Internship Report

Lockheed Martin Aeronautics Company
Quality Engineering at the F-35 Program, Jan. 2017 – Jun. 2017

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Preface

From January 16th to June 15th I participated in an internship program at Lockheed Martin Aeronautics with five other Danish students. My internship was at the Quality Engineering department of Wing at the Lockheed Martin Aeronautics Company in Fort Worth, Texas USA.

During and prior to the internship a lot of people have been involved in making my stay here learning and pleasant. I would like to thank the recruitment team at Terma A/S with special thanks to Michael Ahrndt Lehmann and Thor Paulli Andersen for making this trip possible for me. I would like to thank David LeBlanc which were the responsible person at Lockheed Martin for my recruitment during the initial recruitment process and I would like to thank Eleanor E. Nave, my sponsor at Lockheed Martin Aeronautics. Lastly I would like to thank my team at the Quality Engineering Wing department including Samuel C. Bartholomew, Lacie J. Brown, Kyle J. Anspach, Mellissa R. McGuire, Jennifer M. Martin, Matthew A. Darden, David A. Bryant and my manager Samuel Rodriguez, for making my internship interesting and learning.

Contents

1. Introduction

In this report I will go through my time as an intern at the Lockheed Martin Aeronautics Company. The internship itself is a collaboration between Lockheed Martin, The Technical University of Denmark and Terma A/S. This year we were 6 students from Denmark. I have been working in the same department as my fellow intern Anders W. Jensen.
I have been working on small ad hoc assignments during my internship, but I have mostly been occupied with VBA programming in excel, creating "tools" for the department that made their everyday work easier and more efficient for them to focus on the Quality Engineering tasks.

The report will include some initial background information on the F-35 program and the companies involved. It will include a description of my largest projects and then finally I will conclude on my internship at the Lockheed Martin Aeronautics Company in Fort Worth, Texas.

2. The F-35 program and company background

This chapter will go through some of the basic aspects of the F-35 program while also covering some background information on Lockheed Martin and Terma A/S.

The F-35 Program

The basis of the F-35 program was to create a fifth generation aircraft that could replace older airplanes like the AV-8B Harrier for the U. S. Marine Corps, the F-16 for the U.S. Air Force, the F/F-18 for the U.S Navy and a whole variety of airplanes for other countries [1]. This will be done by creating the three variants CTOL (F-35A Conventional Takeoff and Landing), the STOVL (F-35B Short Takeoff and Vertical Landing) and CV (F-35C Carrier Variant) as shown in Figure 1.

Figure 1: From left to right: CV, STOVL and CTOL [2].

The capabilities of each airplane includes:

- CTOL: Normal runways and designed for typical air force assignments. It will be the most common variant, replacing the legacy F-16 aircraft.
- STOVL: Capable of conventional take off as a CTOL, but has the special capability of short take offs and vertical landings, giving it special use on smaller ships and runways.
- CV: A classic aircraft carrier variant. Due to specific aircraft carrier requirements this variant differs structurally more from the other variants, having larger wings and tougher landing gear. The tips of the wings can fold in order to save some extra room when storing the airplanes on the aircraft carriers.

Lockheed Martin Aeronautics Company

Having approximately 97,000 employees worldwide makes Lockheed Martin a huge global security and aerospace company [3]. Among its four primary businesses: Aeronautics, Missiles and Fire Control, Rotary and Mission Systems and Space Systems, Aeronautics is the largest division. It produces airplanes such as the F-35 Lightning II, the F-22 Raptor and the C-130 Hercules and has locations throughout the U.S. with the production of the F-35, the F-22 and the F-16 being located in Palmdale (CA), Fort Worth (TX) and Marietta (GA).
In 2016 The Aeronautics division was responsible for 37.7 % in sales and there was a general increase in the sales throughout the Lockheed Martin Company from 2015 to 2016 of 17 % [4].
In February 2017 the costs of each the three Joint Strike Fighter variants in Low Rate Initial Production lot 10 were:

- F-35A: $94.6 million
- F-35B: $122.8 million
- F-35C: $121.8 million

This was announced after a large order for 90 jets was confirmed and marked the first time the program got under $100 million for an F-35A [5].
In 2016 a goal on the costs of the F-35A was set to be under $85 million in 2019, which would put the costs of the F-35A equal to or under any 4th generation fighter, fulfilling one of the initial goals of the program [6].

