Figure 1: Denmark's first F-35 recently headed to final assembly (14)

Internship at Lockheed Martin

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April 4, 2024

LOCKHEED MARTIN

DTU Space
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Introduction

The Lockheed Martin F-35 Lightning II, a single-seat, single-engine aircraft, represents not only a remarkable feat in aviation technology but also an exemplar of international collaboration, particularly between the United States and European nations. As a Dane, I find the F-35 program's achievement particularly significant, marked by the delivery of the first four Danish F-35 planes to Denmark in September 2023. Furthermore, the program encompasses an internship partnership between Terma and Lockheed Martin, offering Danish interns the opportunity to work at Lockheed Martin's facilities in Fort Worth, Texas, and Marietta, Georgia, each year. I had the privilege of being part of the team in Fort Worth, where the final assembly of the F-35 planes takes place.

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Acknowledgement

Nutplate debond team

Thank you to the team I have been a part of during my work as a quality engineer. Those people are Alex Castro, Neliam M. Justiniano, Mason J. Bernard and Ibrahim K. Asgharali. It has been a blast working with these people and I am very humbled by the knowledge and experience they possess. The team has given me an insight in working across engineering branches and the value of working as a team / one company.

Alex Castro

Thank you to Alex Castro, who has been a wonderful mentor and manager for the quality team in Fort Worth. The guidance and knowledge gained from working with Alex have been invaluable. I have learned the differences in how to interact with the production line and in meetings with upper management, and how to develop an evidence-based root cause map. I have improved as a person and a colleague through the experiences gained while working under Alex.

AI team in Operations Technology

Thank you to the Opstech team for picking up the torch and allowing us to stay as interns. I am thankful for the opportunity to meet this team and get an inside in their work life and methods. I would especially like to thank, Alexander Tramm, Jonathan Olson and Jean Pierre Njock II (JP). Alexander Tramm and Jonathan Olson are that teams glue allowing for ideas and development between interns and the team to flow. Thank you to JP for the knowledge in coding that he has shared, I can see clearly see how my code has improved as a result of the knowledge shared. Lastly thank you to Alex and JP for including us in their outside of work activities, primarily training.

Terma A/S

I am grateful to Terma and the team there for this incredible opportunity. The support I've received and my involvement in the F35 program in Fort Worth have provided me with unique experiences that I will take back home with me.

Donny Weaver

Although Donald (Donny) Weaver is with Terma, he truly merits a special mention in the acknowledgements. Donny is one of Terma's representative in Fort Worth and has been a significant help to us here. More than just being helpful, Donny is an incredibly friendly and pleasant person, and I am glad to have met him. So, a big thank you to Donny!

DTU

I would like to express my gratitude to DTU and DTU Security, but especially Henning Heiselberg. Without him, I wouldn't have been aware of chance to participate in the Lockheed Martin internship. He has inspired me to get involved and challenge myself. He plays a crucial role in connecting students with the internship and promoting it at DTU.

History of Fort Worth and Air Force Plant 4

Our initial adventure beyond the confines of our apartment complex led us to the heart of Downtown Fort Worth, where we were greeted by the magnificent spectacle of the All-Western Parade. This event was a splendid showcase of the region's rich culture, featuring an impressive array of Cowboys, Cowgirls, Stagecoaches, equestrian troops, and marching bands parading through the city streets. The parade provided not only a wonderful visual spectacle but also a wonderful first impression of the spirited community of Texas.

Following this experience, we visited the Tarrant County Courthouse. Here, we were privileged to receive a guided tour led by a retired clerk, who passed on a wide range of knowledge about the intricate history and development of both Fort Worth and Tarrant County.

Figure 1: The All-Western Parade (1)

Fort Worth, distinguished for its youthfulness in comparison to older East Coast cities, is nearing a population of one million while maintaining the allure of a smaller town (2). Established in 1849 as a military outpost post-Mexican American War (1846-1848), the city was initially intended to expand the nation's frontier and bridge the gap between the Rio Grande and the Red River.

Figure 2: Flag of Fort Worth (4)

Following the Civil War (1861-1865), Fort Worth underwent considerable development, predominantly fueled by the booming cattle and ranching sectors (3). This since 1877, the history is

still prominently reflected in the city's nickname, "Cow town" reflecting the cowboy roots of Texas and its flag adorned with a longhorn motif, we saw when arriving to the Fort Worth airport (4).

The Stockyards, Fort Worth's historic district, serves as a living monument to its status as a central livestock trading hub in the United States. Today, it proudly honors this legacy through daily parades of longhorns with a big celebration in January which were our main activities for the first month of our visit.

