INTERNSHIP AT LOCKHEED MARTIN

By Andreas Nørballe

January to June 2016

Fort Worth, Texas

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Preface

My internship at Lockheed Martin has been a once in a lifetime opportunity. Working at the largest defense contractor, on the largest defense contract ever awarded, is a unique experience for a Danish graduate student.

I am grateful to have been granted this opportunity and experience and I wish to thank the people at Terma A/S, Lockheed Martin Aeronautics, and the people at DTU for making it happen. Specifically, I like to thank Jan Thomas Klinker, Erling Hansen, Thor Pauli Andersen and Anders Hjortsholm at Terma A/S, from Lockheed Martin J. Scott Sadler, Mike Cucinotta, Brenda Gee David LeBlanc, and Mike Lally, and from DTU Hanne Rønne Warburg and my head of study Ole Broberg.

Furthermore, I want to thank my colleagues, especially in Final Assembly, who I have gotten to know and befriend the past 5 months. Their support in my daily work and their help to adjust to life in Texas has been invaluable and much appreciated.

My supervisor, Mike Cucinotta, has involved me and allowed me the freedom to help engage on the interesting projects that my colleagues work on. Projects that I otherwise never would have worked on. This has given me experience that would have been very difficult to obtain elsewhere.

Lastly, I would like to thank my fellow interns; Liane, Magnus, Trúgvi, and Marc, who I have lived with and spend more time in a car with that I would like to admit. Especially, Marc A. Samuelsen who has been my cubicle neighbor and a fine collaborator and sounding board.

As one might say in Texas, thanks y'all,

Andreas Nørballe
Fort Worth, Texas
June 2016

Figure i-1: Air Force Plant no. 4 the home of Lockheed Martin Aeronautics and the main F-35 assembly facility, circa 2010. (Source: https://www.flickr.com/photos/lockheedmartin/7048817975/)

Figure i-2: Norwegians first F-35 being moved from EMAS to Final Assembly. (Source: https://www.flickr.com/photos/lockheedmartin/16984384739)

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Front page photo: Roll out of the first Norwegian F-35. (Source: Norwegian MoD)

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Figure i-4: A F-35 A-model test aircraft performing high angle of attack maneuvers. (Source: https://www.flickr.com/photos/lockheedmartin/8367764193/)

1 Introduction

In a factory, a mile long, with 15,000 employees and a rich history, next to an active Naval Air Station, located in a Metroplex of 6.5 million people. This sentence would have been surreal to me when I started my graduate program, but none the less, my place of work between January 18th and June 16th, 2016, which this report describes.

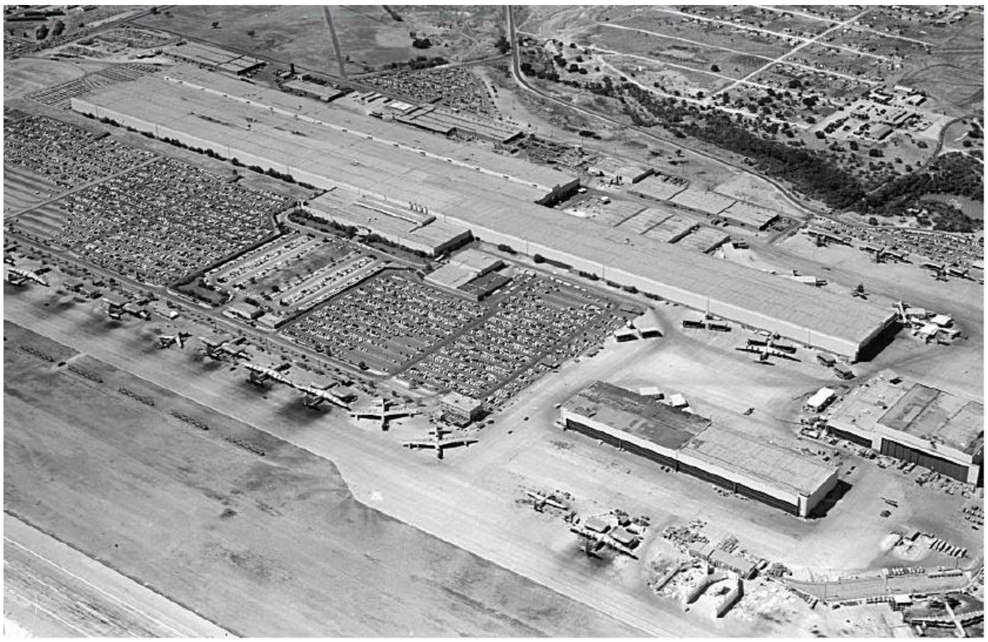

Figure 1-1: Air Force Plant No. 4, current home of Lockheed Martin Aeronautics and the F-35, at the peak of B-36 Peacemaker production (Circa 1950). (Source: http://www.fortwortharchitecture.com/oldftw/bomberaerialb36.jpg)

I am currently pursuing an Engineering degree in Design and Innovation at the Technical University of Denmark, which primarily focuses on product development from the problem definition phase to the proof of concept phase. When I got the opportunity to work in quality engineering on the F-35 I jumped at it. Though it is somewhat out of the scope of my studies I have gained a considerable amount of knowledge while working here. Both in terms of design, quality, manufacturing, working in a large international company, and about myself.

This report documents my internship at Lockheed Martin Aeronautics and my stay in Fort Worth, Texas. I have been working in the Quality Engineering Final Assembly team (QE Fin Assy) under the supervision of Mike Cucinotta. Together with Marc A. Samuelsen (often described as "we"), also from DTU, I have worked alongside Quality Engineers and Manufacturing Engineers to reduce waste in the form of resources used to correct defects. This report contains excerpts of some of the numerous projects I have worked on.

The work done at Lockheed Martin is proprietary and sensitive in its nature. This means that the information contained in this report is fairly superficial. All information has been carefully selected and no data or pictures from the projects I have worked on are shown.

2 Lockheed Martin

The company, and the name Lockheed Martin, is the result of multiple mergers and acquisitions over more than the last 100 years. The latest merger being a "merger of equals" between Lockheed and Martin Marietta in 1995. Thereby, making the combined Lockheed Martin one of the largest aerospace, defense, and technology companies in the world. The Martin name originated with the Glenn L. Martin Company, which started in Los Angeles in 1912 in a rented church. The Lockheed name originated with two brothers (born Loughead), who started their company the same year, but in a San Francisco garage some 400 miles away.

Today, Lockheed Martin Aeronautics is known for the F-16 Fighting Falcon, F-22 Raptor, C-130 Hercules, and naturally the F-35 Lightning II. Previous products Lockheed Martin Aeronautics is known for are the P-80 (first operational jet fighter), the famous high altitude spy planes of the cold war (the U2 Dragon Lady and the SR-71 Blackbird, see Figure 2-1), and the first operational stealth fighter (the F-117 Nighthawk).

Figure 2-1: The SR-71 Blackbird (near) and the U-2 Dragon Lady (far) side by side. (Source: https://www.flickr.com/photos/lockheedmartin/)

Lockheed Martin does work within five business segments (Aeronautics, Information Systems and Global Solutions, Missiles and Fire Control, Mission Systems and Training, and Space Systems) and employs around 125,000 in 590 facilities worldwide.