Denmark and Terma A/S

The Danish government joined the Joint Strike Fighter program in 2002 and has had influence on technical aspects of the F-35 Lightning II. By June 2016, the Danish government confirmed that it would buy 27 F-35As to replace the legacy F-16 aircrafts that the Royal Danish Air Force currently utilizes [7].

Danish companies are contributing the F-35 program with the production of advanced composites and aerostructures. Terma A/S specifically delivers more than 70 parts for the Joint Strike Fighter, with a 25 mm gun pod as an example [8]. This gun pod will be used for the F-35B and F-35C by the U.S. and other allies as well. Figure 2 shows the parts delivered by Terma to the Joint Strike Fighter Program.
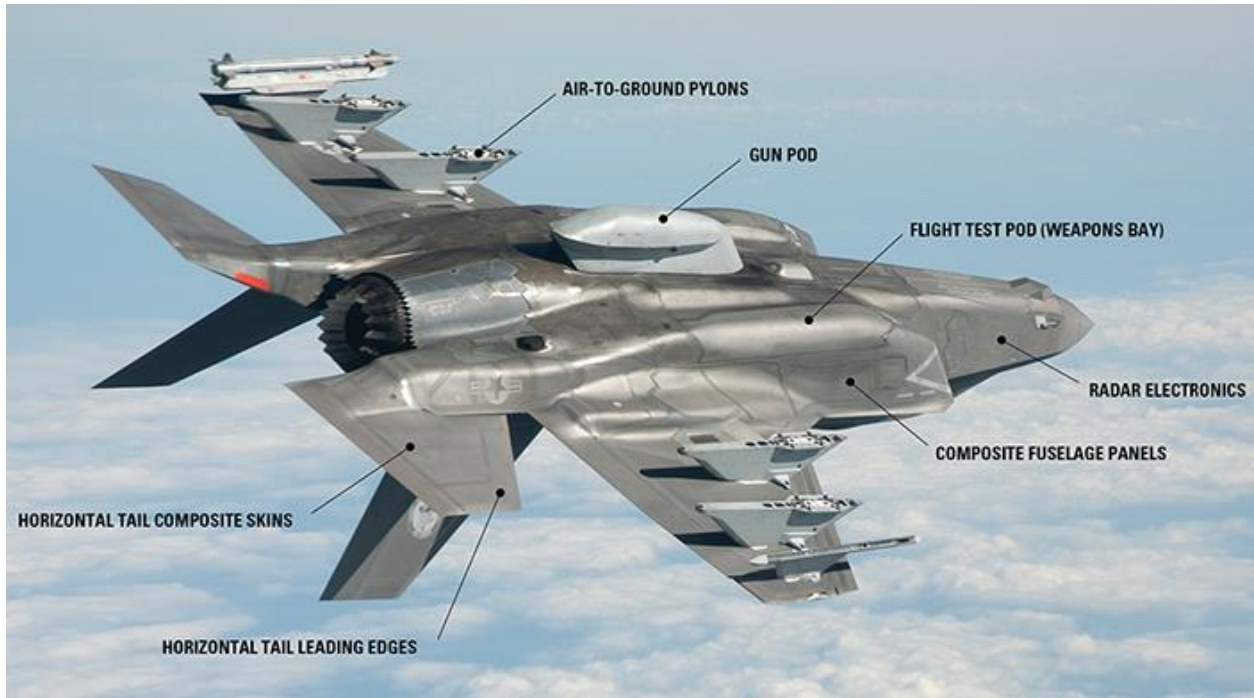
Figure 2: Overview of the parts that Terma supplies for the Joint Strike Fighter [8].

3. Working as an intern at QE Wing

During my stay at Lockheed Martin Aeronautics I mostly did programming in Microsoft Excel using VBA (Visual Basic for Applications) to help with the day to day activities performed in the team. On top of the programming I also did small ad hoc assignments.

