

F-35 Quality Engineering Internship

Lockheed Martin Aeronautics – Terma A/S

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Fort Worth, Texas

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Preface

From January 15th to June 14th, 2018 I had the chance to be an intern within the F-35 project at Lockheed Martin Aeronautics in Fort-Worth, Texas. The internship was within Quality Engineering, I worked both in Mate and Final Assembly.

I am very grateful for this huge opportunity of working at Lockheed Martin. For this I would like to thank all persons, who have made this experience possible, most notably Thor Paulli Andersen, Michael Ahrndt Lehmann and Peter Rankenberg Thomsen from Terma A/S as well as Mike Cucinotta, Glen Brawley, Pamela Baca, Ahmed Aly, Jimmy Mullins, Colin Nguyen and Elyse Michniak from Lockheed Martin.

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Motivation

The field of aerospace has always been a subject, which has fascinated me a lot. In order to learn more about this industry I have studied at the school for Aeronautical and Astronautical Engineering at Purdue University in West Lafayette, Indiana for a semester. After coming back to Denmark, I was looking for other opportunities to learn more about this industry. At that time, I had already read about the possibility of interning at Lockheed Martin, although I didn't consider it as I thought that I was not meeting the wanted qualifications. At a career fair at the Technical University of Denmark (DTU), where I study, I visited Terma's booth, where I had the chance to talk to Thor Paulli Andersen, a previous Danish intern at Lockheed Martin, who now works at Terma. Talking with him convinced me to apply for the Quality Engineering internship, the one I thought sounded the most interesting.

After I sent in my application, the recruitment process consisted of two interviews, a first in person interview with Terma and a second phone interview with Lockheed Martin.

Pre-departure

Once I had been selected, the preparations for the internship started. First the application process for an American J-1 visa was started with the help of Kilroy. A lease contract was signed with Marquis at Stonegate, which is the apartment complex, which has been used by both previous Dutch and Danish interns. Furthermore we made a sales agreement with the previous Dutch interns about buying their furniture and cars.



Figure 1: The 2018 Terma intern Team, from left to right: Emil Holmkjaer, Kenneth Jensen, Lenni Busk, Kristoffer Olesen, Jesper Lund, Nils Toudal, Intern Coordinator Elyse Michniak, Mads Hellemann, Douglas Vanotterloo, Lukas Hoghoj



Fort Worth

Fort Worth is the 16th largest city in the US and is located in the Dallas – Fort Worth metroplex. The city was established in 1849 as an army outpost. Due to its location at the Chisholm Trail, the city has drawn benefit from the Cattle coming through the city. As the Pacific Railway connected to the city in 1876, the Fort Worth Stockyards became the primary livestock center in the area. Even though the wild time of Cattle drives through Fort Worth is over, the Stockyards continue to praise the western culture and heritage. Cattle drives take place twice a day in the Stockyards. Rodeos are also hosted every weekend in the Stockyards.

Besides of the Stockyards, Fort Worth is a very clean city with a very large amount of bars and restaurants. Apart from Lockheed Martin, a lot of large global companies, such as Bell Helicopters, American Airlines, AT&T and Exxon Mobil are present in the Dallas – Fort Worth area, which consequently has a strong local economy.



Figure 2: Cattle Drive in the Fort Worth Stockyards (<http://www.fortworthstockyards.org/play/fort-worth-herd-cattle-drive>)



Lockheed Martin

Lockheed Martin was created in 1995 as a result of a merger between Lockheed Corporation and Martin Marietta. The company employs over 100,000 people within its four main businesses; Aeronautics, Missiles and Fire Control, Rotary and Mission Systems and Space¹. Lockheed Martin Aeronautics has a wide legacy of planes, including the SR-71 Blackbird, U-2 Dragon Lady Spy plane, C-130 Hercules, F-16 Fighting Falcon, C-5 Galaxy, F-117 Nighthawk and the F-22 Raptor. The Skunk Works, which are known for designing some of the most advanced aircraft, including the F-35 are also a part of Lockheed Martin Aeronautics.

