



(Defence-Blog, n.d.)

Lockheed Martin 2024 Internship

Quality Engineering in Wing Systems

Jacob Henrik Neergaard



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A special thanks to alex Castro for being a mentor and a guide on the journey, and always finding a balance between helping while still allowing me to make the mistakes invaluable to learning. He is a tremendous factor in making this internship a success and I do not believe I would have learned half as much if not for his insight, knowledge and network.

I would like to thank Neliam, Mason and Ibrahim for allowing me to be immersed in the nutplate project and wholeheartedly accepting my perspective on issues as their peer, even with my initially limited knowledge of aerospace engineering.

Introduction

When a country considers its geopolitical situation and what threats it might face in the future it typically lists a set of needed capabilities and chooses platforms that can give these. With the aging F-16 fleet, this was the situation Denmark faced in the beginning of this millennium. The needs centered on enforcing sovereignty and participating in internationally led missions.

(Rasmussen & Breitenbach, 2007) These criteria eventually led to the final choice of the F-35 which was made in 2016 winning out over alternatives such as the Eurofighter and the F/A-18F Super Hornet. (Danish Department of Defence, 2016) (Freedberg, 2016)

From the inception of the Joint Strike Fighter(JSF) project which resulted in the F-35 program it was envisioned as a multinational cooperation effort as opposed to being led by a single country. Partner nations were invited to join in the development stage, and would have some degree of influence on the design and an opportunity to participate in the industry supporting the program. (Burbage, Clark, & Pitman, 2023) As the Danish company Terma is a subcontractor for Lockheed, this industrial cooperation eventually led to the forming of the internship, where several Danish students get employed by Terma and sent to Texas and Georgia to gather experience, learn and bring back skillsets for use in the Danish industry.

History of Fort Worth and Air Force Plant 4

Fort Worth was established in 1849 as was part of a military presence by the Republic of Texas to maintain presence on the frontiers of northern Texas. A couple of decades later the now city had grown considerably and became a hub for livestock, hence the nickname Cowtown. (Fort Worth Chamber of Commerce, n.d.)

The cattle days are long gone, and Fort Worth look to other areas for its economic growth. One of the main drivers for this was the aviation industry that boomed around the Second World War, and Air Force Plant 4 which began production in 1942 of the B-24 Liberators. The plant produced almost 3000 Liberators before production was shifted gradually towards other platforms. Today the plant is an assembly plant with a focus on producing the 3 different models of the 5th generation fighter F-35. (Lockheed Martin, 2022)

Work at Lockheed Martin

Foreign object debris (FOD) and the FOD AI

Foreign object debris (FOD) has always been a huge challenge in the aerospace industry. Any object can be classified as FOD as it simply refers to an object that is in a place where it should not be. It could be anything from a bolt, a zip tie or candy paper.

In the beginning of the internship I was working in Operations technology which had a heavy emphasis on reducing and removing FOD. This was done through several initiatives, one of the more ambitious ones was using AI. The FOD AI as it is called uses a camera to view inside the bays of the f-35 and display it live on a screen. Then anything that is classified as FOD gets identified and can be removed by the mechanics or inspectors. My role in this project was quite modest, and centered on improving the recognition software by taking pictures of FOD in the bays of the aircraft and circle the items by hand to feed training data to the algorithm.

Initially I was supposed to work in quality engineering; however, but due to unexpected problems encountered prior to my arrival in Fort Worth, I was temporarily moved to operations technology for roughly the first month of the internship. After suitable contingencies were found to address the issues noted at the start of this internship, I requested a move from operations technology to quality engineering.

The Nutplate Project

After moving to quality engineering as originally intended I was quickly enveloped in the ongoing conversations regarding nutplates and defects related to these.

A nutplate is used as a tool for joining two structures together as an alternative to rivets, that can help reduce weight, and decrease the number of defects as fewer nutplates are needed than rivets. A nutplate consists of a base, a clip and a barrel. The barrel is slightly oval so when a fastener grabs the threads of the barrel, it plastically deforms the barrel to increase friction to secure the fastener.