Triage Delegation Tool - TDT

The first larger project that I worked on was a tool for the QAR TRIAGE that the QEs (Quality Engineers) on my team go through every day. A QAR is a Quality Assurance Report. I received an old VBA code that the former Dutch interns had made during their last days at the department and it seemed to no longer work. The code needed to be updated and it was wanted that the data that the tool used were updated every day rather than every few days. So far the tool had been pulling its data from a file called "Bucket Data -SRR_Analysis_Report" which is a file comprised of QARs and SQWKs (Small Quality Assurance Reports), relevant data and how far the QAR/SQWK is in the correction process. The data goes many years back, but the file is not updated daily. Instead it was wanted to use two other files which, when combined, could produce the same data that the old file did, but had the advantage of being updated daily. These files were the "F35.DEFECTS" and F35.DOCUMENTz excel files.

The two files have one column in common which makes it possible to write code that finds the matching rows, gathers the relevant data and pairs these two separate rows in a single row. The user were able to select the date interval of interest and the work department of interest for the data pull. The program would then proceed to couple the data and perform some basic statistics and create excel tabs with the data in different tabs with respect to which part type the QARs and SQWKs were. The process for this can be seen in Figure 3.
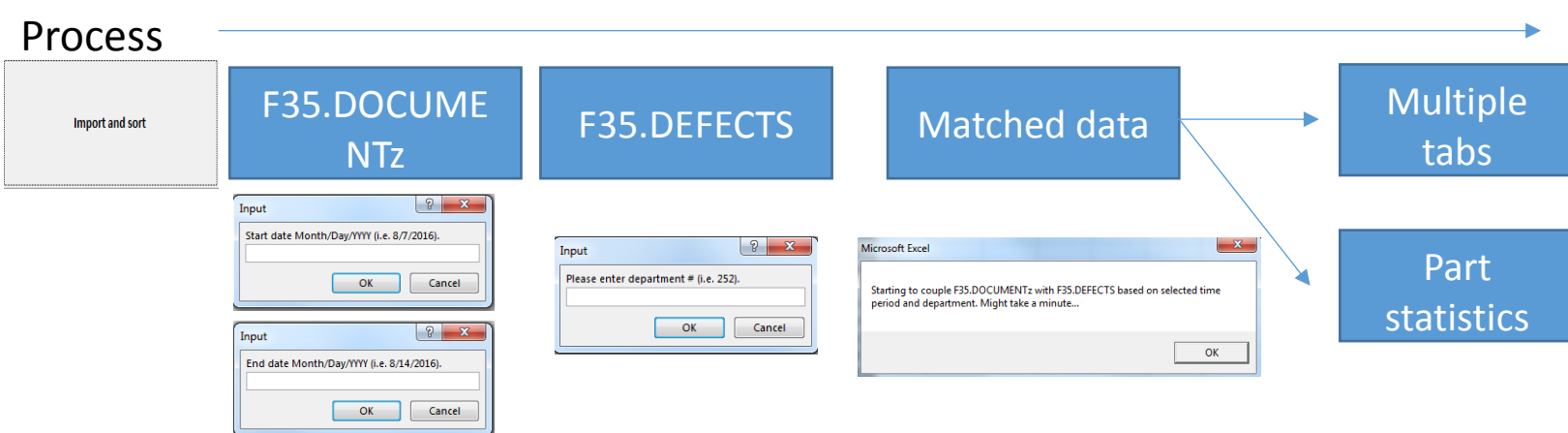

Figure 3: Overview of the process flow of the QAR Triage tool.

After the initial coupling of data the program proceeds to let the user assign the different QARs and SQWKs to the employees of the team. The capabilities of the VBA code includes:

- o User chooses active employees of the day

- o User determines the part type priorities of each employee

- o An employee is not required to have priorities

- o Each employee will get approximately the same amount of QARs

- o New employees can be added at any time and names can be changed as seen fit

- o Employees can have same priorities and the sequence of name determines priority "rank"

- o SQWKs are separated from regular QARs into their own tab

The idea behind this assignment process was to relieve the employees from manually distribute QAR TRIAGE assignments, a process they would go through almost every day and take up quite some time for the employee involved. The tool also made the assignment distribution "smart" so that the part type priorities could be distributed to specific employees that mostly work with specific QARs that are related to specific part types. An overview of the input tab for the assignment distribution is shown in Figure 4.

