Taking control of the after sales

The design of a supply chain control tower, which will help Thales by improving the supply chain visibility of their new type of after sales service.

6th of August 2016

Erik Keppels

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The design of a supply chain control tower, which will help Thales by improving the supply chain visibility of their new type of after sales service.

A Bachelor thesis Technische Bedrijfskunde

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Executive summary (English version)

The assignment

Thales starts two new projects, where they introduce a new type of after sales service, in the form of performance based service contracts. In these contracts Thales is (partly) responsible for the uptime of the radar systems. The most important factor that will determine Thales' success in these contracts is whether they are able to perform all the maintenance and deliver all the parts when needed. To make sure that this is the case, they need to have enough spare parts on stock and to have a good overview of these parts. This means that Thales wants a tool that can be used to increase the supply chain visibility and to create a useful overview of the supply chain of the after sales service. The tool that has be designed is a supply chain control tower, but Thales does not yet know how this tool will function and what input parameters they need to keep track of to make it function.

Main question and sub questions

To solve the problem of Thales, the following question will be answered in this thesis:
What information is needed to create a functioning control tower for the after sales supply chain of Thales and how will it help to create a better overview of the supply chain?

To solve the main question, the following sub questions will be answered:

- *What is the current situation of the after sales supply chain?*
- *How can a supply chain control tower help to improve supply chain visibility?*
- *What are important input parameters for the control tower?*
- *How could a control tower look like for Thales?*
- *How can Thales implement the supply chain control tower in their after sales services?*

Research approach

First, the current situation is investigated, how Thales is handling his after sales service at the moment and how far they are with the implementation of the new service contracts. Then, it is important to determine the definition of a control tower and what is needed for to create one. This is done with the help of literature, but also by attending a ProSeLo Next meeting, a project where multiple Dutch companies try to improve their after sales services with the help of control towers. This information is used to design a control tower model. At last, I will discuss how Thales can implement the model.

Conclusions

A supply chain control tower can be described as: "*a central hub with the required technology, organization and processes to capture and use supply chain data to provide enhanced visibility for short and long term decision making that is aligned with strategic objectives"*. (Bhosle, Kumar, Belinda, Rob, MarieAnne, & Adrian, 2011)

The control tower that has been design in this assignment will function on the operational level of the supply chain of the new type of after sales service and provides an overview of the general specs per part, a prediction on future stock levels and the risks of a stock out in the future (the situation in which Thales needs to perform maintenance, but has required spare parts on stock). The stock predictions are based on the input parameters like the expected demand per year for corrective maintenance, the planned preventive maintenance and the incoming purchase/repair orders. Besides the risk of stock outs, the model also generates signals when an purchase or repair order is exceeding its planned delivery date and the date at which a new part should be purchased to replenish the stock when it is expected to reach the safety stock.

There is only one problem, with the current after sales service that Thales offers, they receive almost no feedback on the usage and working hours of the spare parts. These values are important when it comes to predict the expected demand per year. For the model, the expected demand per year is based on the predictions of the logistic engineers instead. However, these are stochastic values, so they are not completely reliable and can also not be validated since there is a lack of historic data.
The expected demand per year is not the only input parameter that is uncertain. There are also uncertain parameters on the supply side, like the repair and lead times, and together with the lack of historic data, it becomes tricky to validate the model. One way to validate the model is to rank the parts based on their risk of a stock out, this way the part that deserves the most attention will be ranked on top. Then show an unranked list to an employee with a lot of experience and knowledge about the parts (like criticality or the acquirability) and let him pick a own top ten part that should be looked at. When the lists are similar it proves that the model attaches the same priorities to the parts and fits the strategy of Thales. Due to lack of time and resources, the validation has not yet been performed.

The purpose of the control tower model will be increasing the supply chain visibility on operational level, by providing an overview of the input parameters of the spare parts and generate signals that can be used to aid in the decision making. These signals show the risk that a part reaches a stock out before it can be restocked. Thales can use these signals to decide whether they need to buy extra parts or accept the risk when it is small enough. Later on, when the model has been running for a while, the gathered information can also be used to test the used parameters like the MTBF.

The responsibilities that come with the control tower are divided over the different cluster of the organization. The control tower will be located in Cluster C (the customer contact center). Here all the data of the input parameters will be collected and the signals will be distributed to the right clusters, so they can act on the signals. Cluster E (Logistic Engineering) and F (Supply Chain) will provide all of the input of the control tower.

Before implementing the model, Thales needs to make sure that they have complete and reliable data for all of the input parameters.

Recommendations

To further improve the model, some expansions of the model have been recommended:

- ***Try to link the data sources that provide the input parameters directly to the model***
- ***Include the standard deviation of lead and repair times in the model.***
- ***Create a feedback loop to the initial parameters, so they can be checked on their reliability and correctness.***
- ***Add extra priority factors to the risk signals, so the part that is the most important to the success of the service contracts will also get a higher priority in the model***
- ***Add standardized interventions to the model and link them to certain scenarios that can occur, this way Thales can act faster to exceptions.***

Management samenvatting (Nederlandse versie)

De opracht

Thales is bezig met twee nieuwe projecten, met deze projecten indroduceert Thales een nieuw soort after sales service: prestatie gerichte service contracten. Deze conracten maken Thales verantwoordelijk voor de uptime van de radar systemen. De belangrijkste factor hierin is Thales' vermogen om al het benodigde onderhoud te plegen en reserve onderdelen te leveren zo gauw dat nodig is. Hiervoor hebben ze ten alle tijden genoeg reserve onderdelen op voorraad nodig en een goed overzicht over deze onderdelen. Thales wil een software tool dat gebruikt kan worden om een beter overzicht te creëren van de supply chain van de after sales service. De tool die hiervoor ontworpen moet worden is een supply chain control tower, Thales weet alleen nog niet het moet gaan functioneren en welke data ze hiervoor moeten verzamelen.

Hoofdvraag en deelvragen

Om deze opdracht uit te voeren, de volgende vraag wordt gesteld:
Welke informatie is nodig om een functionerende control tower te creëren voor de after sales supply chain van Thales en hoe gaat dit helpen met het behalen van een beter overzicht van de supply chain?

Om de hoofdvraag te beantwoorden, heb ik een aantal deelvragen opgesteld:
- *Hoe ziet de huidige situatie van de after sales supply chain van Thales eruit?*
- *Hoe kan een supply chain control tower het overzicht van een supply chain verbeteren?*
- *Wat zijn belangrijke input parameters voor de control tower?*
- *Hoe kan een control tower eruit zien voor Thales?*
- *Hoe kan Thales een supply chain control tower implementeren in hun after sales service?*

Aanpak

Eerst moet de huidige situatie onderzocht worden: Hoe gaat Thales nu om met hun after sales service en hoe ver zijn ze met het implementeren van de nieuwe service contracten? Daarna moet de definitie van een control tower vastgesteld worden en moet er gekeken worden wat er voor nodig is. Hiervoor wordt literatuur geraadpleegd en maak ik gebruik van definities die gebruikt worden in het ProSeLo Next project, een project waar een aantal Nederlandse bedrijven proberen hun aftersales services te verbeteren met behulp van control towers. Deze informatie wordt gebruikt om een model te ontwerpen voor een control tower. Als laatst wordt besproken hoe Thales dit model can implementeren.

Conclusies

Een supply chain control tower wordt beschreven als: "*a central hub with the required technology, organization and processes to capture and use supply chain data to provide enhanced visibility for short and long term decision making that is aligned with strategic objectives*". (Bhosle, Kumar, Belinda, Rob, MarieAnne, & Adrian, 2011)

Voor deze opdracht is een control tower model ontworpen voor de supply chian van de nieuwe after sales service. Dit model functioneerd op een operationeel niveau en zorgt voor overzicht door het weergeven van algemene informatie per onderdeel, het voorspellen van voorraden in de toekomst en het voorspellen van het risico dat Thales misgrijpt wanneer ze een onderdeel nodig hebben. De voorspellingen zijn gebaseerd op input parameters als de verwachte vraag per onderdeel per jaar, de preventieve ondehouds planning en inkoop- en reperatie-orders. Naast het risico op het misgrijpen genereert het model ook signalen wanneer een inkoop- of reperatie-order te laat is en wanneer Thales in moet kopen, gebaseerd op de veiligheidsvoorraad.

Bij het onderzoeken van de huidige situatie van de after sales service is er een probleem ontdekt: Thales ontvangt nagenoeg geen feedback van hun klanten, dus ook niet over het gebruik en het aantal draaiuren van de reserve onderdelen. Deze waardes zijn belangrijk om de verwachte vraag te voorspellen, maar zijn dus niet te achterhalen uit historische data. Het model maakt in plaats gebruik van waardes die berekend zijn door de logistic engineers van Thales. Dit zijn stochastische waardes, berekend met voorspellende modellen en zullen dus gevalideerd moeten worden met historische data, voordat ze als volledig betrouwbaar gezien kunnen worden.
Daarnaast zijn er ook nog onzekere input parameters aan de leverancier kant van de supply chain, zoals de reperatie- en levertijden. Samen met het gebrek aan historische data zorgen de onzekere parameters ervoor dat het lastig is om het model te valideren. Een manier om het model te valideren is door het ordenen van de reserve onderdelen op basis van het risico dat Thales mis grijpt op dat onderdeel. Laat daarna een werknemer die veel kennis heeft van de onderdelen (over bijv. criticaliteit en verkrijgbaarheid) dezelfde lijst ordenen. Als de lijsten overeenkomen geeft dit aan dat het model dezelfde prioriteiten toekent aan de onderdelen en dus past in de strategie van Thales. Door gebrek aan tijd en data is de validatie nog niet uitgevoerd.

