Optimizing Throughput Across Aviation Repair Activities

Final Report

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for the
Commercial Technologies for Maintenance Activities (CTMA) Program

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Acronyms and Abbreviations

Term	Definition
AGE	Air Ground Equipment
AI	Artificial Intelligence
ASI	Andromeda Systems Incorporated
COE	Center of Excellence
COMFRC	Commander Fleet Readiness Center
CTMA	Commercial Technologies for Maintenance Activities
DAC	Degrader Analysis Center
D-Level	Depot Level
DLA	Defense Logistics Agency
DOD	Department of Defense
DOT	Department of Transportation
ESTA	Engineering Solutions and Technology Applications Incorporated
FRC	Fleet Readiness Center
FRCE	Fleet Readiness Center East
FRCSE	Fleet Readiness Center Southeast
FRCSW	Fleet Readiness Center Southwest
FRCWP	Fleet Readiness Center Western Pacific
I-Level	Intermediate Level
IoT	Internet of Things
IT	Information Technology
MC	Mission Capable
MRO	Maintenance, Repair, and Overhaul
MSR	Monthly Status Report
NAE	Naval Aviation Enterprise
NAVAIR	Naval Air Systems Command
NAVSUP-WSS	Naval Supply – Weapon System Support
NCMS	National Center for Manufacturing Sciences
NSS	Naval Sustainment System
ODASD-MR	Office of the Deputy Assistant Secretary of Defense, Materiel Readiness
O-Level	Organizational Level
O&M	Operating & Maintenance
P2P	Performance to Plan
R2R	Return to Readiness
SPB	Sustainment Program Baseline
TAV	Total Asset Visibility
UI	User Interface
U.S.	United States
WHS	Washington Headquarters Services
WIP	Work in Progress

1. Executive Summary

The commercial airline industry faces many challenges with respect to managing multitudes of scheduled and unscheduled maintenance activities, often globally. Proper management and optimization of repair activity throughput is paramount for organizations to ensure efficient, timely, and safe delivery of people and products to destinations around the world. Inefficiencies of maintenance throughput can cause delays in supply chain operations, safety concerns, unsatisfied customers, and loss of business. The Department of Defense (DOD) faces similar challenges regarding aviation repair throughput. The Naval Aviation Enterprise (NAE) has over 100 repair activities which encompass both scheduled and unscheduled maintenance and repair of aircraft, engines, components, and support equipment. Scheduled and unscheduled maintenance requirements across the NAE require the integration of key data to identify specific support requirements and determine optimal repair processes. Too often, decisions are made without this visibility, resulting in short-term decisions that have long-term effects on flight line readiness. The NAE requires tools and processes that are optimized for long-term maintenance and sustainment. This optimization enables leadership to rapidly assess the impact that today's decisions will have on future readiness. Aviation maintenance organizations must have visibility into all facets of repair, including logistics, engineering, information technology (IT), and cost data to ensure repair decisions are optimized.

Measuring and managing capability and capacity at repair activities has traditionally been more of an art than a science. Production managers are forced to manually identify the impact of a new repair process, adjusted repair schedules, increased demand, or a reduction in one or more of the logistics elements required. This process required an immense amount of effort and was plagued with errors due to the complexity of some of the tasks involved. The equipment sustainers require global visibility of capability and capacity to facilitate the proper allocation of workload, optimization of scarce resources, and maximized throughput. Having data-driven visibility of appropriate capability and capacity increases accuracy of maintenance decisions, and subsequent investments, across the organization.

Repair capability is a function of manpower, training, tooling, facilities, support equipment, and authorized level of repair. Capacity is also a function of these elements but is largely dependent on the proper scheduling and release of workload into the repair activity. Capacity management is executed at four levels:

- Resource requirements planning
- Rough-cut capacity planning
- Capacity requirements planning
- Input/output control

Capacity planning begins with an overarching review of resource requirements, followed by the process of rough-cut capacity planning. Requirements are reviewed by master schedulers to identify any shortfalls with the planned workload. Finally, input/output analysis is conducted by production managers at each repair activity to enable "what-if" scenarios to be executed rapidly. Figure 1 depicts this process.