	A	B	C	D	E	F	G	H	I	J	K	L
						Priority						
		Type in any name:	Need assignments (x for yes)	Structure	Tubes (Taken by 1 person)	Brackets	Harness	Other	AvgItems (Calculated)			
		Sid	x		x				79			
		Sophie	x			x	x		79			
		Bob	x			x			79			
		James	x	x					79			
		Denny	x	x					79			
		Person6										
		Person7										
		Person8										
		Person9										
		Person10										

Start assigning!

The higher on the namelist the higher priority a person has over a person with similar priority
Active person lowest on the list might get a few more QARs than the rest
If a person hits the AvgItems value before being designated all of their priorities they will not get more items
and the item type will go to other active persons on the list with room after priorities have been distributed.

START | Assignments | Structure | Tubes | Brackets | Harness | Other

Figure 4: Overview of the assignment tab.

An example of the output of a selection with the inputs as shown above is shown in Figure 5.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
	DOCUMENT	REW/REP LAB$	SCRAP LAB$	SCRAP MATL$	PART NUMBER	SUPPLIER	INIT DATE	CA STATUS	INIT DEPT	SWBS	TV	TAIL	WL	BL	FS
						Structure									
	xx1	0	0	0	gbh23	location1	1/16/2017		0893	B4321	2XX	0100	0100	0100	0100
	xx2	0	0	0	gbh24	location1	1/14/2017	V	0893	B4321	2XX	0100	0100	0100	0100
	xx3	0	0	0	gbh25	location1	1/16/2017		0893	B4321	2XX	0100	0100	0100	0100
	xx26	0	0	0	gbh48	location2	1/4/2017	N	0893	B4321	2XX	0100	0100	0100	0100
	xx27	0	0	0	gbh49	location1	1/5/2017	N	0893	B1232	2XX	0100	0100	0100	0100
	xx28	0	0	0	gbh50	location1	1/16/2017	N	0893	B4321	2XX	0100	0100	0100	0100
	xx29	0	0	0	gbh51	location1	1/26/2017	N	0893	B4321	2XX	0100	0100	0100	0100
	xx30	0	0	0	gbh52	location1	1/5/2017		0893	B4321	2XX	0100	0100	0100	0100
	xx31	0	0	0	gbh53	location1	1/11/2017		0893	B4321	2XX	0100	0100	0100	0100
	xx32	0	0	0	gbh54	location1	1/23/2017	N	0893	B1232	2XX	0100	0100	0100	0100
	xx33	0	0	0	gbh55	location1	1/23/2017		0893	B4321	2XX	0100	0100	0100	0100
	xx34	0	0	0	gbh56	location1	1/17/2017	J	0893	B4321		0100	0100	0100	0100
						Harness									
	xx121	0	0	0	wnbsns232	location1	1/17/2017		0893	B4321	2XX	0100	0100	0100	0100
						Other									
	xx35	0	0	0	gbh45	location1	1/7/2017		0893	B1232	2XX	0100	0100	0100	0100
	xx36	0	0	0	gbh46	location1	1/25/2017		0893	B4321	2XX	0100	0100	0100	0100
	xx37	0	0	0	gbh47	location2	1/25/2017		0893	B4321	2XX	0100	0100	0100	0100
	xx38	0	0	0	gbh48	location2	1/4/2017	N	0893	B4321	2XX	0100	0100	0100	0100

... | Assignments | Sid | Sophie | Bob | James | Denny | SQWKs | Structure | Tubes | Brackets | Harness | Other

Figure 5: Example of a tab of assignments, in this case showing the assigments designated for a "James".

As seen on the figure, the tabs for each employee are added and the tasks have now been divided to each employee based on their part type prioritizations.

This tool turned out to be used almost every day which made the hours put into the development of the tool very satisfying. The tool was only built for the QE Wing departments, but is was discussed that it could be tailored to fit the other departments as well such as QE Forward, QE EMAS and QE Final.

Addition to the TDT

As an extension to the already existing tool, it was expanded. The QE Wing department gets QARs sent to them from further down the production line in something named "Queue" and sometimes these QARs does not belong in Fort Worth. A tool was developed that could filter through the QARs and separate them into the geographical locations at which they belonged. It does this by pulling different data sheets and comparing relevant data columns, by which it is able to designate the correct location of the build. The reasoning behind this addition was to let the employees quickly know whether the QAR/SQWK even belonged to their team or not.

