TERMA

LOCKHEED MARTIN

DTU Technical University of Denmark

Lockheed Martin Internship Report
Rate Transition – Final Assembly

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Contents

Preface

This report marks the completion of my internship with Lockheed Martin from January 15 to June 14 2018. It contains a very brief description of Lockheed Martin, the F-35 program and the Danish involvement in said program, as well as an overview of my projects and experiences during this period and some of the cultural highlights of this stay.

Figure 1 - The Danish interns in front of the F-35 Demonstrator. Source: https://lmaeronauticsfortworth.smugmug.com

I cannot describe how grateful I am to the people who made this internship possible, and the people who I had opportunity to work with. The list is simply too long to start naming individuals, but I trust you all know who you are. Thank you.

It truly has been the experience of a lifetime, and I had only dreamt of ever coming this close to working on an actual aircraft production line.

Lockheed Martin Aeronautics and Air Force Plant 4

As of 2014, Lockheed Martin is the world's largest defense contractor based on revenue - the result of a series of historical company mergers, the latest in 1995 when Lockheed and Martin Marietta decided to join efforts.[1]

Lockheed Martin consists of four major branches: Aeronautics, Missiles and Fire Control, Rotary and Mission Systems, and Space Systems.[2]

The internship took place at the Lockheed Martin Aeronautics headquarters located at Air Force Plant 4 in Fort Worth, Texas. Plant 4 is one in a series of large aircraft manufacturing plants built in the 1940's, and has served as production site for numerous famous aircraft under the operation of several different companies. It is owned by the U.S. Airforce, but currently operated by Lockheed Martin Aeronautics, who took over after Lockheed purchased the Fort Worth Division of General Dynamics, including F-16 production, in 1993.

Today Plant 4 is dedicated to the production of some major components and the final assembly of the F-35. Parts from production sites located all over the world are shipped here to be assembled and tested before the completed aircraft is delivered to the customer.

The F-35 Lightning II

In 2001, Lockheed Martin's proposed X-35 prototype aircraft was chosen as the preferred aircraft to replace a long list of aging airplane types as part of the Joint Strike Fighter program.[3] The production model would become the F-35, and is considered a so-called *5th Generation jet fighter.* No strict definition of this term exists, but it generally includes aspects such as low-observability ("stealth"), high maneuverability, and advanced software and sensor integration. These abilities are what separate the F-35 from the rest of the pack, and provide easily achievable air superiority.

The development program is funded by 9 partner nations, including the United States and Denmark, although the F-35 is sold to other allied countries as well.

The plane comes in three variants: The F-35A Conventional Take Off and Landing (CTOL) variant, the F-35B Short Take Off and Vertical Landing (STOVL) variant, and the F-35C Carrier Version (CV).

Although the three variants serve three very different purposes, they share a number of components. This means common parts can be produced in larger numbers, and the same tools may be used on different aircraft types, which offers the possibility of keeping tooling and part costs low.

[1] https://lockheedmartin.com/en-us/news/features/history/merger.html
[2] https://en.wikipedia.org/wiki/Lockheed_Martin
[3] https://www.f35.com/about/history

In 2016, after much deliberation, Denmark finally decided to purchase 27 F-35A to replace the aging fleet of F-16. Delivery to Denmark is scheduled in 2022, although the first aircraft will be delivered to Luke Air Force Base, Arizona, in 2021, where they will be used for training the Danish pilots.[4]

A number of Danish companies have contracted with Lockheed Martin to supply parts to the F-35, with Terma A/S supplying more than 70 parts to the program. Some of the easily identifiable parts manufactured by Terma include the horizontal tail leading edges, as well as the horizontal and vertical tail skins.[5] The iconic gun pod, which allows the F-35B and F-35C variants to carry a 25mm gun (identical to the built-in gun on the CTOL variant) should the mission require so, is both designed and built by Terma (sans the actual gun).