Het doel van het control tower model is het verhogen van de supply chain visibility op een operationeel niveau, door een duidelijk overzicht te bieden van de input parameters per onderdeel en signalen te genereren die gebruikt kunnen worden in de besluitvorming. Het belangrijkste signaal geeft aan hoe hoog het risico is dat Thales meer onderdelen nodig heeft dan ze op voorraad hebben, in de periode tot het eerstvolgende bevoorradingsmoment. Dit kan bijvoorbeeld gebruikt worden om te bepalen welke onderdelen ingekocht moeten worden en welke nog voldoende voorradig zijn. Wanneer het model genoeg data verzameld heeft, kan het ook gebruikt worden om feedback te leveren aan eerder gemaakte berekeningen, bijvoorbeeld die van de MTBF.

De verantwoordelijkheden van de control tower zijn verdeeld over verschillende clusters in de organisatie van Thales. De control tower wordt waarschijnlijk geplaatst in cluster C (het klant contact center). Hier wordt alle informatie bij elkaar gebracht en worden de gegenereerde signalen verdeeld over de clusters die kunnen handelen op de signalen. Cluster E (Logistic Engineering) en F(Supply Chain) zullen voor de input van de control tower zorgen.

Voordat Thales het model kan implementeren moeten ze ervoor zorgen dat alle input parameters compleet en betrouwbaar zijn.

Aanbevelingen

Om het model te verbeteren zijn een aantal aanbevelingen gemaakt:

- Creëer een directe verbinding tussen het model en de systemen die voor de data zorgen
- Maak gebruik van de standaard deviatie van de reperatie- en levertijden in het model
- Gebruik de data van het model als terugkoppeling naar de initiele berekeningen van de parameters, zodat deze gecontroleerd en eventueel bijgewerkt kunnen worden.
- Voeg extra factoren toe aan het bepalen van de prioritiet per onderdeel.
- Voeg standaard interventies toe, die gekoppeld kunnen worden aan verschillende scenario's.

Preface

With this thesis, I will finish my bachelor Technische Bedrijfskunde (Industrial Engineering & Management) at the University of Twente. I can look back to three successful years in Enschede. Many students are not sure what they want to study after they finish their high school, but from the moment I read about Technische Bedrijfskunde I knew what bachelor I was going to choose and I have had no regrets since then. The bachelor has taught me both business and analytical skills, but also the necessary skills to successfully operate in a business. During the bachelor, we have made many group assignments, but this bachelor assignment was the first real project where I had to rely on my individual capabilities. Luckily, this was no problem, the bachelor had taught me all the required skills, which meant that I did not have to worry about this during my time at Thales, but could enjoy my time there and experience how it is to work at a big company. I wish to continue after this study with the master Industrial Engineering & Management at the University of Twente.

The fact that I have enjoyed my time is not only thanks to the preparation during the bachelor, but also thanks to the help and guidance I got from my supervisor within Thales: Clemens Harperink. I would like to use this opportunity to thank him for all the useful information he gave me and all the progressive meetings we had every Friday. I would also like to thank all of the other coworkers that were available to provide the information I needed, especially Jord Bolhaar and Rindert Ypma, who I bothered the most I think. The final people I would like to thank within Thales are the coworkers I spent my coffee breaks with and the other interns I spent most of the lunches with.

I would also like to thank Matthieu van der Heijden, my supervisor of the University of Twente. I got this assignment thanks to him and he has helped me a great deal on it. This assignment was also part of a greater, national project where Matthieu participated in and the meetings of this project I attended also gave other insights in my assignment. So I would also like to thank him that he invited me to these meetings and offered a place in his car, so I did not have to use the public transportation.

As final thanks, I thank my friends and family. They always showed their interest in the work I was doing and supported me in it. I hope that everyone who is reading this will enjoy the rest of bachelor thesis.

Erik Keppels,
Laren, July 11, 2016

Contents

1 Introduction and research design

This chapter will provide an introduction to the assignment and the company where the assignment took place. It will also contain a description of the research that will be done during the assignment: The motivation for the assignment, the problem statement, the research questions and the approach to answer these questions.

1.1 The company

The assignment takes place at Thales Nederland (TNL), the Dutch branch of the Thales Group. TLN is internationally active in the Defense, Security and Public Transportation sectors and has almost 2000 employees. Examples of products that Thales delivers in the Defense sector are radar systems, communication systems and command & control systems.

The corporate head office of TNL, which provides work for +/- 1500 employees, is located in Hengelo. The plant at Hengelo is active since 1922 and is a worldwide leader in the latest and most innovative radar technologies and radar systems for naval ships. Other offices of TNL are located in Huizen, Delft, Eindhoven and Enschede.

1.2 Motivation for the assignment

TNL is busy with two projects involving their new radar system, the Smart-L EWC. In this assignment the projects will be called project A and B and the customers of these project will be called customer A and B. Thales has sold two of their new radar systems to the customer A and four of them to customer B. To increase the customer satisfaction and overall quality of their service, Thales also introduces a new type of after sales service with these projects, in the form of a performance based and a logistic based service contracts.

Up till now, the after sales of Thales are mainly transaction-based. When a customer needs spare parts or an overhaul, they contact the after sales organization or service desk of Thales and place an order. So, it was the responsibility of the customer to check if they needed new spare parts or maintenance and plan their purchasing accordingly. With the new service contracts, the responsibility is shifted towards Thales. Together with the customers, Thales has agreed on a certain level of operational and logistic availability of the radar systems. When this availability is not reached, Thales will receive large penalties. To guarantee a high availability, the downtime due to maintenance and repair needs to be low. This can be arranged by having enough spare parts in the inventory, so all maintenance can be performed when needed. However, too much inventory can lead to unnecessarily high costs.

To maintain an acceptable inventory level, the logistic engineers of Thales predicted the amount of spare parts that are needed in the future. This way, the procurement manager can base his procurement planning on the results of the logistic engineers. However, the models that the logistic engineers used are based on expectations and statistical models. It is possible that there is more variation than expected or some unexpected events happen. When this happens and nobody is paying attention, it is possible to run out of spare parts, which means that Thales cannot perform any maintenance or repairs and risk a violation of the service contract. To prevent situations like this, it is important to have a clear overview of the supply chain. This way, Thales can react quickly when a situation like under stocking is likely to happen. At the moment, Thales does not have a proper way of monitoring this new supply chain and thus lack supply chain visibility.

1.3 Goal of the assignment

The goal of the assignment is to provide Thales with better visibility and a better overview of the operational status of their after sales supply chain. In this case it concerns the after sales of project A and B, but the solution that will be found in this assignment should also be easily implementable in new projects with similar service contracts. The goal that results from the higher supply chain visibility is to create something that gives Thales the ability to notice situations like under stocking in an early stadium, such that they can react in time and avoid negative consequences.

1.4 Problem statement

So, the main problem is that Thales lacks a good overview of the after sales supply chain of their future projects. Lacking overview is not a problem that can be solved at ones. For this reason, it is useful to look at the possible causes of this problem and find out which of them can be solved. To do so, a problem cluster will be used, which can be found in Figure 1.