2.1 Joint Strike Fighter (JSF)

The Joint Strike Fighter program, also known as the F-35 program, is the largest defense-contract ever awarded. The program cost is estimated to be $1.5 trillion (in 2015 USD) over the entire lifetime. This is based on the delivery of 2,443 jetfighters that will be supported and operated until 2070[1]. The US defense industry usually sell to only one customer, the US government, and as such acts in a monopoly market. The F-35 program is overseen, governmentally administered, and sold by a military office, the Joint Program Office (JPO), on behalf of the US Government.

Though there is only one customer, the amount and number of stakeholders are considerable. Stakeholders expand from internal ones, in Lockheed Martin and the Government (everything from military to elected and appointed officials); to external stakeholders such as the public, media, international buyers, interest groups etc.

The JSF is a development project that started in 1993 and culminated in 2001 with the System Development and Demonstration contract being awarded to Lockheed Martin. The F-35 is still a development project utilizing concurrent development, which allowed production to begin before flight testing have ended. The concurrent development status of the F-35 will likely remain in place until the Navy, as the last of three US military services, declares initial operational capability (IOC) between August 2018 and February 2019[2].

Lockheed Martin has collaborated with principal partners BAE Systems, Northrop Grumman, and Pratt & Whitney along with a number of smaller sub-suppliers to develop and manufacture the aircraft.

2.1.1 The 6 capabilities that makes the F-35 unique

The F-35 boast advance capabilities that no other plane have combined in a single platform. These are[3]:

1. The ability to fly virtually undetected (stealth)
2. Communication across a secure network
3. State of the art targeting system
4. Big data maintenance environment
5. Enhance situational awareness (sensor fusion creating real-time virtual reality)
6. One platform, three branches of service and 11 planned operators to date

This combination of advanced stealth, sophisticated mission systems suite, seamless communication, sensor fusion, precise targeting, ease of maintenance, better pilot awareness, and reduced pilot workload, as well as expansive cooperation across borders and military services makes F-35 the world's most advanced jet and a 5th generation fighter.

[1] http://www.jsf.mil/news/docs/20160324_Fact-Sheet.pdf
[2] https://www.f35.com/news/detail/department-of-defense-announces-f-35-ioc-dates-for-all-services
[3] http://lockheedmartin.com/us/innovations/060616-webt-f35-capabilities.html

Figure 2-2: The F-35 for the Air Force (CTOL or A variant) (left), the Marine Corps (STOVL or B variant) (middle), and the Navy (CV or C-variant) (Source: [3])

2.1.2 JSF and Denmark

Denmark is one of 9 nations (The United States, United Kingdom, Italy, The Netherlands, Turkey, Canada, Denmark, Norway, and Australia) that have jointly funded the JSF program. Denmark will be 11th operator of the fighter jet. The F-35 won the Danish Fighter Jet competition beating the Boeing F/A-18 Super Hornet and the Eurofighter Tycoon. Denmark has decided to purchase a total of 27 jets[4].

This internship is a collaboration between Lockheed Martin, Terma A/S, Aarhus University (AU), and the Technical University of Denmark (DTU). Terma A/S has been a part of the JSF industrial collaboration since 2004[5]. Terma A/S delivers an array of different components to the F-35, which can be seen in Figure 2-3.

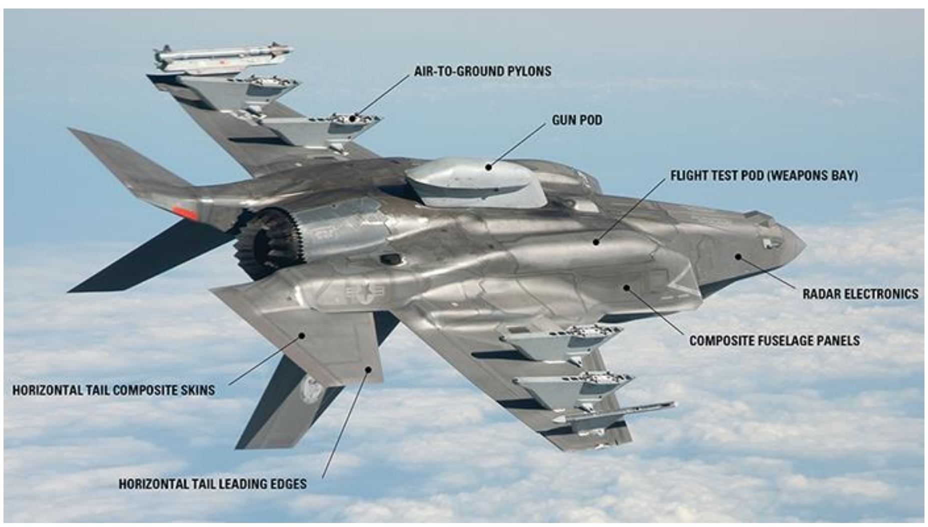

Figure 2-3: The F-35 Joint Strike Fighter with illustration of the parts delivered by Terma (Source: http://www.terma.com/aero/the-worlds-largest-industrial-project/)

[4] http://www.star-telegram.com/news/business/article82722107.html
[5] http://www.terma.com/aero/the-worlds-largest-industrial-project/

2.2 Organization and methods

The principal organization for this internship has been Lockheed Martin Aeronautics and the F-35 program. Lockheed Martin Aeronautics is headquartered at Air Force Plant no. 4 in Fort Worth, Texas, where the primary assembly facilities for the F-35 and F-16 are located. Lockheed Aeronautics have a total of 25,000 employees of which approximately 15,000 are located at Air Force Plant no. 4. The main production facility of the F35 is a single assembly facility that stretches more than a mile and covers more than 4.9 million sq. ft. (about ½ sq. km, see Figure 2-4 to get an idea of the size).

While working in the F-35 program, a lot of acronyms must be memorized and contacts created through-out the facility. Knowing who to ask or where to look is key in much of the work. Engineers have to figure out where to look and who to talk to, because not all of the data can be found in the IT systems. As such, much of the data gathering at the Fort Worth plant is done manually, face to face. Fortunately, the culture is very open and informal one, where most people are very happy to help. Within the program, the organization is organized into a matrix-like structure that uses functional and location oriented teams. Example of functional departments are Quality, Manufacturing, Testing, Design Engineering, and Operations. Examples of locational teams are Wing Assembly, Electronic Mate and Alignment System, and Final Assembly. This makes it somewhat easier to find the right person.

Figure 2-4: The Final Assembly of the production line in Fort Worth, Texas. (Source: https://www.flickr.com/photos/lockheedmartin/8452977387)

2.2.1 Quality Engineering

This internship took place in the department of Quality Engineering Final Assembly, part of the Quality organization. The job of a quality engineer is to ensure that problems and defects are not recurring. To perform job duties, a number of tools are used with the most common being root cause analysis. This analysis tool is used to identify and verify the primary or true cause of a problem and thereby solve the root of the problem rather than the symptoms it caused.

