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QUALITY ENGINEERING AT LOCKHEED MARTIN

Internship report

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Introduction

Motivation

Fighter jets have always fascinated me since early childhood, so when the option to do an internship at Lockheed Martin presented itself, I knew I had to take it. This report will give a detailed account of the internship starting with an introduction to Lockheed Martin, Terma A/S and their collaboration on the F-35 program. This is followed by a breakdown of the internship; the initial process, living in Fort Worth, and the assigned projects and classes taken at Lockheed Martin. Lastly, activities done outside of work are described along with a conclusion on the internship.

Internship

The internship is a collaboration between Lockheed Martin and Terma, thus the first step in the application process is to apply for a job at Terma. Following this, Terma will select the best suited applicants for an interview, which will be conducted at the university, after which the field of potential hires is further narrowed down. The chosen candidates will then move onto a phone interview with Lockheed Martin, which will take place on a different date, but still at the university. Based on this interview, Lockheed Martin picks the candidates and informs Terma of their choice, where after Terma notifies the student.

Once the selection process is complete, the next step is to apply for a J-1 VISA, which is needed in order to do an internship in the US. This procedure is simplified by Kilroy, which is a company hired by Terma to help with the VISA application. Despite this, it's still a lengthy affair and can take several months, thus in order to get everything arranged in time, it's important to start as early as possible.

The last thing to get in order, is to find somewhere to live in Fort Worth. Previously, interns lived at Stonegate Marquis, which is a 15 minute drive from Lockheed Martin, and had a good experience doing so. Furthermore, living in or near the same apartments as previous interns, permits furniture and kitchen utensils to be passed on. This makes the moving process considerably easier, as everything will be ready upon arrival.

Fort Worth

Even though the apartments will be furnished, there is still other practical matters, which need to be considered. An internet provide along with an electricity company is not supplied by the apartment complex, although they do have recommendations, so one needs to be found. The telecommunications company AT&T not only provides reasonably priced internet options, but also phone payment plans, and the process of setting up the plan is quick and simple. (It should be noted that phone payment plans are noticeably higher in the US, which is due to lack of direct & indirect competition and regulation to encourage competition.) There are a variety of available internet providers in Texas, but a good company is TXU Energy, who has a reasonable selection of different payment plans.

Stonegate Marquis

Marquis offers a wider range of different amenities, such as a swimming pool, a small, but well-equipped, fitness room along with a continental breakfast bar every Sunday. The pool is not only reserved for the weekends as the temperature stays high even after work, which makes it an excellent place to relax after work. Furthermore, there is also two large grills, along with outdoor dining opportunities and loung chairs.

Located right next to Stonegate is the Trinity River, where a trail runs on both sides of the river. The trail can be used for a wide range of outdoor activities, such as biking, walking and running, and there are several places along the river to rent bikes, canoes, and fishing equipment.

The area near Stonegate Marquis also offers good shopping opportunities, such as Trader Joe's, Tom Thumb, Walgreens and a bit further away is the Farmers Market. Additionally, there is a local library in walking distance from the Farmers Market.

Lockheed Martin

Lockheed Martin was formed in 1995 through the merging of Lockheed Corporation and Martin Marietta. The company focuses on aerospace, defense, security and advanced technologies on a global plan, and operates through the following segments:

- Aeronautics: Research, design, development, manufacturing and support of advanced military aircrafts. This also includes the F-35 lightning II joint strike fighter.
- Missiles and Fire Control: Provides air and missile defense systems along with fire control systems, and air-to-ground precision striker weapons.
- Rotary and Mission Systems: The design, manufacturing, service and support for a wider range of both military and commercial helicopters along with naval and energy systems.
- Space Systems: Includes development, design and production of satellites along with missile and space transportation systems.

A total of 126,000 is employed by Lockheed Martin worldwide, where Lockheed is mainly known for products such as the F-16 Fighting Falcon, the F-22 Raport and C-130 Hercules. Contrastingly, Martin Marietta is known for the spacecrafts Viking 1 and Viking 2. These were built in the 1970's with the purpose of obtaining high-resolution images of martian surfaces, and search for evidence of life on Mars.

Today, Lockheed Martin is mainly known for the production of the F-35 Lightining II, which is produced at the mile long factory in Fort Worth, Texas. Here more than 300,000 individual parts come together to produce the fighter, which are supplied by a host of international partners.

Additionally, final assembly is performed at facilities in Italy and Japan. (Wikipedia, 2017), (Lockheed Martin, 2017), (Forbes, 2017), (F-35 Lightning II, 2017) .

Figure 1 F-35 in Final Assembly, Fort Worth, Texas (F-35 Fighter Jet, 2014)

The F-35 Program

The F-35 Lightning II is a 5th generation fighter, and descends from the X-35, which is the winning design of the Joint Strike Fighter (JFS) program. The F-35 family consists of three different variants, which will replace the A-10 and F-16 for the U.S. Air Force, the F/A-18 for the U.S. Navy and the F/A-18 and AV-8B Harrier for the U.S. Marine Corps. Furthermore, the F-35 will also replace various jets for at least ten other countries.

Originally, the three different variants were meant to share 80% of their parts in order to keep development, production and operating costs down. However, this common design turned out to be too optimistic and the variants ended up sharing approximately 30% of their design:

- F-35A: Conventional Takeoff & Landing (CTOL) variant. This is to be used by the U.S. Air Force.
- F-35B: Short Takeoff/Vertical Landing (STOVL) variant, designed for the U.S. Marine Corps. As the vertical landing system takes up a considerable amount of space, the fuel tank is smaller in comparison to the A-model, as the two variants are similar in size. The lift fan is

used both during takeoff and landing, although if the runway permits it regular takeoff and landing can be done as well.

- F-35C: The Carrier Variant (CV) is for the U.S. Navy. The C model is larger in comparison to both the A and B variant, due to its larger wings and more robust landing gear. This makes it suitable for catapult launches, and a low-speed approach to carrier landings. Furthermore, the wingtips also fold, allowing for more room on the flight deck.