Inspection Optimization Variance Tool - IOVT

I started the development of a tool for Inspection Optimization (I.O.) meetings with basis on a very basic tool developed by former interns. The idea behind inspection optimization is to lower the inspection rate in areas that are performing admirably and increasing the inspection rate in areas that have a lot of defects, that way increasing the quality of the work done, but also increase the efficiency of the inspections.

Every quarter a group of QEs gather to evaluate the inspections done on the planes as they are built. They decide, based on an automatic calculation, whether the inspection rate should go up or down. This is then presented to the relevant engineers of the department which then has the opportunity to either accept the proposed optimization level or reject it with basis on knowledge that the I.O meeting group might not have or some other specific reasons that only the specific employee knows of at that time. These reasons and correlated specific work stations were in need of a database that could easily be recorded for future reference.

A VBA code was developed in Microsoft Excel and the initial GUI that is presented to the user is shown in Figure 6.

Figure 6: User interface when initializing the I.O. tool.

The GUI lets the user continue from a former session if they wish or they can begin a new session with new attendees.

The tool ended up being tailored so that it would be possible to add data in relation to other things than just the quarterly I.O meetings, as seen under "Reason for Meeting".

The large box under "Select Relevant Attendees" includes all of the regular meeting participants. If any new attendees are present at the meeting they can easily be added under "Add Attendee". When the user proceeds they are able to select which department is relevant for this specific inspection optimization as shown in Figure 7. They can also just select the last used department which comes in handy when wanting to continue a former session that was closed by mistake.
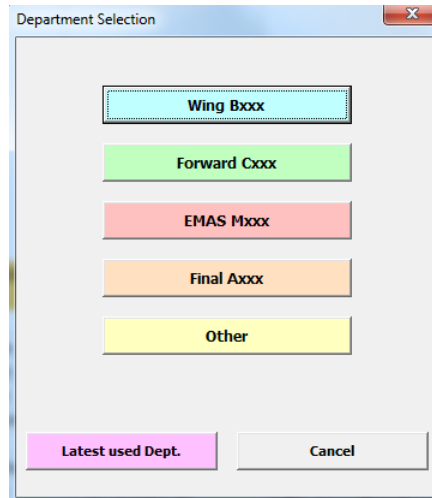
Figure 7: After selection of meeting session. The user can select intended department.

After having selected the relevant department the user is led to the data gatherer shown in Figure 8.
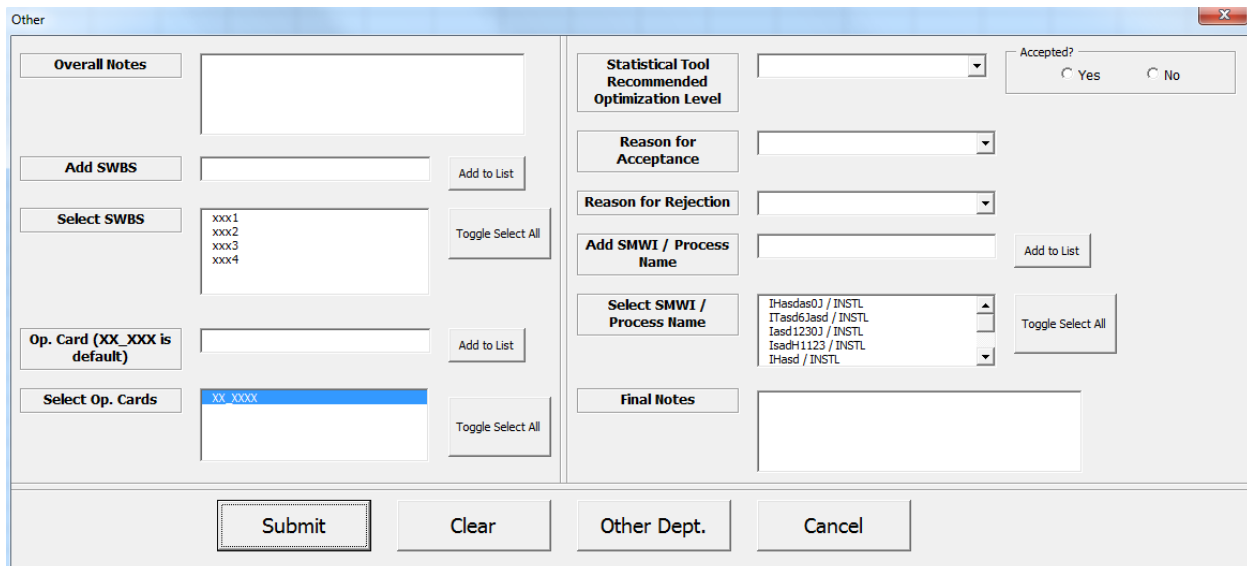

Figure 8: With a department selected, all relevant meeteing data can be put in to the tool, which has a lot of built-in information already at hand.