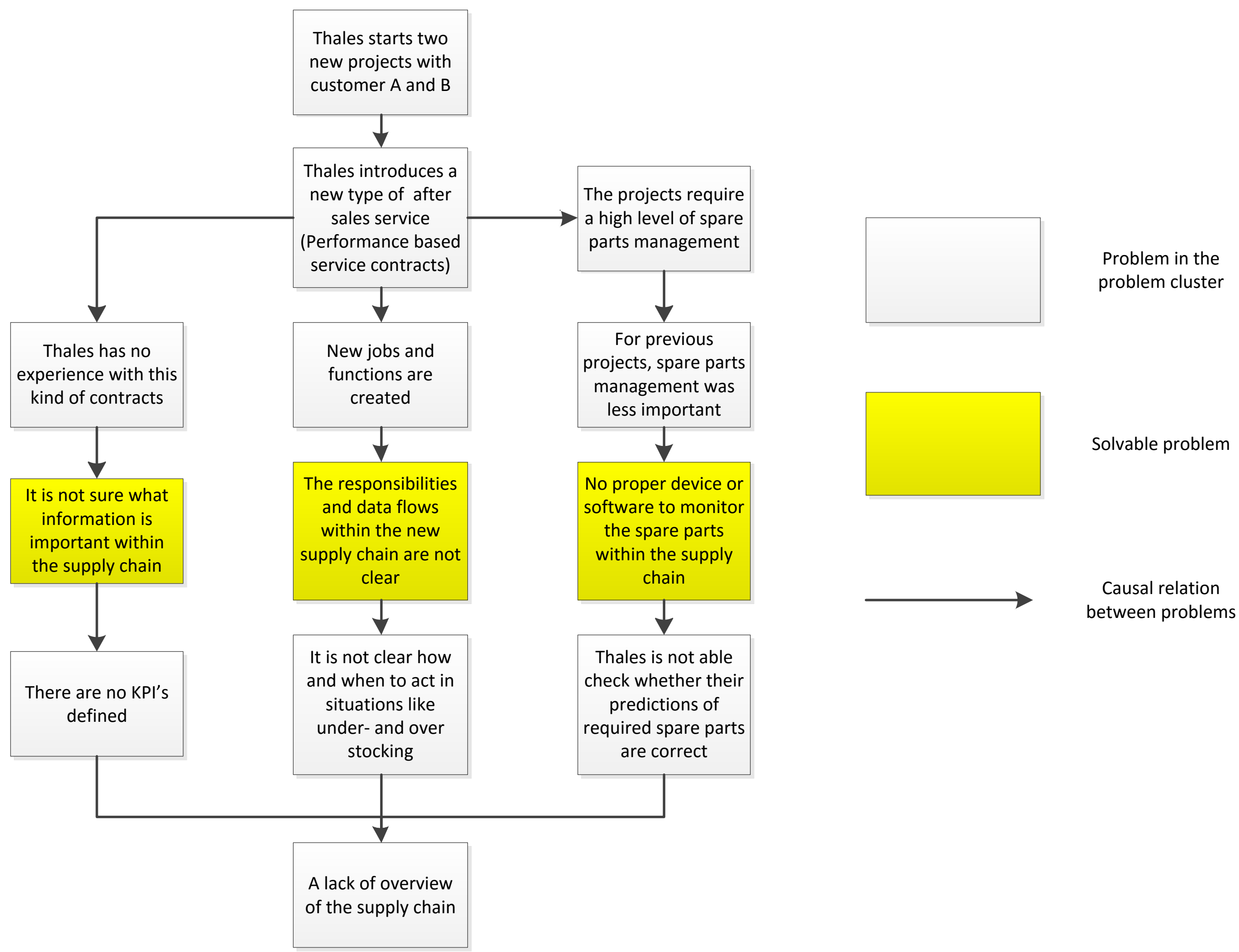


Figure 1: Problem cluster

The problem cluster shows that the lack of overview is caused by the fact that Thales is starting the new projects, where they introduce a new kind of after sales service. The choice to introduce this new kind of after sales service has been made on a strategic level and is made with the future in mind. The intention of this assignment is not to change this decision. However, the introduction of these new services did cause some other problems further down the cluster, problems that can be solved. The three main problems that can be solved are highlighted in Figure 1. Solving these problems will probably solve, or at least help in solving the main problem of having a lack of overview:

1. The responsibilities and data flows within the new supply chain are not clear.
2. It is not sure what information is important within the supply chain.
3. There is no proper device or software to monitor the spare parts within the supply chain.

Making sure that the projects will run smoothly and become a success is very important to Thales, so they have also done their own research and they are largely aware of these problems. A discussion with Thales on how to solve them, has led to the solution of creating a control tower. A system that can be used to keep track of the supply chain, recognize upcoming threats like under stocking and intervene to counter these threats. So, the solvable problems from the cluster can be tackled by creating a control tower, but then the problem becomes how to create a control tower.

1.5 Research restriction

What a control tower exactly is will be discussed in Chapter 3 and 4, but the definition in the previous paragraph gives the general idea: A system that can be used to keep track of the supply chain, recognize upcoming threats like under stocking and intervene to counter these threats.
Designing something that can keep track of an entire supply chain and at the same time recognizes upcoming threats is a very large job. Because this assignment only has a time span of 10 weeks there will be some restrictions to the research.

- For this assignment, the control tower will only look at the physical parts that are needed to adhere to the service contract, which includes spare parts, special tools and test equipment (STTE) and consumables (during the rest of this assignment, all these physical parts will be revered to as spare parts). Required services like employees working the service desk and service engineers are assumed to be always available. Although this may not always be the case, it is something the service contract aims at.
- The control tower will only look and function at the operational level of the supply chain. This includes the purchasing, warehousing, repair and usage of the spare parts. The calculations and assumptions about the spare part requirements that are made on a tactical level will be assumed to be correct at first.
- For this assignment, the design of the control tower, figuring out what useful input and output is and what to do with it is more important than a fully functioning control tower. However, to illustrate how the control tower may look like, a prototype will be made. The prototype will primarily function on the operational level, but it is possible to also already look at how it can be used to give feedback on the initial calculations.
- The costs are also not included in the scope of this assignment. The control tower will primarily look at the availability of the spare parts and generate the warnings on this basis. Costs are important, so including them in later expansions of the model could be useful.

1.6 Research questions

Using the goal of the assignment and the problem statement, a main question can be derived:

> ***What information is needed to create a functioning control tower for the after sales supply chain of Thales and how will it help to create a better overview of the supply chain?***

To solve the main question, the following sub questions will be solved:

- *What is the current situation of the after sales supply chain?*
- *How can a supply chain control tower help to improve supply chain visibility?*
- *What are important input parameters for the control tower?*
- *How could a control tower look like for Thales?*
- *How can Thales implement the supply chain control tower in their after sales services?*

1.7 Approach per sub question

What is the current situation of the after sales supply chain?
This question is about analyzing the current situation. Thales introduces a completely new type of service contract, so how far are they with the introduction of this new service and how does the supply chain of the service look like? However, it is not only about analyzing the coming after sales service, but also the current one. Maybe they are already keeping track of a lot of data that is useful in the new situation and maybe a lot of changes are needed.

To gather all the information of the current situation, interviews will be taken with several employees that are active in different parts of the organization. Interviewing these different departments will hopefully give a good picture of the whole organization and activities like the current after sales and spare parts management are regulated, as well as current situation of the new after sales.

How can a supply chain control tower help to improve supply chain visibility?
After the current situation has been analyzed, it is possible to determine how a control tower can improve it. The most important part of this question is to determine what a control tower is exactly and what its contribution to a supply chain can be.

These questions will hopefully be answered by studying the literature about control towers. This literature then can be used to make a design for the control tower for Thales.

What are important input parameters for the control tower
It is important to keep track of the right information within the supply chain. The control tower needs to be able to spot upcoming threats in the supply chain and generate a warning to deal with them, before they become a problem. These threats can only be spotted when the right information is being monitored, so choosing the right parameters is very important.

To determine whether a certain parameter is important or not, the purpose of the parameter needs to be clear. Having too much indicators can also be a negative thing when the goal is to create a better overview, because it can distract from the important ones. So, the first step will be deciding what signals the control tower needs to check. Then, the right parameters can be chosen to notice these signals in time.

When the signals are known, it should also be possible to come up with interventions that can be used in case of these signals.

The parameters will be chosen with the help of the literature and the expected functions of the control tower. The way they behave will be derived from the overview of the supply chain and interviews with stakeholders that are involved in the supply chain.

How could a control tower look like for Thales?
This is basically the goal of this assignment, designing a control tower for Thales. The purpose of this sub question is to develop a model that will show how a control tower could look like for Thales, so to create a prototype of a real, functioning control tower. It will use the input parameters, signals and interventions from the previous sub question and uses them to create a control tower for the upcoming projects.

How can Thales implement a supply chain control tower in their after sales services?
When it is clear how the control tower is going to function, it is also important to determine who will be responsible for using it and making sure that the warning will end up at the right department. Otherwise, the control tower would still have no function.
Thales is a large company and a lot of functions within the company are regulated with standard procedures. Implementing a new way of monitoring and controlling a supply chain may require changes in the current organization. This sub question will provide Thales with recommendation on how the control tower could be implemented and what changes need to be done to do so successfully.

1.8 Deliverables

The deliverables are a result of the research approach and the main question:

- An overview of the current after sales service, the organization and the status of the upcoming after sales service.
- A research on after sales supply chains and control towers.
- A list of the important input parameters and an overview of how they behave within the supply chain.
- The warning signals that can be generated by the control tower and interventions to fix these warnings.
- Recommendation on the implementation of the control tower within the organization

2 The current situation

In this chapter, the sub question: *What is the current situation of the after sales supply chain?* will be answered. It will describe how the current situation looks like. It will show how the organization is designed, how the after sales service of Thales is regulated, how its supply chain looks like and who all of the stake holders are.

2.1 Organization

2.1.1 One Naval

One Naval is the reorganization of the Naval department of TNL and is designed to tackle the obstacles of the current organizational structure (Thales, 2016). The reorganization will merge the three previous organizations (systems, sensors and services) into one integrated organization, which can be seen in Figure 2. In this structure, the seven clusters of the Naval organization (Strategy & Marketing, Naval support, Sales, Project, SSM, Engineering and Supply Chain) are together responsible for optimally serving the customer through integrated total solutions covering the entire life cycle at a competitive price level. So, the intention of this design is to offer a better customer service at lower costs. In Figure 2 the different clusters of the organization can be found, an overview of all the tasks per cluster can be found in Appendix A. These clusters are important when it comes to designing the control tower, because each cluster is responsible for different tasks within the organization. Some of them will possibly provide the input for the control tower, while other clusters will use the output.