Getting Set Up for the Internship

In 2015 the first team of Danish interns was sent to work at Plant 4 for five months, and every spring since then, a new team has been roaming the Fort Worth area. The interns are engineering students temporarily employed by the Danish company Terma A/S, who has been a long time subcontractor on both the F-16 and the F-35 programs, and the internship is similar in setup to an agreement between the Dutch subcontractor Fokker and Lockheed Martin. The Dutch have had interns at Lockheed Martin during the fall period for the past 15 years, which has left the spring period open for the Danes to practically take over the desks of the Dutch interns.

I first saw the internship opportunity posted on my university's intranet in 2015, and had no doubt that this was something I had to do, despite not immediately seeing the connection between my education and the job description.

After sending in my application, I was called in for the first interview in the spring of 2017 with two representatives of Terma, who would determine whether or not I would go on to the second interview with Lockheed Martin. That interview was done over the phone, with a number of people on the other end – a somewhat alien experience. A couple of weeks after the final interview I was called up by the same two Terma representatives, who would bring me the good news: I was going to Texas to work in the Rate Transition Team.

Most of us arrived in Fort Worth a week before the first day of work. We had bought three cars and all of the furniture we needed from the Dutch, and were able to rent the same apartments they lived in, which made moving in a breeze.

[4] https://www.f35.com/global/participation/denmark
[5] https://www.terma.com/aeronautics/advanced-aerostructures/the-worlds-largest-industrial-project/

Figure 2 - The Spring 2018 interns and Lockheed Martin Representatives

My Tasks

I was placed in the Rate Transition Team – Final Assembly, where I had the opportunity to touch on several projects during my internship. The Rate Transition Team is tasked with supporting the production line with tools and production aids that will help ramp production speed up to "full rate" from the current lower rate. Some of the more time consuming projects I have been involved with are described below. In addition to these, I used any and all opportunities to tag along down on the factory floor when invited to follow one of my fellow Rate Transition team members. I have also participated in the biweekly staff meeting, which serves as a general status update for the Rate Transition team, as well as other meetings relating to the projects described below.

The CATIA Toolbox

Lockheed Martin has a number of standards relating to the design process of tools, including 3D models and drawings, which must adhere to a number of requirements. However, since these requirements are not always intuitive or easy to check for, a small Visual Basic for Applications (VBA) macro was written years ago to help automate some of the checks and ease repetitive tasks in the Computer-graphic Aided Three-Dimensional Interactive Application (CATIA). With the help of previous interns and Lockheed Martin employees, the macro has grown into a full blown toolbox, and is now also made available to vendors so that they may check their designs before submitting for review. The toolbox consists of two parts: a part dedicated to checking for errors / compliance to the standards (to the extent that this can be automated), and a part with numerous tools meant to simplify otherwise hard or tedious tasks. I was tasked with implementing the final missing checks to the error report, as well as adding new tools to the toolbox as the need for them may arise. Some requests are simple to implement, while others are more complicated and involve a certain amount of programming antics, and CATIA Automation ToolBox (CATBox) development has taken up more time than any of my other projects.

Considering I had no previous experience with VBA, this has certainly been a giving experience, with lots of challenges and the occasional towel throwing. Dynamically constructing a HTML file with Javascript and CSS elements through VBA with no experience with any of these languages allows for endless head scratching. The CATBox remains in active development, as new ideas and nice-to-have features keep coming in.

Rate Transition Milestones Overview

Once a month, the Full Rate Reporter is published internally at Lockheed Martin, to keep employees up to date on the current state of the F-35 production. Due to inconsistent publishing, I was tasked with developing a schedule, providing an overview of the upcoming events that might be worth writing about, such as ground breaking or release to production of assembly stations. As it was, each of the six subgroups had their own list of milestones in a PowerPoint presentation, and also listed in a common excel spreadsheet. However, none of these provided a quick overview, and required some amount of filtering. I was able to consolidate the information and put it into a spreadsheet that is easy to update and sort through, although this still has to be updated manually.