Here the user of the tools enters all the relevant data for the specific inspection optimization. Initially with overall notes, selection of relevant workstations (SWBS) and operation cards. Sometimes it is relevant to have multiple operation cards where the rest of the data is the same.

This is still possible and by adding multiple operation cards the program will produce an output for each operation card.

The user then selects the optimization levels and whether or not is was accepted. After which the acceptance or rejection is given a reasoning. More specific work areas are then specified as to which specific work the inspection optimization is made for and finally the user can enter some final notes. When the report is submitted, the output becomes as shown in Figure 9. Here it is seen how the data is stored giving an easy overview of the meeting specifics and with the attendees of the day.

Date: 3/17/2017 - Meeting Reason: Quarterly I.O. Meeting.								
		Attendees:	Name	Title	Email			
			Mickey Mouse	Actor	mickey.mouse@disney.com			
			Donald Duck	Actor	donald.duck@disney.com			
			Clark Kent	Superhero	clark.kent@metrocity.com			
WING - Dept. 0252								
Document Number	Overall Notes	SWBS	Stat. Level	Optimized	Reason	Opt. Card	SMWI	Final Notes
IO_XX_XXXX_1	Overall notes for the optimization report.	Bxx0, Bxx1, Bxx2	75 % (30 =< beta < 40)	YES	Inspector agress with recommendation	XX_XXXX	IG012J / PARTS, IL123J / EDDIE	Here I can add final notes if there were any specifics for this optimization level for these optimization cards.
IO_XX_ZZZZ_1	Overall notes for the optimization report.	Bxx0, Bxx1, Bxx2	75 % (30 =< beta < 40)	YES	Inspector agress with recommendation	XX_ZZZZ	IG012J / PARTS, IL123J / EDDIE	Here I can add final notes if there were any specifics for this optimization level for these optimization cards.
IO_XX_XXXX_2	Overall notes for the optimization report.	Bxx0	75 % (30 =< beta < 40)	NO	Escapes	XX_XXXX	IG012J / PARTS, IL151J / BOLTS	

Figure 9: An overview of the data as it is presented when the user "submits" data to the tool.

Each data addition in form of a data row are given a unique document number for specific reference. The user is able to continuously submit new reports in case of different optimization levels for other or the same optimization cards and even change to other departments if they wish to do so. This way a complete Inspection Optimization report is continuously built and keeps the desired data for future use.

The tool has been built in such a way that it is easily configurable for other types of data that needs to be recorded as well.

Defect Escapes Tool - DET

The former Dutch interns had worked on this program beforehand. It could import relevant data from a data file called "Program_Diagnostics_F35" and combine the data in a excel tab for QAR and SQWK "escapes". My initial task was to include more data from the data file"Program_Diagnostics_F35". On top of that the tool was expanded to sort the data with respect to a file called "Firing Order" which keeps track of the order at which the planes have been built. This way it was possible for the team to keep track of escapes with respect to the building order.