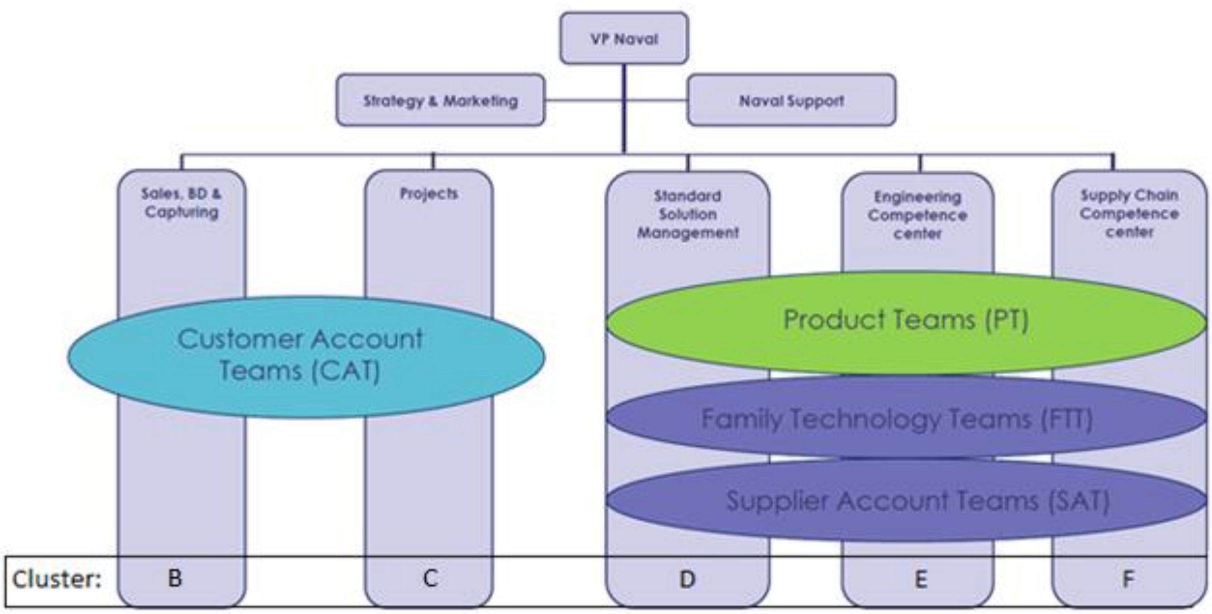


Figure 2: One Naval governance structure

2.2 The after sales service

2.2.1 What after sales service is Thales used to?

The current after sales service of Thales is mainly transaction based. This means, when Thales sells a product like a radar system, the customer can buy an additional package of spare parts. What parts they will buy, how many and what they do with them is all up to the customer. Although, Thales does give a recommendation on which parts to buy and how many. This is all handles by the after sales organization of Thales (the customer contact center). After the sale is done, the spare parts are property of the customer and Thales does generally not get any feedback on what spare parts are actually used and how long it took for the part to break down. The only thing they know is when the customer needs new spare parts, because they will call for a new order. However, it is also possible that the customer had ordered from another company in the meanwhile or cannibalized one of their systems to use its parts.

So, the way Thales is handling its after sales service at the moment barely gives them any feedback on the actually usage of the spare parts. This also means that the logistic engineers of Thales have no idea if their predictions on the amount of initial spare parts are correct. Because the amount of spare parts that Thales recommends when selling a product, is based on predictions by the logistic engineers. Without any feedback, it is not possible to check whether these predictions are right or not. This might seem a problem, but, with the current way of handling the after sales, it does not really matter for Thales. When they sell too many spare parts, it means they earned extra money and will not make a problem out of it, and when they sell too little, the customer will place the next order earlier than expected.

Because everything is transaction based and there are no performance based contracts, Thales will not be penalized for having long delivery times, other than maybe annoy the customer. The only thing they need to worry about is delivering the product on the day they agreed on with the customer. This means that Thales does not need to have a lot of parts on stock and is more flexible with ordering new parts only when they need them, they will just have a longer lead time for the customer. One thing they are doing now is to just have cheap, general items on stock (soft pegging parts) and place an order for the more specific and expensive parts (hard pegging parts). An overview of the customer service flow can be found in Figure 3. Because customers usually do not return any feedback or used/unnecessary spare parts, there are no direct reverse logistics involved in the supply chain.

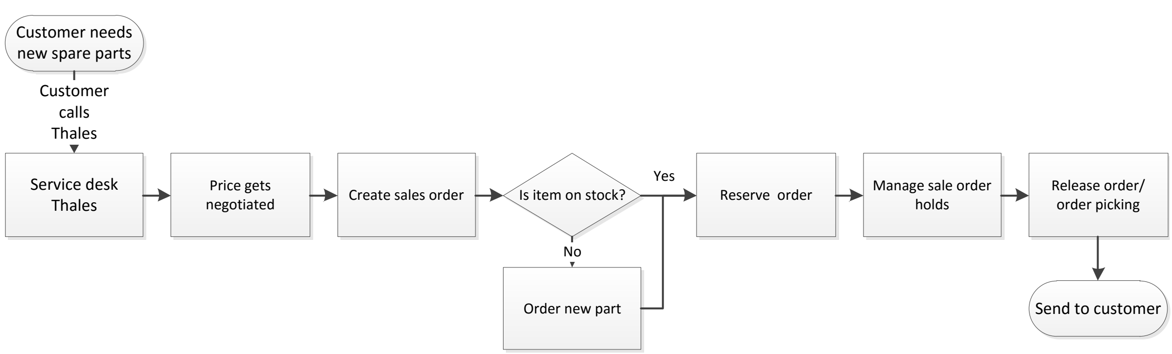


Figure 3: Customer service flow

Customers can also call Thales when they have a part that needs to be repaired. The flow looks similar to the flow of the procurement of a spare part, except there are multiple options of what can happen to the part and will repair it. An overview of the service flow for the repair can be found in Figure 4.

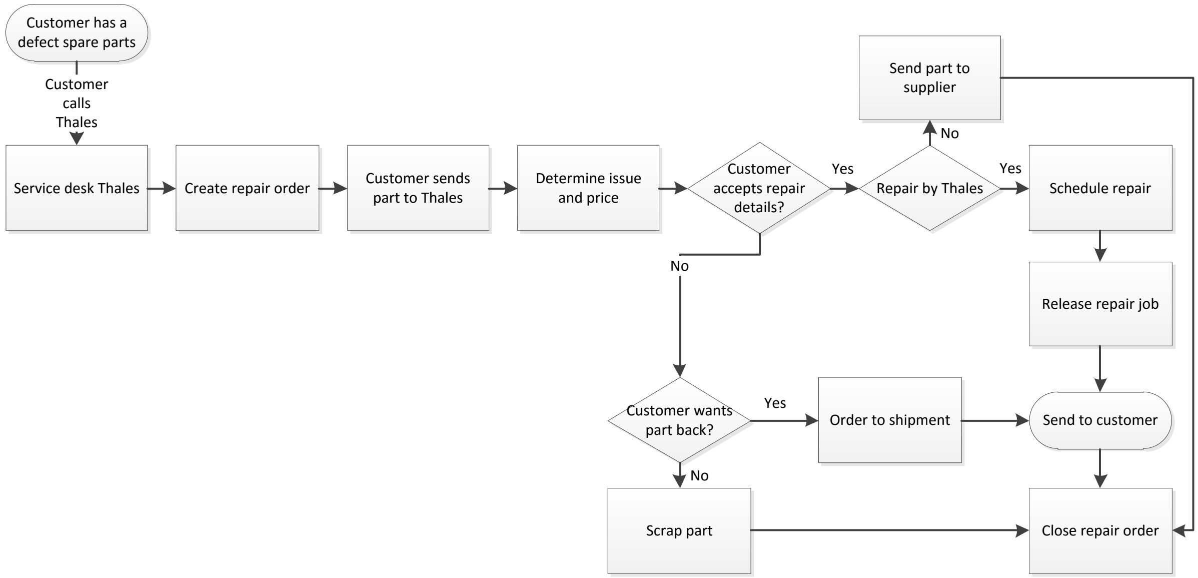


Figure 4: Customer service flow repair

2.2.1.1 The current dashboard

Inventory management:

The dashboard Thales currently has for the inventory of parts is based on the planning of orders and the expected and known demand. This way, the dashboard can calculated the cumulative stock level every time a spare part get ordered or used. This way, Thales knows when the stock level drops below the re-order level, so they can order new parts. This dashboard includes both parts meant for production and spare parts for the after sales. It is also not based on real time information, but gets updated once a week. The fact that Thales already takes the expected upcoming demand in account when they calculate the stock levels could be useful for the control tower. Things that needs to change however is that it should separate spare parts from production parts and it should update as soon as a stock mutation happens, so when a part gets used that is not planned.