Lockheed Martin is the main contractor on the F-35 program, but it is developed, produced, and supported by an international team of aerospace companies. Here, Terma is one of the companies supplying the following parts to the F-35:

- Composite Conventional Edges for the Aircraft Horizontal Tails
- Advanced Lightweight Composite Components for the Center Fuselage
- Missionized Gun Pods for the STOVL and CV Variants
- Data Acquisition Pods for Flight Test Instrumentation
- Air-to-Ground Pylons
- Radar Electronics. (F-35 JSF, 2012), (Strategic Supplier, 2012)

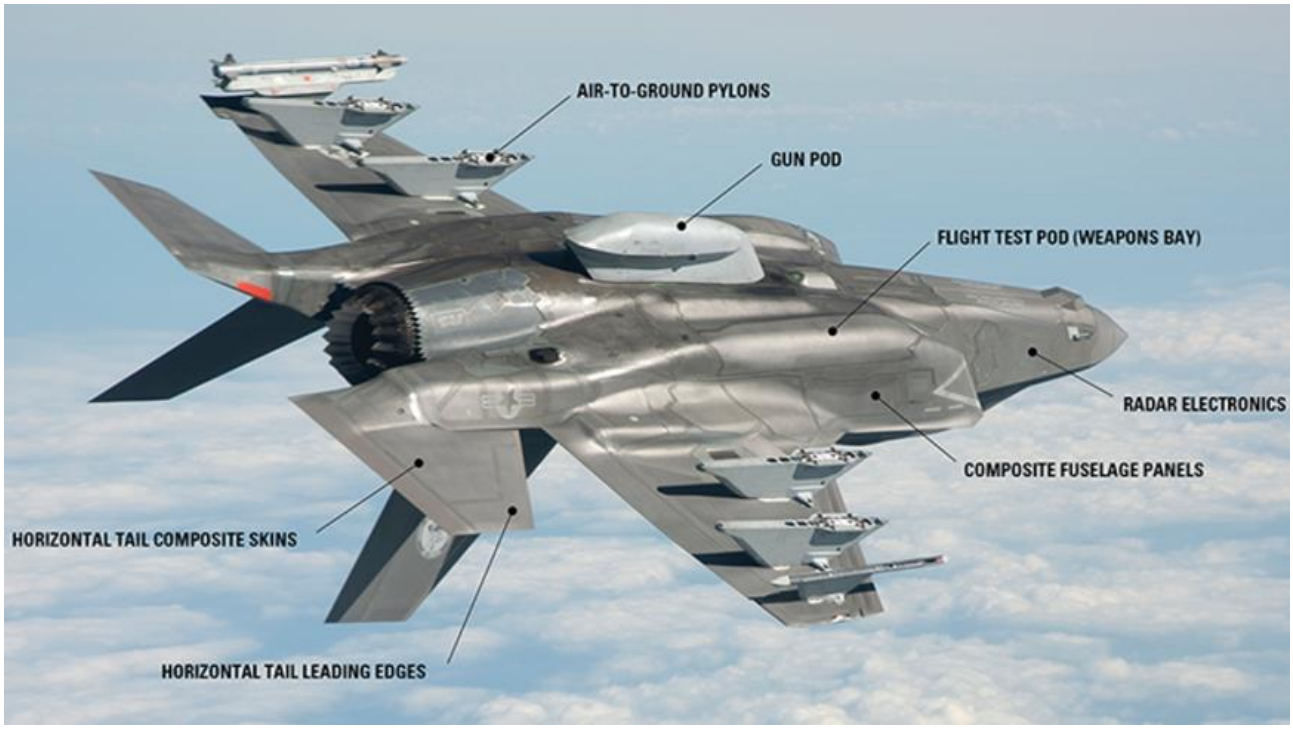

Figure 2 F-35 parts supplied by Terma

The factory in Fort Worth, formally known as Air Force Plant 4, carries out the major assembly on the forward fuselage and wings on the F-35, where a ¼ of a mile is dedicated to wing assembly. The other main sections are assembled elsewhere. Center fuselages are made by Northrop Grumman in Palmdale, California, and by Turkish Aerospace Industries in Ankara, Turkey. The aft

section is made by BAE Systems in the U.K. Final assembly focuses on mating the three fuselage sections, namely forward, center and aft fuselage, with the wings.

The initial production strategy for the F-35 was to install a continuously moving final assembly line. Here, the production team would keep up with the movement of the jets, attaching control surfaces, installing the engine along with performing system testing, at a pace of 1.22 m. per hour. However, this was deemed too costly, and complex, and instead the concept of a "pulse line" was adopted for the F-35. This means the parts move to a station and remain stationary while work is being performed before moving to the next station. The actual assembly of the F-35 is based on a flow-to-takt model. In this model, the component assemblies, such as the wings, move from one built area to the next, at a rate corresponding to the delivery rate. Furthermore, in order to effectively construct the F-35, the production floor is divided into different build areas, which is associated with one or more Ship Work Breakdown Structures (SWBS). A SWBS is a deliverable-orientated breakdown of a project into manageable sections, which ensures that the necessary work is being done to reach the intended target.

The full rate production of the F-35 is targeted to reach 20 jets per month by 2019, and currently 4 jets are being produced per month. Two of the main challenges in reaching this target is the alignment and mating of the fuselage sections and wings. These components are merged from an international supply chain, and each section has to be mated precisely, as any misalignment will lead to stealth degradation. To solve this particular problem Lockheed Martin developed an electronic mating and alignment system (EMAS). The four different sections to be mated are lifted into a platform, shaped like the F-35, after which laser trackers in the EMAS are used to achieve a precise mating configuration. This is followed by a virtual mating of the parts before the actual mating occurs. This ensures that the tolerances are confirmed before errors occur. (Flight Global, 2015), (Waurzyniak, 2007), (Work Breakdown Structure, 2017), (Lockheed Martin F-35 JSF Final Assembly, 2017).

Working at Lockheed Martin

The primary role of a quality engineer (QE) is to prevent defects as well as eliminating recurring problems using a number of different tools. Root cause analysis is the most common, which is a tool used to undercover the actual cause of a nonconformance. Once the root cause has been identified, a corrective action is decided and implemented in production. Another common tool used by QE's is Microsoft Office, and in particular Excel, which contains most of the data used to analysis the defects. Thus, as an intern Visual Basic for Applications (VBA), which is the programming language of Excel, will be used extensively, because many manual process in Excel can quite easily be automated. This means a vast reduction in time spent on tedious and timely Excel projects.