This project utilized NAE aircraft repair throughput issues as a surrogate to demonstrate better efficiencies that bring together collaborative tasks across the logistics, engineering, and IT communities of practice resulting in more reliable, more predictable, and more accurate decision-making.

Results of this project facilitate several DOD initiatives including but not limited to:

- Naval Sustainment System (NSS)
- Sustainment Program Baseline (SPB)

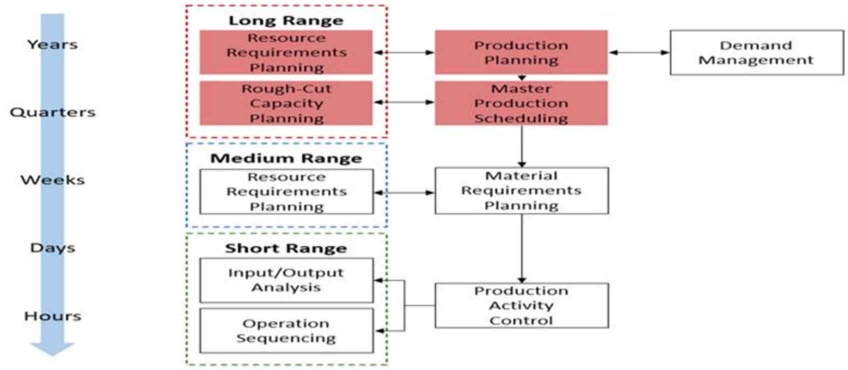

Figure 1. NAE Capacity Management Process

- Degrader Analysis Center (DAC)
- Return to Readiness (R2R)
- Performance to Plan (P2P)

DOD and industry participants now have a common view of current and planned workload utilization, enabling simulation of alternate workload distribution scenarios that better optimize available capability and capacity. Furthermore, the project has resulted in dual-use enhanced tools that quantify the impact of investments into manpower, infrastructure, material, or other considerations that are identified through analysis.

Funding was secured for the collaborative initiative through the National Center for Manufacturing Sciences (NCMS) Commercial Technologies for Maintenance Activities (CTMA) Program and the Office of the Deputy Assistant Secretary of Defense, Materiel Readiness (ODASD-MR).

1.1 Results

This project enhanced tools that were piloted under a previous effort by integrating the capabilities into a seamless toolset that can be accessed by decision-makers across the NAE. The integrated toolset demonstrates enterprise visibility of each repair activity's capability to perform specific repairs and identifies any repair limitations that might exist. As part of this integration, each site's capacity is available to further enable the proper allocation of workload and resources. This initiative also enhances the maintenance activities themselves by identifying best practices and optimizing time to perform maintenance, as well as improving processes, steps, tools, and other required resources.

1.2 Benefits

Although the project was relatively short, the DOD realized numerous benefits. The benefits were primarily centered on the ability to perform "what-if" scenarios at each repair site to optimize workload, increase throughput, and optimize costs. Specific benefits include:

- An updated model provided the Commander Fleet Readiness Center (COMFRC) with the ability to run what-if analyses on future workload possibilities. The model now also provides COMFRC with a Rough-Cut Capacity Tool.
- Performing Maintenance Task Analysis for F-35 Age Exploration Program provided the detailed maintenance actions to be performed.
- Documenting the workflow for the Fleet Readiness Centers (FRCs) provided an understanding of the current state and serves as a baseline by which to optimize future throughput for the COMFRC enterprise.
- Incorporating a Manufacturing Model into the Capacity Optimizer provided

COMFRC with the ability to manage the potential influx of workload at the Headquarters level through an integrated model.

- Additionally, the lessons learned through this effort will significantly benefit the commercial airline industry, and any other commercial or government maintenance organization facing capability and capacity planning challenges.

1.3 Recommendations

It is recommended that COMFRC and its subordinate commands adopt the Capacity Optimization techniques and tools developed during this project. As is the case with any software application, the accuracy of the tool will increase with increased data. It is projected that the application of Capacity Optimization can have a positive impact on all levels of maintenance across the DOD.

1.4 Technology Transition

Technology developed under this project was turned over to the government with government purpose rights. This provides the government with unlimited use of developed technology, tools, techniques, and processes. Data and information were regularly exchanged due to the cooperative partnership that was established during this project. Incremental development of technology was reviewed as part of recurring engagement meetings, mock-ups, and issue/requirement tracking processes. Through agile development, regular release scheduling, and an integrated testing process; technologies that were developed and approved for release were successfully transferred and deployed to production environments for use.