Air Force plant 4

The United States Air Force Plant 4 was built in 1941 and originally used to produce the B-24 Liberator. In recent years, the plant has been used for the production of F-16 (originally produced by General Dynamics) as well as for components of F-22. The plant is now entirely focused on the production of the F-35 as the last parts of the F-16 production line have been moved to Greenville, South Carolina in the end of 2017.



Figure 3: F-35 final assembly in Air Force Plant 4 (<https://www.pinterest.com/pin/502714377146020233>)

Besides from mating the main four fuselage elements – forward-, center-, wing- and aft-sections, performing final-assembly and -finishes, the plant in Fort Worth also produces the forward section, which includes the crew station, the wing skins, which are the mated with the wing center section produced by Lockheed Martin in Marietta, and some composite parts. The

¹ <https://lockheedmartin.com/content/dam/lockheed-martin/eo/documents/2018-lockheed-martin-fact-sheet.pdf>

center fuselage is produced by Northrup Grumman Corporation (NGC) and the aft section is produced by BAE Systems in England.

The plant shares its runway with the Naval Air Station, Joint Reserve Base Fort Worth. The runway divides the facility, the Naval Air Station being on the East side and Lockheed Martin to the west. The Reserve Base has a variety of aircraft flying in and out, including C-130, F-16, F-18 and F-35.

The F-35 program and Denmark

The F-35 Joint Strike Fighter program is a program, which has the aim to deliver a 5th generation of fighter aircraft to replace the F-16, A-10, F/A-18 and AV-8B/Harrier. Two prototypes competed against each other; the Boeing X-32 and the Lockheed Martin X-35. The X-35 won the competition and became the F-35.

The F-35 comes in three different variants, which have different ways of taking off and landing. The F-35A has Conventional Take-Off and Landing (CTOL). The US air force will, among others, be using this variant. The second variant is the F-35B, which has Short Take-Off and Vertical Landing (STOVL), this version is intended for amphibious ships of the US Marine Corps. Finally the F-35C is the Carrier Variant (CV), which is intended for the aircraft carriers of the US Navy.

Denmark joined the Joint Strike Fighter program as a Level 3 partner nation in 2002 as the program was in the System Development and Demonstration phase². The Royal Danish air force has contributed to the program by making a Danish F-16 available to the JSF 461st Flight test Squadron (see front page) at Edwards AFB. The F-16 served as a chase plane for F-35 Development, Test and Evaluation from 2008 to 2016.

Danish industry has also contributed and drawn benefit from the F-35 program. Terma, has been awarded several contracts by Lockheed Martin, BAE systems and Northrop Grumman Corporation for the production of composite and machined parts³. An overview of the main components manufactured by Terma can be seen in Figure 4.



Figure 4: Components on the F-35 manufactured by Terma

(https://www.terma.com/media/295277/global_supplier_to_the_f-35_lightning_ii_700.png)

² <https://www.f35.com/global/participation/denmark>

³ https://www.terma.com/media/426046/f-35_and_terma_171012_screen.pdf

Terma has also been awarded a contract by General Dynamics Armament regarding the design, development and production of the F-35 Missionized Gun Pod. This pod contains the aircraft gun and is intended for the Short Take-Off and Vertical Landing (STOVL) and Carrier Variants (CV), as these do not have an internal gun.

In June 2016, a majority of Danish parties decided to buy the F-35 as a successor for the F-16 aircraft, which the Royal Danish Air Force is using right now. In December 2017, a majority in the Danish parliament approved the acquisition of 27 F-35A (Conventional Take-Off and Landing) for the RDAF. The first Danish F-35 are first expected to be delivered to Luke AFB for pilot training in 2021 and the first ones are scheduled to be stationed in Skrydstrup starting in 2022.

Work at Lockheed Martin

During the time working at Lockheed Martin I had the chance to work on a few different projects. A brief overview of the different tasks will be given in the sections bellow.

