMPONENT 168	36	36	16678.61111	7R	600430	51.04	51.04	14234	213820	726503.3579	21%	42%
COMPONENT 169	37	37	16395.37838	7R	606629	29.92	29.92	17989	56145	538230.8739	11%	19%
COMPONENT 170	37	37	743.5135135	7R	27510	39.64	39.64	720	2769	28540.79983	4%	7%
COMPONENT 171	38	38	46241.07895	7R	1757161	40.60	40.60	25839	65121	1049063.392	40%	7%
COMPONENT 172	38	38	19996	7R	759848	34.44	34.44	21187	262269	729680.2755	4%	9%
COMPONENT 173	38	38	13779.57895	7R	523624	40.16	40.16	13148	16436	528023.6773	1%	6%
COMPONENT 174	39	165	128331.4872	7R	5004928	227.04	22.56	90574	821199	2043349.443	59%	42%
COMPONENT 175	39	39	75068.71795	7R	2927680	39.04	39.04	92442	829988	3608935.656	23%	0%
COMPONENT 176	39	39	9441.076923	7R	368202	102.04	102.04	6709	48878	684586.3633	86%	162%
COMPONENT 177	39	39	8822.358974	7R	344072	31.20	31.20	8031	64265	250567.1985	27%	20%
COMPONENT 178	40	40	8800.95	7R	352038	24.52	24.52	5819	13369	142681.8789	59%	39%
COMPONENT 179	41	43	5970.317073	7R	244783	37.00	37.00	4396	8066	162651.9996	34%	10%
COMPONENT 180	41	44	11389.82927	7R	466983	37.28	37.28	10680	29260	398150.3957	15%	9%
COMPONENT 181	41	41	4832.04878	7R	198114	31.88	31.88	7241	12585	230843.0782	17%	22%
COMPONENT 182	42	42	7329.547619	7R	307841	15.08	15.08	7539	14594	113688.118	63%	64%
COMPONENT 183	42	42	6502.309524	7R	273097	44.28	44.28	3753	22054	166182.8386	39%	5%
COMPONENT 184	42	42	40544.57143	7R	1702872	39.44	39.44	39442	126909	1555592.472	9%	6%
COMPONENT 185	42	44	792264.5	7R	33275109	53.76	53.76	788881	1261581	42410242.52	27%	28%
COMPONENT 186	43	43	11490.37209	7R	494086	97.24	97.24	15517	39325	1508873.078	205%	126%
COMPONENT 187	46	95	5708.391304	7R	262586	93.44	93.44	4450	5918	415807.9997	58%	103%
COMPONENT 188	47	47	2625.021277	7R	123376	63.44	63.44	2814	14977	178520.159	45%	35%
COMPONENT 189	47	47	64058.82979	7R	3010765	22.12	22.12	61083	76356	1351155.944	55%	53%
COMPONENT 190	47	56	611597.8936	7R	28745101	104.04	50.40	507914	634895	25598865.65	11%	7%
COMPONENT 191	47	47	10852.17021	7R	510052	67.16	67.16	12951	40754	869789.1579	71%	43%
COMPONENT 192	47	442	14668.93617	7R	689440	525.96	31.88	12660	15827	403600.7973	41%	32%
COMPONENT 193	48	238	60064.14583	7R	2883079	299.52	93.40	30706	60507	2867940.418	1%	95%
COMPONENT 194	49	50	815919.7551	7R	39980068	66.64	11.32	788881	1237604	8930132.891	78%	77%
COMPONENT 195	50	50	14001.6	7R	700080	53.24	53.24	13461	16829	716663.6367	2%	6%
COMPONENT 196	50	50	61352.06	7R	3067603	22.92	22.92	35995	257613	825005.3869	73%	54%

COMPONENT 197	51	101	152508.1373	7R	7777915	135.48	36.20	132261	525464	4787848.183	38%	29%
COMPONENT 198	52	52	6509.634615	7R	338501	36.68	36.68	6291	19718	230753.878	32%	29%