1.5 Invention Disclosure

☐ Yes Inventions ☒ No Inventions
DD882 Invention Report sent to NCMS ☒

1.6 Project Partners

Optimizing Throughput Across Aviation Repair Activities brought together a highly capable team of industry participants to meet the problem set facing the DOD. Each participant was selected based on a specific capability and skill set, and their ability to deliver high-quality products and services. Specific DOD and industry participants included the following:

- U.S. Navy
- U.S. Marine Corps
- Naval Air Systems Command (NAVAIR)
- Commander Fleet Readiness Centers (COMFRC)
- Naval Supply Systems Command
- Defense Logistics Agency (DLA)
- Andromeda Systems Incorporated (ASI)
- Engineering Solutions and Technology Applications Incorporated (ESTA)
- National Center for Manufacturing Sciences (NCMS)

2. Introduction

2.1 Background

Repair activities across both the commercial airline industry and the DOD are plagued by challenges that hamper their ability to repair aircraft, engines, components, and support equipment at a rate that meets fleet demand. These challenges include inadequate forecasting methodologies, non-standard work practices, undefined or misunderstood capacity constraints, and the inability to quickly identify alternate repair sources. The result is increased Work in Progress (WIP), decreased throughput, and escalating repair costs that negatively impact operational readiness.

This effort utilized NAE aircraft repair throughput issues as a surrogate to demonstrate better efficiencies bringing together collaborative tasks across the logistics, engineering, and IT communities of practice enabling more reliable, more predictable, and more accurate decision-making. Industry participants leveraged technology and advanced processes developed on previous CTMA projects to further enhance decision-making for leaders across the NAE.

Results of this project facilitated several DOD initiatives including but not limited to: NSS, SPB, DAC, R2R, and P2P. DOD and industry participants have a common view of current and planned workload utilization, enabling simulation of alternate workload distribution scenarios that better optimize available capability and capacity. Furthermore, the project resulted in dual-use enhanced tools that quantify the impact of investments into manpower, infrastructure, material, or other considerations that are identified through analysis.

2.2 Purpose

The overall objective of this project was to develop an integrated set of tools and processes that would provide a common operating picture of all repair activities across an aircraft maintenance organization to help improve overall Maintenance, Repair, and Overhaul (MRO) operations and throughput. Due to the varied nature of repair requirements at the NAE Intermediate (I-Level) and Depot Level (D-Level), two models were required. As the DOD explored alternative maintenance practices, including certification of I- Level maintainers in D-Level tasks, the opportunity existed to pilot an integration of these models to further optimize resource allocation.

These optimized tools and processes, and subsequent integration, resulted in better support to the flight line, increased operational readiness, significant cost savings on maintenance and sustainment, and generated lessons learned for other Services and the commercial airline industry. Results can directly benefit the public good through improved efficiency, less maintenance downtime, lower costs, and improved flight schedules.

2.3 Scope/Approach

A collaborative effort was used that established a government and industry co-aligned team to operate across functional areas. The project leadership team adopted an agile approach to ensure interoperability of all pilot projects and developmental cross-team collaboration between the functional areas. For the public, the completion of these tasks will serve as an example to the commercial industry providing new ways for commercial aircraft, ship, vehicle, medical, and construction industries to improve asset maintenance, sustainment, and repair throughput using an integrated data environment. Specific tasks that supported the effort included:

- Development of data requirements to expedite the workload planning for critical components, engines, and support equipment.

- Design and development of drill-down capability that facilitates identification of materiel and non-materiel barriers to improved production.
- Assessing the manpower, tools, special equipment, and other resources required to perform specific maintenance tasks and their frequency of occurrence/use.
- Exploration of optimized inspection intervals for inducted aircraft.
- Identification of Maintenance Planning tools and improvement opportunities to increase availability, increase maintainability, and reduce cost.