Repetitive Defects

As a quality intern, I was working on keeping track of the defects, which can be deemed to be repetitive. For this a main data dump, F35.DEFECTS, is used. This file contains information about all QARs and Sqwaks (documents reporting a nonconformance) written within the program. A *unique ID* is created by merging the part number and the defect code for every defect. If a *unique ID* occurs on 3 or more different jets of the last 20 CTOLs, it will be deemed as repetitive. The threshold is 3 out of 15 and 2 out of 10 for STOVL and CV, respectively.

The macro then finds the corresponding Integrated Corrective Action (ICA), which is the process for resolving nonconformances, and assigns it to the *unique ID*. For validated ICA issues (which means the issue should not occur anymore), it is then checked if there have been Occurrences Past Validation (OPV).

The top 10 most repetitive *unique IDs* and their level of repetitiveness are then exported to a PowerPoint slide for all build areas, respectively. Also a slide is created for the top 10 issues of all build areas combined and for the top 10 issues, where the disposition is *Use As Is*.

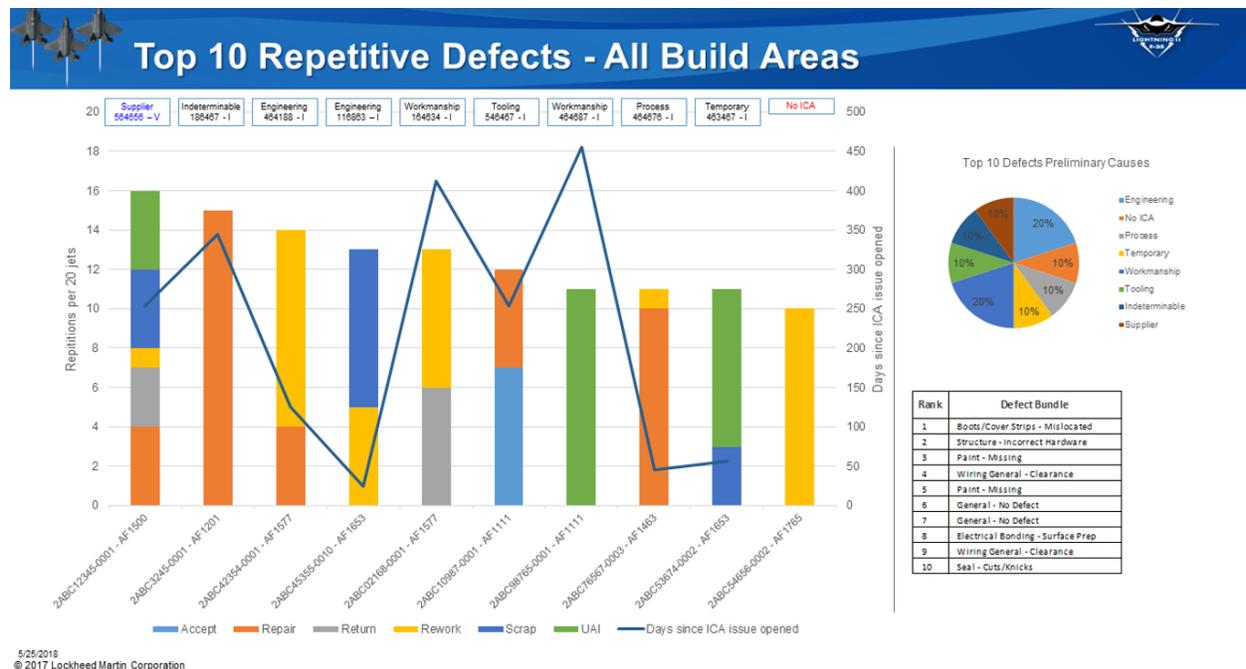


Figure 5: Example of an output slide generated by the macro (dummy data was used for this example)

As a part of this project, I had the opportunity to extend the macro doing this analysis in different ways. One of the tasks has been to change the way, the macro assigns the ICA issues

to the unique ID. A new function, that has been created, is the addition of a *mini scorecard* for each build area, where it can be seen how many repetitions have been added, dropped and validated since last month. An issue is considered to be dropped if it hasn't occurred within a year but the ICA issue hasn't been validated yet or doesn't exist, hence it is deemed as validated if the ICA issue has been validated and there have been no OPVs.