Work is prioritized as a combination of the largest recurring problems (high drivers) and certain issues that substantially effect cost or customer confidence. During production, the product is inspected and a Quality Assurance Report (QAR or SQWK) is written up if non conformances are found. The number of defects and the scrap, repair, and rework hours (SRR hours) taken to fix the problem are also written in the QAR or SQWK. The overall goal of Quality Engineering is to reduce defects and the resources used on fixing them.

The quality engineers' most used computer tool is probably the Microsoft Office suite. Excel and its data analysis capabilities is primarily used. Using the Quality Assurance Documents System (QADS, which contain all QARs and SQWKs) data is gathered for further investigation and with Excel the data is analyzed.

Since it is a large organization, meetings are often used to inform colleagues, management, and other stakeholders about projects that are being worked and their progress. Two such regular meetings are the Corrective Action Review Team (CART) and the Corrective Action Board (CAB). In these meeting projects are presented and discussed along with, in CART, a review of the key performance indicators (KPIs) that makes up the Quality Performance Index (QPI), which is the most important indicator of quality's performance. During these meeting new tasks might be assigned, these tasks are called action items. If a certain problem appears or is presented during these meetings a separate meeting group might be created, in order to create a corrective action plan.

2.2.2 Courses

During the internship I received courses in PDCA (Plan, Do, Check, Act), PPV (Product Process Verification), Process Capability, CATIA (industry standard CAD software), FOD (Foreign Object Debris), GD&T (Geometric Dimension and Tolerancing), and F-35 Familiarization.

The PDCA training was specifically used in a project involving electrical harnesses described in section 3.2. The process capabilities was specifically used in the missing paint project described in section 3.1. The FOD course and F-35 Familiarization are, respectively, a prerequisite and nice to have tool when you are studying the airplane up close.

3 Activities in Lockheed Martin

The following is an excerpt of the projects worked during the internship. Since all the projects deal with proprietary information, many details are intentionally left out or made unrecognizable. Many of the methods used in each project was learned in the project described but has on multiple occasion been leveraged in smaller ad-hoc and analysis assignments.

Defect or SRR drivers means that there is a significant number of defects or used resources associate with the problem. Thereby, if such a problem is relieved an overall impact can be made.

3.1 Missing Paint

3.1.1 Defect Documentation

The missing paint project was a project that previous interns had worked on. The motivation behind the project is that missing paint is a defect driver in Final Assembly. Using, among other things, a Pareto analysis the high drivers were identified and two bays was chosen as focal points for ongoing inspection and documentation. The previous interns had started this extensive documentation process by using defect reports (SQWKs and QARs) and photos taken by inspectors. We continued and expanded this effort.

The documentation included gathered data regarding defect count, defect types, physical location, responsible work area, and an analytical breakdown hereof. The data was based on inspection of incoming planes in Final Assembly from the previous station. Data was presented in an easy comprehensible manner with a picture of each discrepancy item, which might hold multiple defects, responsible party, defect report number, and defect description. To manage and analyze the gathered data, an Excel document was created to store the data and bucket each defect by a category.

The Excel document was developed concurrently with the data gathering and the legacy data collected by the previous interns was imported. The document essentially works as a database with two data tables, some calculated tables, PivotTables, and PivotCharts that represent the data in a more comprehensible manner. By also incorporating slicers, which essentially are filtering and search options that work across PivotTables, data could easily be viewed with different basis and comparisons. Using the build-in Pivot and table functions in Excel, all graphs and tables can be quickly and easily updated as new data is entered into the data tables. The data showed that most defects originated in two departments and one bucket category of defects was predominant.

Multiple graphs were made to visually present the data. The graphs included distribution graphs of defect type, responsibility, etc. and run-charts with moving averages, defect reduction goals, and actual defects. Finally, as an investigative measure a table and corresponding graphs with process capability was created. This was done in order to gain insight into the process stability and trend. The conclusion of this was that the process was somewhat instable and that there were no significant trend.

3.1.2 Sensory Scoring Transform

During the project several questions was raised regarding the specification for paint bleed-through. To accommodate this and clearly define the acceptability of bleed through the development of a sensory scoring transform was initiated. At the time of writing the sensory scoring transform is still in development, and is being verified. The sensory scoring transform works by creating a measurement system for attribute data, which is something perceived (human sense; hearing, smelling, seeing, tasting, and touching). As such, the goal is to make measurements of the human perception repeatable. This scoring system will be verified by using an isoplot that compares a minimum of 2 people individually scoring 30 samples using the transform scale.

3.1.3 Learning outcomes from Missing Paint Project

This project has introduced me to Red X terminology and some of the tools within the Red X framework. It also helped me understand some of the basic processes and tools that Lockheed utilize to document, investigate, and instigate corrective action. It has also improved my documentation, data analysis, processes analysis, and how to do work in cross-functional groups.

3.2 Harness defects

As a continuation of a previous harness (wiring) defects project, which attributed the root of the problem to an incorrectly categorization of the defect reports, we investigated how to manage the overall number of harness defects. The reason for the continuation was that even though each single category of harness problems were not a particular defect drivers or resource drainers, the accumulation of all harness problems were significant.

This project denotes the first instance where we used PDCA-methodology. However, the Pareto-analysis described within the following have been used on multiple occasions and can be referred to as a data-deep dive and is often complemented with information from mechanics, specialists, engineers, and inspectors.

3.2.1 PDCA-methodology

The start of the project coincided well with our training in PDCA (Plan, Do, Check, & Act). As such, the tools from this training was leveraged to standardize the project and increase the communication and quality of it. PDCA is a problem solving tool and a project cycle that is used to target a problem and solve it through multiple iterations (see Figure

3-1). The theory and use of PDCA is developed from Lean Six Sigma. At Lockheed Martin Aeronautics PDCA-training is a subsititution for Lean White Belt -training.

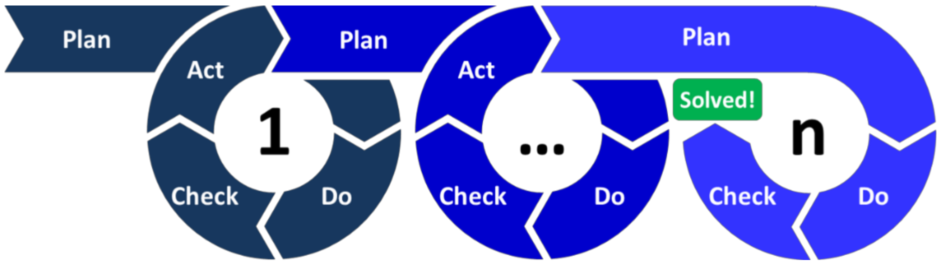

Figure 3-1: Framework of the PDCA-cycle. (Source: "Christoph Roser at AllAboutLean.com", CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=47640479)

The cornerstone in PDCA is a standard tool called the "PDCA problem solving A3" or an A3 in short (see Figure 3-2). The first step is to define the problem and do a GAP-analysis, which describes the gap between the current state and the target state.