Figure 3: Longhorn at the Fort worth Stockyard (1)

The growth of Fort Worth and population persisted steadily, driven by key developments such as the construction of the Texas and Pacific Railway, and the discovery of oil in the early 20th century. These events have left an enduring mark on the city, crafting a unique fusion of historical depth and modern progress. (3) For a general size comparison, the population of Fort Worth since July 1, 2022 about 950 000 people (2) which is about 100 000 more people then what live on Zealand one of our islands in Denmark. Furthermore, the Dallas-Fort Worth metropolitan area, being significantly larger than the entire population of Denmark, underscores the vast urban expanses that characterize the America.

Even though the amount of people living in Fort Worth is a lot. The city still have a small time feel and the big skyscrapers primarily in the center of Fort Worth around Sundance Square. Which was highlighted especially when we visited the Stockyards and witnessing the daily longhorn parades, felt like stepping back in time.

Air Force Plant 4

Air Force Plant 4 (AFP4) commenced its operations in West Fort Worth during World War II, specifically on April 18, 1942. The facility was primarily dedicated to the production of the B-24 Liberator bomber, earning it the moniker ”bomber plant.” A remarkable total of 2,743 B-24s were manufactured in Fort Worth (5). A particularly fascinating aspect of AFP4’s history is that, during the war, over 30,000 individuals were employed there, with women constituting a third of the workforce. This led to the development of Liberator Village, located south of the plant, to accommodate many of these employees. My experience of holding one of the riveters on display provided me with a tangible sense of why Rosie the Riveter is famously portrayed flexing her arm in the iconic ”We Can Do It!” poster, and it was a reminder that I could benefit from more physical exercise.

Figure 4: F-35 flying out from AFP4 (15)

Transitioning into the 1960s, AFP4 embarked on the production of the F-111 Aardvark, a supersonic tactical aircraft, which shifted its nickname to being known as the ”fighter factory.” The 1970s saw the commencement of the F-16s development, with an impressive total of 3,630 units being produced in Fort Worth (5). This was followed by the production of the F-22 Raptor where the final assembly now has switched to Marietta. Over the past three decades, the focus in Fort Worth has been on the development and production of the F-35. The enduring history of AFP4 is a testament to the resilience, ingenuity, and success of its workforce and the Dallas-Fort Worth community, marked by 76 years of continuous innovation in production, manufacturing processes, and more in Fort Worth.

Work at Lockheed Martin

My work at Lockheed Martin was in two departments: Qualtech and Quality Engineering.

- In the Qualtech department, I was a part of the Manufacturing Simulation and Modeling AI team. This team is developing neural networks for automated inspection and defect identification. There, I chose a project to improve the pipeline for data generation used in AI model development. The AI in development will help improve the efficiency and accuracy of the manufacturing processes of the F-35 planes.

- As a part of Quality Engineering, the goal was to perform big data analysis to discover trends and uncover root causes. This allowed for the development of solutions to reduce rework hours and defects. In this department, I participated in a project that gave me a unique experience of the process and culture involved in building a highly complex product while striving for zero defects. Furthermore, I got the opportunity to learn how to tackle problems in production and implement actions to increase the production rate and improve workflow in such an environment.

What is FOD? And why do we care?

In Qualtech the team I worked there primary project is to develop a foreign object debris (FOD) AI. An AI tool that can help the mechanics and inspectors to detect FOD. The goal is to provide a tool to enhance the ability to detect FOD in the aircrafts as part of Lockheed Martin's motto to provide 100 % quality airplanes to all customers.

To develop an AI capable of detecting FOD or other defects, comprehensive data on these defects is crucial. Gathering and producing data for AI model to use is crucial. As the model rely on it to learn, identify, and predict outcomes by recognizing patterns within a provided dataset.

Project: FODget spinner

I choose a project to improve the data generation for the AI pipeline. In my project I increased the automation of the Fake FOd Studio. The goal of the studio is to capture multiple images of objects that can be used as data which can be superimposed on to images of desired backgrounds. The Fake FOd Studio build around a UR10 robot arm which performs a 360 image capturing. The UR simulation tool and RoboDK was a two new systems I had to get familiar with as I began this project. The RoboDK system allowed me to develop python code that sufficiently could move the robot arm around in a desired path and capture images using OpenCV. Using UR simulations I could plan path-ing which could be used in the real-world execution of the robot.

When I arrived the current program could only take capture one item per run. I developed a turn dial using a stepper motor, stepper driver and an Arduino UNO which then could be integrated in the python program. This required a study into Arduino integration with stepper motors and how to communicate with them. Furthermore I had to learn 3D CAD drawing and how to produce prototypes using 3D printers.