Another improvement made to the macro, was to add a count of days since when the ICA issue corresponding to a *Unique ID* were opened to the chart. This helps keeping track of the progress in resolving the issues, which has been requested by the customer (DCMA).

Conversion of data dump formats

During my time interning at Lockheed Martin, the way data for quality was stored changed. The legacy way of storing data concerning nonconformances were the previously mentioned excel data-dump, F35.DEFECTS and a similar one called F35.DOCUMENTz.DETAIL.ONLY. As a way to make the data acquisition more efficient, the data acquisition has been transferred to HANA, a Business Objects (BO) system. From the new BO, files similar to F35.DEFECTS and F35.DOCUMENTz can be created. However, the filters used to create the legacy files could not be exactly replicated. Furthermore a lot of formatting and syntax changes happened in the transition.

My task has been to write a macro which takes the files created with the BO as input and outputs replicated legacy file. This is quite important as a lot of macros and other programs are relying on the format and syntax of the legacy files are used in the program.

The conversion macro loads the BO output files, changes the format, modifies data in some columns and filters some data out. The transformed files are then saved as copies.

Extension of InspectApp

Previous interns created a tool that should help inspectors to keep track of the different items to inspect during an inspection. This is done in an app that first separates the area in several sub areas. The different sub areas, are the divided into different categories to check (sealant, clamps, harnesses, etc...).

During my internship, I worked together with an inspector, where I extended this app, such that it can now be used to report defects. When using the app to look at one specific category in an area, one can now click on the "Report Defect" button. A window then pops up, where the user can select the part and a defect. The parts are numbered on the picture associated to the area and category. The parts and defects to be shown in this menu can be edited in excel sheets.

Once the user has selected a part and the corresponding defect, the text for a SQAWK sheet is then written to a txt file. This file is the saved to a directory, which the user has previously selected.

Other projects

During the internship I have also had the chance to assist and help out by performing smaller tasks. These have been very interesting due to the large variation of tasks and challenges I have encountered when performing those.

Staffing tool

At Lockheed Martin, all employees have a level, which represents their salary and career advancement. All groups have a target mean level, which has to be considered when hiring new employees or moving them around in the different subgroups.

Therefore I was asked to make a tool, which takes the DART report, a file containing information about employees, as input. The tool then computes the number of employees and the mean level for a selected group and for all its subgroups. The user can then use a table, to change the number of employees at the different levels in the subgroups, which then gives an overview of how the mean levels would evolve with these changes.

Program diagnostic charts

Program diagnostics is a file, which monitors Scrap, Rework and Repair (SRR) hours and number of defects per jet, per build area. The results are then set up on charts for each area, where the SSR hours and number of defects, respectively, are divided by LM responsible and supplier responsible. My task has been to make a plug in, which divides the LM responsible part in the charts for EMAS into *EMAS responsible* and *Other LM responsible*. The plug in can easily be extended to any other build area.

Assisting PPV observations

During the time interning at Lockheed Martin, I have also had the chance to assist some PPV observations (see section on PPV training). For the most part, the observations took place in Final Assembly and concerned the installation of harnesses in the Weapons Bay. At the time being, this is one of the larger issues in the production.

Trainings

Especially at the start of the internship I had the opportunity to attend different Trainings. Getting through the different training was a very good way to get familiar with the different common procedures and rules applied at Lockheed Martin. The duration of the trainings have been anywhere between a couple of hours to an entire week.

PDCA – Plan Do Check Adjust

The PDCA training focused on problem solving and working in a structured way. First off, one has to identify and state the problem and set a goal for improvement. Then a method such as the 5 whys can be used to determine the root cause of the problem, which then can be solved.

