Simulation of the Support Fleet Maintenance of Modern Stealth Fighter Aircraft

Staci Colbacchini, Allison Gahafer, Lindsey McEvoy, and Bryan Park
United States Air Force Academy, C16Staci.Colbacchini, C16Allison.Gahafer, C16Lindsey.McEvoy, C16Bryan.Park@usafa.edu

Abstract - The F-35 Lightning II is a 5th Generation, multirole stealth fighter aircraft that is expected to replace the aging “legacy fighters” and their roles in our national defense. The plane was designed and is currently produced by Lockheed Martin. Lockheed Martin and the U.S. Air Force recognize that a proper information infrastructure is critical to sustaining a functional and mission ready aircraft fleet. Thus, to provide the information technology backbone and capabilities to support current and future Warfighters across the U.S. and allied military services, the U.S. Air Force started adapting a modern electronic information system. The F-35 has been equipped with an Autonomic Logistics Information System to allow operators the ability to plan ahead, to maintain, and to plan and sustain its systems of the newly created fleet. Within the system is a problem ticket system that serves as a means to resolve issues with F-35 systems. An Action Request System, which utilizes this ticketing system, to efficiently funnel the tickets to an appropriate engineering organization and back to the originator for issue resolution. This paper studies that ticketing process with the goal of creating a model that can be used to study and optimize the time it takes to move a ticket through the process from creation to closure (resolution). To best understand this problem, we have worked closely with the Luke Air Force Base Maintenance Group to create a discrete event simulation that exposes different bottlenecks in the current process. Using this simulation, we identify which stages in the process will benefit most from a reallocation of resources. The simulation tool will be used by the client to perform future analysis.

Index Terms – Aircraft maintenance, Discrete event simulation, Maintenance tracking information systems

INTRODUCTION

The F-35 Lightning II is a 5th Generation multirole fighter produced by Lockheed Martin that is designed as a stealth fighter capable of performing ground attack, aerial reconnaissance, and air defense missions for the United States. Three variants for the F-35 will replace current fighter platforms for the U.S. Air Force, U.S. Navy, and the U.S. Marine Corps. In addition to the United States, the F-35 will be flown by eight partner nations. With the F-35 taking its first flight in December 2006, the program is still in its infancy. Since the F-35 is expected to be the workhorse for the current U.S. legacy fighter fleet, getting the F-35 to fully operational status is a high priority for our national defense.

In order for the U.S. to reliably depend on the F-35 as a multirole platform, it must be able to fly. Solid logistical information for the F-35 will maximize aircraft effectiveness towards the mission. Building a reliable and efficient Action Request (AR) System is a priority with the development of the F-35 program. The F-35 at Luke Air Force Base (AFB) consists of two fighter squadrons (61st and 62nd). The 61st Fighter Squadron supports training of US and Australian pilots and is maintained by the 61st Aircraft Maintenance Unit (AMU). The 62nd Fighter Squadron supports the training of US, Norwegian, and Italian pilots.

Lockheed Martin recently adopted the Autonomic Logistics Information System (ALIS) for the F-35. Upon landing an aircraft a computer system is attached to the airplane and gathers all the information needed to decide whether the aircraft has a maintenance issue or if it is ready to fly again, enabling pilots, maintainers and military leaders to make proactive decisions to keep jets flying. A technician then reviews the problems with the aircraft and if a known fix is not available, sends an AR through the AR System to get Lockheed Martin engineers familiar with the issue and to help with a resolution. There are three different categories of ARs: Category 1, Category 2, and Category 3. Category 3 ARs are the least critical and still allow the aircraft to fly. Category 2 ARs are more escalated and require more immediate action than Category 3 requests, but still allow the aircraft to fly. Category 1 ARs are the most severe and require the aircraft (or sometimes the entire fleet) to be grounded until the problem is resolved. The simulation presented in this paper models the processing of Category 1 ARs via their routing through different manual processes in conjunction with the AR System. The AR System, which monitors and routes Action Requests, is just one of many applications within the ALIS.

1. Problem Statement

Within 24 hours from the time the initiator begins an AR request, the initiator should receive a proposed solution from the Lockheed Martin engineers. However, this process often takes upwards of weeks because the ARs are not resolved or getting through the AR System correctly. Within the AR System, where the problems and solutions are routed, are numerous checkpoints where the AR needs to be reviewed.
and sent through to the next checkpoint. The ARs often incur wait time in the AR System due to human delay and take beyond the exceeded time to get resolutions regarding F-35 maintenance problems.