Customer service:

The customer service also has a dashboard already. This dashboard focuses on how well Thales has performed in the previous period, with respect to the spare parts order handling process. So, it is a tool that can be used to get feedback on the performance of the after sales. The KPI's it keeps track of are: On time delivery, Average lead times and shipment facts, Backlog, Average days late and the created order lines. All of these KPI's are based on the orders that are placed and the shipment dates that are agreed on with the customer. The performance on the KPI's gets updated after every period. The same KPI's are used to check the performance on the repair orders of parts. Because all of these KPI's are checked only after a certain period, the dashboard is completely reactive. The main advantage of a control tower is that it can be used proactive.

Some of the KPI's of this dashboard will not be very useful for the control tower, like backlog and average days late, but the others could be useful additions. It will be useful to keep track of how long it takes to repair a certain issue and how often it occurs.

2.2.2 The new type of service contracts

For their upcoming two projects (A and B), Thales introduces a new type of after sales service, namely service contracts. Both project A and B have a service contract, but the agreements are slightly different.

For project A, Thales has sold two Smart-L EWC radar systems to customer A, which will be placed on two different locations in the Netherlands. For these two systems, Thales has the responsibility to keep them up and running and they agreed to maintain a certain operational availability. The service contract is set at an operational availability of 90%. This means that the radar systems may only be down for maintenance and repair maximum 10% of the time. This counts 24/7, not just during regular working hours. Exceeding this maximum will result in significant penalties, as can be seen in Appendix B. The values in the second column are the penalties during the training period of the radar systems. During this period, an operational availability of 80% must be reached and better results will be rewarded with credit that can be used to compensate possible penalties in the future.

Project B is slightly different. For this project, Thales has sold 4 Smart-L EWC radar systems to customer B and these systems will be installed on four different ships, with their main harbor in the Netherlands. For this project, customer B will be responsible for the maintenance of the systems themselves and Thales has to guarantee 90% spare parts availability (logistic availability). So when Thales receives an order from the harbor, there is only a "down time" of 10% allowed. In this case down time counts as the time that customer B needs to wait on a spare part, when they are out of stock and already placed an order. The orders can only be placed at regular working hours. The penalty scheme for this project can also be found in Appendix B. Because customer B handles the spare parts from the moment that they are delivered at the harbor, Thales does not have the complete overview of the parts. So, it is important that there is clear communication between customer B and Thales, so Thales is up to date of the status of their spare parts.

The projects have the same type of radar systems, so they use the same spare parts. It is possible to exchange spare parts between the projects.

	Project A	Project B
Customer	A	B
Amount of radar systems	2 (placed in two different locations in NL, the radars are controlled from a central point)	4 (placed on four different ships, with their main dock at a harbor in the Netherlands)
Type of service contract	90% Operational availability per radar per year. Or Max. 10% down time	90% Spare parts availability per sailing period per year. Or Max. 10% "down time"
Definition of down time	The time that the radar sensor is not functioning according to the customer A.	The time that customer B has to wait on their order while their radar system is down.
Downtime counter stops when	The radar system is functioning again.	The spare part is delivered at the harbor. Further transport to the ship is the responsibility of the customer.
How has Thales prepared for the demand of needed spare parts	Thales has spare parts on stock based on: The planned preventive maintenance in the "periodieke onderhouds kalender" (POK) of Thales' logistic engineers The predicted corrective maintenance by Thales. (based on stochastic (Poisson) distribution of the MTBF)	Thales has spare parts on stock based on: The planned preventive maintenance in the "Operationele jaar planning" (OJP), made by the customer The predicted corrective maintenance by Thales. (based on stochastic (Poisson) distribution of the MTBF)

Table 1: Overview of the projects

2.3 The supply chain

The supply chain can be found in Appendix D, but the stakeholders and other aspects of the supply chain will be discussed in this paragraph. When possible, the stakeholders will be linked to the clusters of 2.1.

2.3.1 Stakeholders

2.3.1.1 Suppliers

There are two kinds of suppliers in the supply chain: regular suppliers and subcontractors. The regular suppliers function just as always. Thales needs to go through the same flow as they used to; decide a price, place an order and after a certain lead time the part will be delivered at Thales.

The subcontractors do have a contract with Thales to have a certain availability of their parts. Figure 5 shows the radar system that will be delivered to the customer A. The radar system on top will be produced by Thales, but the radar tower, liquid cooling system and power distribution system, as well as their spare parts, are produced by a subcontractor. Thales relies on the availability of spare parts to keep the radar system running and meet the contract, so they also need to be able to use the spare parts of the subcontractor any time they need them. The subcontracts are not yet set, but will possibly contain agreements about the availability and repair of the spare parts. This also counts for the regulator suppliers

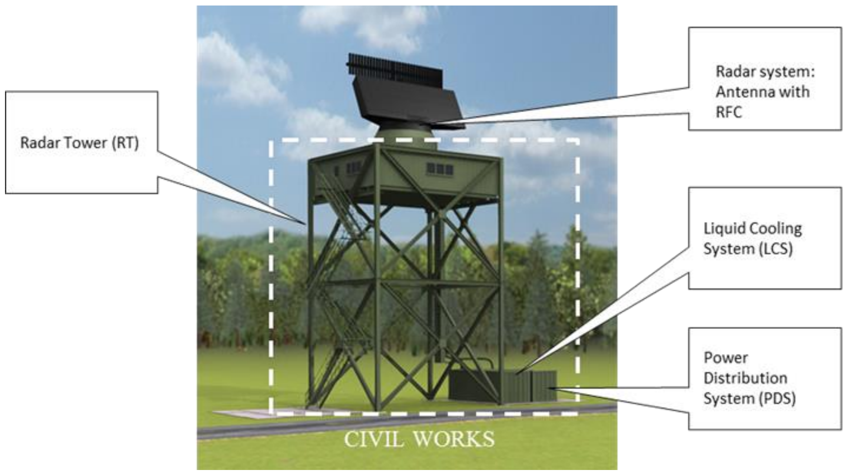


Figure 5: Radar system (land)

2.3.1.2 Thales

Within Thales there are several stakeholders. In Chapter 6.2.2 the responsibilities of the stakeholders will be discussed, but here they will be already announced with their possible benefits and roles with respect to the control tower. Not all of these stakeholders are yet present in the current situation of Thales, but this is a proposal of how it will look.

2.3.1.2.1 Customer contact center (Cluster C)

The customer contract center (CCC) is the place that customers call when they are having problems with their products. The CCC tries to offer help and when they do not have the sufficient knowledge or skills, they sent the issue to the appropriate person. This is also something that fits the activities of a control tower, making sure that the issues end up at the right department, so that actions can be performed.

2.3.1.2.2 Logistic Engineering (Cluster E)

Logistic engineering is responsible for the forecasts of the initial spares and the planning for the preventive maintenance. They also calculate parameters like the MTBF, which can be used to predict the demand of the corrective maintenance. So, the logistic engineers deliver very important input for the supply chain and thus for the control tower. On the other hand, the control tower could allso benefit them by giving information whether their forecast was correct or when parameters are changing.

2.3.1.2.3 Supply and logistics (Cluster F)

Supply and logistics is responsible for purchasing, warehousing, shipping and reverse logistics, making sure that the spare parts are at the right place at the right time. They are have to cooperate with the repair department to adjust the inventory level with the time to repair a spare part. The output of the control tower could be very useful this.

Warehouse (manager)
The warehouse at Hengelo (TNL) is the main location where the spare parts will be stored. The control tower needs a real time input of what spare parts are on stock and what their location is, so the warehouse manager is an important stakeholder for the input of the control tower. The exact location and manner of storing the spare parts is not yet decided, but having a clear separation between spare parts and production parts could be useful. It should also be 24/7 accessible by the service engineer.

Reverse logistics
Project A: In project A, the maintenance will be performed by Thales, so all the used and/or spare parts also return to Thales where can be decided to repair or scrap them. It is also possible that the parts cannot be repaired by Thales and need to be sent back to the original supplier for repair. On the other hand, the reverse logistics also consist of unused spare parts, which have been brought to the radar system during corrective maintenance, but were not necessary and return to the warehouse. When this is not registered properly, the inventory might be bigger than on paper and unnecessary spare parts will be bought, or they might unexpectedly run out of stock.

Project B: At project B, the radars are stationed on board of four different ships and all preventive and corrective maintenance will be performed by customer B. To make sure that the overview of the spare parts remains, Thales has stated in the service contract that every spare part that has been replaced, repairable or not, will be returned to Thales. In this case, returning to Thales mean that the broken spare part has to return to the harbor within 60 days. As soon as it is delivered there, it counts as possession of Thales again and Thales will be responsible for further transportation. From here, Thales will retrieve the part and it will be repaired by Thales, repaired by the supplier or thrown away.

2.3.1.2.4 Maintenance (Cluster F)

The name says it already, but the maintenance department is responsible for the preventive and corrective maintenance, so they follow the maintenance planning, but also need to repair the radars as soon as possible, when needed. They will be the main users of the spare parts. It is important the parts are available when maintenance needs them, but it is also important that they pass on the information when they use spare parts, so the stock level get adjusted right away and the control tower can send a warning when it is necessary.

