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The Logistical Delays and Manpower Requirement for Future Attack Reconnaissance Aircraft

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Author Note: Thomas Bizub, Jack Carlson, Ethan Paraiso, and Colton Wheeler are senior Cadets at the United States Military Academy and part of West Point's Department of Systems Engineering. Jack, Ethan, and Colton will commission on May 27, 2023, as Army Aviation officers, while Thomas will commission as an Army Signal Officer, branch detailed Infantry. The views expressed in this article are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Abstract: The U.S. Army is developing the next generation of vertical lift aircraft. The Future Attack Reconnaissance Aircraft (FARA) will assume the armed reconnaissance mission. This analysis informs the Program Manager (PM) FARA, on logistical delay impacts to a Limited Maintenance Operating Period strategy in multi-domain operations. This effort provides a predictive maintenance model applicable to the upcoming generation of Army aircraft, specifically the FARA program. Modified AH-64E data was used as a surrogate for FARA, as there is no current data for this future aircraft. This analysis used ProModel® to translate logistical delay data into distribution streams that incorporated into the overall aircraft operational availability model. In addition, this research provides an assessment of the skills and personnel required to sustain the aircraft and optimize availability. Exploratory research of Army Military Occupational Specialties (MOS) relevant to Army aviation maintenance informed maintainer needs requirements for FARA.

Keywords: Limited Maintenance Operating Period (LMOP), Multi-Domain Operations (MDO), Future Attack Reconnaissance Aircraft (FARA), Military Occupational Specialties (MOS)

1. Introduction

The U.S. Army is in transition, pivoting from counterinsurgency to preparing for near peer threats in a multi-domain environment. With regard to Army Aviation, future aircraft, such as Future Attack Reconnaissance Aircraft (FARA), will be utilized to fight these battles. A key FARA requirement is the reduction of maintenance down time. The main issue that Army Aviation currently faces is a lack of organization relating to part distribution and a very ineffective maintenance strategy. This has led the project team at West Point researching two tasks: first, analyze and recommend the optimal maintenance personnel structure required for a small FARA unit (company or battalion) operating under a Limited Maintenance Operating Period (LMOP) strategy in Multi-Domain Operations (MDO). Second, capture the impact of logistical delays on an LMOP strategy in MDO. By completing these tasks, the capstone team will provide Project Manager (PM) FARA with a deep analysis of the personnel required for the future aircraft and the impact that logistical delays have on an LMOP strategy in MDO.

2. Background

2.1 MDO Operations

The Multi-Domain Operations concept created in 2019 by the Department of the Army, accounts for near peer threats, stating that complexity will increase due to the convergence of land, air, water, cyber, and space powers in their domains (Army University Press, 2022). Most notably, the air superiority that the United States forces experienced during the past few decades will no longer be present. Airways will be contested due to the enemy's enhanced capabilities in the previously mentioned domains (ADP 6-0). Because of this situation, the United States must adapt its aviation forces to ensure smaller logistical footprints. The aviation forces must be lighter, quicker, and more sustainable than ever before to compete with rising adversaries.

2.2 Transition from MFOP to LMOP

While the Army currently utilizes a maintenance strategy known as Maintenance Free Operating Period (MFOP), the nature of this style of maintenance may not be suitable for new aircraft operating in a MDO environment. MFOP was originally introduced by the British Royal Air Force in a study titled "Ultra Reliable Aircraft Pilot" in the 1990's (Beigh, Bellocchio, Burgess, & Schrage, 2020). It was eventually adopted by the DoD for submarine maintenance in the Navy leading to the implementation in Future Vertical Lift (FVL) in 2017. The concept of an MFOP, developed by the British Royal Air Force in the 1990s, is the duration of flight hours that the aircraft can operationally sustain before maintenance is required. The period during which the aircraft is grounded for maintenance is called the Maintenance Recovery Period (MRP), shown in Figure 1. The goal of the MFOP is to consolidate the maintenance issues into the MRP to maximize the operational availability of the aircraft (Beigh, Bellocchio, 2020).