COMPONENT 199	52	52	59295.90385	7R	3083387	31.68	31.68	35227	252114	1115991.351	64%	39%
COMPONENT 200	54	54	4872.574074	7R	263119	83.88	83.88	5010	46759	420238.7989	60%	55%
COMPONENT 201	54	64	606522.7037	7R	32752226	71.40	37.60	508656	635822	19125465.58	42%	30%
COMPONENT 202	54	54	8750.944444	7R	472551	68.64	68.64	8250	41585	566279.9965	20%	27%
COMPONENT 203	55	55	169178.6727	7R	9304827	48.04	48.04	659081	5917579	31662251.02	240%	13%
COMPONENT 204	56	142	45057.60714	7R	2523226	91.32	39.16	19061	46426	746428.7616	70%	30%
COMPONENT 205	56	56	10700.35714	7R	599220	26.84	26.84	7196	25412	193140.6391	68%	52%
COMPONENT 206	56	56	7946.446429	7R	445001	34.00	34.00	7650	32889	260099.9982	42%	39%
COMPONENT 207	58	123	124391.3621	1R	7214699	166.44	74.84	55215	141903	10620020.46	47%	29%
COMPONENT 208	58	58	38662.22414	7R	2242409	43.12	43.12	26548	68359	1144749.751	49%	26%
COMPONENT 209	59	79	41154.91525	7R	2428140	111.40	72.72	40795	58622	2966612.377	22%	23%
COMPONENT 210	59	59	17013.9661	7R	1003824	55.48	55.48	16380	53308	908762.3956	9%	6%
COMPONENT 211	60	60	459419.6333	7R	27565178	115.04	115.04	353960	442452	40719558.59	48%	92%
COMPONENT 212	61	61	4531.081967	7R	276396	41.72	41.72	4488	5612	187239.3592	32%	32%
COMPONENT 213	61	61	2970.540984	7R	181203	80.12	80.12	2678	131168	214561.3585	18%	31%
COMPONENT 214	63	702	21970.57143	7R	1384146	845.32	44.28	17539	90526	776626.9237	44%	30%
COMPONENT 215	63	65	495543.6032	7R	31219247	80.44	80.44	403065	503834	32422548.71	4%	28%
COMPONENT 216	65	1040	143401.8769	7R	9321122	1328.72	199.92	116510	145641	23292679.15	150%	208%
COMPONENT 217	66	69	437739.5152	7R	28890808	138.12	134.52	345502	431880	46476929.12	61%	104%
COMPONENT 218	67	67	5547	7R	371649	55.64	55.64	3044	15660	169368.1598	54%	17%
COMPONENT 219	69	69	8782.043478	1R	605961	60.16	60.16	2140	17858	1074337.28	77%	13%
COMPONENT 220	69	69	7633.362319	7R	526702	84.56	84.56	6441	35469	544650.9594	3%	23%
COMPONENT 221	69	268	36068.91304	7R	2488755	218.84	47.00	24699	51061	1160853.001	53%	32%
COMPONENT 222	69	69	22769.76812	7R	1571114	42.32	42.32	23416	29271	990965.1151	37%	39%
COMPONENT 223	69	90	397448.4058	7R	27423940	106.16	73.68	70465	516161	5191861.188	81%	7%
COMPONENT 224	70	227	46762.61429	7R	3273383	411.60	84.24	58712	73393	4945898.839	51%	20%
COMPONENT 225	71	76	79176.46479	7R	5621529	82.04	82.04	59549	179543	4885399.952	13%	16%
COMPONENT 226	71	71	276387.1268	7R	19623486	79.40	79.40	120739	553884	9586676.58	51%	12%
COMPONENT 227	72	116	15109.44444	7R	1087880	145.40	106.08	19295	25888	2046813.589	88%	47%
COMPONENT 228	73	194	3895.684932	7R	284385	243.64	243.64	2058	5276	501411.1194	76%	234%