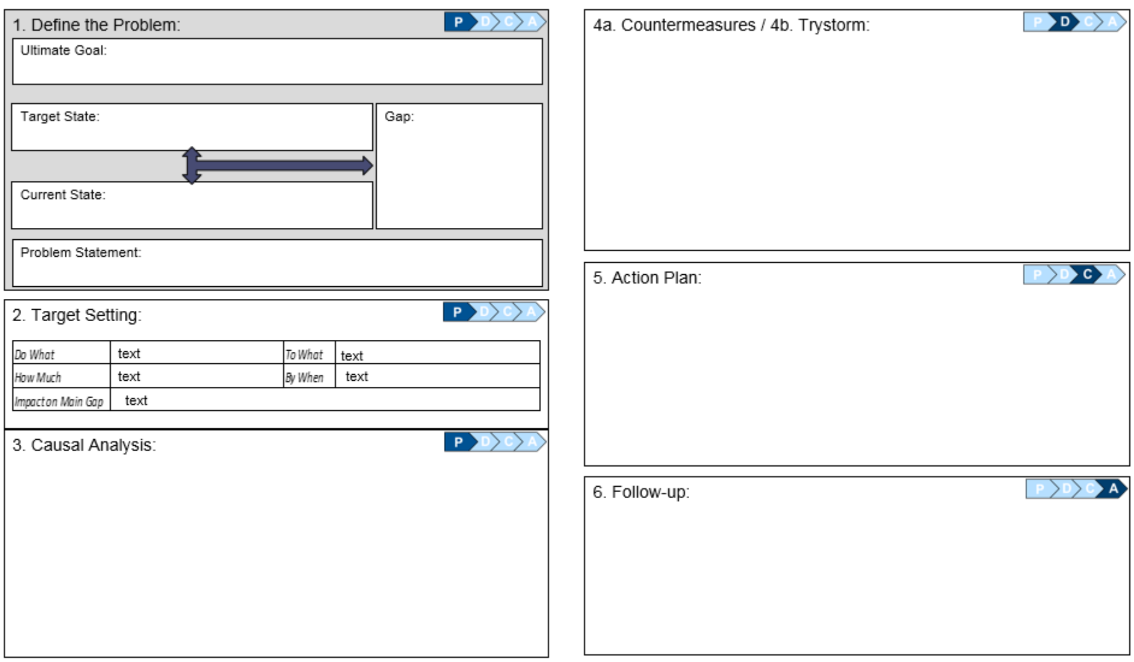

Figure 3-2: PDCA problem solving A3. Each area constitutes a different part of the PDCA-cycle.

In the case of harness defects, the problem was defined by using a Pareto-analysis. This type of analysis was used for multiple other projects. Overall the process was used to figure out if a specific problem could be identified. The first Pareto was already made when harness defects were chosen as the project focus. However, in general, the problem needs to be specified even further in order to be more manageable. In Figure 3-3 the typical process of honing in on a specific location and part can be seen. This can also be denoted as a data deep dive. Though some defects are neglected, as one hones in on a specific problem, all links between categories are constantly investigated and seen if there are other problems there might constitute a trend across location, parts, areas, and/or types. This makes it an iterative process.

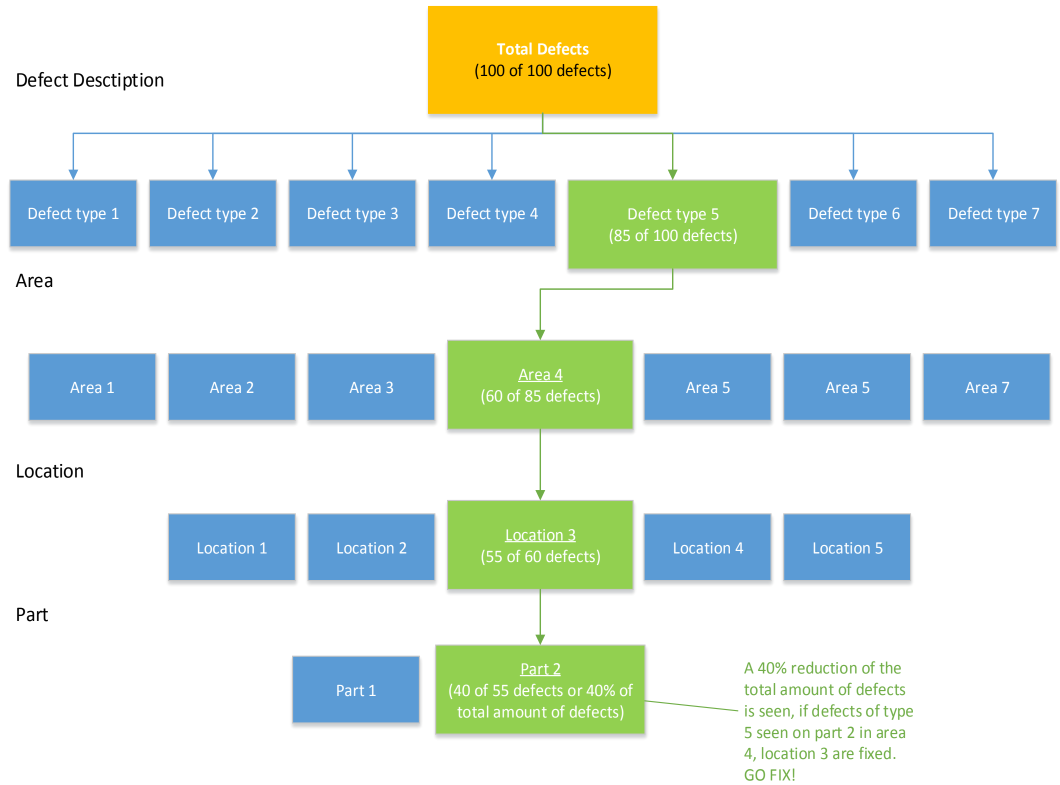

Figure 3-3: Example in the scoping of project. Using the Pareto tool and enquire where the greatest benefit can be achieved with the lowest cost.

The specified problem enabled us to hypothesize a Fishbone- and a 5 Why's-diagram (see Figure 3-4), which investigates the causes and effects of the problem.

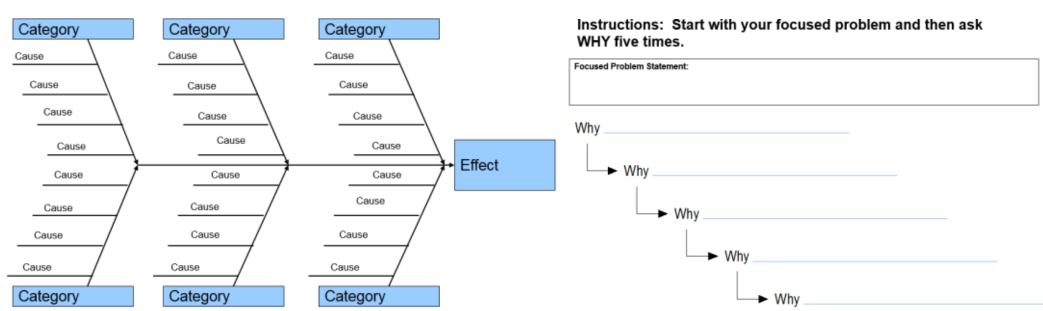

Figure 3-4: Fishbone-diagram (left) and 5 Why's (right). Two standard tools for investigating cause and effect in PDCA.