As shown in the picture below a nutplate is installed on a surface using an adhesive. While the adhesive cures a disposable installation fixture holds the nutplate in place, and prevents adhesive from seeping into the bore of the hole. These disposable installation fixtures are often colored in bright colors, so as to identify debris left as it is removed after curing.

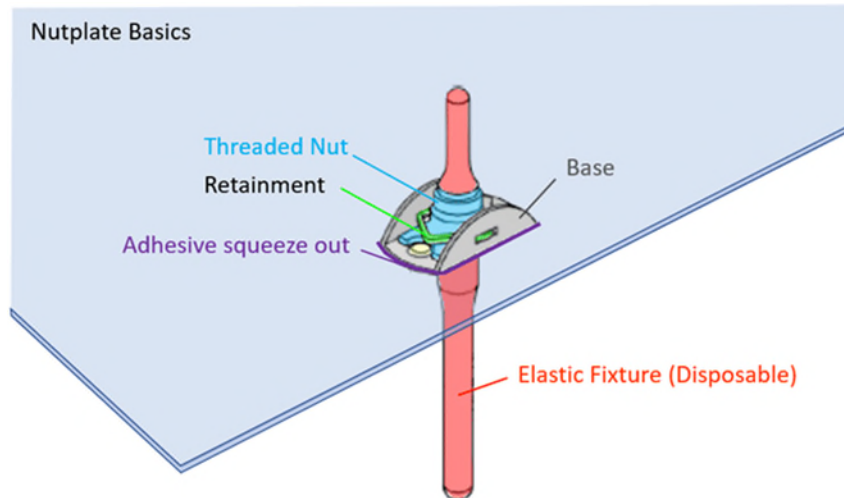


Figure 1: Installing of a nutplate (Composite Envisions, n.d.)

The main risk introduced by nutplates, is that the nutplate debonds from the surface when a fastener is installed, and thus losing its ability to bind the two surfaces together. However, the design of the plane is made with such a margin that even several debonding nutplates does not reduce the reliability of the part, but there are other complications generated from this incident. When the nutplate debonds, it becomes loose and is classified as FOD as it can cause damage to the aircraft. Thus removing the nutplate after debonding is essential.

In the case of the upper wing skin install this is a particularly problematic issue. Below can be seen an example of a wing box (f-16) and an upper wing skin (f-35). Nutplates are installed on the backside of all the spars, and are used to hold the wing box and the upper skin together. When the upper wing skin is joined with the wing box, there is no easy way to reach the debonded nutplates that are now loose inside the bays of the wing.



Figure 3: An F-16 Wing box (Tyrrell, 2021)

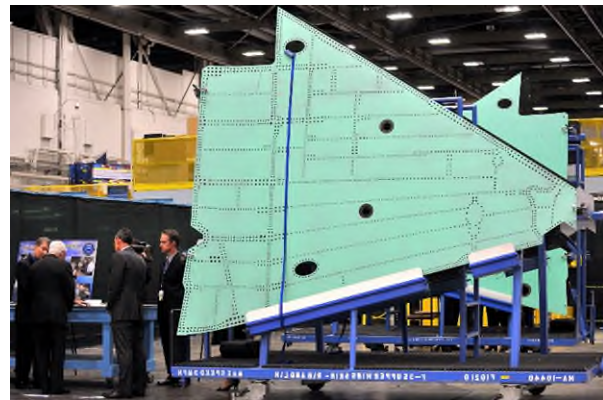


Figure 2: Upper wing skin (Air recognition, 2014)

The debonds during this installation is a particularly high driver of unplanned work, and causes both delays and high costs, that directly impacts the bottom line of the company. Therefore it is

vital to reduce these to a minimum in order to help secure the economic viability of the project, and perhaps contribute to a reduction in the cost for customers as well.