As a quality engineer, data on defects and scrap, rework and repair hours (SRR) is especially important. Defects are the number of differences between the actual product and the technical drawing, where every differences is counted as a defect. SRR hours is the amount of labour hours

related to the correction of defects. The data is generally collected by inspectors, where the defects are written into a Quality Assurance Report (QAR) or a squawk, where a QAR generally contains the more complex defects. The SRR hours, on the other hand, is noted down by the mechanic using an internal system down on the production line. Based on this data, quality engineers can locate any repeated defects and certain issues, which has a significant effect on cost, and decide on the best corrective action with the overall aim of reducing time and resources spent on defects.

The QARs and squawks are recorded in the Quality Assurance Document System (QADS), where all the data is gathered and further analyzed with Excel. Excel in particular is used to make a visual representation, which is then discussed at various meetings. Meetings are especially important in large organizations, as this is the best way to keep everyone informed and up to date on current projects. Two valuable meetings for a quality engineer are the Corrective Action Review Team meeting and the Corrective Action Board (CAB) meeting. In the CART meeting a wide range of issues and projects are discussed along with Quality Performance Index (QPI). This index is used as a way to assess whether the accumulated SRR hours and defects accumulated for each department is on target. If the target is not being met, reasons behind this are discussed along with solutions and how to implement these. The CART meeting also serves as a filter for the CAB meeting, where only the more significant problems and projects are discussed. Following the CAB meeting is the senior CAB meeting, where only critical issues are discussed.

Courses

During the internship I was assigned a variety of projects and attended various classes. First, the attended class will be presented followed by a discussion of a few selected projects.

The courses attended at LM all served the purpose of getting more familiar with the job along with learning more about the aerospace industry. Thus, this is an excellent learning opportunity for attending classes, which will not be offered at most universities.

FOD Class

FOD is an acronym and stands for Foreign Object Debris, which is any debris or alien particles found on or around the aircraft. Two FOD classes are available, where the first class is a mandatory class for everyone on the production line. In this particular class you are taught how to identify FOD and avoid FOD, along with how to document any FOD, which might be found on the aircraft. The second class is a FOD free Audit class, which is needed in order to become a qualified FOD auditor. FOD inspections are important during the manufacturing of the jets, as FOD can lead to terrible accidents and fatalities.

Before an audit is carried out, the supervisor is informed to ensure no testing of the aircraft is happening or anything else which might hinder the audits from being conducted. Once the audit is completed any individual findings are corrected on the spot by talking to the supervisor and

informing them of them of any FOD encounters. Following this, the data is transferred to the Audit Management System, where a monthly report for all compliance audits is generated. The report is then presented to management, where a decision will be made on whether to issue an Internal Corrective Action Request (ICAR) for a specific area.

F-35 Familiarization Class

The F-35 familiarization class is offered to all new employees at Lockheed Martin and gives a basic, but thorough, introduction to the various F-35 jets. An overview is given of the history of the F-35, along with an introduction to the different systems making up the jet, such as the vehicle systems and propulsion systems. Safety around the aircraft is the last thing taught in the class, and focuses on how to behave around the aircraft in order to avoid injuries. The class lasts three days, where a certificate will be given at the end of the course.

PDM – Product Data Manager

The PDM class lasts two days and gives a general introduction to product data management, which is the use of software to manage and control data related to a particular product or part. PDM focuses on capturing, managing and tracking all information related to a product, where this information includes important engineering data such as CAD models, technical drawings and the documents associated with the product. Furthermore, PDM will also handle information such as owner of a file and release status of any product parts and ensures optimization of product lifecycles.

One of the main advantages of PDM is the accessibility of the system from multiple teams across an organization, which ensures that everyone has the same knowledge with regards to a product. This makes communications a great deal smoother, and reduces errors. (Product data management, 2017)

PDCA Class

PDCA stands for Plan – Do – Check – Adjust, and is a four step model for continually carrying out change in an organization. The model involves systematically testing possible solutions to a problem, and continuing until at suitable solution is found. The class gives an excellent understanding of how change can be made in an organization and explains which tools to use when carrying out PDCA on a problem.

The course lasts a full day and involves a variety of different interactive activities, which further developes an understading of why this particular method is useful. This all culminates in a capstone assignment, which focuses on solving an actual problem at work.

Capstone Assignment: PMT Scorecard

PMT stands for Perfomace Management teams and focuses on the tracking the performance of teams from different areas. These areas include manufacturing engineering, industrial

engineering, production planning, quality engineering and safety. Meetings are held once a week where performance metrics are reviewed and ways to improve product and service quality along with efficiency are identified. The meetings are also a way for the employees on the production line to raise any issues or relevant topics. The PMT scorecard is simply where the performance of each team is recorded and measured against the target in order to evaluate the progress. Furthermore, the scorecard is also used to come with any corrective action needed to reach the goal.

For this particular assignment the focus was on automating the process of completing the PMT Scorecard. Different tools are avilable to carry out the analysis of this particular problem, where the main one is reffered to as Problem Solving A3, see Figure 3 Problem solving using A3Figure 3. The advantage of using this tool, is the ability to define the problem in short, concise statements. Furthermore, it provides an excellent opportunity to find the root causes, countermeasures and is effective for any size problems. The first step is to define the different states, whereby the gap between current and target state can be found, and an analysis can be carried out. For the PMT scorecard problem a process flow map was made in order to discover the steps involved in the process and the time spent on each. This enables a complete examination of which activities may impact the process perfomance. Furthermore, it can highlight problem areas along with unnecessary loops and show where simplification may be possible.