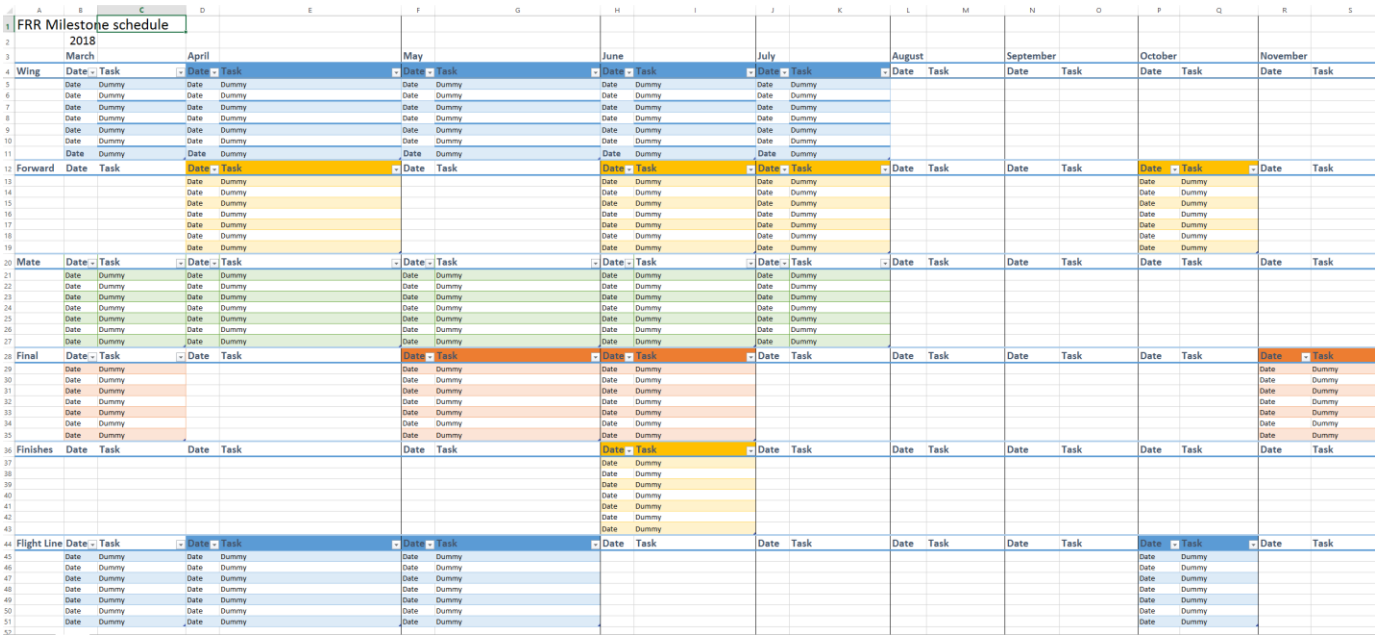

Figure 3: Snippet from Milestone schedule with dummy entries

HT Dolly Model Cleanup

Almost every single part of the aircraft has a transportation dolly, usually designed and manufactured by a third party vendor. The design is required to be made in CATIA and the model must follow a certain set of rules and standards (as also mentioned in the CATIA Toolbox section above). However, sometimes a model may contain numerous errors due to being changed by many different people, with as many different ways of doing things. Although I was inexperienced with CATIA, the 3D model of the horizontal tail dollies was given to me for a cleanup: Several parts were linked to other parts that no longer existed in the model, part materials were applied improperly or not at all, part descriptions were missing, etc.

After a few days of restructuring and modifying the model to match what was actually built, the latter requiring me to go down on the floor and noting mismatching materials and placement of details, I handed the model over to the next person for the final fixes, which I lacked the knowledge to perform.