Finally the tool was expanded such that it produced key statistical data and relevant charts. These charts showed the most important overview of the data correlated with "Escapes" and included data such as defect types and quantity of defects with respect to airplanes in the correct building order as shown in Figure 10. The axis' have been removed to protect sensitive information. What is seen is a quantitative representation of total defects for each airplane considered together with the contributions of a defect type towards the total defect number, as marked by the different colors. The line graph represents a running average of total defects as the amount of built airplanes progresses. It is clearly seen that often a specific defect types dominates at certain times in the build process.
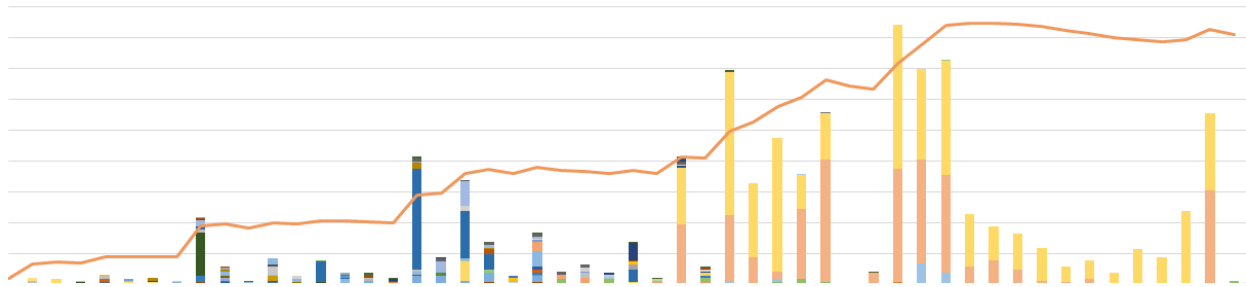

Figure 10: Example of an automated chart showing defect types and quantity with respect to one y-axis, a running average of defects with respect to the other y-axis and the airplanes on the x-axis. The axis' have been removed to protect sensitive information

Among other data represented was a chart showing total work hours and contributions of each defect type for each airplane together with a running average of work hours. Also a chart showing the total number of registered QARs for each airplane together with a running average was made and finally a chart showing the defect count, number of affected airplanes and total work hours for each defect type was also made.

These charts were made manually before the tool was developed and took up a lot of the users time. Now with a simple click of a button, the statistics behind the charts and the charts themselves are made within a minute.

As a final touch to the tool, a selection menu was developed such that the user could specify which SWBSs they were interested in when making these charts. Letting the user focus on

specified work areas if wanted. Figure 11 shows the input form, in which the user can specify the SWBSs that they are interested in.

Figure 11: User interface for selection which data
is wanted for the consequently made charts.

The program has been continuously expanded during the internship, letting the user create a wide variety of charts.

Metrics compiler - COPQ

As a side project similar in coding to the Defect Escapes Tool I made an automization of statistical metrics that had the purpose of showing the work spent on QARs, SQWKs and total defects for the Wing Structures area, the Wing Systems area, the Wing Mate area, Forward Fuselage and the whole of department 257-2 in terms of equivalent headcount. With 1 headcount being 40 hours. The tool creates relevant charts for all areas automatically after having imported and calculated all the necessary metrics beforehand by the push of a button.

Helping with RedX project

I have been fortunate enough to be included in some minor parts of a RedX project that is owned by Edgar Dominguez. The RedX project is in short about investigating damage to holes on a composite skin that is going onto the forward fuselage of the aero plane. In order to help find the causes of the problem one of the investigations included using a pressure film to see whether an uneven pressure distribution during drilling could correlate to the damages that were observed on the drilled holes. Furthermore investigations of the gaps between composite and the underlying structure were investigated with a filler gauge in order to see if there was any correlation between gap sizes and hole erosion. The work on this project is ongoing.

4. Training

During my internship I have been fortunate enough to participate in a series of training classes that expanded my capabilities as an engineer. A short description of these classes will be given.

FOD

I had a class in FOD (Foreign Object Debris/Damage) awareness. Here the idea and importance behind FOD prevention was taught. I also participated in a FOD Free Audit class where we were taught how to look for FOD. After the classes I had a good understanding of the importance on FOD awareness and how critical it can be to any aircraft or production in general when FOD are present. Once the right mindset towards FOD was learned one was quickly able to identify potential FOD risks when walking the production line.

F-35 familiarization

During a three day period, I participated in a F-35 familiarization class. The class included people from both suppliers and stakeholders such as the U.S Airforce. The class taught the overall concepts behind the F-35 aircraft, but also went into detail about some of the technical aspects of the Joint Strike Fighter. Especially some of the software capabilities and thus the communication capabilities of the advanced aircraft were elaborated on. Having this class relatively early in the internship greatly helped understand some of the abbreviations that are being used around the offices while also given an interesting insight in the magnitude and advanced technology that goes into the Joint Strike Fighter.

PPV

I participated in a PPV (Product Process Verification) class in order to be able to help with the PPV process if that was to be required by my QE team. The class was a rather short class going through the processes required during PPV, making one qualified to assist in such processes.