In general PDCA is an iterative tool, where the mentioned procedure is performed until one gets a satisfying result.

FOD – Foreign Object Debris

Foreign Object Debris is a major concern in the entire aerospace industry. The term applies to any object, which is alien to an aircraft, this can both be internal or external. There are three different FOD area levels, the lowest one is FOD awareness, followed by FOD control and FOD critical, respectively. FOD critical applies in the shadow of the aircraft and on the flight line.

The class reviewed methods to limit FOD, such as tool accountability - at Lockheed Martin, employees have to scan their badges in order to get tools, such that the tools can be accounted for. If a tool is not returned, a Lost Tool Incident procedure is initiated. Another way to limit FOD is to count the number of small loose items one takes to the aircraft, and to transport them in a closed container.

In the class we also learned on how to properly check bays and other areas for FOD with mirrors and flashlights.

CATIA

CATIA is a Computer Aided Design (CAD) software, which is used to draw various components. The F-35 is designed in CATIA. Having some CAD experience, it was pretty easy to get used to the CATIA interface and functions.

PPV training

Product Process Validation (PPV) is a process used to verify that the processes used in the production can repeatedly produce an acceptable product. The verification includes a review of the planning and operation cards used in the production step. This generally includes an observation of the process. The process is then reviewed and the operation card modified or completely rewritten.

Sealant training

As a potential task included work on tank sealant issues, we got to participate in the sealant training for the mechanics, where they learn how to apply it. There are several different sealants, which all have a different area of application.

Applying sealant is a very rigorous task, where it is important to have very clean surfaces in order not to contaminate the sealant. Most sealants come in two components, the correct proportions of both components are packaged in one tube, separated by a membrane. Once the surface is ready for the application of the sealant, the membrane in the tube is broken and the components mixed. The sealant is then applied, and spread out, such that it meets the overlap tolerances specified by the blueprints. The hands on experience made this training very interesting, as it gave us an insight on how the work is performed on the floor.

Working culture in general

The aerospace industry has its very own set of rules and different procedures than most other industries. This is because aircraft require the highest possible level of safety, as even the smallest problem can have fatal consequences, this applies to both civil and military aviation. Consequently, all employees take their job very seriously and put a large emphasis on eliminating all problems.

All employees at Lockheed Martin are also aware of the critical character of their work to the US and its allies. A lot of people working at Lockheed Martin have a history in the armed forces, which gives a very good influence on the working culture, as these people know how the product is going to be used. Lockheed Martin also has a lot of employees that have gained a lot of experience through different programs, most notably the F-22, C-130 and F-16. This is very beneficial as they are always willing to help out less experienced coworkers with their experience.

Formal meetings in Texas

During the time working at Lockheed Martin, a delegation from the Danish Metal Workers Union (Dansk Metal), the Confederation of Danish Industry (Dansk Industri) and Multicut (a Danish F-35 supplier) visited the facilities in Fort Worth. This was among others to prepare the internship of three Danish machinist interns, which are interning at Lockheed Martin for two months. We got to meet the delegation and shared our experiences and gave them some advice on how to settle down in Texas in the best possible way.

The Danish Minister for Industry, Business and Financial Affairs, Brian Mikkelsen, also visited the facility during our time interning at Lockheed Martin. The intern group met with him and his delegation, where we shared our experiences and impressions about the workplaces and the F-35 program in general.



Figure 6: Danish Minister for Industry Brian Mikkelsen with the Terma intern group

As the three Danish machinist interns arrived in Fort Worth, a welcome dinner was arranged for them, where we also were invited to participate. We were also invited to try the F-35 simulator together with them – which both was very interesting and a lot of fun.

The Terma intern team also got a chance to visit the Terma North America branch in Fort Worth. During that visit we learned more about Terma in general and its work in the F-35 program.

Extra – curricular activities in the US

During my time in Texas I have had the chance to travel a lot. Before Arriving to Fort Worth, I visited to Florida. The trip of course included a visit of the Kennedy Space center. For the rest of the time in Florida, I visited Miami and went to the Everglades.