The goal of this project is to determine how to minimize time in the AR System for Lockheed Martin’s F-35 aircraft. This consists of modeling and analyzing the current process used for the system using data obtained from Luke AFB. The final result of this project will consist of a model that represents the AR System, demonstrating the bottlenecks of the system. The goal is to minimize time the aircraft is grounded due to Category 1 Action Requests at Luke AFB in the 61st Fighter Squadron. The reliability statistics of the different stages of the AR System will also be provided to Lockheed Martin to aid in recommendations. Ultimately, the results of the model will be used to advise program directors on the best allocation of resources within the AR System in order to minimize average downtime of the F-35 fleet associated with delayed maintenance due to wait time inherent in the AR System. The results will benefit the appropriate users on a globally-distributed network to technicians in the U.S. and allies worldwide.

II. Related Work
In August 2014 there was a study conducted on the information technology (IT) service desk of a specific company. The goal of this study was to use discrete simulation to improve the service time at the IT help desk. Similar to our study of the AR System, this study looked at many aspects of the service including station times and complexity of the issue. The author of the study chose three techniques to focus on throughout the study: what if analysis, system operation analysis, and optimization [1].

An additional study conducted by the Air Force Research Laboratory simulated production modifications of a C-130 engine repair facility. This research is beneficial to our study because it provides an example of how to properly perform a simulation study within a military aircraft maintenance context. The engine repair flow exhibited in this work is similar to the AR System simulation [2].

The possibility of an Air Force Autonomic Logistics System (ALS) was researched in 2003. In concept, researchers found the ALS to potentially save money, increase aircraft availability, and better system performance. The study employed an Arena discrete simulation model to explore the effect of an ALS on the sortie generation process for a fighter squadron. The study presented in this paper is now analyzing the bottlenecks of a similar information system using discrete event simulation [3].

Finally, in order to properly build a valid and credible simulation model we examined a tutorial on the creation of simulation models by Dr. Averill Law. In the tutorial, there are step-by-step approaches and techniques for developing models. These approaches and techniques assisted in the development, validation, and verification of our simulation model [4].

III. Organization
The remainder of this article is organized as follows. In the next section we describe the methodology. The Methodology section is broken down into the following subsections: Action Request System where we describe the process, Action Request Data where we describe our data, Assumptions where we list our assumptions, Discrete Event Simulation where we explain the model, and Validation where we explain how we ensured accuracy in our model. In the subsequent section we explain our analysis and results. In our final section, we give recommendations as well as ideas for future research.

METHODOLOGY

I. Action Request System
We traveled to Luke AFB in November 2015 to interview managers and maintainers from the 61st Fighter Squadron about the AR System. Maintainers explained that the AR System begins with an initiator, which can be any maintainer working on the F-35. The request from the initiator then goes through an Optional Screening Point (OSP) and Required Screening Point (RSP). These checkpoints ensure that the request is detailed and complete before sending the request to the Lockheed Martin engineers. The process is shown in Figure 1.
After the Lockheed Martin engineers formulate a solution, the AR ticket is then passed back through the RSP, OSP, and finally to the initiator. Once the initiator completes the repair and the repair is sufficient for the aircraft the initiator accepts the resolution and the AR ticket is resolved.

II. Action Request Data

We received all data from a Lockheed Martin software engineer. The data comprised of the name of the AR, the location, the category, the organization, and time-stamped comments from the OSP, RSP, and Lockheed Martin engineers. We only received data from the 61st Fighter Squadron at Luke AFB. Unfortunately, the dialogue between the people involved did not give a name of the author of each comment.

III. Assumptions

One assumption is that the data from the 61st Fighter Squadron at Luke AFB accurately represents the AR System. We also assumed that the distributions made from historical data will accurately represent the AR System. While analyzing the data provided by Lockheed Martin, we assumed that the first person to respond to the AR is the OSP, the second is the RSP. We also assumed the final time recorded in the AR System by the different checkpoints (e.g., OSP, RSP) via their comments indicated the completion time at that step in the process.

The data sheet that we were provided with did not indicate if an AR was rejected by either the OSP or the RSP, and thus returned to the initiator to correct an error. To overcome this obstacle, we assumed that the only reason an AR would take over 5 days to process through the OSP, or 10 days to cycle through the RSP, was because the AR was sent back to the initiator to make a correction to the AR.

IV. Discrete Event Simulation

The AR System was modeled using the YASAI add-in for Microsoft Excel. YASAI was chosen for this project because it is a simple tool that can model discrete event simulation using Microsoft Excel [5], which both the Lockheed Martin staff and the Luke AFB maintainers already have access to. We created a user guide with detailed instructions on use and interpretation of the simulation model and the features associated with YASAI.

The empirical data for one year’s worth of data for each checkpoint was fitted to exponential distributions and the distributions were then used to build the simulation model and find bottlenecks. Arena (Input Analyzer) was used to fit the data to the exponential distributions. The exponential distributions were then used to create variables to simulate arrival and/or service times of the AR System’s different checkpoints. These are used for the baseline distributions in our simulation model.