There are many root causes that can result in a debond and a lot of the groundwork had already been done before my arrival at the plant. The task for me and my team was to map these out, and figure out which areas could address each root cause. This project was by its very nature both ambitious and required teamwork and concerted efforts to lift off the ground, due to the size and many different stakeholders. Initially roughly 50 root causes were identified and efforts were made to begin addressing the largest contributors. As the scope of the project grew so did the root causes, and we ended up with over 200 root causes, resulting in a huge flow diagram style map, that was over 5 meters long.

Before my arrival torqueing sequence during the install was suspected as a major factor, and therefore a standardization was introduced in a trial, where I was supporting towards the end of the run. The purpose of the torqueing sequence was to reduce the magnitude of stress on the nutplates during install and should theoretically lead to fewer debonds. A lot of data handling and statistical analysis was required for this part, to take incomplete and often suboptimal data and both visualize it, but also draw conclusions. This was one of the major projects I contributed to, and am especially proud of taking the step from a qualitative assessment to a quantitative one. At my departure there was still insufficient data to conclude decisively on the trial, but indications showed a positive effect.

The JK fastener

Another item on the root cause map pertained to the use of a specific temporary fastener. This fastener consists of 4 parts. Two halves and a middle part that when torqued splits the halves causing the fastener to apply an outwards pressure and thus stay in its position. The halves are bound together by a collar at the head that prevents the fastener from falling apart.

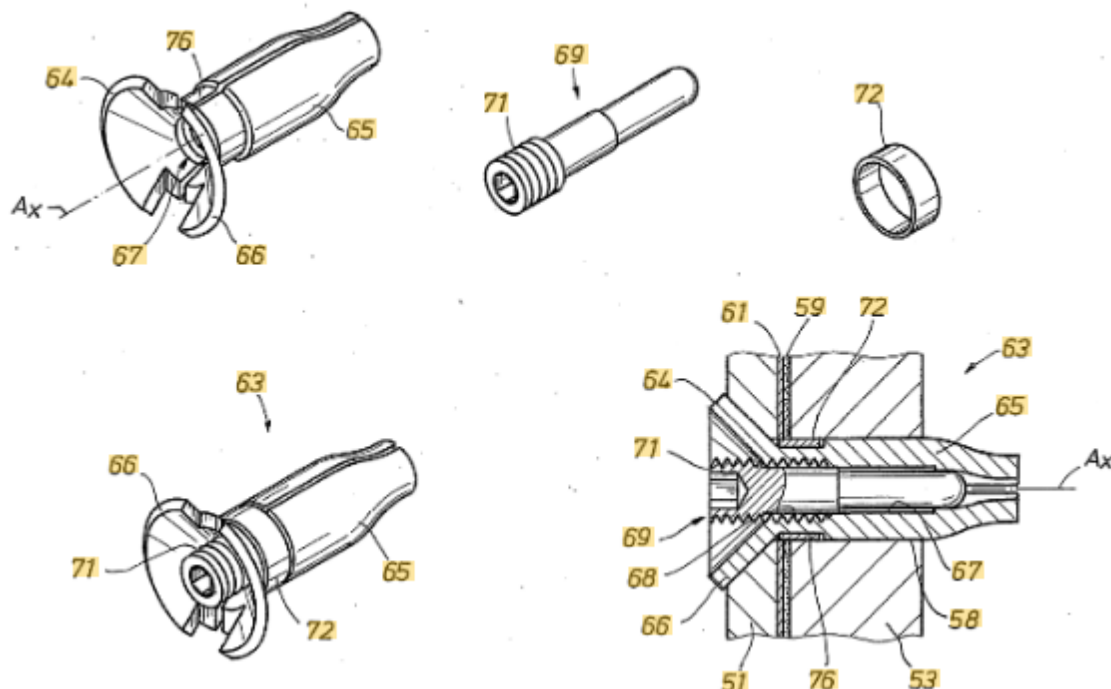


Figure 4: The temporary fastener known as the JK fastener (United States of America Patent No. US20100308171A1, 2009)r