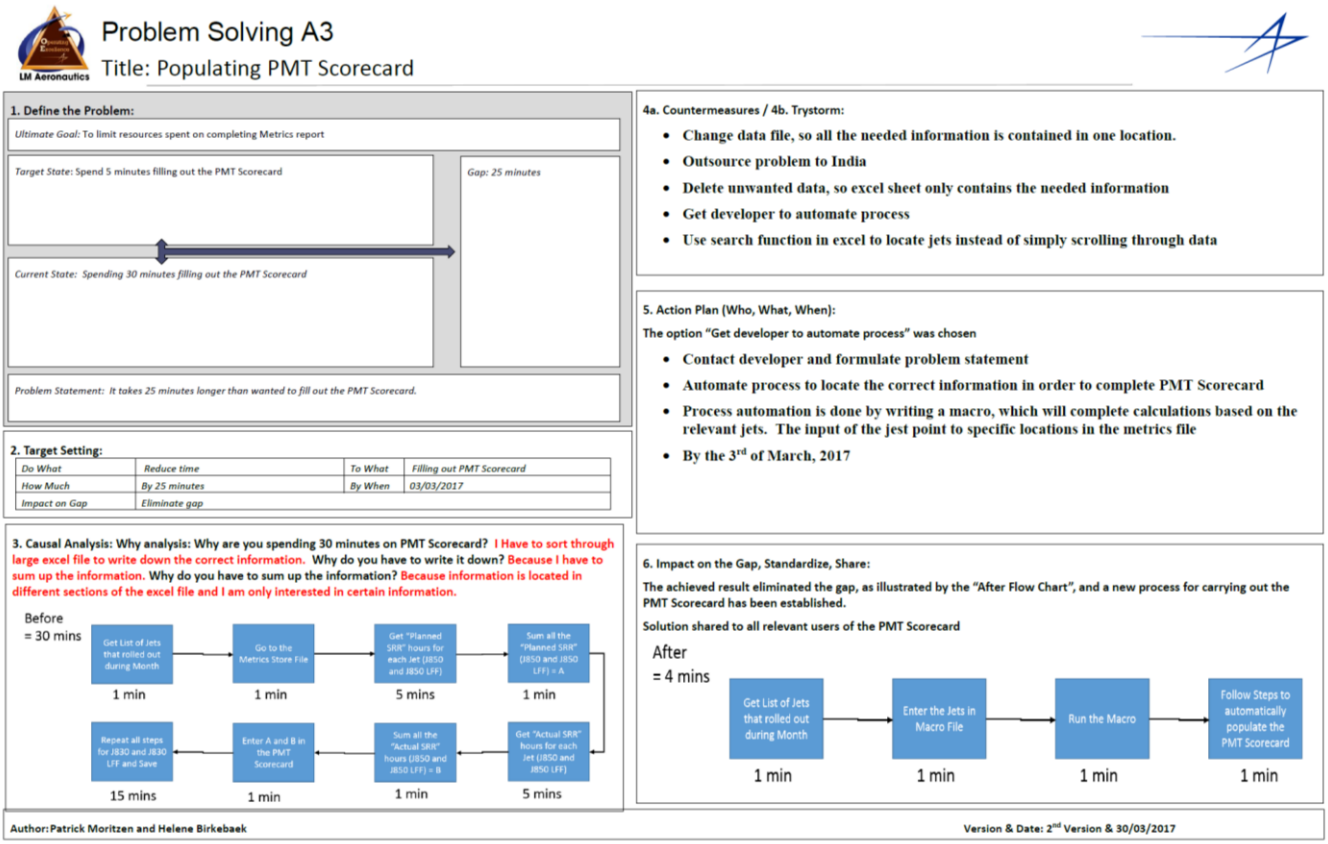

Figure 3 Problem solving using A3

illustrates the different steps involved in the process before any improvements were made. Further analysis of the problem was made by using the 5 Why's for an in-depth root cause analysis. The 5 Why's method was used as it is useful for less complex problems, and can often identify more than one cause. Based on this causal analysis, countermeasures can be developed, where a wide variety of ideas are considered and lean methologies are incorporated. Once all the ideas have been considered, the best one is chosen and an action plan is created. Finally, the impact of the plan is evaluated and it's verified that it can be sustained over time.

For the PMT problem, the time spent on completing the scorecard was shorten considerably by creating a macro, which performs calculations and fills out the card. The final flow chart, after the changes have been implemented, is shown in the A3 form as well.

PPV Class

Product Process Verification (PPV) is a complete, independent review and documentation of all aspects of an operation to verify production methods can repeatedly produce an acceptable item as specified by engineering drawings/specifications, planning, and purchase order. (Company, 2015)

The class details the process of doing the verification, which involves several steps in order to do a thorough evaluation of the planning/operation cards used to manufacture assembly parts. It also goes through the process of changing an operation card. The PPV class lasts 2 hours and a test will be given at the end, so it's essential to take notes, as PPV can be a complex and intrinsic procedure.

Projects

During the internship I was assigned a variety of projects, and in the following chapter I have chosen to focus on a few of these projects. Many aspects of the different projects deal with proprietary information, thus any real information has either been replaced by fake data or simply left blank.

Top defect and SRR drivers

An important part of being a QE is being able to narrow down the top defect or SRR drivers in order to target these problem areas to try and reduce or eliminate the problem.

In this particular project, the overall aim was to create 3-Dimensional graphs displaying the top 5 defect (or SRR) drivers for each date within a particular range. The graph is created for each build area, and inserted into a PowerPoint slideshow. The Excel interface can be seen in Figure 4, which enables the user to control which graphs to include in the PowerPoint. The data needed to create the graphs is pulled from an Excel file, containing collected information on both defect count and SRR hours, and into a new Excel document. The information covers a range of jets for each department, where a new file is created each week with updated information. Thus, the new excel file needs to be updated each week, which is done using a link, as illustrated in Figure 5. The next step is to identify the top five drivers for each date, make a list of these drivers and remove any duplicates. After this, the list is copied into a separate Excel sheet. Next an in-built Excel function is

used to find the correct defect count for the drivers on the list, which is done for each date. Figure 5 illustrates the table, where the list to the far left shows the top defect drivers. The final step is to create the graphs for each department, which is also illustrated in Figure 5, and insert these into PowerPoint. This tool is particular useful when a more visual representation of the data is needed, and shows the progress of each build area. Thus, it is used at meetings with the customer to show the continuing progress of reducing defects and SRR hours.