The A3 is a tool that ensures that almost everything is codified. Therefore, with an initial analysis and hypotheses a realistic targets can be specified and the gap analyzed. The causal (initial) analysis is written down, ideas for Countermeasures and Trystorms are specified, an action plan is created, and follow up actions are assigned and instigated. This ends the plan section of the PDCA cycle. In the initial action plan the hypotheses and analysis were to be tested (do), verified (check) and further developed (act).

After the A3 was created and executed, it was possible to "Go & See" what might cause the problem and get a better understanding of the problem. In this case it constituted a second iteration of the PDCA-cycle. Here, we talked with the production (the mechanics and specialists on the floor), manufacturing engineering, and observed a system closure test.

Through reiterations of the PDCA-cycle we updated the A3 and created new countermeasures and ranked those using a PICK-chart (see Figure 3-5). PICK stands for possible, implement, kill, and challenge and is a chart with an axis of pay-off size and one of implementation difficulty. The idea being if something is easy to implement and has a big payoff it should be implemented right away and if it is hard to implement and has a low payoff it should probably be removed (killed). The potential impact each solution could have on the different defect types was sought to be quantified and coupled with the solution.

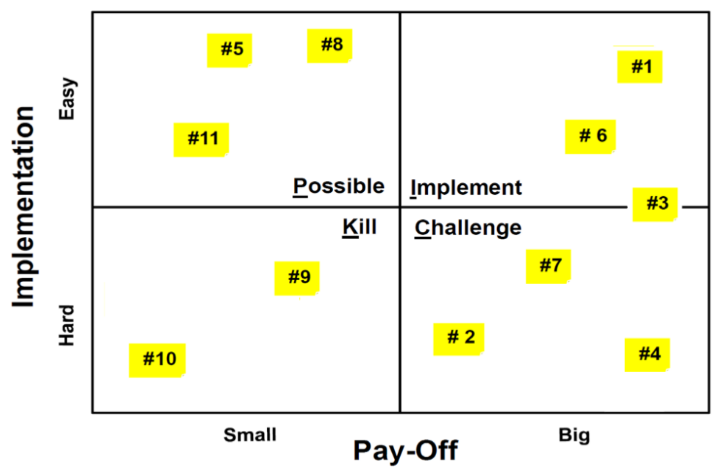

Figure 3-5: PICK (Possible, Implement, Kill, and Challenge) chart. Used to prioritize the efforts which could reduce or eliminate the problem. Each "Post-It Note" correspsonds to a specific effort.

Finally, the process, solutions, PICK-chart, action plan, and follow-up was presented to quality management. In this presentation the project was given a go-ahead to develop a more specified implementation strategy of some of the solutions and further investigate the problem and develop more solutions (preferably those with big pay-off and easy implementation).

Currently, the next iteration is ongoing. It focuses on specifically showing and proving the exact problem and a path to a solution that can reach across defect types.

3.2.2 Learning outcomes from the Harness Project

The tools used in this projects gave a big insight into Pareto analysis and lean thinking. It also showed that almost any information one receives will always, in some way or another, be incomplete. Therefore, the need to investigate, gather, and compare information is extremely important, especially in dealings with complex problems.

The lean thought-set showed itself to be really useful and a reminder that one needs to be targeted in the problem solving approach in order to achieve results, especially measurable results. That being said, such a complex project can produce results that are anywhere from unnoticeable to highly impactful. The A3 and material was used for and passed the Capstone-assignment for the training course.

3.3 Leaks project

During the internship, a small but unacceptable number of fluid leak occurrences were found. To correct this, a larger cross-organizational team was assembled. During recurring weekly meetings actions were assigned to each department and participating individuals. One of these actions was a data triage that was assigned to a combination of each relevant quality engineering and manufacturing engineering team. The data revealed certain inconsistencies and some missing information. In order to gather more information several action items, based on the analysis of the data, were created. One of these actions was to document leaks found during different system tests. For this purpose a template was created that could collect high fidelity data and gather multiple data point in a relatively short timeframe. An example of how the template would look like can be seen in Figure 3-6. This example can record 3 leaks, which would also be referenced on attached CAD-models.

Documentation template

Name & position of author ____				Notes/Comments
Supervisor: ____	Date: ____	Test type	Fluid-system	
Department: ____	Pos: ____	☐ Test # 1	☐ Fluid #1	
Airplane: ____		☐ Test # 2	☐ Fluid #2	

Document no. and line item no.	Bay		Connection Type & Observation	Assy type, P/N, & ENG/INSTL drawing #	Specific for Con. #1 Observation and measured/blueprint state of conn #2	Specific for Con. #2 Observations and state for conn #2?	Problem fix & Leak type
DOC #:	☐ Bay #1	☐ Bay #7	☐ Con. #1	☐ Asssembly type # 1	☐ Observation #1	☐ Observation #1	☐ Fix #1
____	☐ Bay #2	☐ Bay #8	☐ Con. #2	☐ Asssembly type # 2	☐ Observation #2	☐ Observation #2	☐ Fix #2
Line item #	☐ Bay #3	☐ Bay #9	☐ Con. #3	P/N: ____	☐ Observation #3	☐ Observation #3	☐ ____
____	☐ Bay #4	☐ Bay #10	☐ Prob. # 1		☐ ____	☐ ____	☐ Leak type #1
	☐ Bay #5	☐ Bay #11	☐ Prob. # 2	Drawing no.	Measured ____	☐ State #1	☐ Leak type #2
____	☐ Bay #6	☐ ____	☐ ____	#: ____	Blueprint ____	☐ State #2	Pressure ____
DOC #:	☐ Bay #1	☐ Bay #7	☐ Con. #1	☐ Assembly type # 1	☐ Observation #1	☐ Observation #1	☐ Fix #1
____	☐ Bay #2	☐ Bay #8	☐ Con. #2	☐ Asssembly type # 2	☐ Observation #2	☐ Observation #2	☐ Fix #2
Line item #	☐ Bay #3	☐ Bay #9	☐ Con. #3	P/N: ____	☐ Observation #3	☐ Observation #3	☐ ____
____	☐ Bay #4	☐ Bay #10	☐ Prob. # 1		☐ ____	☐ ____	☐ Leak type #1
	☐ Bay #5	☐ Bay #11	☐ Prob. # 2	Drawing no.	Measured ____	☐ State #1	☐ Leak type #2
____	☐ Bay #6	☐ ____	☐ ____	#: ____	Blueprint ____	☐ State #2	Pressure ____
DOC #:	☐ Bay #1	☐ Bay #7	☐ Con. #1	☐ Asssembly type # 1	☐ Observation #1	☐ Observation #1	☐ Fix #1
____	☐ Bay #2	☐ Bay #8	☐ Con. #2	☐ Asssembly type # 2	☐ Observation #2	☐ Observation #2	☐ Fix #2
Line item #	☐ Bay #3	☐ Bay #9	☐ Con. #3	P/N: ____	☐ Observation #3	☐ Observation #3	☐ ____
____	☐ Bay #4	☐ Bay #10	☐ Prob. # 1		☐ ____	☐ ____	☐ Leak type #1
	☐ Bay #5	☐ Bay #11	☐ Prob. # 2	Drawing no.	Measured ____	☐ State #1	☐ Leak type #2
____	☐ Bay #6	☐ ____	☐ ____	#: ____	Blueprint ____	☐ State #2	Pressure ____

Figure 3-6: Template for easy documentation of leaks

The development of the template was iterative. Initially rough drafts of the template were used. By observing different tests they were filled out and unnecessary or lacking fields were respectively removed from or added to the template.