Key project deliverables from this initiative lend themselves to transition to both the commercial industry and the public sector. These deliverables demonstrate to commercial aircraft, ship, vehicle, medical, and construction industries a model for improving repair throughput, asset maintenance, and sustainment using the integrated data environment. The key project prototype deliverables are listed below:

- Model of Naval Supply – Weapon System Support (NAVSUP-WSS) components Integration of Manufacturing data into Capacity Optimizer.
- Investigation of F-35 enhanced Age Exploration techniques.
- Demonstration of Engine Capacity Models.
- Integration of Maintenance Planning, scheduling, and execution of software applications on a secure network.
- Enhancement of User Interface (UI) for Capacity Optimizer.
- Demonstration of Strategic Workload Planning.
- Demonstration of Machine Learning Algorithms to forecast resource requirements.
- Quarterly Reports that contained highlights from the Monthly Status Report (MSR), compiled and presented in CTMA format.
- A Final Report (contained herein) provides a complete description of project results including test data, projected benefits to industry, the general public, and the sponsoring organization, followed by recommendations and any appendices necessary for a complete understanding of results. The CTMA Final Report will be delivered to the Office of the Deputy Assistant Secretary of Defense, Materiel Readiness (ODASD-MR) and Washington Headquarters Services (WHS) by NCMS with copies to all project participants.

3. Project Narrative

Repair activities across both the commercial airline industry and the DOD are plagued by challenges that hamper their ability to repair aircraft, engines, components, and support equipment at a rate that meets fleet demand. These challenges include inadequate forecasting methodologies, non-standard work practices, undefined or misunderstood capacity constraints, and the inability to quickly identify alternate repair sources. The result is increased WIP, decreased throughput, and escalating repair costs that negatively impact operational readiness.

The project team performed work across two major functional areas, noted below.

Workload Planning

ASI was tasked to map current and projected COMFRC workload, to include aircraft, engines, and components. This mapping exercise provided COMFRC leadership with a clear, 10-year picture of workload across all three major organic Level 3 repair sites. The mapping revealed the impact of this workload on hangar space, resource allocation, as well as the requirement for personnel across the timeline.

Results of this project will facilitate several DOD initiatives including but not limited to, NSS, SPB, DAC, R2R, and P2P. DOD and industry participants will have a common view of current and planned workload utilization, enabling simulation of alternate workload distribution scenarios that better optimize available capability and capacity. Furthermore, the project will result in dual-use enhanced tools that will quantify the impact of investments into manpower, infrastructure, material, or other considerations that are identified through analysis.

Maintenance Optimization

This project enhanced the Capacity Optimizer tool that was piloted under a previous effort by integrating the capabilities into a seamless toolset that can be accessed by decision-makers across the NAE. This integrated toolset will demonstrate enterprise visibility of each repair activity's capability to perform specific repairs and will identify any repair limitations that might exist. As part of this integration, each site's capacity will be available to further enable the proper allocation of workload and resources. This initiative will also enhance the maintenance activities themselves by identifying best practices and optimizing time to perform maintenance, as well as improving processes, steps, tools, and other required resources. The DOD will benefit by having the ability to conduct "what-if" scenarios at each repair site to optimize workload, increase throughput, and lower costs. Lessons learned have the potential to significantly benefit the commercial airline industry, and any other commercial or government maintenance organization facing capability and capacity planning challenges.

3.1 Deliverables

The products highlighted in the following sections contain the deliverables for this project, together with a short description of the work performed under this deliverable. Product deliverables were provided directly to the government partners on the project.

3.1.1 Deliverable 1: Updated Components Model with New Schedules

Problem: When the components model was originally developed, ASI was provided with the basket market of components scheduled for rework at that time. Over time, the DOD partner realized that all components that may be worked in the Depot needed to be added to the components model.

Solution: ASI retrieved the potential components to be worked from the COMFRC and mapped these components from the operation line of the router to the equipment and then to the artisans including quals and certs.

Benefit: The updated model provides COMFRC with the ability to run what-if analyses on future workload possibilities. The completed model provides COMFRC with a Rough-Cut Capacity Tool.

Lessons Learned: Develop a draft technical solution for web-basing the models up front and early in the process.

3.1.2 Deliverable 2: Maintenance Task Analysis for F-35 AGE Program

Problem: The F-35 Joint Strike Fighter requires enhanced and optimized maintenance practices to ensure maximum availability at a reduced total ownership cost.