After having completed the necessary formalities and getting settled at work, we took our first long weekend (employees at Lockheed Martin get every second Friday off) trip to Big Bend National Park. The park is huge and offers a lot of different landscapes. We managed to combine sightseeing from the car and two hikes.



Figure 7: Hiking in Big Bend National Park

As most Danish interns are aircraft enthusiasts, we took a trip to Arizona, as both the airshows at the Marine Corps Air Station in Yuma and at Luke Air Force Base were to be held in the same weekend. This was a great opportunity to see a large selection of different new and vintage aircraft. Some of the most impressive performances were the F-22, A-10, OV-22 Osprey, F-35 and of course the Navy Blue Angels. A smaller part of the group also took off the following Monday, so we could go to Tucson and visit the Aircraft Boneyard at Davis Monthan Air Force Base.

Having met some of the Danish student pilots in Dallas a couple of weeks earlier, one of the Danish instructors invited us over to Sheppard Air Force Base in Wichita Falls. During our visit, we got to see the trainer aircrafts, T-6 and T-38, and we also got a chance to try out the T-38

simulators, which has been an amazing experience! In the evening, a pilot class had its drop night, which is when the pilots get to know, which aircraft they have been selected to fly after finishing initial pilot training.



Figure 8: Visiting Sheppard AFB, where the Danish fighter pilots are trained in the ENJPT program

Texas is just huge, there are lots of great travel destinations nearby. Some of the other trips we have taken have been to Austin, Dallas, Fredericksburg, San Antonio and to Houston, where we got an extensive tour of the Johnson Space Center (level 9 tour), which has just been amazing! There are also a lot of nice natural parks nearby. One of the other interns and I took advantage of the amazing conditions for rock climbing at Milton Reimers Ranch Park near Austin, we have also been climbing out at Mineral Wells State Park a couple of times. We have also been to Dinosaur Valley State Park, where there are dinosaur tracks in the rocks.



Figure 9: Graffiti Park in Austin



Figure 10: Clockwise from top left: Hiking in Dinosaur Valley State Park, Climbing in Mineral Wells State Park, Visiting the Missions in San Antonio

Also, I took advantage of being in Fort Worth, a city that has a lot of activities to offer. I have had the chance to attend a couple of Rodeos, which has always been a very fun experience. In the Stockyards, I have also visited some other iconic places, such as Billy Bob's, Joe T Garcias, White Elephant Saloon and Cattlemen's. We also took the opportunity to see a NASCAR race at the Texas Motor Speedway (it was very loud).

As a big part of the Texas culture is centered on food, especially Tex-Mex, Burgers and Barbeque, I have taken the opportunity to eat out a lot – at over a 150 restaurants.

Two trips are still planned; one going to Montreal to see the Formula 1 Canadian Grand Prix in the last weekend, while still working at Lockheed Martin. After the end of the internship, two other interns and I will go on a road trip from Las Vegas to San Diego.

Yield from the internship

After having spent five months working on a project of a size that seemed utopic to me not that long ago, I can definitely say that I feel that I have acquired a lot of capacities that will be very helpful during my future career. This both concerns my understanding of the structure in such a big project and my abilities to interact in those structures. I have also learned that it is very import to have a structured leadership.

The internship had a quite steep learning curve. One of the first things I was required to learn was to code in Visual Basic for Applications. I had done some functional programming in Matlab, Python and Arduino, but I had only completed one larger project in Object Oriented programming, which is the preferred way of programming in VBA. Working a lot with Office, especially Excel, I learned to use it and apply it in a more effective way.

The internship also helped me get more insight into the work procedures in the aerospace and defense industry. This might be very useful in the future, as I really see myself working within these fields in the future.

Finally, this internship has been an amazing experience, both at work and outside of work. I strongly encourage any student, who is motivated and has a strong interest for aeronautics to apply for this internship. The skills I have acquired will not only help me in my future professional career but also in my future academic and personal life.