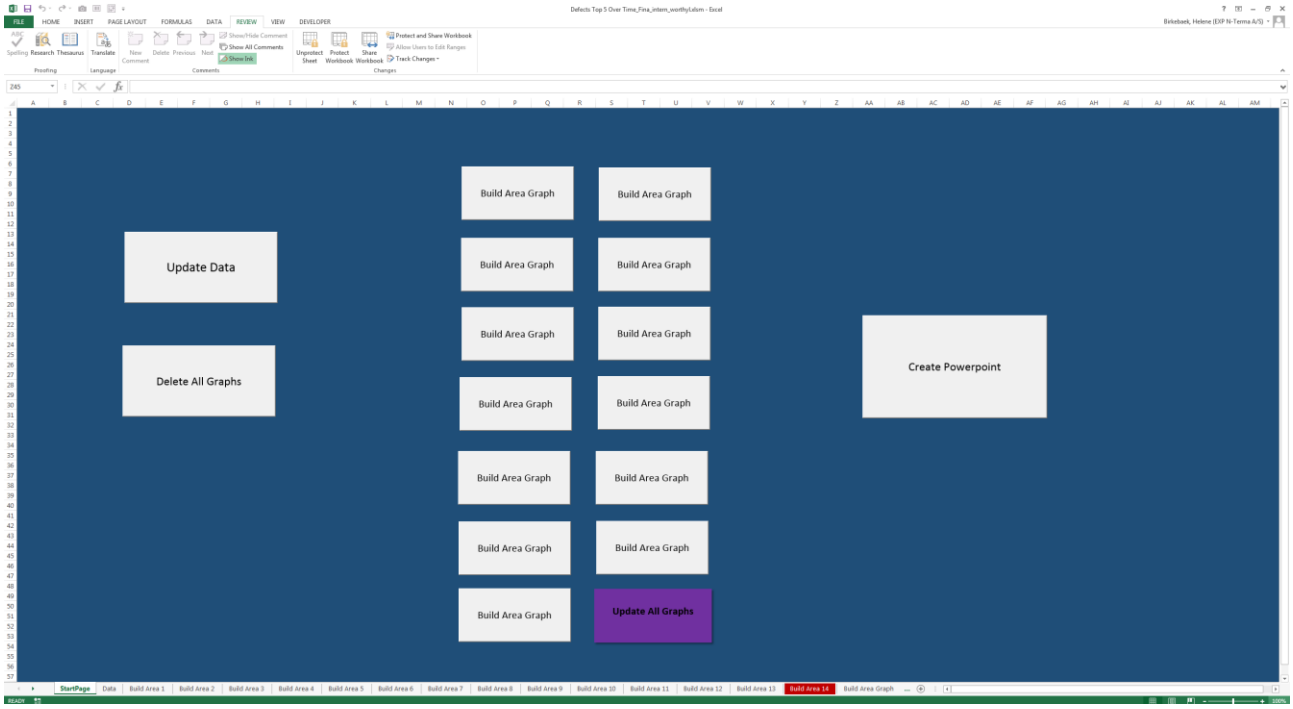

Figure 4 Excel Interface for Top SRR and Defect Drivers

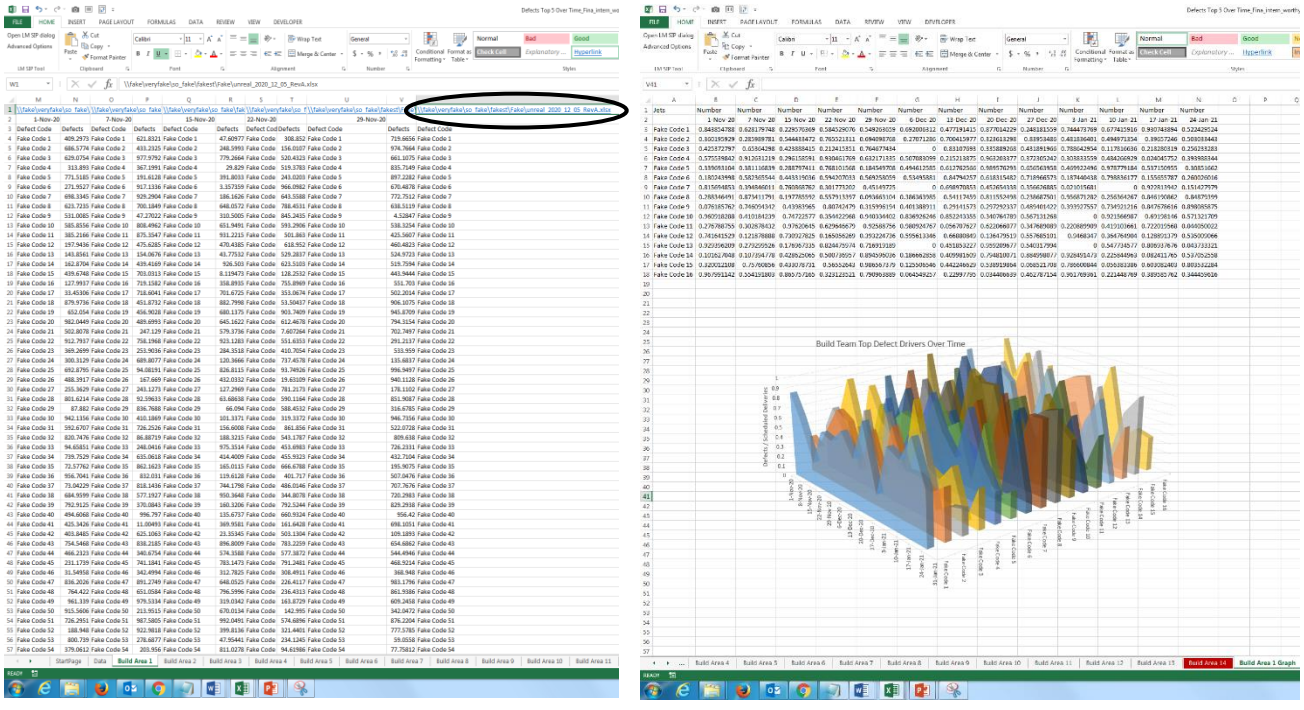

Figure 5 Black circle highligting link to update data and table containing top drivers along with corresponding graph, left and right respectively.

Triage Project

The aim of the triage project was to create different . More specifically, a pie chart showing the top 10 drivers, a bar chart with the top 5 part numbers for the five highest drivers, and a table containing relevant information, was build.

An existing excel file containing a pivot table along with a variety of slicers was used as a base for creating the different charts. The slicers are used to select the date range, specific jets, along with Ship Work Break-down Structure (SWBS). Once the user has selected the required information, the VBA program creates the different charts. For the pie chart, VBA creates the pivot table from the defect class along with the SRR hour field, ranking the defects in descending order based on the sum of the SRR hours. Next the top 10 defect drivers are copied into a new sheet containing a template for the pie chart, thus the pie chart is created.

