Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
April 29, 2021
A Regional Conference of the Society for Industrial and Systems Engineering

Simulating Aircraft Block Modification Processes

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Author Note: Cadets Benoit, Dotson, Morel, and Yanoschik collaborated with the Project Management Office Aircraft Survivability Equipment (PM ASE) office as part of the capstone program with the Department of Systems Engineering. We would like to thank the PM ASE team, COL Kevin Chaney, Mr. Raymond Pickering, MAJ William Schreiner, and CPT Laura Fuerst for their continued sponsorship and guidance throughout the project.

Abstract: Project Management Office Aircraft Survivability Equipment (PM ASE) oversees the rotary wing aircraft modification process for the United States Army. Due to the complexity of the required modifications and the large number of variables involved, PM ASE faces issues with scheduling aircraft survivability maintenance within the constraints of the Army's operational tempo. Fort Hood and Fort Campbell are currently implementing a Block Modification maintenance program and provide two case studies for both developing process maps and collecting historical data. This study used these process maps to inform a discrete event simulation that would allow PM ASE to simulate the modification process given number and type of aircraft, amount of hangar space, and additional variables to produce total modification time. As a result, the simulation shows that electrician utilization was the primary constraint of the process, and not hangar space.

Keywords: Block Modification, PM ASE, Modification Work Order, Discrete Event Simulation

1. Introduction

1.1 Background

To maintain readiness, the United States Army's rotary wing aviation fleet must be equipped with the most updated survivability packages and maintenance servicing to be prepared for combat deployments and training rotations. In their 2020 paper, Murdock et. al. described the growing threat to rotary wing aircraft beginning in the 1980's from ground-based weapon systems. During the subsequent Global War on Terror, the increasing threat combined with increasing operational tempos necessitated a response from the Army Aviation community, and the Army developed individual modifications in response to the varied threats. These individual modifications are called Modification Work Orders (MWOs). MWOs explain the purpose of the modification, as well as the steps and projected time necessary to upgrade and install equipment in the aircraft. The Army uses private military contractor companies to install the MWOs on Army aircraft, specifically on the AH-64, UH-60M, HH-60M, and CH-47.

PM ASE currently manages the individual MWO's through the Block Modification process which essentially "blocks" multiple MWOs into a single maintenance period. The goal of the Block Modification process is to cost effectively modernize a Combat Aviation Brigade with advanced capabilities in the most efficient process possible while optimizing the unit commander's ability to maintain operational readiness (PM ASE, personal interview, September 22, 2020). This increased aircraft availability from the Block Modification enables the unit to accomplish its flight hour requirements, unit level training, and assigned missions prior to operational deployment.

However, the Block Modification process is not without issues. Resources for units undergoing Block Modification, such as hangar space and workers, are not necessarily synchronized with either unit deployment or PM ASE's schedules. Additionally, aircraft in maintenance for modifications affect a unit's reported readiness rate making commanders reluctant to provide aircraft in large numbers for the length of a Block Modification. These friction points have amplified PM ASE's scheduling problems in the past (PM ASE, personal interview, September 22, 2020).

This paper will present a multifaceted, adaptable research project that supports PM ASE's aircraft Block Modification process initiatives using stakeholder analysis, process mapping, and simulation to optimize the schedule while minimizing time that aircraft are out of operation. Through the creation of a discrete event simulation, commanders and contractors can synchronize and identify the resources needed to upgrade the Army Aviation fleet while staying on the timeline imposed by unit deployment schedules.

1.2 Literature Review

Discrete event simulation models a system's variation over time in a manner where variables change states instantaneously at different points (Law, 2015). These state-based variables allow the user to understand which factors are most important in their model. Discrete event simulation has become popular for problems in the military because it allows for testing of tactics and strategies without a need for actual threats and hostilities (Mittal, 2017). This is important because of both the time and resources saved and the risk-reduction factor when using computer-based simulation. Without the computer, simulations would require active participants and equipment, taking time away from daily activities and training. In addition, the use of computers in discrete event simulation allows for the observation of multiple scenarios at an accelerated rate.

Aircraft maintenance problems have been previously solved applying the principles of discrete event simulation. Mattila et. al. used discrete event simulation to improve the maintenance system for aircraft in the Finnish Air Force (2008). They were hindered by a scarcity of time data and component design. However, even with these limitations, accurate process models were created using discrete event simulation and stochastic time properties for each of the activities involved in the system. They concluded that the largest impact to efficiency in the maintenance scheduling problem is the number of workers and the shifts that they are working to upgrade the aircraft (Mattila, 2008). Considering the principles of discrete event simulation and previous applications, a discrete event simulation was the most fitting solution to analyze the aircraft scheduling problem for PM ASE.