The data only had arrival times for the problem detected, initiator, OSP, RSP, and completion. The difference in arrival times represents the time spent at the checkpoint. For example, if the OSP received the AR at 0830 on 20 January 2016 and the RSP received the AR at 1330 on 20 January 2016, then the OSP was in possession of the AR for 5 hours. This is how we cleaned the data to determine arrival and/or service times. Both the OSP and RSP had outlier times (mentioned in the assumptions) that we used as OSP and RSP send back times. To model these times we broke the OSP and RSP times into two groups and have a percentage of the data going through each group that
was gathered from the data. For example, 95% of the ARs that an OSP reviewed were completed in less than 5 days. In our distribution we have a node that randomly assigns data to the direct route or send back, using the 95% and 5% split gathered from the data.

Using a combination of Visual Basic for Applications (VBA) code and the YASAI Microsoft Excel Add-in package, the model allows users to input an average time for each checkpoint process, as well as the percent of times that the OSP and RSP send an AR back. After the simulation is completed, the user can compare the results between the current process times and the process times inputted by the user. For instance, Figure II shows the amount of time the process would take if the time the engineers at Lockheed Martin took to solve the ARs was cut in half compared to the actual (baseline) time.

V. Validation

We sent our calculated averages to personnel at Luke AFB to validate our distributions. These personnel include an OSP, an RSP, and a maintainer. Once we knew our analysis of the data gave us accurate distributions, we created the model. To validate the model, we compared the total project completion time from our simulation with completion time in historical data to ensure accuracy.

RESULTS AND ANALYSIS

Based off of the distributions derived from the data, we found that an AR should take an average of 17 days to navigate through the AR System. Table I shows the average length (in days) of each process.

<table>
<thead>
<tr>
<th>Process</th>
<th>Baseline (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation Process</td>
<td>1</td>
</tr>
<tr>
<td>Initiator</td>
<td>0</td>
</tr>
<tr>
<td>OSP</td>
<td>1</td>
</tr>
<tr>
<td>RSP</td>
<td>2</td>
</tr>
<tr>
<td>Resolution</td>
<td>13</td>
</tr>
<tr>
<td>Completion</td>
<td>17</td>
</tr>
</tbody>
</table>

According to the standards set by Luke AFB personnel, there should be a maximum of 24 hours from the time a problem is discovered to the sending of the AR to Lockheed Martin. The maintainer should receive an initial response 24-72 hours later, an interim response 48-96 hours after the initial, and have a final response from Lockheed Martin engineers within 90 days. Our data shows the initiation process (which includes the initiation process, initiator, the OSP, and the RSP) takes 48 hours. It takes an average of 13 days for the Lockheed Martin engineers to resolve the AR, and it takes approximately four days for the maintainers to fix the aircraft and close out the AR. Thus, the initiation process is the only process that is not currently meeting Air Force standards [6].

I. Most Significant Process

While analyzing the model, we set each process time to equal one-tenth of the original time. From this experiment we saw that the only statistically significant reduction in overall production time came from modifying the RSP process time and the process time of the Lockheed Martin engineers. The reason the time reduction was the most significant for these two processes is because the RSP and Lockheed Martin engineers have the largest average length in time to complete the process, based on historical data. These results are shown in Figure III.
II. Sensitivity Analysis

As part of our sensitivity analysis, we analyzed the effects of changing the percentage of ARs that need to be sent back by the OSP or the RSP. We concluded that reducing the amount of times the AR is sent back either from the OSP or the RSP from 5% to 1% reduces the total production time by approximately 17%. We also noted that reducing both the OSP and RSP percentages to a more realistic 3% reduces the total production time by 8%. These results are shown in Figure IV. The reduction in percentages of ARs that are sent back can come from an increase in training on ARs at the initiator level.

![Figure IV](image.png)

**Fig. IV**

Change in process times resulting from changes to the percentages of ARs sent back due to errors.

Conclusions and Future Research

Ultimately, we have two major recommendations to reduce the process time of an AR. First, we recommend that Luke AFB personnel could increase training on the AR System and the details of the paperwork to avoid the amount of times the OSP and RSP have to send back reports. Second, Lockheed Martin could hire more engineers to reduce the amount of time the maintenance squadron needs to wait for a resolution.

In the future, we recommend analyzing the costs of the additional allocation of resources to the recommended processes, such as hiring more engineers at Lockheed Martin or increasing training. Also we recommend finding data to derive distributions for each process completed by the Lockheed Martin engineers when resolving maintenance issues to aid in process improvement.

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**References**


**Author Information**