Solution: ASI performed Maintenance Task Analysis of the F-35 Landing Gear, to include a full review of previously conducted Supportability Analysis. ASI also provided an enhanced Data Collection process for future analyses.

Benefit: Properly performed, Maintenance Task Analysis provides decision-makers with the information required to optimize maintenance policies that increase weapon system availability and reduce costs.

Lessons Learned: Because of the current policies in place between the F-35 Joint Program Office and the Original Equipment Manufacturer (OEM), this task was suspended. It is recommended that this type of analysis continue to allow DOD to make informed decisions regarding maintenance policies.

3.1.3 Deliverable 3: Documented Workflow for Aircraft, Engines and Components at Fleet Readiness Center East (FRCE) and Fleet Readiness Center Southeast (FRCSE)

Problem: COMFRC has no standardized method of capturing the impact of future workload on facilities and repair centers. Documenting the workflow for the FRCs is vital to understand the current state and to serve as a baseline for the ongoing tasks ahead to optimize the throughput as a COMFRC enterprise.

Solution: ASI captured and documented workflow and workload out to FY 2030 for aircraft and engines for FRCE, FRCSE, Fleet Readiness Center Southwest (FRCSW), and Fleet Readiness Center Western Pacific (FRCWP). Figure 2 shows decision logic diamonds necessary for timely COMFRC decision-making. Aircraft hangar layouts for each site were created for use with aircraft workflow diagrams. Hangar layouts were created to accompany the workflow diagrams. Figure 3 provides a graphical representation of the hangars at each FRC.

Benefit: Capturing projected workload across each FRC allows COMFRC and the FRCs to make informed investment decisions.

Lessons Learned: COMFRC should strongly consider an automated system to capture changes in workload, facility configuration, future military construction projects, and capacity requirements.

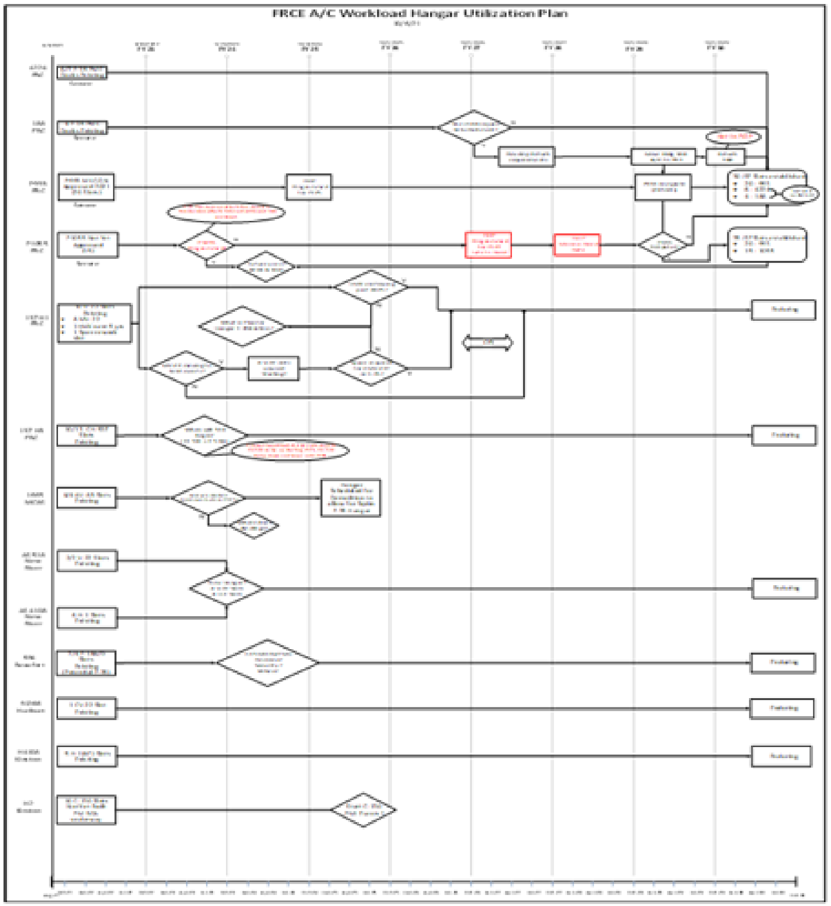

Figure 2. Engine Workflow Decision Logic

Figure 3. Hanger Layouts

Insight gained as part of this project allowed ASI to capture the impact of future changes in the Arena Capacity tool/modeler for use in Center of Excellence (COE) discussions. The data was presented for all 27 Federal Supply Class Commodity groups. Figure 4 applies.