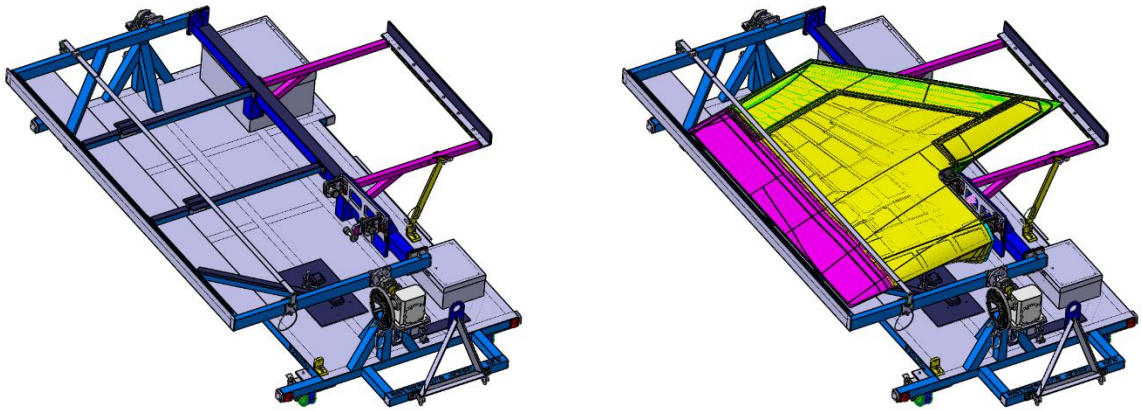

Figure 4: Horizontal Tail Dolly with and without the horizontal tail

F-35 Load Bar Concept

Due to the layout of some of the assembly stations where the aircraft is still at a relatively light stage, a device has been built that makes it possible to lift the incomplete aircraft out of the station if the need should arise.

This device is not rated to lift the aircraft at any later stages due to the added aircraft weight, which will increase stresses on the factory building and the three monorail cranes required to distribute that weight. I was therefore asked to find out if a “beefed up” version of the existing solution would be enough to lift the aircraft in a heavier state. Since the current setup is simple, I decided to find out if basically extending the main load bar and using a fourth crane would be enough.

I modelled up a simplified version of the extended load bar in CATIA in order to do a preliminary stress analysis, to determine if the modifications required to keep the stresses low would increase the weight of the bar too much for the cranes to handle. Having never used a commercial software suite to do stress analysis before, I also modelled the existing load bar and performed a similar simulation, so that I could verify the results I was getting were at least close to what I would expect.

I was able to show that with deeper webbing and thicker flanges, the stresses in the I-beam could potentially be brought down sufficiently, although a more thorough analysis of the final design would definitely be required.