The first step in creating the bar chart is to copy the top five drivers, into the same excel sheet containing the pie chart. The drivers make up the different series of the bar chart, where their corresponding total SRR hours, is displayed on the graph as a scatter plot. Next, the part number field is added to the pivot table. VBA selects the top five part numbers for each defect, and copies and pastes these into the new excel sheet. If five part numbers are not available, then VBA will simply copy and paste the available part numbers. As with the pie chart, a template was created beforehand, thus once everything has been copied, the bar chart is constructed.

Lastly, the table, containing all relevant information for the different defects, is made. This is done by selecting document number field along with defect description field. Each part number can have more than one document attached to it. Thus, the top five part numbers for a defect might not be a unique value, making it important that VBA can distinguish between each unique part number. The issue is highlighted with a red circle in Figure 6. Following this, the top five part numbers for each defect is copied, along with their corresponding information from the remaining fields in the pivot table, into the new excel sheet.

A PowerPoint is created by coping the two different charts along with the table into a new slide. Once the PowerPoint has been created, it is used to see which defects has the biggest impact, if there's a trend between the jets, and how to effectively target the highest drivers.

As an additional feature, the Corrective Action (CA) status description field is optional. This was done through the use of a checkbox, which is an in-built function in excel. This particular feature was added, as it's only needed for the CART meeting, and is unnecessary for the CAB meetings.

Class	Part Number	QADS Doc Num	Defect Bundle	CA Status Description	Sum of Actl Labor Hrs
Class 1	Part Number 1	AP71514	Class 1-Description4	Description2	
Class 1	Part Number 1	AP80458	Class 1-Description3	Description3	
Class 1	Part Number 2	AP96126	Class 1-Description3	Description3	
Class 1	Part Number 3	AP90757	Class 1-Description2	Description2	
Class 1	Part Number 4	AP77104	Class 1-Description9	Description2	
Class 1	Part Number 5	AP2241	Class 1-Description6	Description2	
Class 1	Part Number 5	AP62044	Class 1-Description4	Description3	
Class 2	Part Number 6	AP49759	Class 2-Description3	Description1	
Class 2	Part Number 7	AP76604	Class 2-Description3	Description3	
Class 2	Part Number 8	AP36393	Class 2-Description6	Description1	
Class 2	Part Number 9	AP87131	Class 2-Description3	Description3	
Class 2	Part Number 10	AP74697	Class 2-Description5	Description2	
Class 3	Part Number 11	AN61805	Class 3-Description7	Description1	
Class 3	Part Number 12	AN64603	Class 3-Description4	Description3	
Class 3	Part Number 13	AN67542	Class 3-Description1	Description1	
Class 3	Part Number 13	AN33550	Class 3-Description7	Description3	
Class 3	Part Number 14	AN31896	Class 3-Description4	Description3	
Class 3	Part Number 15	AN79349	Class 3-Description2	Description3	
Class 4	Part Number 16	AN79349	Class 4-Description3	Description1	
Class 4	Part Number 17	AN43805	Class 4-Description4	Description3	
Class 4	Part Number 18	AN39634	Class 4-Description9	Description1	
Class 4	Part Number 19	AN35464	Class 4-Description3	Description3	
Class 4	Part Number 20	AN31294	Class 4-Description4	Description3	
Class 5	Part Number 21	AN27126	Class 5 -Description2	Description1	
Class 5	Part Number 22	AN22953	Class 5 -Description6	Description2	
Class 5	Part Number 23	AN18783	Class 5 -Description8	Description2	
Class 5	Part Number 24	AN14613	Class 5 -Description6	Description3	
Class 5	Part Number 25	AN10442	Class 5 -Description2	Description1	

Figure 6 Final PowerPoint for the Triage project

Belly Band project

The belly band on the F-35 A-model is illustrated in Figure 9, but is found in the same location for the remaining two jets. The aim of the project was to investigate reoccurring fastener problems in the installation process of the belly band.

Prior to installation of the band, the affected areas on the aircraft is primed with a promoter, which will enhance the coupling characteristics of the ensuing sealant. Next, the skin is temporarily fastened in order to put in three types of fasteners. The blind fastener is used on the majority of the skin, as the structure design does not allow access from both sides. This particular fasteners is also the cause of the majority of the problems with the belly band. The configuration and installation process of a blind fastener is exemplified in Figure 7 and Figure 8. This is not the exact same process as the one used on the F-35, but gives a clear indication of how the procedure is carried out.

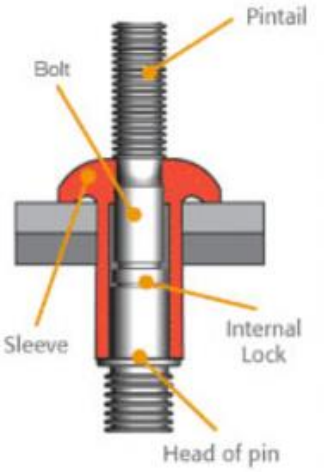

Figure 7 Blind fastener design

The fastener is inserted into a hole, which is drilled through the parts needed to be joined, and a specialized tool is placed over the fastener pintail. As the tool pulls the pintail, the blind side of the fastener is deformed effectively locking the fastener. At a predetermined force the pintail breaks and falls away.

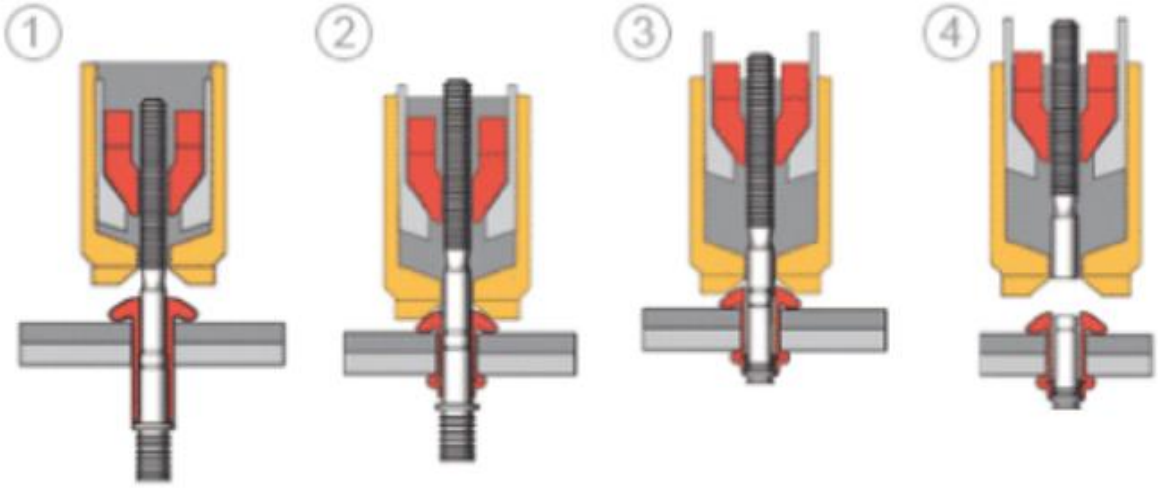

Figure 8 Installation sequence of a blind fastener. (How Huck Works, 2017)