This data has been used to run workload movement scenarios for all Federal Supply Class commodities in work at the FRCs. All 27 Federal Supply Class Commodity groups were studied and charted with 13 chosen for scenario runs to support potential movement of workload across sites. Outputs of the capacity model scenario runs have been iterated per COMFRC direction and provided to COMFRC Leadership and the site Executive Directors for study. Figure 5 applies.

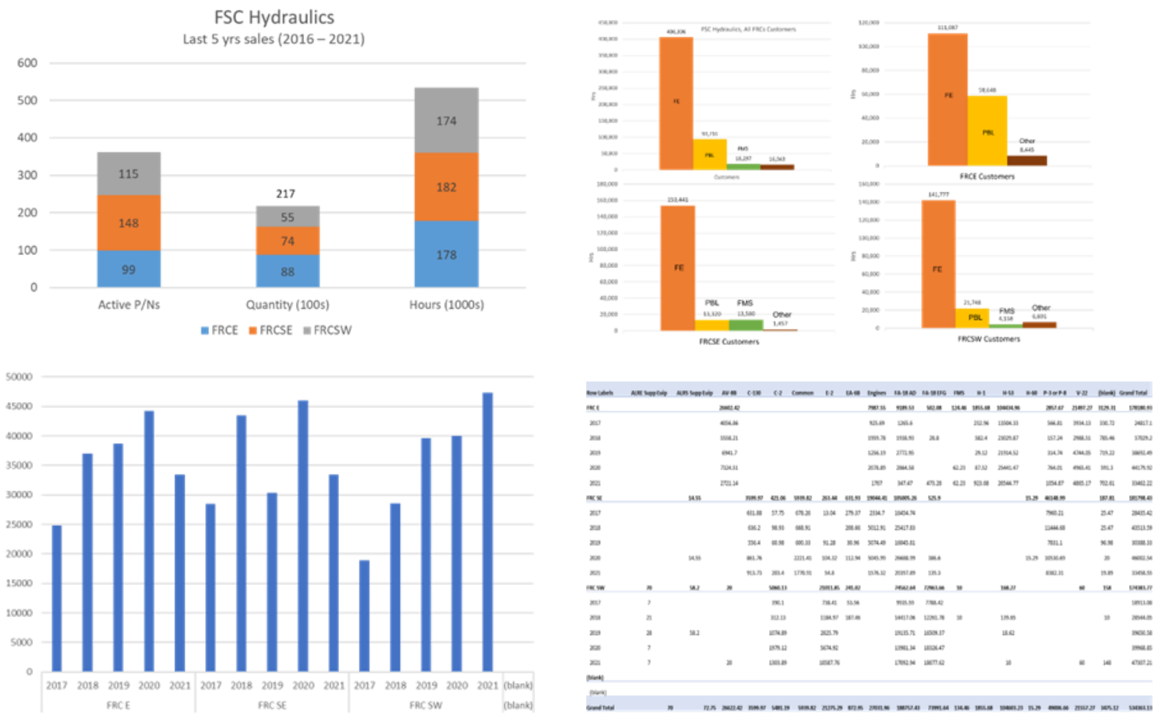

Figure 4. Arena Modeling Workload Capacity Data

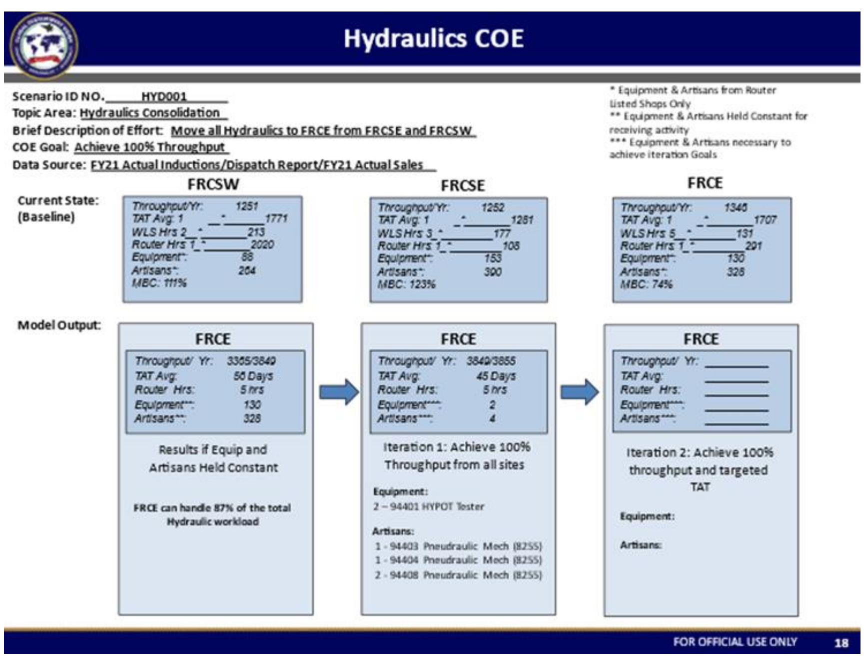

Figure 5. Hydraulics Workload Movement Scenario

In total, just under 200 artifacts and project milestones were developed and delivered to document the workflow in various forms of flow diagrams, charts, space diagrams, and Arena outputs. All of these serve to document the current state and form the basis from which this effort will be automated to the highest degree possible. The desired end-state being a system that will provide real-time scenario results fed by the COMFRC data systems and critical information identified in this project resident in those systems.

4. Conclusions

The Optimizing Throughput Across Aviation Repair Activities project explored the application of data analytics across various facets of Naval Aviation operations, including work planning, Total Asset Visibility (TAV), supply chain management, sustaining intellectual capital, and in-service logistics engineering. Overall conclusions demonstrated improvements in efficiency, cost optimization, risk mitigation, knowledge enhancement, and strategic alignment of objectives. The following conclusions are drawn from the project deliverables:

- Data analytics significantly optimized work planning processes by enabling more accurate and timely decision-making. Enhanced predictive analytics illustrated a more efficient allocation of resources and improved productivity. By anticipating potential disruptions and suggesting adjustments proactively, the application of data analytics in work planning leads to an overall improved operational efficiency and reduced downtime.