COMPONENT 229	74	74	39785.87838	7R	2944155	61.04	61.04	21905	37744	1337081.197	55%	18%
COMPONENT 230	77	77	8076.853377	1R	621917.71	149.52	149.52	4629	6211	928668.7197	49%	94%

COMPONENT 231	77	77	5968.519481	7R	459576	120.56	120.56	5044	8646	608104.64	32%	57%
COMPONENT 232	78	78	9837.423077	7R	767319	93.64	93.64	9701	74500	908401.639	18%	20%
COMPONENT 233	78	80	532862.1026	7R	41563244	63.68	63.68	409961	512453	26106316.38	37%	18%
COMPONENT 234	79	79	24202.31646	7R	1911983	126.72	126.72	15247	19063	1932099.845	1%	60%
COMPONENT 235	80	95	270399.1375	7R	21631931	120.00	80.36	211202	264005	16972192.7	22%	0%
COMPONENT 236	80	80	27604.7	7R	2208376	141.12	141.12	31096	38872	4388267.52	99%	76%
COMPONENT 237	81	83	79213.41975	7R	6416287	73.64	73.64	57810	179543	4257128.398	34%	9%
COMPONENT 238	82	109	280935.4024	7R	23036703	116.28	89.12	216020	270027	19251702.53	16%	9%
COMPONENT 239	83	84	13260.28916	7R	1100604	106.08	76.52	12456	98808	953133.1138	13%	8%
COMPONENT 240	83	84	15848.79518	7R	1315450	164.24	138.76	14738	22097	2045044.883	55%	67%
COMPONENT 241	85	85	93458.04706	7R	7943934	90.56	90.56	48173	358310	4362546.877	45%	7%
COMPONENT 242	91	91	402826.0549	7R	36657171	65.16	65.16	256665	709093	16724291.37	54%	28%
COMPONENT 243	91	91	5228.395604	7R	475784	117.40	117.40	4205	27073	493666.9997	4%	29%
COMPONENT 244	92	92	18736.22826	7R	1723733	109.12	109.12	14144	115084	1543393.277	10%	19%
COMPONENT 245	92	92	4376.25	7R	402615	114.00	114.00	3811	38263	434453.9991	8%	24%
COMPONENT 246	95	95	50253.11579	7R	4774046	40.08	40.08	29008	190207	1162640.63	76%	58%
COMPONENT 247	96	96	58182.77083	7R	5585546	137.76	137.76	64758	107307	8921062.076	60%	44%
COMPONENT 248	96	96	47029.38542	7R	4514821	118.76	118.76	28123	68497	3339887.474	26%	24%
COMPONENT 249	97	97	17853.47423	7R	1731787	17.24	17.24	14962	73744	257944.877	85%	82%
COMPONENT 250	99	99	15345.13131	7R	1519168	106.44	106.44	14305	111318	1522624.204	0%	8%
COMPONENT 251	99	102	6549.323232	7R	648383	99.16	99.16	5325	78206	528026.9994	19%	0%
COMPONENT 252	101	802	11054.46535	7R	1116501	913.72	129.44	8293	277773	1073445.924	4%	28%
COMPONENT 253	101	288	29993.60396	7R	3029354	260.52	98.44	38606	247956	3800374.661	25%	3%
COMPONENT 254	102	102	10899.83333	7R	1111783	146.64	146.64	12076	25362	1770824.635	59%	44%
COMPONENT 255	104	104	1598.836538	7R	166279	134.24	134.24	1391	20953	186727.84	12%	29%
COMPONENT 256	104	104	6772.288462	7R	704318	162.28	162.28	5350	78849	868198.0024	23%	56%
COMPONENT 257	104	104	15968.57692	7R	1660732	89.96	89.96	11308	642225	1017267.676	39%	14%
COMPONENT 258	105	105	9824.133333	7R	1031534	57.64	57.64	9131	24627	526310.8382	49%	45%