All leaks found by using the template was then inserted into a PowerPoint slide with details of the occurrence and an Excel sheet containing leak data. This was done in order to share the information with the larger project team and other stakeholders.

In general, as the project progressed, more work was done in smaller and more focused groups that reported to a short bi-weekly meeting. As such, the purpose of the meeting was to review the actions taken and revise the corrective action plan as needed.

3.3.1 Learning outcomes from Leaks Project

The team used an approach where the problem area initially was investigated subsequently expanding the problem space. Then the problem space was then reduced to a fairly specific problem through the use of the information gathered by the different teams. Afterwards, the possible root causes and relieves for this problem was investigated and specific actions were finally created. This process is fairly similar to the double diamond (see Figure 3-7) that is used in design thinking. The model describes how a problem is first discovered, investigated and afterward defined – being a divergent form for thinking and afterward a convergent. The same applies to a final solution. Several solutions are developed and looked at (divergent) and then concretized into a specific solution (convergent).

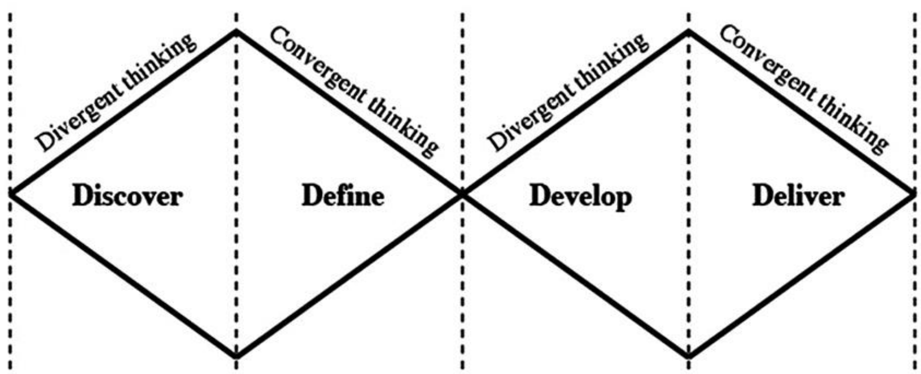

Figure 3-7: Double-Diamond model in design thinking (Source: http://journal.frontiersin.org/article/10.3389/fnhum.2013.00656/full)

The idea of the double diamond can also be seen in how the meetings went. In the beginning the meetings in the large team (named a "Tiger-team") were very large and comparatively unspecific. One example is that people who did not needed to be included was and people who did was not. This was remedied as the problem space was discovered and in particular when it was better defined. From there the right people could be involved and the irrelevant people could spent their time better.

In order to ensure that the meetings created results, action items were used. These items were used as a way to define a corrective action plan. During each meeting a specific person would be assigned an action with an estimated due date.

This was my first time working in such a large and diverse group, organizationally speaking. In the first couple meetings there were around 25 participants from different build areas, departments, and levels in the organizational hierarchy. Using the action item list and by creating a corrective action plan the key participants were identified and it was made sure that participants had a purpose in the group.

3.4 QE Tools developed

During the internship we were asked to develop some different tools that could alleviate some manual work. These tools were developed in Access and Excel where some used VBA scripting and macros in order to work.

3.4.1 Documentation tool

A tool that was developed, was an access database a Quality Engineer in another department requested. It would help document the findings of a visual walk of the airplane before it left that particular station. This could be considered a sell off to the next station.

Figure 3-8: Input sheet after the walk-through. It is being used by mechanics.

Using Access, a graphical user interface (GUI) to input and verify the data was created (see Figure 3-8 as an example). Production had already created a rough draft of how they wanted to input the data. The challenge was to make it functional, compliant, and enable it to show the inputted data in a meaningful way. By connecting the Access database with Excel, the data could be presented in a more meaningful way in Excel. Using PivotTables and PivotGraphs the data could be functionally presented, and automatically be updated whenever new entries were made to the database.

3.4.2 Investigative and triage management tool

In order to document and manage investigation of issues a better graphical user interface (GUI) was requested. This would build on top of a previously developed workflow for which an Excel macro had been made. It was decided to use Access to create the GUI and handle the data management. As such, an Access database was created that pulled data from an external central source. The data was combined with other tables to create a human (easy) readable table. To manage the functions a dashboard was created (see Figure 3-9).

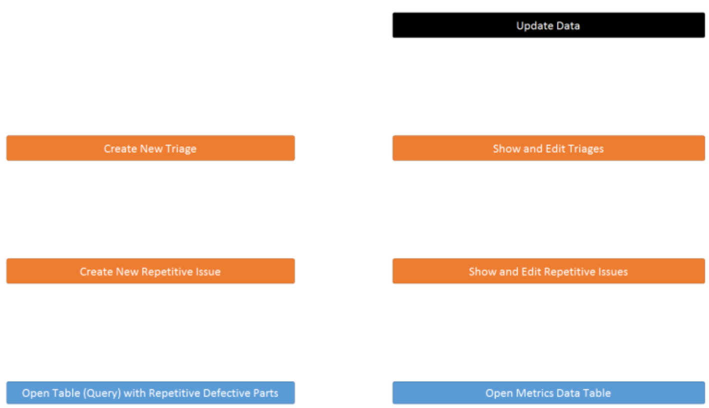

Figure 3-9: GUI dashboard for database

Using the data different queries could be created by using the GUI and SQL functionality. Such a query was used to find repetitive issues. By combining queries and Access ability to make forms a GUI could be made where the user could to create a new repetitive issue by simply clicking on one of the found repetitive issues. This would then show all planes and documents related to that specific issue. The user can then enter some notes/thoughts, and create the issue (see Figure 3-10).

Similarly, the user is able to easily create and manage an investigative issue based on a quality document, this is called a triage. Later, the user can show all issues on a list where the user easily can view all related information and edit them (see Figure 3-11).

The strength of this access database compared to the original excel document is that all data, from many sources, are able to be aggregated, combined, and presented in a structural manner. Furthermore, it utilizes built-in SQL functions rather than the need for a complicated VBA script. However, it was necessary to use some a VBA scripting.