2.3.1.3 Customers

As was mentioned before, there are two customers: A and B. An overview of the customers and their contracts with Thales can be found in Table 1.

2.3.1.3.1 Customer A

Customer A has bought two radars that will be placed at two different locations in the Netherlands. They will have a central control point, controlled by the customer. Thales will be responsible for the up time of the radar systems. This means they will have to perform maintenance and repair work when needed. The spare parts are always in possession of Thales, so when they replace a part at the radar, they bring the part from their warehouse and return with the broken part. Then this part can return in the supply chain via the reversed logistics or be scrapped.

2.3.1.3.2 Customer B

Customer B has bought four radars that will be placed on four different ships. The ships will have a main dock at a harbor on the coast of the Netherlands. Thales will be responsible for the spare part availability when the customer places an order. Spare parts will be delivered to the harbor and the customer will make sure the parts end up on the ships. The spare parts remain property of Thales until they are installed in the radar, from that moment they belong to the customer. As soon as a spare part gets replaced and is taken out of the radar it belongs to Thales again. When it gets taken out of the radar, but the ship is at sea, customer B has 60 days to return the part to the harbor. All replaced parts must return to Thales, repairable or not, to make sure the overview of the spare parts remains. The ships of customer B operate according to a mission schedule. When there is no mission, the ships will be docked in the harbor, where they are maintained. As a standard, there will be always at least one ship docked at the harbor. The complete overhauls of a radar system are not included in the service contracts, but are arranged separately.

2.3.2 Possible locations of spare parts

In the contract, the main locations for the inventory are the set as either at Thales in Hengelo or on board of a ship. The logistic engineers already included these locations in their initial spare part calculations. However, other possible storage locations may also play a role in tracking the spare parts, so the possible locations are:

Main storage locations

- TNL Hengelo
- On board of ship

Other locations

- At a land radar
- Transport vehicle

  The maintenance vehicle could offer room to store spare parts, but an interview with the Test & Integration department, the department that will be responsible for the maintenance of the radar systems of project A, indicated that this will only be possible for consumable. The vehicles are unconditioned, so spare parts could deteriorate unnecessarily fast. (Dam, 2016)
- At the harbor
- Repair shop
- Supplier
- Subcontractor

2.4 Conclusions

Thales has been busy to reorganize to lay more focus on the whole product life cycle, instead of just the sales of new products. However, the existing after sales service is still based on order-driven service. The customer places an order for spare parts or a part that needs to be repaired and Thales delivers. This way the amount of feedback that Thales received from the customer was very little. Customers do not provide feedback on the actual usage of parts, only on the amount they order. This may very well differ, due to multiple causes.

Thales does use some dashboards, which are spread out over multiple clusters, to monitor this service. The dashboard of the Customer Service uses a dashboard to reflect on the service they delivered in previous periods, with respect to indicators like on time delivery and the amount of order. The inventory department has a dashboard that tracks the inventory levels of the spare parts. This dashboard includes the planned demand to calculate the cumulative stock levels in the future, to know when the reorder level is reached and a new order needs to be placed. This, plus the option to assign a location to the spare part, could be useful functions for the control tower.

The supply chain of the after sales service for the new service contracts has also been determined, giving an overview of all the entities and stakeholders, which can later be used to in the design phase of the control tower.

3 The theoretical framework

This chapter will be used to find out if there is existing literature that can help with the understanding of supply chains and after sales services. The literature will also be searched for a framework that has been used in earlier research to set up a control tower.

3.1 After sales service

After sales service includes all the services provided during and after the sale. This can involve keeping contact with the customer, helping them install their product, but here will mainly be looked at how the company handles the maintenance and repair after the sale. These services become more and more important in today's market, because the perceived value of is changing. Instead of just looking at the product they are buying, customers look at the whole package and base the value of the product on that. Studies have proven that there is a correlation between the successful use of after sales service and both the customer satisfaction and stock price of the company (Cohen, Agrawal, & Agrawal, 2006). Cohen et al. (2006) define seven different types of business models of after sales services (Appendix C). These business models range form none (where the customer just throws away the product when it is broken) to a "power by the hour"-service (where the customer only pays when he actually uses the product, the product itself and its maintenance remains the suppliers responsibility). In the case of Thales, they come from an ad hoc type of after sales services, based on the current situation and move towards service contracts that can be compared to the performance based model. Thales has a couple of big upcoming projects, where they will sell radar systems. Together with these systems, they will also sell a service contract. With this contract, the customer will pay a monthly fee and in return, Thales makes sure the system will be maintained and keeps running at a high quality. This means that the product is owned by the customer, but Thales is fully responsible for its performance. When Thales cannot meet these requirements they risk a penalty. To make sure this will not happen, they have to be able to perform all planned maintenance and the radar needs to be repair as quickly as possible, when it goes down due to failure. This means that Thales needs to make sure there are enough spare parts in their inventory, when they are needed. To make sure that the inventory stays high enough, without overstocking, companies use spare parts management.

3.2 Spare parts management

Having spare parts in inventory is necessary when a company wants to provide a high service level, however having too many spare parts in stock has multiple disadvantages. Having an inventory costs both space and money and on top of that, stored spare parts also need to stay in good condition, so they need to be controlled and possibly maintained.

With spare parts management, companies try to find the ideal amount of spare parts to keep in stock. Logistic engineers use statistical models to predict the amount of spare parts in the future and companies can use these predictions to make a procurement planning. However, there are many different ways to manage the spare parts. For example, a product can often be broken down in modules, which can be broken down in sub-modules and finally into individual parts. Replacing a whole product when the original is broken is faster than replacing individual modules, but it also is more expensive. The same counts for modules and sub-modules. Although slower, a company can probable more flexible with repair and inventory when they only have spare parts in stock. All of these aspects are important with spare parts management. This is called the product hierarchy (Cohen, Agrawal, & Agrawal, 2006). Another aspect is the geographical hierarchy. For example, Thales can choose to store all its spare parts in a central warehouse, which means they can divide their spare parts over all the customers, but can also choose to store them at local warehouses or even at the customer, which means they will need more spare parts in total, but the response time will be much higher.

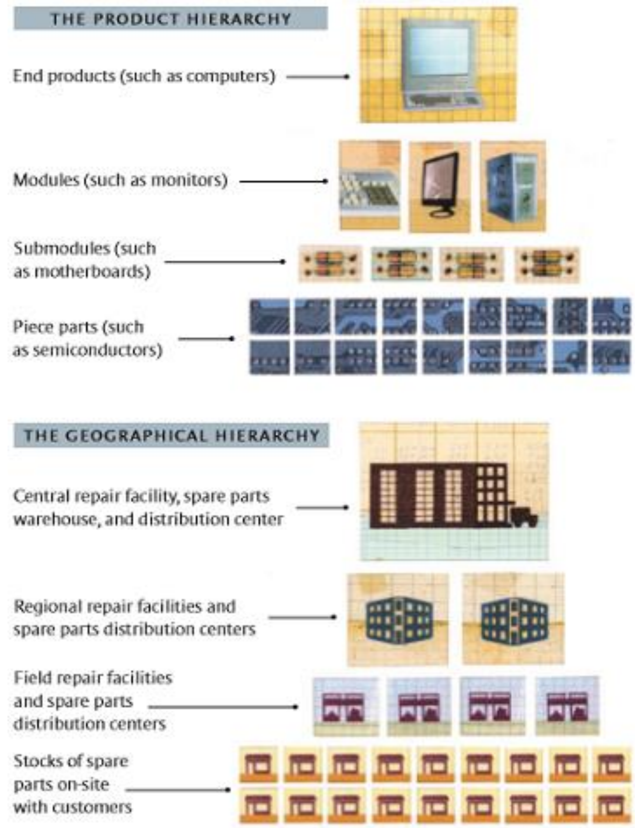


Figure 6: Product and geographical hierarchy (Cohen et al., 2006)

The performance of the spare parts management can be measured with two kinds of metrics (Cohen, Agrawal, & Agrawal, 2006). Customer-focused and internally focused metrics. Customer-focused metrics can include waiting time for technical assistance, waiting time for diagnostics and waiting time for spare parts, that can measure the customers' perception of the spare parts management. Internally focused metrics can include fill rate per SKU or the obsolescence costs per SKU.

3.2.1 Repairable inventory systems

Repairable inventory systems are systems in which failed parts are repaired and returned to service, rather than scrapped (Hausman & Scudder, 1982). This system is often used by companies that use and/or maintain high value capital assets. In case of Thales, these assets are the radar systems that they need to maintain according to the service contract. The assets are maintained according to a 'repair-by-replacement' strategy: parts that require maintenance are removed from the asset and replaced by a working spare part (Dinalog, 2015). When there are no available spare parts on stock, the repair request will be backordered and fulfilled as soon as the requested part becomes available. This means, however, that the asset will be down until the maintenance can be fulfilled.