PDM

PDM training was a short introduction of the Product Data Management tool developed by Siemens. Lockheed Martin and many of its partners throughout the world use this tool to store and share for instance CAD models, manufacturing instructions and parts information. It enables for

quick access to important production information and has the capability of increasing productivity rather drastically. The class itself was a walkthrough of the basic functionalities in PDM while also letting the attendees have some 'hands on' assignments. Even though I never used the system in practice during my internship I see great advantages in having been introduced to the tool, since it is used in many large production companies worldwide.

CATIA V5 Fundamentals

Over the course of 4 days I had a basic CATIA class. The class taught all the basic functions of CATIA like sketching and creating geometries based on work drawings. Due to the fact that I had worked in CAD before (SolidWorks and Creo Parametric), the class was not very difficult, but since every program differs slightly in setup and capabilities, it was still an interesting and learning class. Since many large manufacturing companies use CATIA it was a great opportunity to get acquainted with the program.

CATIA V5 Assembly Design and Drafting

As an extension to the CATIA V5 Fundamentals class, I got the opportunity to participate in Catia V5 Assembly and Drafting. It was basically a short walkthrough of the assembly functions in Catia V5, teaching how to assemble parts and the logic behind the program to get correct assemblies while constraining the final assemblies with accordance to Lockheed Martin procedures. In the same manner a session going through the drafting in Catia V5 taught how Lockheed Martin uses drafting and the correct procedures to follow when during so. The basic drafting functionalities of Catia V5 were also learned.

PDCA Problem Solving

A PDCA or Plan - Do - Check - Adjust class was offered to the Interns. It was a one day class that went through all the basics of Lean Six Sigma in order to equip the attendees with the basic tools needed to solve problems and improve processes. Some of the tools taught in the class included a 'Problem Solving A3' which included all the considerations and steps necessary to make during the PDCA process, there was also flow charts to get an overview of the process being investigated and where possible optimizations could be made. The "5 Whys" and the "Fishbone Diagram" methods were used to determine the causes of the problem and the method of "Waste Reduction" gave an idea of where ones processes that the problem that one could have caused problems and the consequences of such problems.

For my PDCA Capstone project, I worked together with Anders W. Jensen, a fellow QE Wing Intern. Our project was on improving the time it took to look up a list of QARs in a program called

"HeatMap". A program with the capabilities of visualizing the placement and quantity of QARs on an F-35A aircraft.

By the use of the tools taught in the class it was possible to bring down the process time from approximately 5.5 min to 1 min. The tools used included the "Problem Solving A3" for an overview of the problem solving process, a flow chart to map process flow before and after changes were made, the "5 Whys" to find the cause and a "Waste Reduction Table" to identify the areas affected by the problem that was being had.

5. Internship conclusion

I had never worked in VBA before my internship at Lockheed Martin Aeronautics. I had used MATLAB for educational purposes, but other than that my programming experience has been very limited throughout my studies. The learning curve with VBA was rather steep initially, as with any new thing that one is trying to learn quickly. Now that my internship is coming to an end I have become much more familiar with VBA programming, its benefits and its limitations.

During the internship I have been following some of the daily QE engineering procedures and activities. This has given me a great insight in what it entails to be a quality engineer and has helped me in my further career decisions. Working in a big company like Lockheed Martin has definitely made a big impression on me. I am surprised at how long some procedures can take due to the organizational structure within a large American company and have found that I would prefer to work in a medium sized company with a more flat organizational structure.

My time in Fort Worth and as an Intern at Lockheed Martin Aeronautics has been amazing. I believe that I will be able to cherish and draw upon the experiences that I have gained during my internship throughout my life and working career.

6. For new interns

The first couple of weeks can be slow and especially the first week will be mostly practical things like getting the computers installed and updated with the software that you need.
After a few weeks there will probably be some larger projects ready to start working on. Until then the interns should make sure to participate in as many meetings as allowed and try to do so throughout the whole internship. It really gives a good overview of what is going on on a day-to-day basis.
The interns should be active in their search for assignments and projects to work on. Their work team will most likely have some assignments, but they are also busy and it is therefore a good idea to actively search for projects if they have run out of work.
Other than that the interns should look forward to 5 months of work that are both learning and giving the possibility to contribute with valuable work to their respectful work teams.

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