When a fastener is not installed correctly, it's referred to as a "bad pull". This can occur for a number of reasons, which will be explained later, but the consequence is the same: The blind fastener has to be removed. In order to remove the fastener, the head of the protruding fastener needs to be grinded down, where after a small indent is made to the center of the stem, which is used to drill out the body of the pin. Lastly, the rest of the stem is removed with a punch. The removal of a fastener is timely and challenging, as the stem on the back of the panel drops off into a closed off area, and can only be removed from a small drain hole at the bottom of the panel. The exception to this is the fasteners used at the top of the panel, which fall into a small area with easy access through a large opening at the top.

As only a small drain hole is available to find the stem, a borescope is used to try and locate the part. Once it's been located, a long, thin rod with poster tack at the end is used to collect the stem. If the fastener is not removed correctly, it can mean that the stem breaks off into more than one piece, thus more time is spent locating the fastener. Furthermore, some of the borescopes are too big to get through the hole, and time is spent looking for the correct tool. These are often in high demand, which means it can take time to find one not in use. Another issue, which might arise due to lack of acceptable borescopes, is poor lighting. The borescopes come equipped with a small flashlight, but unfortunately on some of them the light is not good enough to locate the stem, which slows down the process quite considerably.

One of the main reasons for a bad pull occurring is the lack of good gauging practice. The depths of the fastener holes need to be measured periodically to ensure that the correct fasteners are inserted into the correct hole. Although a detail description of which fastener to use is include on the part, this does not always hold true as the promoter can alter the required fastener length. When a wrong fastener is being used pull-through of the stem can occur, which can damage the

skin around the fastener. Furthermore, putting up the belly band requires good technique and skill, as holding the gun at incorrect angle can easily lead to the fastener being inserted wrong or damaging the skin around the hole. A small percentage of the bad pulls occur due to a defective fastener, and as a considerable amount of fasteners are used for the belly band, this also contributes to the number of bad pulls. However, the fasteners are slowly being replaced, which should eliminate this problem from reoccurring.

Figure 9 Location of belly band on the F-35A

Another major reason for the occurrence of bad pulls is improper locking of the ring surrounding the head of the stem. If the ring doesn't lock correctly the fastener is not securely fixed, and it has to be removed. Furthermore, inaccurate countersinking of the holes, into which the fasteners are inserted, will also lead to a bad pull. The countersinking is done by at a station prior to the installation of the belly band.

Previously, using the wrong equipment lead to a considerable amount of fastener defects, which includes not only bad pulls, but also damage to the skin. The tool marks on the skin is due to an incorrect gun being used, however this was corrected by clearly stating which gun to use for the procedure.

It was difficult to collect a reasonable amount of data as installations often occurred outside normal working hours. However, once a rapport had been established with one of the mechanics, he was able to pass on any relevant information from the belly band installations. The outcome of this

project was a report, which established the different findings along with suggestions for improvements. The process of installing the belly band has already been greatly refined, as the tools are now marked to ensure the mechanics are using the correct one, and faulty fasteners are being replaced with better ones. However, the project was still able to highlight a few places to make improvements, such as assuring that the necessary tools are available, and these are all in working order. These problems were particularly evident when it came to the borescopes. Another suggestion for improvement is expanding the size of the drain hole to double the size. Enlarging the hole would enable the mechanic to locate and remove the fastener both quicker and easier.

FOD Audits

FOD audits are carried out routinely to ensure the jets are free of FOD, which includes metal shavings, string tie, loose fasteners or any misplaced equipment. However, the audits also comprises of checking for general housekeeping, ensuring the work station is clean, along with the tools being in the correct place and functioning correctly.

During the internship audits were frequently carried out on the jets, which included both A- and B models. Once the supervisor had been informed of our presence, a systematic inspection of the jet began. Typically, it would start with checking all the bays on the jet at ground level, before moving up to the top part of the jet. Here, it was necessary to climb on to the jet in order to inspect the bays. The most common type of FOD includes string tie, missing caps on various tubes, along with pieces of tape. Another problem is bird droppings, which is due to birds escaping into the factory through large doors. These doors open and close frequently to allow both jets and carts in and out of the factory. Certain measures have been put in place to try and avoid this type of FOD showing up. This includes covering the jets up when work is finished, and overhagning nets stopping the dropppings from reaching the jet.

These audits were an excellent opportunity to apply the knowledge learnt in the previous FOD training classes. Furthermore, it was opportunity to get down to the production floor, talk to the mechanics and supervisors, in order to learn more about the construction a fighter jet.

Experiencing USA

Doing an internship abroad offers a unique opportunity to experience different cultures, and working in Texas was no exception to this. Texas in itself is gigantic and packed with an immense range of things to do and see, but visiting other states is also a possibility as the DFW airport is only 40 minutes away from Stonegate. As such, the time outside work was spent visiting and seeing a whole range of different places. However, in order to keep this report at an acceptable length, only a few selected places will be described in detail.

New Orleans, Lousiana

One of the first 3-day weekends was spent in New Orleans, which is an eight hour drive away from Fort Worth. In order to make the trip more managable, stops were made on the way, where the

first stop was at East Texas Oil Museum, which was a fascinating look into the boom of the oil industry during the 1930's. After this, another stop was made at an old slave plantation called Evergreen, where a guided tour depicts the haunting slave quarters along with the main house.

New Orleans was visited during Mardi Gras, which is a two week celebration starting in the middle of February. The main parade contains a lot of different floats, all competing with each other to be the most extravegant, and throwing out beads to the parade-goers.

San Antonio, Texas

San Antonion was all about the River Walk, which is a system of connected footpaths following the banks of the San Antonio river. Lining the paths are different restaurants, pubs and small shops, and guided boat tours are also available. The tower of Americas is a short distance away from the trails, and offers an amazing view of the city, along with a stationary bar and restaurant.