Due to the developmental nature of FARA, there is no operational prototype meaning there is no usable maintenance data available. For this reason, this study utilizes data based on an enhanced AH-64E model. The goal of FVL is to reach a high probability of no maintenance required through 80 flight hours. The MFOP was found to have a very low likelihood of reaching these set goals. Due to the inability of an MFOP model to achieve this requirement, the LMOP is better suited for FARA (Razon & Bellocchio, 2022). The LMOP strategy concedes that throughout 80-hours of flight time the aircraft will require minimal scheduled and unscheduled maintenance, to be performed during Limited Recovery Periods (LRP). The LRPs are held to strict maintenance manhour constraints to ensure only essential maintenance actions are taken. Within the LMOP strategy, a larger emphasis is placed on predictive maintenance during an MRP, as depicted in Figure 2. The nature of this system allows the fleet to increase their operational availability in a combat environment (Razon & Bellocchio, 2022).

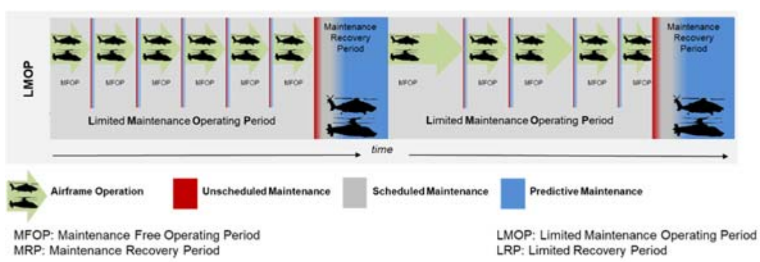

Figure 1. LMOP accounting for short periods of MFOP

2.3 Operational Availability

Operational availability is a quintessential concept in understanding the effectiveness of a fighting force and is a primary requirement of PM FARA. This statistic is needed to understand the availability of aircraft in a MDO environment. Due to FARA not being operational yet the supply chain and customer wait time for the AH-64E was the most identical data available and was utilized in our model. The achieved availability shown in the equation (1) below is the availability found in prior project iterations and provides an availability in a perfect world, without supply chain considerations which the operational availability equation (2) accounts for. Using data that does not account for the supply chain delays would be a naïve approach, so the logistical down time is accounted for to provide a more accurate representation of the availability of the force to PM FARA, as shown by the highlight.

Achieved Availability – what the current model uses

$$A_A = \frac{Time\ Between\ Maintenance}{Time\ Between\ Maintenance + Mean\ Maintenance\ Time} \tag{1}$$

Operational Availability – what the USMA Capstone team will discover through the implementation of the logistical down time

$$A_O = \frac{Time\ Between\ Maintenance}{Time\ Between\ Maintenance + Maintenance\ Time + \mathbf{Logistical\ Down\ Time}} \tag{2}$$

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The logistical down time is the sum of the time it takes a replacement part to reach an aircraft in need of repair. It includes an estimated 24-hour delay between FARA and a nearby support area, plus the customer wait time (CWT), or the time it takes to receive a replacement part from the supplier. Figure 2 below outlines the general process that determines the logistical down time. This year's team focused on the CWT and frequency that the wait occurs. The team determined an expected CWT and conducted a sensitivity analysis on the frequency, as there is limited data tracking parts located at the support area. A more in-depth explanation of this process is included Section 3.