The amount of stored spare parts depends on the rate and sequence in which the repairs are conducted, including a certain safety stock. This requires a certain level of coordination between the inventory department and the repair shop, otherwise the inventory department may plan its stock levels based on wrong expectations. The inventory department often assumes a fixed lead time, when they determine the stock levels. In practice however, the repair time can be dependent on uncertain factors; the part may need a specialized technician with a high occupancy rate or recourses that need to be ordered. Clear agreements between the repair shop and inventory department is necessary and defining the structure of the repair shop helps with this.

3.2.2 Repair shop type

(Driessen, Wiers, van Houtum, & Rustenburg, 2013) has defined four types of repair shop structures. These types are based on the variables: Capacity complexity and material uncertainty (Figure 8). Capacity complexity concerns the requirements of specialized skills of repair men to complete a repair job. Material uncertainty is the extent to which repair jobs for the same spare part require different materials. The repair shop at Thales that is important in this assignment score high on both variables. The capacity complexity is high, because it involves the repair of large unique radar systems. A lot of specialized knowledge and experience is involved with the design, and also the repair, of a system like that. This knowledge and experience has been build up through many years of work and is not easily replaceable. There is also specialized tooling involved for radars like this. The material uncertainty is high because a large part of the repairs are electronics and PCB's. These kinds of parts can require a lot of different materials to fix them. Another reason for the high uncertainty is because the same type of part needs to be used for many years and there is a risk that these parts or the necessary materials become obsolete. Scoring high on both variables, the repair shop in the supply chain of this assignment will be a type IV shop.

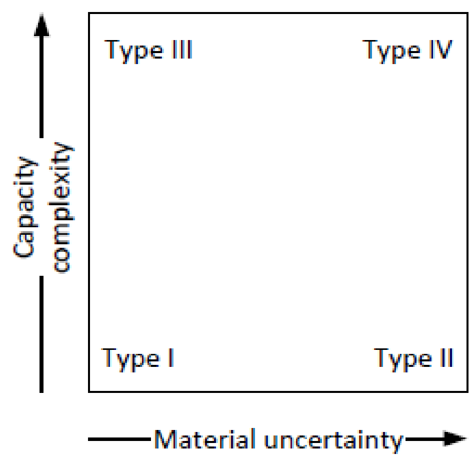


Figure 7: Typology of repair shops for maintenance spare parts (Driessen, Wiers, van Houtum, & Rustenburg, 2013)

Besides defining these four different type of repair shop, Driessen et al. have also designed a control structure per type that can be used to set up or redesign the control structure of repairable inventory systems (Driessen, Rustenburg, van Houtum, & Wiers, 2014). Only the control structure for the type IV repair shop will be discussed though, since this is the only relevant type for this assignment.
Because the type IV repair shop is characterized by a high capacity complexity and material uncertainty, the main issues, that cause the uncertainty in repair time, often is the lack of certain materials or specialized technicians available. The control structure tries to solve this by decoupling the inspection and the repair phase of the repair process. This way the defect LRU's (Line Replaceable Unit / Spare parts from the radar), can be inspected en planned accordingly, resulting in a more reliable repair time estimation and is the inventory department able to make a better estimation of the needed LRU's. The inventory departments is also responsible for the SRU's (Shop Replaceable Units), that are needed to repair the LRU's.

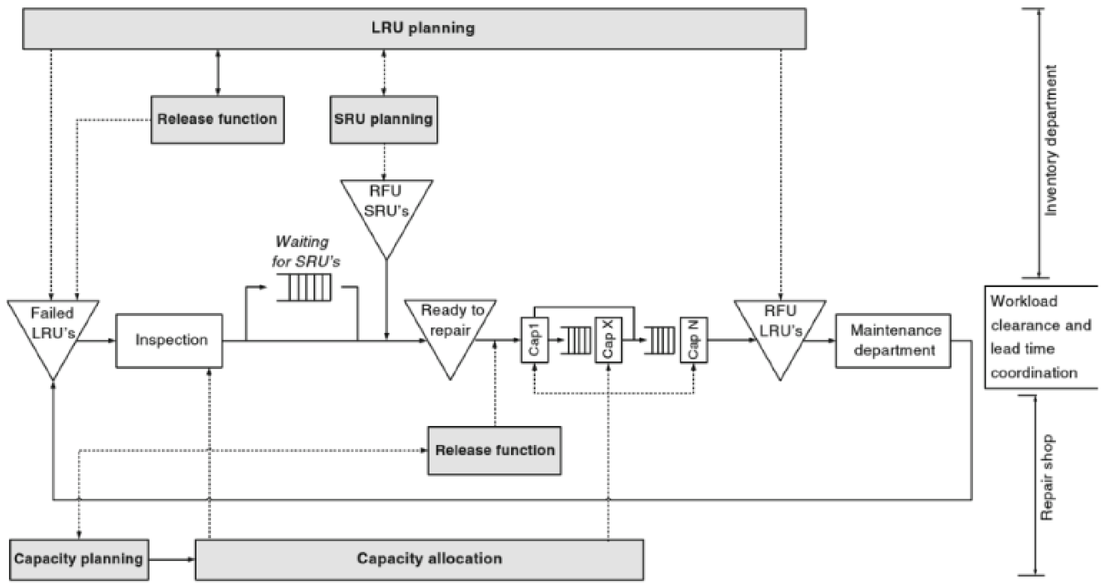


Figure 8: Process and control structure design (Driessen et al., 2014)

3.3 Maintenance strategies

Maintenance can be divided in reactive and proactive maintenance, where the asset is replaced or repaired either after or before it fails (Kothamasu, Huang, & VerDuin, 2006). Figure 10 gives an overview of the types of maintenance and their characterizations.

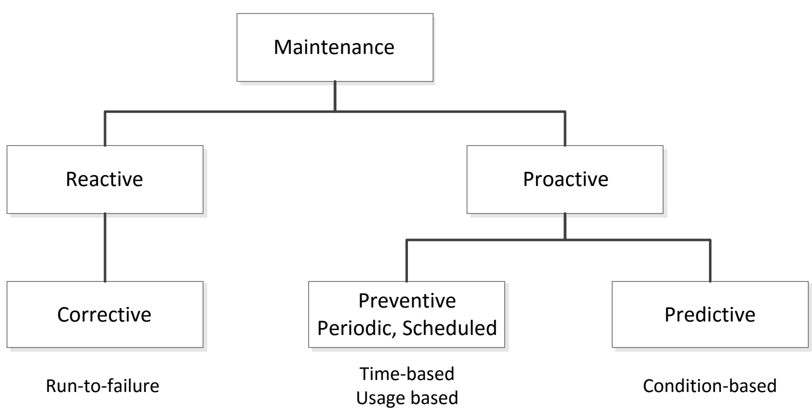


Figure 9: Categorization of maintenance strategies

Of these types of maintenance, Thales will perform corrective and preventive maintenance on the radar systems of project A.

Corrective maintenance:
Maintenance that will be performed after a breakdown occurs and the asset is down. Maintenance workers will replace the broken part with a functioning piece and make sure the asset is working again. This type of maintenance does not require a maintenance planning, but does require maintenance worker to stand by and available spare parts, in case there is a breakdown. This is especially true in the case of Thales, since the service contract of project A states that the radar systems may only be down max. 10 percent of the time. Because corrective maintenance is unplanned and can randomly occur,

spare parts management is very important. Having enough spare parts on stock is essential to keep the downtime at a minimum.

Preventive maintenance:
As the name describes, preventive maintenance is used to prevent breakdowns of the system. The maintenance is planned a long time ahead, in the case of Thales the preventive maintenance planning is set for the coming 4 years. This maintenance does include replacing spare parts that are expected to be worn out after a certain amount of time or working hours, as well as replacing consumables like oil filters and electrical cables. Preventive maintenance also requires the availability of technicians and spare parts, but because all the maintenance is planned, it is much easier to make sure everything is available at the right time. (Yan, Tan, Koh, Tan, & Zhang, 2012)

3.4 Supply chain control towers

The concept of the supply chain control tower has been gaining momentum over the past few years. A general used definition of a supply chain control tower is:

"A supply chain control tower is a central hub with the required technology, organization and processes to capture and use supply chain data to provide enhanced visibility for short and long term decision making that is aligned with strategic objectives" (Bhosle, Kumar, Belinda, Rob, MarieAnne, & Adrian, 2011).

So, a control tower monitors the information of the supply chain. When this information shows any upcoming risks or unexpected events, the control tower can create a signal and make sure that it reaches the right person, who can act on the signal and make sure that the risk does not become a problem. This way, there will be a single point of contact, the control tower, that checks all the necessary information of the supply chain. Having a single point of contact will provide a high level of visibility along the supply chain.

CapGemini (Bhosle et al., 2011) has defined different level of supply chain visibility, depending of the phase in which the control tower is. These levels of visibility can be found in Table 2 on the next page.