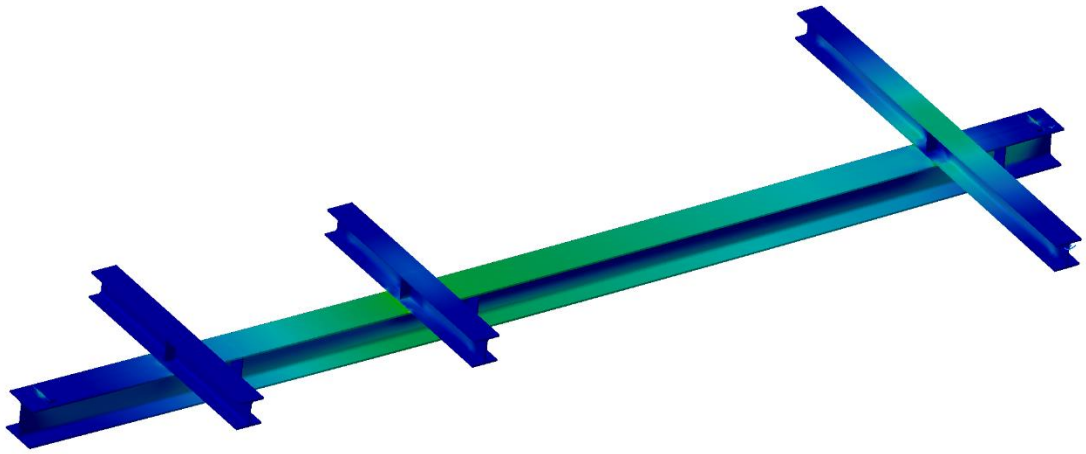

Figure 5 - Stress distribution in the main load bar

Next-Gen 850 Stands

A new set of production stands for the so-called “850” positions are, at the time of writing, currently being designed. Although I have not been directly involved in the project, I have participated in most of the meetings with the vendor up until this point. This includes the “kick-off” meeting, which involved a very thorough discussion of the needs and requirements for the new stands. It was a very giving experience, and I have learned much about the complicated process that is stand design. The project involves many people: The mechanics, who will be working on the stands every day for many years, the vendor, who designs, produces, and maintains/supports the stands throughout their lifetime, and the Rate Transition team, whose task it is to translate and convey the needs of the mechanics into requirements and instructions to the vendor. In order to better do so, several meetings with the mechanics were (and will be) held, where the mechanics are shown the current design state and asked for input relating to improvements or problems they foresee.

Training Classes

Various classes were offered to us during the internship. The following is a short description of the classes I was able to participate in.

Plan, Do, Check, Adjust – Problem Solving Training

Plan, Do, Check, Adjust (PDCA) is part of the integration of lean thinking and six sigma methodologies throughout the organization. The goal is to involve all employees in streamlining the production and provide a standardized method to solve all kinds of problems. The class involves coming up with possible solutions to hypothetical or real problems from anywhere between the production floor to everyday life. The class is concluded by a personal report to show that you are able to utilize the tools you have learned on a problem of your own choosing. I chose to write about the CATBox, which I had already been working on extensively at the time.

Product Data Management Navigation and Application

Product Data Management (PDM) is a piece of software used to manage everything from technical specifications to tool manuals. The class is supposed to be an interactive 1 day class, teaching you to navigate the software, but due to technical problems on the day we received the light version consisting of the slide show meant to support the training. It should be noted that despite being able to log in to PDM, the interns do not have access to any data, and I never used it after the initial log in.

CATIA Introduction

This four day course provides a thorough foundation for modelling in CATIA. Although having only briefly been introduced to SolidWorks in the “Introduction to engineering” course about 6 years ago, I found many of the principles to be familiar, and the course was an excellent refresher and made the transition to CATIA very smooth. Additional classes expanding on the topics of drafting and assembly design also exist, but were not available at the time I asked.

Foreign Object Debris Certification

Mandatory for all employees working with the aircraft, this class teaches you how to prevent and find foreign object damage/debris through proper clothing and properly managing tools and consumables. Apart from the different ways of preventing Foreign Object Debris (FOD), the course also made an effort to ensure we understood the dangers and possible consequences of FOD in and around the aircraft.

A Few Takeaways from My Internship

One may argue I was already borderline obsessed with aircraft before this internship, but spending half a year working in Fort Worth has not helped remedy this diagnosis. I have no doubt that my future career will involve the aerospace industry, and I fully believe this internship has made me better equipped, both mentally and professionally, to continue down that path.

My initial fear of not having the "right" background for this internship was quickly dissipated. No one ever expected that I would be able to pull the solution to a task out of my school notes. Instead, I was allowed to learn what I needed to know as I went along. For example, I spent the first couple of days learning the Visual Basic language syntax, which I needed to know in order to work on the CATBox macro. Granted, the fact that I had some experience with other programming languages made the transition a lot easier than starting from scratch. I quickly realized that after a few days, I knew a lot more about the inner workings of the CATBox than most of the people using it. This contrasts my experience from years of education, where everyone in the group is expected to at least have a basic understanding of the other members' subjects.

To quote Donald Douglas: "When the weight of the paper equals the weight of the airplane, only then you can go flying." At Lockheed Martin, this applies to everything related to the production of the aircraft. The amount and detail level of documentation is simply astounding, and I don't think I realized before coming here just how much work goes into the design of tools and production aids.