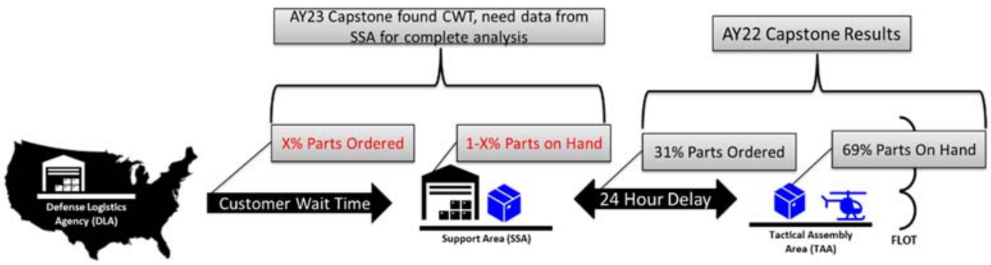

Figure 2. Logistical Down Time Process Diagram

3. Logistic Delays

3.1 Method of Gathering Data

The data required to solve the two tasks outlined in the Statement of Work provided by the client needed to have the customer wait times to fit distributions to each major subsystem in the AH-64. The fitted distributions would allow the model to determine the operational availability. Data used for logistical delay in repair part orders came from the Army Database known as Army Enterprise Systems Integration Program (AESIP) which included the customer wait times, start location, end location, and National Item Identification Number (NIIN) of AH-64 parts. The supplementary database used during this iteration was i2Log, which linked the NIIN to the item description of that part and consequently the subsystem it related to. Further analysis into the sources of data revealed critical issues with the Army's logistical processes that, if corrected, would streamline and enhance the Army's ability to analyze the logistical delays. The Army Data Platform (ADP) only displays and retains 6 months' worth of request data, does not match the NIIN to an item description, or record the Work Unit Code (WUC). Retaining achieved data and annotating the aforementioned identifiers at the time of the request would drastically reduce the hours spent to identify significant logistic delays. The lack of a comprehensive collection of data spanning multiple years across the operational force inhibits the Army from accurately determining logistic delays by WUC. The research team used a bootstrapping method as a substitute in WUC categories that were lacking sufficient data, allowing us to determine the most accurate logistical delays with the provided data. Additionally, adjusting the existing simulation to result in the maintenance manhours per subsystem allows for further analysis of the personnel required.

3.2 Technical Approach

The technical approach evolved greatly throughout the process of completing this project. The initial approach consisted of analyzing a variety of different models that could be used to capture the impact of logistical delays on an LMOP strategy in MDO. The four modelling approaches considered at the start of the process were efficiency-focused models (with an emphasis on the continuous flow model), responsive-focused supply chain models (with a focus on the custom-configured model), transshipment models, and value stream mapping and analysis models. After review, it appeared that the transshipment model was most applicable for the FVL project. However, the process soon revealed that gathering the data necessary to develop a transshipment model is not available or possible to obtain, as previously discussed. Namely, the data source utilized did not have the available start and end locations for the transportation of parts around the world. However, the project team recognized that it was not necessary to create a transshipment model to capture the logistical delays on an LMOP strategy. Rather, the project team made the decision to utilize Microsoft Excel to manipulate the data collected and find the logistical delay.

In order to do this, data found from July 2022 – January 2023, was compiled which included NIIN and customer wait time for parts from AH-64E Apache helicopters of several different units. Utilizing the NIIN given within the data set, the Army Logistics Modernization Program's i2log database was used to find the nomenclature of parts. From this step, a function was developed using Microsoft® Excel®'s fuzzy lookup feature to match the nomenclature found from i2log to the specific subsystem present in the current model. This process was necessary to ensure that the customer wait times found could be used in the model that the Department of Systems Engineering's Operations Research Center (ORCEN) is utilizing.

Once the proper NIINs were matched to the current subsystems present in the model, the customer wait times given in the data set were used to fit a distribution that would be utilized within the current model. Due to the small amount of data available, we used the technique of bootstrapping to resample our dataset to create many simulated samples. For each subsystem, we generated 100 samples using the bootstrapping technique and then fit the distributions to our data. To find these distributions, the project team utilized ProModel®'s Stat:Fit feature which matches several different distributions to the data input. This feature of the program provides a "rank" statistic for each distribution matched which demonstrates how well each distribution fits the data sets provided.

4. Personnel Required

4.1 Analysis of current MTOEs

Based off of a Modified Table of Organization and Equipment (MTOE) for an Aviation Sustainment Battalion in 2021, Figure 3 displays the personnel in an Aviation Support Company:

MOS	Description	# MOS in Aviation Support Company
15N	Avionic Mechanic	2
15F	Aircraft Electrician	4
15H	Aircraft Pneudraulics Repairer	4
15R	AH-64 Attack Helicopter Repairer	5
15G	Aircraft Structural Repairer	5
15D	Aircraft Powertrain Repairer	5
15B	Aircraft Powerplant Repairer	7
15Y	AH-64D Armament/Electrical/Avionics Repairer	10