COMPONENT 259	108	108	36742.73148	7R	3968215	75.88	75.88	30973	97884	2350231.232	41%	30%
COMPONENT 260	109	540	39530.3945	7R	4308813	584.04	80.12	46453	163061	3721814.36	14%	26%
COMPONENT 261	109	109	20436.3945	7R	2227567	104.16	104.16	18724	63837	1950291.836	12%	4%
COMPONENT 262	112	112	11712.03571	7R	1311748	76.64	76.64	9579	12116	734134.556	44%	32%
COMPONENT 263	115	115	1555.017391	7R	178827	162.80	162.80	1268	26128	206430.3999	15%	42%
COMPONENT 264	115	115	65422.32174	7R	7523567	144.00	144.00	10708	93276	1541952.003	80%	25%

COMPONENT 265	116	116	22686.90517	7R	2631681	137.88	137.88	21698	30355	2991720.247	14%	19%
COMPONENT 266	117	117	19042.05983	7R	2227921	69.12	69.12	13728	98963	948879.3608	57%	41%
COMPONENT 267	117	136	321092.0513	7R	37567770	128.80	34.04	399100	498875	13585363.95	64%	71%
COMPONENT 268	118	118	22326.47458	7R	2634524	130.20	130.20	17311	69468	2253892.207	14%	10%
COMPONENT 269	118	118	13223.02542	7R	1560317	194.64	194.64	13452	52364	2618297.282	68%	65%
COMPONENT 270	119	119	57459.42857	7R	6837672	115.60	115.60	54773	68469	6331758.805	7%	3%
COMPONENT 271	120	120	22270.25	7R	2672430	106.00	106.00	16425	79975	1741049.999	35%	12%
COMPONENT 272	121	121	7098.528926	7R	858922	41.68	41.68	7060	19367	294260.7989	66%	66%
COMPONENT 273	123	123	97384.61789	7R	11978308	127.32	127.32	79235	152090	10088200.18	16%	4%
COMPONENT 274	123	123	62586.50407	7R	7698140	162.88	162.88	55702	69629	9072741.747	18%	32%
COMPONENT 275	123	123	15862.82927	7R	1951128	157.72	157.72	11849	24900	1868824.281	4%	28%
COMPONENT 276	124	1699	15127.44355	7R	1875803	1776.68	77.04	12718	74452	979794.7241	48%	38%
COMPONENT 277	128	128	20384.36719	7R	2609199	176.64	176.64	19156	123441	3383715.83	30%	38%
COMPONENT 278	131	131	7251.854962	7R	949993	135.72	135.72	7430	11271	1008399.599	6%	4%
COMPONENT 279	136	339	7176.367647	7R	975986	438.48	421.60	4450	41269	1876120.002	92%	210%
COMPONENT 280	137	137	19585.25547	7R	2683180	157.28	157.28	18964	39080	2982657.925	11%	15%
COMPONENT 281	138	139	1852.681159	7R	255670	197.08	197.08	1897	6667	373860.76	46%	43%
COMPONENT 282	139	139	44013.4964	7R	6117876	104.52	104.52	44851	294023	4687826.535	23%	25%
COMPONENT 283	140	140	18141.68571	7R	2539836	147.88	147.88	12714	261586	1880146.323	26%	6%
COMPONENT 284	141	358	21067.68085	7R	2970543	529.48	215.60	5616	86794	1210809.602	59%	53%
COMPONENT 285	141	141	11111.96454	7R	1566787	129.96	129.96	10544	22513	1370298.242	13%	8%
COMPONENT 286	141	141	5167.432624	7R	728608	177.76	177.76	5268	16764	936439.6829	29%	26%
COMPONENT 287	142	142	64943.66197	7R	9222000	118.36	118.36	54440	133043	6443518.411	30%	17%
COMPONENT 288	144	144	17537.72917	7R	2525433	129.12	129.12	7042	32440	909263.0419	64%	10%