Working here at Plant 4 has in many ways lived up to my expectations about work life for the engineers, but I have also been surprised more than once. It requires a lot of intelligent people to support the production of the extremely complicated contraption that is the F-35, and being able to watch and learn from these people has taught me that even though you may find yourself working with your own little project, being able to reach out to your coworkers for assistance sometimes is not only an advantage, but often a necessity.

I had been to the US several times before coming here, and spent a semester at the University of Illinois a few years ago. I was therefore not surprised to once again encounter the American pride that permeates *everything (!)*; even the dust covers for the F135 engines are labelled "*Powering Freedom"*. That being said, Texans have turned the pride-dial to 11, and are very keen on showing newcomers why, which has resulted in an extremely guest-friendly and open attitude that I have not seen elsewhere.

Life Outside of Air Force Plant 4

So far, all the Dutch and Danish interns have stayed at Marquis at Stonegate on Hulen Street. The place is really convenient, and the drive to work is usually between 10 and 15 minutes, depending on traffic. Not bad at all, when you realize just how many cars and trucks there are in Fort Worth, and how much time people here usually spend in traffic.

Although workdays are long in the US, there's still plenty of time to explore the state. The Fort Worth area is full of restaurants for any dietary preferences, and the extended weekends provide ample opportunity to drive out to see some of the cities and sights that are not within immediate reach. Make no mistake, Texas is a big state, and you will want to travel most of it during the internship.

We started planning early, in order to get cheap plane tickets and hotels, so the long weekends quickly filled up with travel plans. *Some* of my personal trips worth mentioning:

- **Washington D.C.** The National Air and Space museum(s) at The Mall and Dulles are excellent.
- **Phoenix, Arizona.** It just so happened that the Yuma Airshow was moved to the same weekend as the Luke Days (Luke Air Force Base, Arizona) in March, so I planned a trip for 7 of us to go see the airshows. Both airshows were definitely worth the trip, and I would go again given the chance. A few of us decided to take an extra day off and go down to see the Pima Air and Space Museum, where we had booked the special AMARG (Aerospace Maintenance and Regeneration Group) Tour, which took us around the world's largest military aircraft boneyard.
- **New York City.** Always worth a visit. There's something to do for anyone, although I do recommend the Statue of Liberty / Ellis Island trip, along with making a visit to the top of one of the skyscrapers to get a view of the city.
- **Corpus Christi and San Antonio, Texas.** We made the long drive south to the Mexican Gulf to see the USS Lexington (a decommissioned aircraft carrier), and spent a little time on Padre Island before driving back up to San Antonio to see The Alamo.
- **Big Bend National Park.** Because National Parks are always awesome.
- **Johnson Space Center (Houston, Texas).** We booked the level 9 tour (well in advance). It was definitely worth it.

Figure 6 -"Heritage Flight", personal photo taken at Luke AFB Airshow

Other activities in the vicinity of Fort Worth:

- NASCAR
- Gun ranges
- Stock Yards
- Rodeo

I was also able to get an American private pilot's license issued based on my existing Danish license, and rent an aircraft at a small airport not too far from the apartment. Getting a bird's eye view of the city is always a great experience, and on one occasion watching the large Airborne Warning and Control System (AWACS) plane circling the Naval Air Station Joint Reserve Base Fort Worth out in the distance with sunset in the background was truly awe-inspiring.

Future Interns

Terma A/S and Lockheed Martin are offering you a very special chance to gain work experience in an environment that does not resemble anything you have seen before. You might think this internship is only relevant to people with a burning passion for aircraft, but the projects you will be involved with are definitely not just relevant for the aeronautical industry. You will more than likely be able to apply the skills you develop here to a wide range of problems you encounter in your continuing career.

The internship application and start up processes are streamlined, and you will be given a handy guide containing tips and tricks to help you get all the practical stuff sorted before your first day at Lockheed Martin.

I urge anyone who is not afraid to dive into the Texas experience to apply for the coming internship positions. It will take you places - both professionally and physically.