- The demonstration of data analytics provided a comprehensive view of the assets, aiding in tracking, management, and optimization. The real-time visibility of assets facilitated immediate identification and rectification of any discrepancies or irregularities. When expanded, the enhanced asset visibility will lead to better asset utilization, reduced losses, and improved financial management.
- Data analytics plays a pivotal role in forecasting, planning, and monitoring the supply chain in real-time. Analytics allowed for deeper insights into market demands, inventory levels, and supply chain risks. Employing a series of dashboards, the program manager was able to optimize inventory, reduce costs, enhance supplier relationships, and respond more effectively to readiness changes.
- Data analytics was instrumental in the management and optimization of intellectual capital. It was concluded that analytics allowed for effective knowledge management, capturing, and leveraging organizational knowledge to foster innovation and improve decision-making. By identifying knowledge gaps and areas for development, data analytics can facilitate targeted learning and development initiatives, which concluded in enhanced employee performance and intellectual asset growth.
- The application of data analytics in in-service logistics engineering yielded improvements in equipment maintenance, downtime reduction, and resource allocation. Analytics provided insights into equipment health, enabling predictive maintenance, and reducing unplanned downtime. This use of analytics can increase equipment longevity, improve service quality, and optimize operational costs.

Much of the work accomplished on this project continues today. Additionally, several of the specific deliverables continue to be refined to ensure technology maturity levels are achieved for transition to DOD as a minimum viable product. The following recommendations are proposed to continue the progress accomplished in this effort:

- Continue refining analytics models to adapt to changing organizational needs and external environments. Regularly update algorithms and models to ensure accuracy and relevance.
- Invest in ongoing training programs to enhance employee skills in leveraging data analytics for various operational domains.