COMPONENT 289	145	145	37323.48276	7R	5411905	112.16	112.16	16323	22750	1830787.681	66%	23%
COMPONENT 290	149	149	12483.45638	7R	1860035	137.20	137.20	13197	112378	1810628.407	3%	8%
COMPONENT 291	150	151	15703.11333	7R	2355467	185.32	185.32	15123	21886	2802594.346	19%	24%
COMPONENT 292	150	246	45510.59333	7R	6826589	388.24	110.04	28521	288825	3138450.832	54%	27%
COMPONENT 293	153	153	38858.60131	7R	5945366	161.56	161.56	37616	49191	6077240.948	2%	6%
COMPONENT 294	153	317	6679.104575	7R	1021903	336.80	255.28	6332	66082	1616432.955	58%	67%
COMPONENT 295	157	157	3538.847134	7R	555599	145.48	145.48	3434	20252	499578.3193	10%	7%
COMPONENT 296	158	158	2499.012658	7R	394844	188.72	188.72	2521	6566	475763.1203	20%	19%
COMPONENT 297	163	163	23537.88957	7R	3836676	224.44	220.44	19753	36802	4354351.34	13%	35%
COMPONENT 298	171	171	20326.18129	7R	3475777	203.48	203.48	19449	62225	3957482.521	14%	19%

COMPONENT 299	172	172	5146.97093	7R	885279	220.60	220.60	3740	8912	825043.994	7%	28%
COMPONENT 300	173	173	6017.872832	7R	1041092	210.76	210.76	5361	8924	1129884.362	9%	22%
COMPONENT 301	174	174	13170.60345	7R	2291685	196.04	196.04	12718	30433	2493236.712	9%	13%
COMPONENT 302	181	181	21445.61878	7R	3881657	168.44	168.44	25714	160254	4331266.171	12%	7%
COMPONENT 303	181	250	9144.359116	7R	1655129	345.12	87.60	7154	17296	626690.4002	62%	52%
COMPONENT 304	186	186	38659.55914	7R	7190678	197.12	197.12	22603	80859	4455503.349	38%	6%
COMPONENT 305	193	194	3139.668394	7R	605956	210.16	210.16	3935	22816	826979.5973	36%	9%
COMPONENT 306	200	200	10310.27	7R	2062054	157.28	157.28	15000	32505	2359200.002	14%	21%
COMPONENT 307	200	200	24385.74	7R	4877148	179.28	179.28	23696	63702	4248218.891	13%	10%
COMPONENT 308	210	211	51075.48095	7R	10725851	246.40	246.40	54496	74902	13427814.42	25%	17%
COMPONENT 309	211	211	6602.957346	7R	1393224	207.48	207.48	6670	20267	1383891.598	1%	2%
COMPONENT 310	218	218	31989.5	7R	6973711	281.32	281.32	12711	150348	3575858.512	49%	29%
COMPONENT 311	219	219	7206.767123	7R	1578282	311.84	311.84	6442	13960	2008873.28	27%	42%
COMPONENT 312	225	225	5344.946667	7R	1202613	256.68	256.68	5303	9753	1361174.044	13%	14%
COMPONENT 313	229	229	196172.8428	7R	44923581	256.36	256.36	224009	380466	57426947.3	28%	12%
COMPONENT 314	233	233	48714.63519	7R	11350510	241.36	241.36	45135	190482	10893783.59	4%	4%
COMPONENT 315	233	279	19151.34335	7R	4462263	330.44	330.44	17809	211186	5884805.932	32%	42%
COMPONENT 316	235	235	45400.15319	7R	10669036	294.60	294.60	32062	133671	9445465.187	11%	25%
COMPONENT 317	238	277	7407.890756	7R	1763078	324.36	324.36	1674	108207	542978.6401	69%	36%
COMPONENT 318	246	247	11950.00813	7R	2939702	240.72	240.72	12275	26237	2954837.996	1%	2%