On several occasions this collar has been stuck in the skin after the fastener was extracted, and then caused a debonded nutplate and potentially a FOD issue, when the regular fastener is introduced in the hole. This project was of particular interest for me as I have a background in materials science, and thus eager to investigate the point of failure regarding the fastener. It was determined that a project was introduced some time ago to recycle these fasteners, as this could be a savings potential for the program.

The problem was that there was no governing document that could determine how many times a fastener could be reused or on what criteria it should be discarded. As such the fasteners were more or less recycled until failure.

Our responsibility to this project was two-fold. First of all determine what the cause of failure was. Was it the collar breaking, being plastically deformed during expansion after torque, or getting caught on something in the hole? Second was to establish the intention of the design and create a document clearly describing how to use the fastener and most importantly when to discard one.

A large portion of the work on this project seemed almost detective like. Firstly identifying the source of the problem, and then backtracking to installation point on finding out where they are coming from, to eventually, by chance, finding out the initiative of the recycling. This journey in particular showed to me the value of networking inside the company, as a lot of information was difficult to track, but was revealed bit by bit, by talking to the right people and figuring out who to talk to next.

Unfortunately the project wasn't finished, but I left it in a state where it can easily be picked up and finished in a reasonable timeframe.

Adventures outside work

We have also been experiencing American culture outside of work. It is quite different to Danish culture in some ways. Transportation is immediately obvious, as it is necessary to drive everywhere here as opposed to biking or public transportation in Denmark. Within the US there are very big local differences as well, as can for example be seen on the different food styles where Texas is well known for their barbecue, and due to having a large part of the southern border, Mexican food as well which was my favorite.

New Orleans and Mardi Gras

In February we went to New Orleans. New Orleans was originally founded by the French around the beginning of the 18th century. It was eventually sold to the USA in 1803 and it quickly became the wealthiest city in the US. This was mainly because of the city working as a port for goods transferred on the Mississippi river that were shipped to Europe, The Caribbean and other places. The city had a large population of enslaved African Americans, and after the emancipation racial tensions remained. In recent history hurricane Katrina had a huge impact on the city when it hit in 2005. Over 1800 died and the cost was over 100 billion dollars. Even 5

years after only 80% of the population had returned after fleeing the flooding. (History.com, 2010)

Mardi Gras is a celebration that has roots in the feasting tied to the days of Lent. In this way it can be somewhat compared to the Danish tradition of Fastelavn, however the celebrations are quite different. Mardi Gras spans over two weekends and consists of many different parades where beads are thrown to the spectators. These beads are literally everywhere and sometimes you cannot even see the street due to the amount of beads littering the street.

Puerto Rico

In March I travelled to the Caribbean island of Puerto Rico to meet up with my family from Denmark. Puerto Rico is a US territory which is interesting as it is part of the US but doesn't have the right to vote in elections. It is poorer than mainland US but is still one of the richest islands in the Caribbean. The reason to go here was twofold. One of my longtime friends got married to a Puerto Rican girl, and my grandmother was originally from Puerto Rico, so I still have family there, some of which I have never met. The wedding was a unique experience as it was so different from a Danish wedding. The concepts were the same, but where we would sit at tables and eat for several hours, this ordeal was finished in 45 minutes, and quickly replaced by traditional dancing. After recovering from the wedding we traveled to a small island called Vieques where we experienced an old decrepit sugar mill, snorkeling on vibrant reefs, bioluminescent bays, beautiful panoramic views and free roaming wild horses. Then we travelled to the southwestern part and saw where my family had their ranch and spent a couple of days seeing the surrounding area. Thus the trip came to an end, and I travelled back to Texas while my family travelled to Denmark.

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