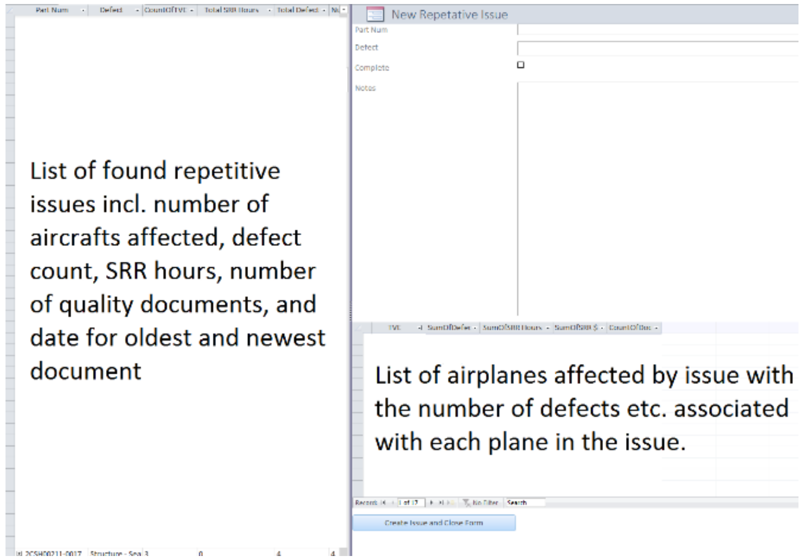

Figure 3-10: GUI for "Create Repetitive Issue". It contains three parts: A list of uninvestigated repetitive issues (left), fields where the user can enter notes (top right), and information related to the issue (bottom right).

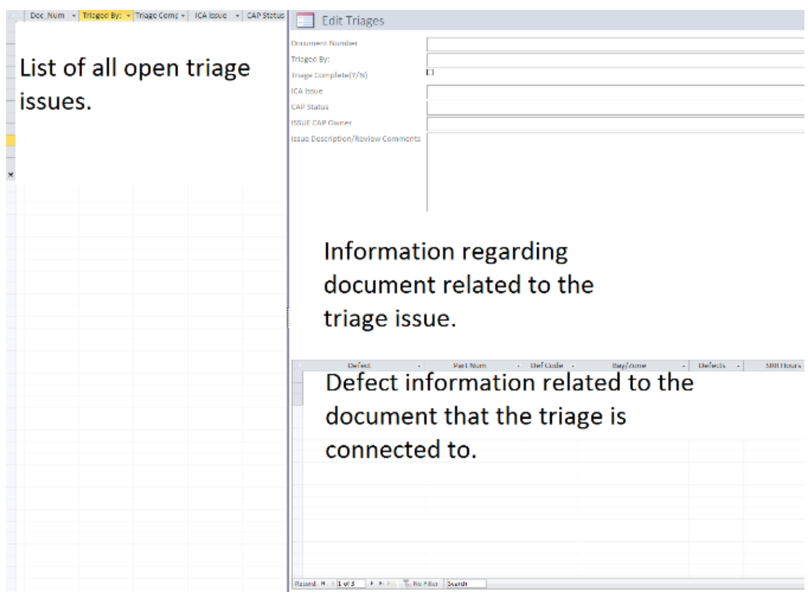

Figure 3-11: GUI for "Show and Edit Triages". It contains three parts: A list of open triage issues (left), fields where the user can edit information (top right), and information related to the issue (bottom right).

3.4.3 Learning outcomes from developing tools

These two tools introduced me to Microsoft Access and its vast features. Through the projects I got around table creation, table manipulation, SQL queries, form creation, reports, macros, and VBA. Since I have worked with other databases before it was interesting seeing the differences and the possibilities with Access. Furthermore, it gave a good opportunity to learn more about the workflows that quality engineers work in.

4 Cultural Experiences

Texas is huge. The Dallas-Fort Worth Metroplex is big (see Figure 4-1 to compare). There are many things to see and experience and I have far from seen it all.

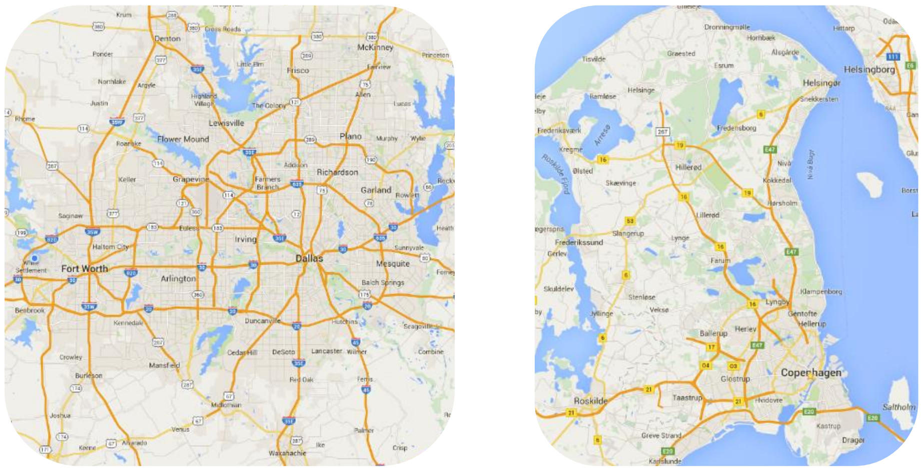

Figure 4-1: The DFW-Metroplex (left) and the capital area of Denmark (right) in the same scale. (Source: http://maps.google.com)

Although the size of Texas and the US made it hard to see everything, I did get to experience quite a few things. From when I first arrived in the US and spent an evening in Boston and a weekend in the union's smallest state, Rhode Island, to my visit in Denver, Colorado, and the intern group's multiple road trips. The longest of which were to New Orleans, LA, and South Padre, TX. But in honesty, some of the most memorable experiences of this internship have been right here in Fort Worth (FW or Cowtown). Experiencing FW and working in an American office setting (see Figure 4-2). Neither am I soon to forget the nature and environment of Texas, which have sent me to beautiful locations (both nature, see Figure 4-3, and city, see Figure 4-4) and shown me how treacherous the conditions can become (see Figure 4-5 and Figure 4-6).

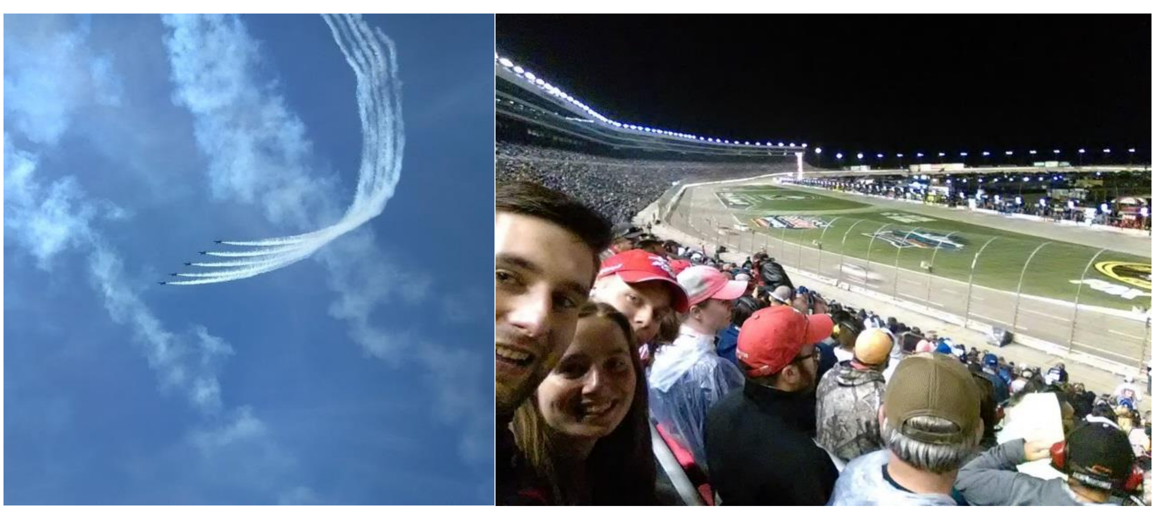

Figure 4-2: Amazing experiences such as Fort Worth Air Power Expo (left) and NASCAR (right) in FW.