1.3 Problem Statement

Using stakeholder analysis, this paper will present a discrete event dynamic simulation for MWO installation that predicts modification timelines. The goal of the model is to minimize time that aircraft are out of operation, provide a reliable schedule for decision makers, and minimize contractor turnover.

2. Methodology

2.1 Stakeholder Analysis

A large part of the methodology for the project included conducting stakeholder analysis to identify processes and gain inputs for the model. The development began with sponsors from PM ASE who oversee the entire aircraft Block Modification process. These initial meetings formed the problem definition and overview of the processes that became the foundation for building the simulation.

Another stakeholder who proved to be critical to the development of process maps was the manager who oversees the Block Modification process for Regional Aircraft Sustainment Manager - West (RASM-W) at Ft. Hood. RASM-W provided a process overview, and a description of how the contractors from DynCorp currently perform all the necessary MWOs. One issue that arose at this point of the stakeholder analysis was the lack of specific information and process maps that the stakeholder was legally allowed to share. The MWO team manager at Regional Aircraft Sustainment Manager - East (RASM-E) provided similar insight to help facilitate inputs for the models.

In addition, these clients connected us with other members of the PM ASE team who were able to give a holistic understanding of the problem based on their various roles and responsibilities. Aviation officers and commanders are key stakeholders in the Block Modification system, and they had a very difference perspective from PM ASE or DynCorp. These subject matter experts were able to identify issues from the unit perspective, add realism to the model, and help to make process improvement suggestions. Overall, stakeholder analysis was a critical part of the methodology and assisted with process map creation, data collection, and system verification and validation.

2.2 Process Maps

Key takeaways from the stakeholder analysis directly led to the development of the process maps for the Block Modifications. Figure 1 below shows a broad overview of the process beginning when the aircraft arrives at the Block Modification location and ending when the aircraft departs. In this map, there are six different "loops" that the aircraft flows through from beginning to end. PM ASE originally scheduled the total process for no more than 30 days, but based on stakeholder analysis, this timeline is often shifted. These shifts can occur for a variety of reasons including aircraft not arriving to the site with proper software updates, MWO parts are not immediately available, and a pause in work for holidays. In the model building process, this map is the basis of the general flow that the aircraft follows from the time it arrives at the site to when it is inspected and departs back to its home station.

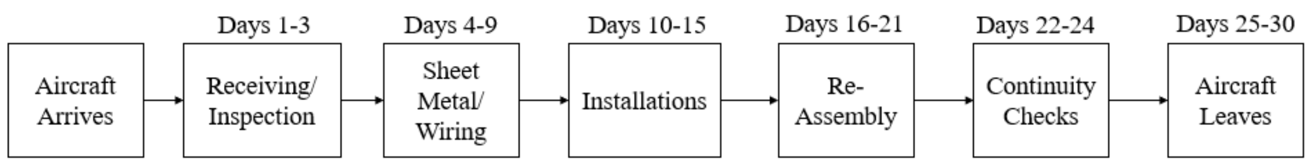

Figure 1. General Outline for Block Modification Process Map

2.3 Simulation

Incorporating the Block Modification process map into a discrete event simulation was done with the simulation software, ProModel. Simulation in ProModel allowed PM ASE to visually see the movement of aircraft and provide additional feedback on the process. Stochastic attributes were added to increase the complexity and make the model more indicative of the real-world processes. Finally, workers such as electricians and sheet metal mechanics were added to address variability in labor and analyze resource utilization. Figure 2 presents a screenshot of the simulation during a run with 5 of 12 hangars currently filled by aircraft undergoing the Block Modification process.