COMPONENT 319	251	252	13029.30279	7R	3270355	311.60	311.60	4930.93	19643.2	1536477.791	53%	24%
COMPONENT 320	252	252	6922.293651	7R	1744418	251.00	251.00	3698.28	13329.63	928268.2808	47%	0%
COMPONENT 321	258	258	22368.62016	7R	5771104	219.36	219.36	21116	74054	4632005.742	20%	15%
COMPONENT 322	258	258	12000.25581	7R	3096066	290.72	290.72	11697	26560	3400551.847	10%	13%
COMPONENT 323	271	326	954501.2288	7R	258669833	260.72	142.52	764211	955266	108915352.1	58%	47%
COMPONENT 324	283	283	9938.982332	7R	2812732	337.36	337.36	7957	15619	2684373.521	5%	19%
COMPONENT 325	345	345	4411.457971	7R	1521953	66.44	64.28	8163	14202	524717.6388	66%	81%
COMPONENT 326	359	361	48411.50975	7R	17379732	500.48	322.80	18532	347488	5982129.559	66%	10%
COMPONENT 327	366	1846	57538.51913	7R	21059098	1683.52	649.88	50392	240709	32748753.3	56%	78%
COMPONENT 328	382	382	19093.50785	7R	7293720	291.72	291.72	22346	71721	6518775.113	11%	24%
COMPONENT 329	397	397	18789	7R	7459233	391.04	391.04	20534	131399	8029615.346	8%	2%
COMPONENT 330	407	407	3718.307125	7R	1513351	461.72	461.72	3279	50250	1513979.88	0%	13%
COMPONENT 331	452	452	64784.79425	7R	29282727	464.80	464.80	50084	111051	23279043.25	21%	3%
COMPONENT 332	454	454	3566.328194	7R	1619113	454.00	454.00	3218	31971	1460971.999	10%	0%

COMPONENT 333	462	462	1562.480519	7R	721866	533.00	533.00	1326	22109	706758.0006	2%	15%
COMPONENT 334	482	482	17898.96888	7R	8627303	543.08	543.08	17293	217198	9391482.38	9%	13%
COMPONENT 335	515	3893	80699.49126	7R	41560238	5907.92	532.68	40427	474327	21534654.33	48%	3%
COMPONENT 336	524	627	31033.52481	7R	16261567	626.96	588.20	19491	44703	11464606.21	29%	12%
COMPONENT 337	565	565	19824.78584	7R	11201004	530.36	530.36	19495	205251	10339368.18	8%	6%
COMPONENT 338	609	609	18535.00821	7R	11287820	688.04	688.04	14222	17779	9785304.873	13%	13%
COMPONENT 339	613	1192	16206.73573	7R	9934729	1485.56	1485.56	8654	88309	12856036.25	29%	142%
COMPONENT 340	631	632	18099.37718	7R	11420707	776.48	776.48	10710	42310	8316100.793	27%	23%
COMPONENT 341	714	716	21324.77451	7R	15225889	631.16	631.16	23522	29987	14846145.5	2%	12%
COMPONENT 342	809	809	11636.13103	7R	9413630	1473.52	1473.52	9745	16047	14359452.39	53%	82%
COMPONENT 343	832	832	33413.58413	7R	27800102	1098.48	1098.48	32064	46188	35221662.7	27%	32%
COMPONENT 344	1653	1653	3974.097399	1R	6569183	1772.40	1772.40		3606	6391274.394	3%	7%
COMPONENT 345	3459	3459	2942.321769	1R	10177491	3571.32	3571.32	2061	2595	9267575.413	9%	3%
COMPONENT 346	4472	4472	3700.625671	1R	16549198	4659.44	4659.44	2817	3256	15171136.65	8%	4%

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