Denver, Colorado

One of the last places to see during a long weekend was Denver in Colorado. The Rocky Mountains, which is a more than 3,000 miles mountain range runinng through Colorado, were one of the main reasons for visiting. Even during Spring the hiking can trails can be covered in snow, which can make hiking more challenging, however the reward is a beautiful view of the

mountains. Another point of interest in Denver is Pikes Peak, which offers an amazing view of Colorado Springs and the Garden of Gods, as it is the farthest east of the big peaks in the Rocky Mountain chain.

As mentioned previously, this report would become very lengthy if every visited place had to be outlined, so instead the remaining places are listed below along with various pictures.

Fort Worth

- Rodeo
- Aviation Museum. Here a guided tour is giving by war veterans, where many have served during the Vietnam war.
- Stockyards in Fort Worth. This is a place to experience the Old West, and a daily cattle drive of the infamous long horns.
- Cowgirl Museum
- Drive-in cinema
- WWE Wrestling
- Various pubs and restuarants, but most notably: Blue Mesa, The Flying Saucer, taps and Caps, Kincaids and Spiral Diner.
- Outdoor Shooting Range. Tried a handgun, assault riffle along with shotgun clay shooting.

Dallas

- Sixth Floor Museum
- DMA: Dallas Museum of Art

Houston

- NASA: Space Center Houston

Galverston

- Pleasure Pier

Austin

- Hiking at Westcave
- State Capitol

Mineral Wells and neighbouring towns

- Mineral Wells State Park
- Clarks Botanical Garden
- Fishing and kayaking on Brazos River
- Dinosaur Valley State Park

South Padre Island and Corpus Chrisit

- USS Lexington

The list does not include the Southern dinner at a good colleagues house, complete with chicken fried steak, cornbread and gravy, playing tennis, going bowling, and general exploration of Fort Worth.

Business as usual

LMents is a society at Lockheed Martin, who organizes different social events, in order to create a sense of community within the organization. There is a whole range of different activities, which can be attended, but during the internship two events were attended, namely the LM meet and greet before the rodeo and at The Point for engineering week. The Point is a local restaurant, which also serves as a bar. These events were an excellent way to socialize and meet people outside of work.

Terma North America (TNA)

Terma headquarters are located in Lystrup, Denmark, but has a wide range of locations including an office in Fort Worth, Texas. The U.S office has been an excellent support and help throughout the internship and several social events have been attended together, such as the TNA Christmas party and an informing visit to their offices.

Figure 10 Meeting with terma North America

Conclusion

The initial motivation to do an internship at Lockheed Martin was mainly based on my interest in fighter jets, and the desire to work on the F-35 program. Having nearly completed the internship I can safely say that all of my expectations have been exceeded. I have been involved in a large range of different projects, all involving daily contact with the F-35.

The classes at Lockheed Martin all enabled me to get a better understanding of the various aspects of the planning, development and production of the F-35. The manufacturing of a fighter jet is an enormous process and can initially seem overwhelming, but the classes all introduce various aspects of the process and breaks it into understandable parts.

Working as an intern have included a great deal of programming in Excel, thus it's been excellent opportunity to improve my coding skills. VBA is a universal programming language and

understanding how to optimize a process in Excel is useful in many different situations. Furthermore, working on the different projects have given me an insight into the different work a quality engineer experiences during the day. There are many different problems, which will need to be solved all with the common goal of reducing defects. This includes working together as a team, making sure everyone is informed with regards to current problems and projects, which is mainly done through meetings. As such working as intern in quality engineering have improved my team working and communication skills along with making me more confident in work situations.

The internship at Lockheed Martin has been an amazing experience, both academically and personally. It's been an opportunity to improve my problem solving skills in an analytical manner, and use knowledge obtained through my education on real life problems. Finally, working at Lockheed has made me courageous and confident, and it has certainly been worth it.

References

Company, L. M. (2015, march 25). *Q2A – First Article Inspection (FAI) – AS9102.* Retrieved from http://www.lockheedmartin.com/content/dam/lockheed/data/aero/documents/scm/quality/clauses/q2a/q2a_rev11.pdf

F-35 Fighter Jet. (2014, July 24). Retrieved from Huffington Post: http://www.huffingtonpost.ca/2012/07/24/f-35-fighter-jet-lockheed-martin_n_1698678.html

F-35 JSF. (2012). Retrieved May 22, 2017, from Terma: https://www.terma.com/about-us/doing-business-with-us/customer-stories/f-35/

F-35 Lightning II. (2017). Retrieved May 20, 2017, from https://www.f35.com/about/life-cycle/production

Flight Global. (2015, January 22). Retrieved May 27, 2017, from http://www.defenseone.com/business/2016/05/f-35-production-set-quadruple-massive-factory-retools/128120/ https://www.f35.com/about/variants/f35c

Forbes. (2017). Retrieved May 30, 2017, from https://www.forbes.com/companies/lockheed-martin/#

Here's what pilots who've flown the F-35 have to say about the most expensive weapons project in history. (2017). Retrieved from Business Insider: http://www.businessinsider.com/why-f-35-worth-every-penny-heritage-foundation-2016-8

How Huck Works. (2017). Retrieved from Arconic: https://www.afsrhuck.net/us/en/Huck_Technology/how_huck_works.html

Lockheed Martin. (2017, May 27). Retrieved May 30, 2017, from Wikipedia: https://en.wikipedia.org/wiki/Lockheed_Martin

Lockheed Martin F-35 JSF Final Assembly. (2017). Retrieved from Advanced Integration Technology: http://www.aint.com/projects/large_scale_integration_projects/lockheed_martin_f_35_jsf_final_assembly

Product data management. (2017, April 3). Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Product_data_management

Strategic Supplier. (2012). Retrieved from Terma: https://www.terma.com/aerostructures/the-worlds-largest-industrial-project/

Waurzyniak, P. (2007, May 1). *Manufacturing Engineering*. Retrieved May 26, 2017, from http://www.sme.org/MEMagazine/Article.aspx?id=21135&taxid=1424

Wikipedia. (2017, May 22). Retrieved from Viking program: https://en.wikipedia.org/wiki/Viking_program

Work Breakdown Structure. (2017, March 28). Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Work_breakdown_structure