Figure 3. MTOE Breakdown for an Aviation Support Company

The most utilized MOS in a support company according to the figure is the AH-64 Armament/Electrical/ Avionics Repairer (MOS 15Y), making up almost 25% of the personnel. Due to the critical nature of armaments, electronics, and avionics systems to the AH-64E mission, 15Y's are assumed to be critical to sustaining these systems. Additionally, the majority of the avionics repairers are in the support company of a sustainment battalion because there are simply not enough. Ideally, the total number of personnel in the aviation support company (battalion level) and the flight company (company level) would all decrease since the FARA is supposed to be more maintainable.

Apart from the current MTOE for an Aviation Support Company, Figure 4 displays the top 5 subsystems that require the most maintenance man-hours per aircraft in one LRP or MRP respectively, which is important to consider when a new part needs replacement or maintenance. This figure is based on the ORCEN model which is the predictive MMHs for FARA.

Subsystem name	MMH per LRP per AC	MMH per MRP per AC
POWER PLANT INSTALLATION	0.62	3.12
FLIGHT CONTROL SYSTEM	0.43	0.56
AUTO PILOT SYSTEM	0.87	2.83
ELECTRICAL INSTALLATION	0.71	10.33
DRIVE SYSTEM	0.66	2.60
OTHER	2.32	26.66
TOTAL	5.61	46.10

Figure 4. Top 5 Subsystems that Require the Most Maintenance Man-Hour by MRP per AC

5. Findings and Results

5.1 Model Analysis

The current model supplements a FARA airframe by using the current AH-64E performance outputs as a baseline and estimating the areas where the FARA is expected to outperform the AH-64E. The result is a *FARA surrogate*, as the exact performance data does not yet exist. The model will then run a single FARA surrogate through a simulated mission and record the impacts to each of the 28 subsystems. After a series of iterations on 20 different FARA surrogates, the outputs are used to calculate the probability of success using an MFOP based operating cycle. Using 20 unique airframes, varying MFOP cycles, and the most current supply data available, the team was able to produce an estimated operational availability for FARA.

5.2 Personnel Analysis

The updated version of the simulation model run from last year breaks the maintenance man-hours (MMH) by subsystems and location (MRP or LRP). The number of personnel in the LRP is calculated by first taking the average of the MMH per company for one LMOP phase. The capstone team added this average of MMH per aircraft into a new column. The capstone team multiplied this MMH by the number of days per LMOP. Lastly, this rate of MMH per day was divided by hour shifts per day. The researchers assumed an average of 8.7-hour shifts per day according to the Capability Development Integration Directorate from Fort Rucker, Alabama. The team divided the rate of MMH per day by 8.7-hour shifts per day to yield the number of personnel for the given subsystem. The method for calculating the number of personnel at the MRP is generally the same, except the cycle time for the LRP is 80 hours, and the sum of MMH is the hours from the MRP Predictive, MRP Scheduled, and MRP deferred. The last step was to match the personnel for each subsystem with the MOS. Due to the change in having an expeditionary fleet, the organizational elements at the LRP and MRP would adjust from an Aviation Support Company in the Aviation Support Battalion to a forward flight company and a maintenance company in the MRP. The pie charts below display the percent number of personnel required at MRP and LRP locations by MOS (Figures 5a and 5b).