The stepper motor had to turn what I named the lazy deck in reference to a lazy Susan table which was where I got the inspiration for the design. This was my first 3D build and went perfect, however drawing and generating the washer which connected to lazy deck and the stepper motor required multiple iterations. Lastly I made a stand for the whole system to rest on, where the stepper motor could fit in the center and four wheels can be attached to stabilize the turn dial as it rotates.

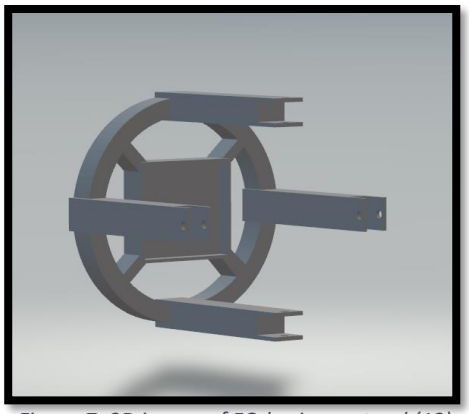

Figure 7: 3D image of FOd spinner stand (13)

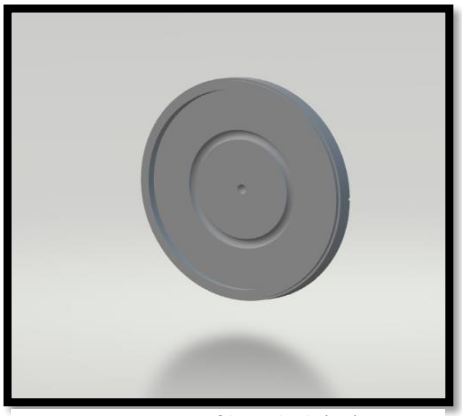

Figure 7: 3D image of lazy deck (13)

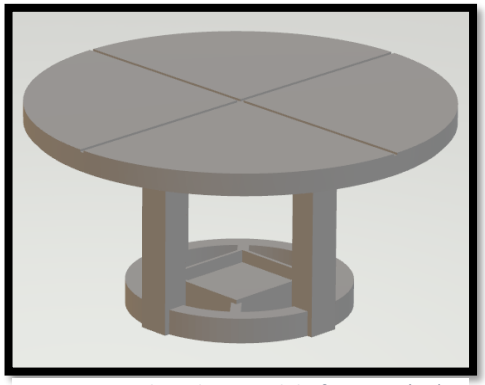

Figure 7: Combined 3D model of system (13)

The hardest part was determining how the stepper driver received a signal form the Arduino and how to make sure it was passed to the stepper motor. This was solved by learning about the correct directory registration of the stepper driver and the stepper motor. The next step was then to send the correct amount of pulses to the stepper motor such that turn dial turned such that the next item was centered.

After I established communication with the stepper motor through the Arduino I created a python function which transmit a pulse to the Arduino. In order to integrate this function into the existing Fake FOd Studio code, I had to make some modifications and this also allowed me to improve the code in certain places.

Final and FwD requirement analysis

The position I wish to end up at is regarding systems, quality and test engineering. Systems engineering for me is to define a system, manage stakeholders and define the future path of a product development and lifecycle. I got to be a part of defining the future path of the FOD AI Cart, where we meet up with the stakeholders of FwD and Final to identify project requirements for their needs and what we need to do in order to develop make the product best for the people who will be using it. I teamed up with David

Coleman who has previous experience with product development. He and I went through data for defects to determine which the most detected items of FOD. This process gave me an understanding of how to manage stakeholders and determine the best cause of action at early stages of product development.

Nutplates

When I arrived in the Quality engineering department, we were introduced to debonded nutplates. Nutplates are used for construction of aircrafts, used for fastening. A nutplates fastener design eases alignment and replacement of the nut, since it eliminates the need for backside access on bolt installation thus making it easier to close an aircraft during building.

Debonding nutplates are nutplates that becomes separated or detached from the surface which it was bonded to. A debond is a defect that can compromise the integrity of the fastening and will increase the amount of hours used to build the aircraft. There are multiple factors that can attribute to the debonding.

We set out to do some detective work to understand the defect and determine the causes of action to diminish occurrence of this defect. Throughout this internship I have learned from some of the smartest people in their respective fields and been guided on how to build a strong case for root cause analysis by using a technical and engineering mindset. This was especially a fantastic experience as I have been working in a team comprised of multiple engineering fields and areas of production.