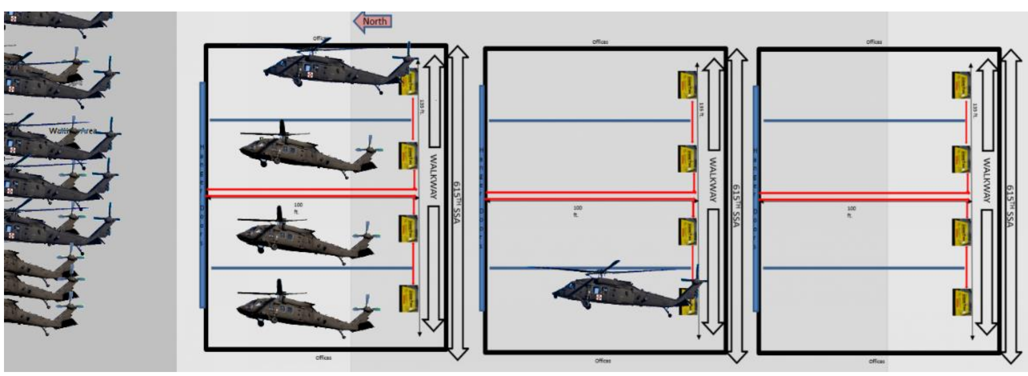

Figure 2. General Overview of the Simulation Visualization

2.3.1 Requirements, Assumptions, and Constraints

The most basic version of the model had the following requirements: the simulation shall be managed by an Excel sheet, shall accept MWO inputs from this excel sheet, shall have editable man hours per MWO, shall be able to vary the number of each aircraft, and shall accept different inputs for each type of aircraft. The first version of the model was not designed to generate complex results, but instead intended to create a baseline simulation that moved aircraft through a Block Modification process. Version two of the model included the ability to edit available hangar space, account for aircraft that required updates upon arrival, have different numbers of workers on each MWO, and a learning curve for aircraft. These requirements added variability and realism to the baseline model, which allowed for greater analysis of the Block Modification process.

For the simulation to meet the given requirements, we had to make several assumptions. The first assumption was that the man-hour times listed in the MWO technical instructions provide accurate real-world times for the installations. These numbers were used as the baseline. The next assumption that was regarding the stochastic properties of the MWOs. Triangular distributions with minimum and maximum parameters that are ± 10% of the peak value were used in the simulation to add variability and realism to the results. Additionally, a learning curve was assumed to be involved with workers where the process times are 10% longer than expected the first time a modification is made, 5% longer the second time a modification is made, and meet the expected time for each subsequent modification. Finally, it was assumed that 20% of the aircraft required an update upon arrival and that aircraft requiring updates took an extra day and a half of worktime in the MWO process.

The biggest constraint on the model is the lack of real-world data from the actual Block Modifications occurring at RASM-E and RASM-W due to contract stipulations.

2.3.2 Inputs and Outputs

The inputs of the simulation were the independent variables including number of aircraft, hangar space, number of workers by type, the learning curve rate, man-hours available, and individual MWO times. The simulation also allows for future MWOs. The output, or dependent variable of the simulation was the time required to complete a block modification based on the inputs and the scenario. We conducted 30 replications of each simulated scenario to utilize and demonstrate the stochastic capabilities within ProModel.

3. Analysis and Results

3.1 Verification and Validation

Verification and validation ensures the dependability and usability of a model. Verification is the process of ensuring the model meets the specifications and runs correctly. Validation is the process of ensuring the model addresses the real-world need (Law, 2015). During the verification phase, a ProModel consultant ensured the simulation was working as intended. Additionally, he helped add complexity to the model by introducing additional functions of variability. His feedback led to the model's verification by ensuring the simulation met the client's intended goals. To validate the simulation, bi-weekly meetings were held with the clients from PM ASE. These meetings established the requirements of the model, the code in ProModel, and eventually the functioning simulation. Their real-world understanding of the system allowed the usefulness of the model to be validated and ensure the realism of the scheduling scenarios. The simulation was also verified by contractors from RASM-W and RASM-E by checking process times and modification schedules against their real-world experience conducting the same block modifications. The base scenario included 24 UH aircraft and 11 HH aircraft, which align with the amount of each aircraft RASM-W sent through the process in a recent Block Modification update.

Validation of individual aircraft times was done through a comparison with data collected at RASM-W. 95% confidence intervals of mean times for modification were created for the 24 UH and 11 HH aircraft most recently modified. For the HH, the confidence interval for the true mean of aircraft modification time was between 9.31 and 11.36 weeks. For the UH, the data's confidence interval had lower and upper bounds 7.38 and 8.71 weeks. This real-world data was then compared to simulation data of the mean times to complete each aircraft. The simulated scenario had a singular aircraft move through the block modification process with 30 replications. The simulation found that the true mean of modification time for the HH falls in between 9.79 and 9.87 weeks, while the UH time was in between 5.48 and 5.52 weeks. The HH's confidence intervals overlap in the simulation data and observed data, validating the HH's simulation is a representation of the Block Modification process. Although this is validated data, it is important to note that the simulation generally took less time than the observed data and the variation was much smaller. The UH's simulation interval also had smaller values than the observed confidence interval, and these two intervals do not overlap. This is evident in Figure 3.