Figure 4-3: Trip to Enchanted Rock State Park (left and middle) and to Colorado Bend State Park (right and bottom).

Figure 4-4: Austin Trip (5 pictures). From top-down, left-right: 6th Street Saturday Night, 5 Turtles congregating, Bats under Congress Ave. Bridge, and Austin 360 View.

Figure 4-5: The day after a big hail storm.

Figure 4-6: Lightning storm forming west of Austin.

Figure 4-7: Fort Worth Stock Show and Rodeo (left) and a Bouldering QE (right)

5 Reflection and conclusion

5.1 Personal motivations for internship

My primary motivation for the internship came from many years of interest in aerospace. I have previously completed a semester in the US where I primarily focused on aeronautics and loved the challenge of learning a completely new subject. Furthermore, I was getting ready to apply for another semester abroad when the opportunity presented itself.

Another motivator for me, was to experience how a product comes to life. Since my major is an engineering degree in Design and Innovation I have spent a lot of time learning about creating and developing products, and thereby the early stages of a product life cycle. However, I felt that I was missing a clear understanding of how you implement design and solutions in general, and what consequences a bad or unclear design decision can have in operations. Therefore this was also a perfect opportunity to learn about exactly that.

To the above, I must say, I have not been disappointed. It has been challenging, exciting, and interesting, but sometimes a slow process. Specifically, due to the specifications, processes, and shear number of people and stakeholders involved.

In general, it has reminded me of something I already knew, but which is easily forgotten in a delimited academic setting: Having a great idea is the easy part, successfully executing and implementing it is where the difficulty lie.

5.2 Learning outcomes

Some of the most important lessons that I have learned are in many ways just a reiteration of what I already knew (at least theoretically). But now I better understand the importance. Three of these crucial points being overview, communication, and documentation.

I found overview to be important because I have often been dealing with very specific datasets and while those in themselves can give an important and large insight, the even more valuable insight is gained by understanding the connection and relevance across data, information, and the knowledge there exists. This is especially true when solutions and knowledge can be leveraged across projects.

Good communication and documentation in some ways go together. They are almost self-explanatory but must be reiterated. Personally, I have learned to better structure my own line of thought and the need for it. But also to understand others and make sure that any ambiguities might be removed through proper clarification. I also learned that in a large organization such as Lockheed Martin one must be really aware of the argumentation and its fallibility because of the impact and costs it might create elsewhere.

In some projects overview, communication, and documentation can be traced back to the quality of the original data and any additional data gathered. Recursively, the quality of the data can be described as how good it fulfills the communication and documentation needs between the creators and users.

Working at a large organization have given me tremendous insight. Unfortunately, it feels like when I just barely learned how to organization, and in some ways how the business, works, moves, and who different stakeholders are, I am about to leave. In general, I have come to realize that in aerospace one realizes the amount of requirements that defines a very specific thing are almost incomprehensible. As such, only a handful of individuals can understand all the requirements and reasons for certain designs. But nobody can understand all the requirements for the entire design.

Unfortunately, this means that whenever a change is needed many people must give their input, which all must be considered and discussed. An oversight in input or involvement of the correct person can put the entire change at risk. After a decision have finally been made many resources must be used on implementation and execution. Therefore, the full benefit of an optimization might not be seen or felt in quite a while. Nothing is impossible but most things are either hard or slow since support must be obtained from relevant stakeholders and direct sponsorship from influential stakeholders.

5.3 Conclusion

The experience of working in one of the world's largest companies with a new generation of highly advanced aircrafts have been truly fantastic. I have gained considerable knowledge and grown as a person.

I found that using my engineering degree as basis for doing problem solving is the core competence I have gained during my studies. Furthermore, I enjoy solving problems using my skillset, which are not necessarily highly technical. While I still believe that my choice of graduate program is the right choice for me, I like knowing that I can and enjoy doing a job that requires analytical and problem solving abilities in many contexts. However, a thing that I have missed is the freedom to do product improvements, development, and more general free-spirited solution creation.

I have done a lot of good work here, but unfortunately working 5 months one place barely lets you see the results of your work (especially, in aeronautics). But the experience and knowledge gained will without any doubt be very valuable in my career and the memories will be everlasting in my life.

6 Thoughts for future interns

When you apply, you likely do it based on a somewhat short and unclear description, which is what I did. But don't despair. If you are interested in aerospace or the defense sector, you like problem solving, and studying how things work (or why they don't) then you likely be a good fit. If you are in doubt or like more information do not hold back – just ask. Previous interns and the representatives from the universities or partner companies will be more than willing to help and answer any questions you might have.

Moving to Texas is in many ways like starting over. You have to arrange everything from getting an apartment to getting some basic furniture and kitchenware. You have to learn how to buy and register a car in Texas along with getting everything set up. It can feel chaotic but exciting at the same. Getting set up in another country is an experience in itself. Luckily, there is a lot of help and experiences from previous interns and your contact at Lockheed.

Once all the practical stuff is in place, or at least a large part of it, then comes the time to create a life for yourself in Texas. Since you are here for 5-6 months you might as well get comfortable and get the most out of it. Your coworkers and supervisor are going to help you meet new people and get comfortable but you have to make an effort yourself. Do not expect to get introduced to everybody but rather make sure to say hello and introduce yourself to the people around you early on. If you have interests or hobbies utilize that to meet new people and try new activities. You must not be afraid of stepping out of your comfort zone – in all likelihood you are already going to be somewhat out of your comfort zone, so why not go a few steps further.

The other interns are going to be your greatest support. Make sure to talk to each other and plan together – make sure to invite the others if you get invited to an event.

Early on you should develop priorities of what you want from the internship. In the end you have a lot of influence on what you take home with you from the internship. Make sure to communicate these and other wishes to your supervisor. More than likely they will be happy to help if it is relevant. This is also good way to manage and fulfill your expectations of the internship.

Finally, you have to utilize the time you have. Before you know it the time at Lockheed Martin is going to be finished.

At Lockheed Martin Aeronautics we have had every second Friday off, which gave us ample opportunity to explore. I will however say this, Texas has so much to offer and you could easily spend all your long weekends exploring Texas and the surrounding states so prioritize and choose wisely. Finally, do not underestimate Fort Worth. Take your time to get to know it and what is has to offer. Meet people and build friendships here and explore American and Texan culture. Fort Worth has become one of my favorite cities in the US.