The members of the team are Neliam M. Justiniano, Mason J. Bernard, Ibrahim K. Asgharali and Alex Castro. I am very grateful to have meet these people, to be part of such a dedicated team, and the knowledge gained from this experience. This team highlights the drive between all departments and also the need within Lockheed Martin to ”break down silos” (increase across team projects).

Root cause analysis

A root cause’s analysis is the methodical approach to finding root causes for a problem and identify an appropriate action/solution.
Before I arrived the ground work had already been laid by our team and previous interns, so we needed to come up to speed. In the first weeks of our onboaring to this project, we moved around the plant with Mr. Castro. Here we interacted with colleagues from almost all professions working in the plant gaining knowledge about debonding nutplates. Through these interactions and meetings with our team which we then could use to develop root cause for the defect. This allowed us to build a comprehensive root cause summary map, which we named the Hyde park map. Since it became a combination of a fishbone and root cause analysis map. Throughout the internship we refined the map, from the map we driving 54 actions (with more to come) to various root causes identified during this project. The goal of all these actions are to

1) Eliminate variability
2) Understand the defect further
3) Determine priority, to understand which root causes will drive the most efficiency and value.
4) Prevent further issues

Upper wing skin installation template

One of the root causes that needed to be tackled was the installation of the nutplates. One action to tackle this was by a Manufacturing engineer and Quality engineer. They developed a standardized method of how installation of the skin through a torque sequence. The goal of the project was to standardizing the installation is to rule out variation in installation. This will ensure a more standardized installation.

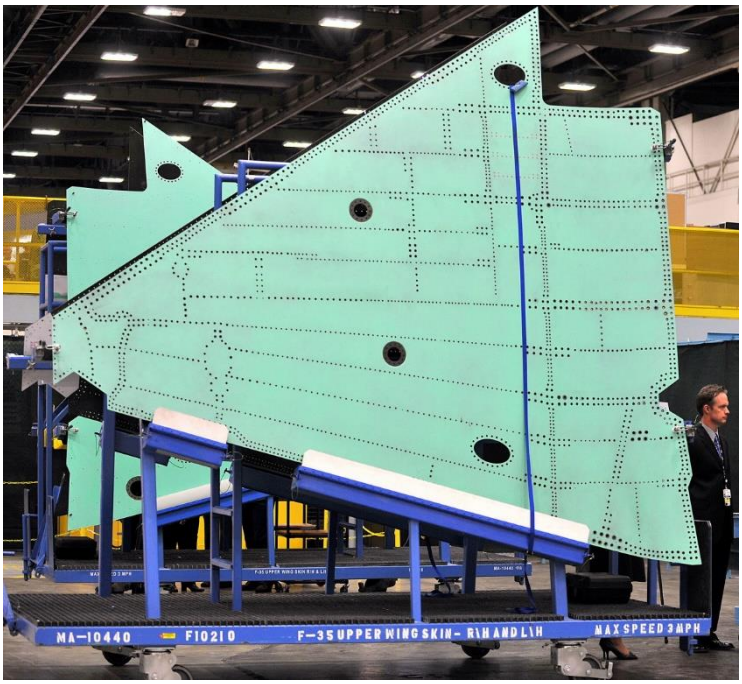

Figure 8: Left upper wingskin (16)

Torque sequence was expected as a root cause of debonds, as the stress of causes on the nutplates during skin install would cause the nutplates to debond. We got to experience an install of the upper right hand wing skin with their torque sequence and to draw the sequence on the tape template which is applied to the skin indicating the sequence.

To understand the effects of the torque sequence, we needed to determine the best way to study the data, whether it would be the total data study or a statistical study through a control data set. The statistical study.

Heat mapping tool and data science using python

When we arrived the previous teams had developed a ground breaking tool for displaying and mapping the number of debonded nutplates occurring across the aircrafts. Together with Jacob H. Neergaard, we have taken the tool to newer levels by determining a measurement of effectiveness and long term productivity improvements.

Furthermore we developed a script to automate report generation for the monthly nutplates reports. This script will increase the effectiveness and allow Quality engineers to focus on tasks rather than 3 day number crunching.

Thanks to Mai Cuu, we were able to introduce a statistical element to the already existing data studies which allowed us to gain a better metric of success and efficiency. The work with Mai Cuu gave me a further understanding into how statistics can be applied to study a production line, to evaluate the efficiency and how changes either increases or decreases efficiency. We developed two proportions test for our data, interval plots and control P-charts for the production of the aircrafts data sets provided.

Adventures outside work

Outside of work I have been traveling a lot around the east coast of USA and sightseeing around Texas. Two of the biggest adventures were New Orleans and Six flags but I was also blown away of the size of New York, the Smithsonian museums of Washington DC and the national parks scattered around USA.