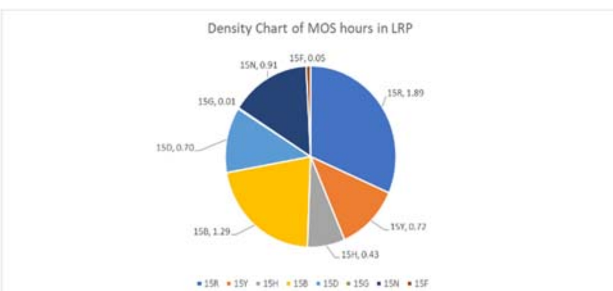

Figure 5a. Density Chart MOS Hours in LRP

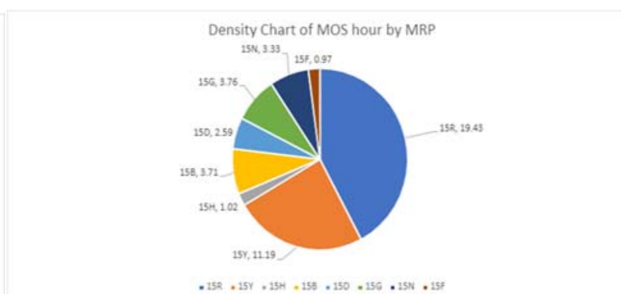

Figure 5b. Density Chart MOS Hours in MRP

The capstone team compared the number of personnel from the spreadsheet to an approved MTOE for the First Battalion of the 501st Aviation Regiment in October 2021. Based on the figures above, the FARA aircraft would require most hours at the LRP (~6 hours) and MRP (~46 hours) to resolve 15R-related issues; however, compared to current MTOEs of flight companies and maintenance companies, the model shows an increase in personnel regarding MOS's allocations other than 15R and 15Y. This change makes sense since the LRP will have short periods of time to repair. Additionally, the number of personnel at the MRP based on the model is roughly 8 people assuming the theoretical maximum OPTEMPO where an LRP occurs every 5.33 days.

6. Conclusion

Answering the first task outlined in the statement of work, the team looked at the personnel required of a small unit (company or battalion), equipped with FARA, to conduct maintenance in an MDO environment. Figure 5a compares the personnel requirements of example MTOEs to see differences between current and future attack reconnaissance helicopters. Based on this analysis from the density charts by LRP and MRP, the team concluded that FARA aircraft require less personnel.

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When comparing the findings at the LRP with an MTOE, the LRP requires seven total maintainers while the current MTOE on an attack reconnaissance flight company requires 10 total maintainers. When comparing the findings at the MRP with an MTOE from the aviation support company (which is at the battalion level), the MRP requires 29 total maintainers while the current MTOE on an attack reconnaissance flight company requires 42 total maintainers. To iterate, the composition of MOS's in each organization will change based on the density charts. These charts indicate that most maintainers will still be 15R's, but there should be an increase in specialty MOS's such as 15N's, 15B's, etc. both at the LRP and the MRP.

Regarding the second task, the team developed a model in Microsoft® Excel®, as detailed above, to capture the impact of logistical delays on an LMOP strategy in MDO. The team was able to find customer wait times for each of the sub-components presented to them. These times were then put into the ORCEN model and then into ProModel® so that further conclusions could be drawn. The graph below represents the Assembly Area logistics delay percentages based on MFOP Hours. This graph shows the chance that a part is not at the SSA and will experience the customer wait times we have calculated after a certain amount of MFOP hours, including data points from 2022.

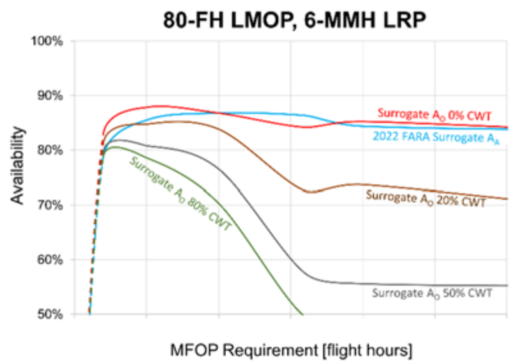

Figure 6. Assembly Area Log Delay Percentages Based on MFOP Hours

Our primary recommendation for the Army is to develop a centralized system to better manage the data collection process. Finding a database containing information regarding logistical delay presented the Capstone Team with many challenges that required reaching out to several different individuals within the Army aviation community. Eventually, the AESIP database was utilized in conjunction with the Army's i2log website to find customer wait times that can be used in the ORCEN model. However, there were many limitations to this dataset, namely only containing six months of data at a time with the deletion of previous months on a rolling basis. This restriction limited the amount of data available resulting in a lack of data for some of the subsystems analyzed. To fix this problem, the USMA Capstone Team recommends that a new database be developed that tracks all information regarding aviation maintenance, or a significant upgrade to the existing systems that tracks information regarding requested parts from the initial request to delivery.

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