While the simulated individual aircraft tend to have lower average times in system, this was expected because one aircraft in a system has greater access to resources than multiple helicopters being modified concurrently as in the real-world data. Although the confidence intervals do not overlap, the UH times would be expected to increase as a part of a block modification, making it a more accurate representation of the Block Modification process.

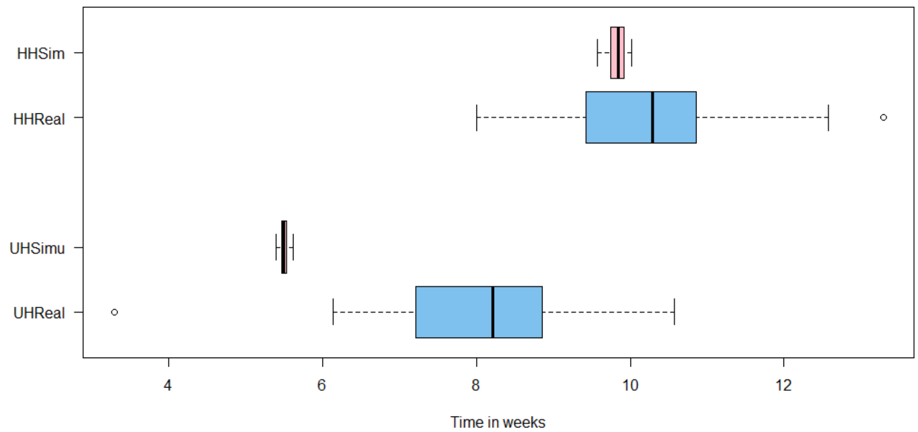

Figure 3. Simulated Block Modification Times versus RASM-W data

3.2 Results and Analysis

After running 30 repetitions of the base scenario, the average amount of time the Block Modification scenario is expected to take is 78.16 weeks as shown in Table 1. To expedite the process, one iteration was run with an extra electrician and another iteration with an extra sheet metal mechanic. These workers appeared to be constraining the problem because they had the highest percent utilization in the baseline trials. With an extra sheet metal mechanic, the data was similar to the original with a mean of 78.06 weeks. The biggest change, however, came from adding an electrician, which shortened the expected time over 20 weeks to a new mean time of 56.24 weeks as shown in Table 1.

Table 1. Simulated Results for 24 UH Aircraft and 11 HH Aircraft

	Base Scenario	Extra Electrician	Extra Sheet Metal Mechanic
Number of Trials	30	30	30
Mean	78.16 weeks	56.24 weeks	78.06 weeks
Standard Deviation	0.55 weeks	0.61 weeks	0.65 weeks
T Confidence Interval	0.20	0.22 weeks	0.24 weeks
95% Confidence Interval	(77.95, 78.37)	(56.02, 56.47)	(77.82, 78.31)

Analysis of the simulated scenarios compared to the data from aircraft that have undergone modifications at RASM-W were mixed. This same scenario with 24 UH and 11 HH took 77.60 weeks at RASM-W. This falls outside of the 95% confidence interval for the base scenario, which means that the initial prediction that the population mean is 78.16 weeks is likely not true. While it does not fall within the confidence interval, the simulation does a considerable job of estimating the time of completion. The T-confidence value is 0.21, which is approximately a day's worth of work time, which concludes that our confidence interval covers about 2 days of work. As more data is collected on the block modification process, the variability will increase and MWO times can be updated to better reflect the population of interest.

Based on the simulation results, the greatest improvement will occur in the process through an increase in number of electricians working on Block Modifications. Currently, the number of electricians is a limiting factor and critical path entity that causes the buildups of queues and idle aircraft in the system. This resource has the highest utilization of the resources, and an increase in the electricians would affect every MWO in contrast to other workers who only work on some of the UH-60 and HH-60 MWOs.

4. Conclusion

Overall, the simulation of the Block Modification process gives an accurate timeline for how long units will take to update all their aircraft. From the analysis that has been conducted, increasing the number of electricians on the project greatly decreases the total time it would take to send aircraft through the system due to their high utilization percentage. This means that one of the main limiting factors causing bottlenecks in the current process is the lack of availability of electricians to work on aircraft.

For future work, the model inputs, data, and variables can be manipulated to reflect the Block Modification process more accurately. As PM ASE runs more units through modifications at RASM-E and RASM-W, more accurate data about process times, worker utilization, bay space, learning curves, and schedules will become available Additionally, future teams who work on this project can add to the complexity of the simulation to gain more data points for the client including the addition of cost parameters and worker turnover analysis at each modification site.

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