New Orleans, Mardi gras & Jazz

Our first adventure outside of Texas took us to the Crescent City, also known as New Orleans. The nickname comes from the position of the city relative to the course of the Lower Mississippi River. We spent 4 days exploring the city of New Orleans and the swamp around it.

Figure 9: Swamp tour around New Orleans (1)

We flew late Thursday night and traveled straight to the hostel to sleep after a long work day. The next day we spend exploring the city, with the first thing on our agenda being breakfast. As I had been told that a proper New Orleans Breakfast is a Beignet and black coffee.

New Orleans is a very unique and beautiful city with a lot of history. This especially came in play when we first visited the French Quarter and saw the old architecture reminiscent of the colonial times, when the French and Spanish first came to that area. This was a nice change of scenery compared to the Dallas Fort Worth area with modern skyscrapers and cowboy boots. New Orleans' rich history is steeped in the legacy of French colonialism and the WW2, notably marked by its role as a pivotal slave market in the transatlantic and international slave trades. The 1808 abolition of the transatlantic slave trade curtailed the influx of enslaved individuals from the Caribbean or Africa (6). The colonial historical influences were noticeable as we walked through the streets of New Orleans, with French street names and the French Quarter's architecture. The fleur-de-lis, the logo of the New Orleans Saints, further showcases the colonial heritage. (6)

New Orleans also played a significant role in the Second World War, specifically through the construction of the Higgins boats. Andrew Higgins, the owner of Higgins Industries in New Orleans, designed and produced the LCVP (Landing Craft, Vehicle, Personnel)/ the Higgins boat (7). This is the reasoning for why the national WWII museum is located in New Orleans. Since these boats allowed troops, vehicles, and supplies to be efficiently landed on beaches, especially during amphibious assaults such as the D-Day invasion of Normandy in 1944 (8). It was a blast to see the museum, especially since it depicted the internal political struggle between isolationism and interventionism which I only had heard learned a small amount of in school. Furthermore it further described the events leading up to Pearl Harbor and the attack on Pearl Harbor.

Six Flags over Texas

We went to six flags in the cold middle of February to avoid the park being too crowded from the spring break which usually starts around late February to early March, for most southern universities and colleges. This resulted in the park having almost no queue to all the big roller coasters. Six Flags over Texas opened on August 5, 1961, and was the first one in the Six Flags chain out of 27 parks (9). However the age of the rides did luckily not match the state of the rides. My goal arriving at the park was to try all the roller coasters and after 5 hours and 30 minutes, we had done it. Below you will find my top three picks for roller coasters in Six Flags over Texas:

1) Titan (10):
   The titan was the fastest and tallest roller coaster in the park. With the highest point being 245 feet (74.7 m) to the ground which also was the height it dropped from. On that drop the coaster reached around 85 mph (137 km/h), and due to the cold Jacob had a beanie on which vanished before I could blink. After trying all the other roller coaster, we went back to try it again. We wanted to see if the beanie could be seen from the ride, however we were dead wrong; we went way too fast.

2) New Texas giant (11):
   The New Texas Giant, our first ride at the park, which was a classic wooden architecture that belied its thrilling performance; to my surprise, it was exceptionally fast and wild, which I did not expect to be something a wooden roller coaster could deliver. Notably, it had the longest wait time of all the rides we experienced that day, with a queue lasting about 45 minutes, a stark contrast to the subsequent rides where the wait times were around 5 minutes, offering a much-appreciated relief.

3) Mr. Freeze (12):
   Mr. Freeze was the scariest we tried. Half of the ride is experienced going backwards, and the scariest part was the loop going backwards. Usually roller coasters use the simple law of Conservation of Energy (Transform potential energy into kinetic energy and reverse), where the potential energy is generated from the first ascent. However this used coaster used an electromagnetism to launch the coaster with an impressive acceleration in the beginning of the ride into a loop. It was interesting seeing this use case of electromagnetic propulsion.

Conclusion

It has truly been an incredible journey living in the USA, particularly in Texas. I am deeply appreciative of everyone I've met who has guided and supported me throughout this time. The Lockheed Martin internship opportunity provided by Terma has been immensely rewarding, offering me a firsthand glimpse into Texan culture and lifestyle over the past six months. The work has been fulfilling, and I have gained significant knowledge and skills that will undoubtedly benefit my future endeavors.

Figure 12: Visit to dinosaur valley state park (1)

Figure 11: Danish minister of defense visit (13)

Figure 10: Danish minister of defense visit (13)

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