- Further integrate data analytics with other technological solutions like Artificial Intelligence (AI) and Internet of Things (IoT) for more comprehensive and insightful analyses.
- Regularly engage with stakeholders to understand their needs and adjust analytical models to address evolving requirements and expectations.
- Allocate sufficient resources and investments to sustain and enhance the data analytics capabilities, focusing on both technological advancements and human capital development.
- Focus on the scalability of data analytics solutions to cater to the growing and changing needs of the organization.

The leveraging of data analytics across the examined areas has undeniably contributed to enhanced operational efficiency, risk mitigation, and strategic alignment of organizational goals. The technologies demonstrated have paved the way for a more informed, proactive, and data-driven organizational culture, positioning Naval Aviation for sustained success.

5. Project Benefits

5.1 Benefits for the General Public

This initiative used NAE Data Analytics as a surrogate for industry to demonstrate how the integration of disparate datasets will enable collaboration across both DOD and industry partners. Today, DOD and industry partners are generally reluctant to share data in a collaborative environment. This effort helped to showcase the benefits of a more integrated approach to sustainment across the enterprise. Using this improved view of global capability and capacity, improvements to repair time throughput, supply chain, logistics, facilities, operations, reduced human errors, and a safer working environment will be realized. Organizations that manage large, disparate fleets of vehicles will benefit from improved MRO throughput and data integration. These include the commercial airline industry (such as Delta and American Airlines) and other multi-modal logistical industries (such as FedEx, UPS, and Matson). Smaller organizations, such as state and local Departments of Transportation (DOT), construction, first responders, and other ground vehicle fleets, would also benefit from this initiative. Integrated sustainment efficiencies and improved repair time throughput can have a wide, positive impact that directly results in lower vehicle fleet lifecycle costs. This frees up maintenance resources and funding to provide better goods and services which build better customer relationships through improved satisfaction.

By integrating and aligning the variety of datasets, companies will be able to have access to collaborative information, which will enable optimized decisions in near real-time. Companies will benefit from decreased time spent aggregating information, which will reduce repair time and unnecessary costs. The reduction in time spent collecting and stratifying information will allow companies to focus on more strategic objectives, which will improve productivity, decrease costs, and improve overall profitability. This profitability will lead to a lower cost of goods and services and a lower overall cost of ownership for consumers. Profits can be reinvested into the organization, thereby realizing more and better paying jobs, long-term benefits for employees, and a higher quality of life.

Companies face the same challenges that DOD faces regarding proper distribution of key resources. This project demonstrated a quantifiable and sustainable methodology for determining resource requirements, acquiring those resources, and ensuring optimal utilization of those resources to meet company objectives. Through cutting-edge data analytics techniques, companies will be able to make better decisions regarding how to balance cost, scheduling, and performance in a highly competitive market.

5.2 Benefits for DOD

Optimization of throughput through improved integration, particularly pertaining to the maintenance and sustainment activities, will improve man-hour efficiencies, reduce aircraft downtime, reduce materials costs, and help all the Services enable more effective resource allocation.

Optimizing Throughput for Repair Activities forces a deeper discussion regarding the way maintenance and sustainment activities view capability and capacity. The results are opportunities for increased transparency of repair processes, improved forecasting, increased throughput, and reduced costs. Using the best practices and outcomes from this project, U.S. Navy and U.S. Marine Corps activities will have more accurate forecasts for their Operating & Maintenance (O&M) budgets, greater fidelity when developing contract requirements and deliverables, and improved accuracy on its reporting of these publicly owned assets on financial statements and audits.

Additional benefits to the Navy and DOD will include:

- Increased transparency of repair processes.
- Increased speed of decision-making.
- Improved collaboration between engineering and logistics providers.
- Optimized sustainment policies and practices at the Program Office, Field Repair activities, and Field Supporting agencies.
- Increased mission capable (MC)/full MC weapons systems available to the warfighter
- Decreased Turnaround times for Organizational (O-Level), I-Level, and D-Level repair activities.
- Decreased operational maintenance and sustainment costs.
- Enhanced mission planning capabilities that facilitate improved mission success rates. Improved mission success rates for Combatant Commanders to enhance predictive capabilities for mission planning.

Lessons learned from this initiative can be applied across the other Services maintenance organizations, with the potential for adoption by managers of ground vehicle fleets, engineering equipment, power generation, ship repair, and a multitude of other applications.