Supply chain visibility
Phase One - At the most rudimentary level, the focus is on achieving operational level visibility on supply chain data such as shipment and inventory status. The scope of the solution is usually limited to one or two processes, such as either outbound or inbound logistics depending on the strategic importance of one or the other. The tools focus on collecting data. The capabilities of staff are very much on operational level.
Phase Two - The second phase focuses on following the status of shipments across multiple supply chain nodes and tracing the problems occurring in between. The scope includes all the processes related to inbound and outbound logistics. The tools provide alerts for exceptions and events. These applications are incorporated with some basic reporting and analytics capabilities and a knowledge bank for decision support. The organization and supporting staff has capabilities to pro-actively act upon (potential) issues in the supply chain.
Phase Three- The third (advanced) phase, known as predictive visibility, focuses on self-learning algorithms to predict the potential problems and generate alarms for upcoming events. These solutions are gaining popularity by providing proactive monitoring of supply chain functions and helping with decision support systems. This type of visibility is useful in the short term, assuming the operations provide the real time information. Such visibility also enables improved planning capabilities and allows shippers to make better tactical or strategic decisions on optimization of the supply chain.

Table 2: Supply chain visibility

Looking at the current situation of Thales, as has been described in Chapter 2, it is fair to say that Thales has barely reached phase one in creating supply chain visibility, the way Thales is gathering information of their supply chain is very spread out. Every department has his own way of keeping track of the information, which results in a silo-based operation, where information does not really leave its department. Moving from this phase to phase one will be a very big first step.

Furthermore, CapGemini has defined these steps to create a successful control tower

- Deciding on the goals and objectives of Supply Chain Visibility
- Identifying the list of functions, processes or departments to be monitored
- Determining the new organizational design
- Identifying which functions or processes can be run collaboratively or outsourced
- Deciding the technology solution to be implemented and potentially selecting a solution provider to build the Control Tower
- Deciding whether to outsource the Control Tower operation or manage it in-house

These steps go much further than just designing the control tower, like determining whether there are functions that have to be outsourced and who will build the control tower, but the order in which to approach the design do get clear.

3.5 Supply chain visibility

So, a control tower is a tool to create supply chain visibility. There is not an exact definition of supply chain visibility, but there is a general trend in the definitions:

"Supply chain visibility is the capability of a supply chain player to have access to or to provide the required timely information/knowledge about the entities involved in the supply chain form/to relevant supply chain partners for better decision support." (Goh, De Souza, Zhang, Wei He, & Tan, 2009)

"Supply chain visibility refers to an organization's ability to collect and analyze distributed data, generate specific recommendations, and match insights to strategy." (Tohamy, Orlov, & Herbert, 2003)

For this assignment, these two definitions will be combined to: An organization's ability to collect and analyze available data in the supply chain, generate specific recommendations and making sure that the data and recommendations are provided to the relevant supply chain partners for better decision support.

(Yan, Tan, Koh, Tan, & Zhang, 2012) have developed an approach to increase the supply chain visibility within a company, the S-ConTrol approach. It consists of two phases, the first phase is a two-stage analysis process, to find out what the needs of the business are and to identify the challenges, and the second phase is the implementation of the solution.

Analysis phase
The first stage of the analysis phase is a top-down business analysis. The objective is to get an understanding of the company's business, finding out what the challenges and issues are at the moment and to find ways to solve them. The steps in this analysis are:

- Identify key customer requirements
- Map the current business and operational processes.
    - Mapping out as-is process and the supply chain network
    - Determining the critical points within the supply chain network
- Identify the challenges and gaps
- Plan the new business and operational processes
- Plan the IT framework to support the new business and operational processes

The second stage of the analysis phase is a bottom-up data analysis. This analysis is used to find out what data is needed and where this data comes from. Its three main purposes are:

- Understanding the requirement of the target data
  At the first stage of the analysis phase, the key requirements of the customer are determined and the challenges are defined. Now the task is to find out what data is required to gain more insight in these challenges.
- Understanding the data source
  Knowing what data is needed is the first step, but acquiring data at a company is not as easy as it sounds. Most companies use various ways to manage all their information and use different kinds of software (CRM, ERP, Excel). This step includes identifying the data formats of the source data and determining data relationships and dependencies between different tables. Do serial numbers of the same part match for example.

- Mapping the source data to the target data
  The final step is to establish the relationship between the data source and the target. How can these different sources come together and be used in a single control point.

Implementation phase
In the implementation phase, the software architecture is defined. In the case of the paper that is used (Yan, Tan, Koh, Tan, & Zhang, 2012), a custom designed software system has been used, S-ConTrol. This system consists of a data converter, which checks the data quality and converts the data from the ERP of the data sources to its own database. Besides that, it consists of a B2Bi Gateway that provides connectivity between supply chain partners and a master data profile management, which feeds the necessary data to applications like demand management, inventory planning, order tracking, event notification/alert, report and order consolidation. As said, this is a custom design system, so it will not be used in this case, but to use similar components seems viable.

3.6 Implementation of the theory (Conclusions)

The theories in this chapter have provided background information about after sales services and spare parts management, and have shown some approaches on how to design a control tower and how to gain better supply chain visibility for a supply chain. These theories may not all be focused on after sales services, but the general approach can be used to design a control tower for the after sales supply chain of Thales.

The theory shows that Thales is coming from an ad hoc after sales service, where the customer basically pays for a service when they need it, and they move towards a performance based service. This means that the service priority shifts form low to very high all of the sudden. This sudden change can cause problems when the overview of the service is lost. Because the service priority is very high, the customer is expecting more and when these expectations are not met, Thales will be penalized. That is why a system that can provide overview is so important.

The theory also showed that there are multiple maintenance strategies that should be considered. Corrective and preventive maintenance have very different demand patterns. Preventive maintenance is planned, so the inventory should be tuned with this planning, but the corrective maintenance is random and the demand can only be estimated with the mean time between failures (MTBF) for example, so keeping the inventory at a certain stock level is much more important. This asks for a more intense monitoring policy and perhaps different data.
For Thales, the control tower will be more important for the corrective maintenance. The preventive maintenance is planned, so Thales should be able to purchase the required spare parts in time for the maintenance. The corrective maintenance will be a much bigger problem for Thales. Their performance with respect to the service contracts is mainly based on how fast they can solve this corrective maintenance. The control tower can be a big help with help with this, accurately showing the locations and stock levels of the spare parts and warn when there are irregularities or threats that could indicate a possible disability to perform the corrective maintenance.

The researchers at CapGemini described a control tower as an information hub that can detect risks and help with the long- and short term decision making, so to help both on tactical/strategic and operational level. Helping on tactical level could be monitoring the parameters that have been used to predict the initial spare parts. When these parameters change, the predictions probably need to be recalculated. What Thales wants however, is a control tower that can monitor the processes on an operational level

and indicate the risks that they will not be able to perform the maintenance. Of course, the predictions on the required spare parts are important in this, but what they really want is to detect the risks on operational level, to warn them when they need to intervene and replenish some spare parts for example. (Harperink, 2016). This will be the first step to get visibility to perform the operation.
This vision of the control tower highly corresponds with the functions that CapGemini describe as phase one of creating supply chain visibility (Table 2). Because Thales is sort of stuck in "phase 0" in their current situation, task one will be to design a control tower that can monitor the supply chain. When that is achieved, possible risks and interventions could be implemented (Phase two in Table 2).

The two approaches of setting up a control tower and gaining supply chain visibility do share some similarities. Step one of the control tower approach is to decide on goals and objectives for supply chain visibility and both of them involve identifying the current processes and determining new ones. Because of the similarities, the two approached will be combined in order to create a successful control tower for Thales.

- A first logical steps seems to decide the goals and objectives of the control tower, based on the key customer requirements.
- Then using the analysis of Chapter 2, of the current situation, to identify the list of processes and parameters that need to be monitored and determine what signals can be detected.
- Try to design a control tower, check whether all the parameters that need to be monitored are available and how they can be translated to signals.
- Determine how a supply chain control tower can be implemented in the current organizational structure of Thales and who will be responsible.

4 The control tower design

The control tower will function on the operational level, it monitors the status of the supply chain when the projects are in progress. This means that its task is not so much to check whether the initial predictions were correct or not, but to monitor the mutations in the supply chain and to tell the user when someone needs to perform an action. The main objective of the control tower is to make sure that Thales is able to adhere to the requirement of the contract. This means that they always need to be able to perform maintenance or to deliver a spare part. So, the control tower needs to be able to pick up signals that indicate a risk of not being able to perform maintenance, but what are these risks? This assignment constraints to just looking at the physical parts (spare part, STTE's and consumables) and the corresponding processes and information flows (purchasing, warehousing, maintenance, delivering and repair). These processes mainly relate to the stock mutations of the parts. The cost aspect of keeping inventory and performing action will not be within the scope of this assignment.

4.1 Function of the control tower

Before starting to design the control tower, its function needs to be clear. In chapter 3.4 a control tower was described as:

"A supply chain control tower is a central hub with the required technology, organization and processes to capture and use supply chain data to provide enhanced visibility for short and long term decision making that is aligned with strategic objectives"

For this assignment there will only be tried to improve the supply chain visibility on an operational level. Since the projects can be divided in multiple phases, it is important to make a clear distinction. The project can be divided in two phases, the initial phase and the operational phase.

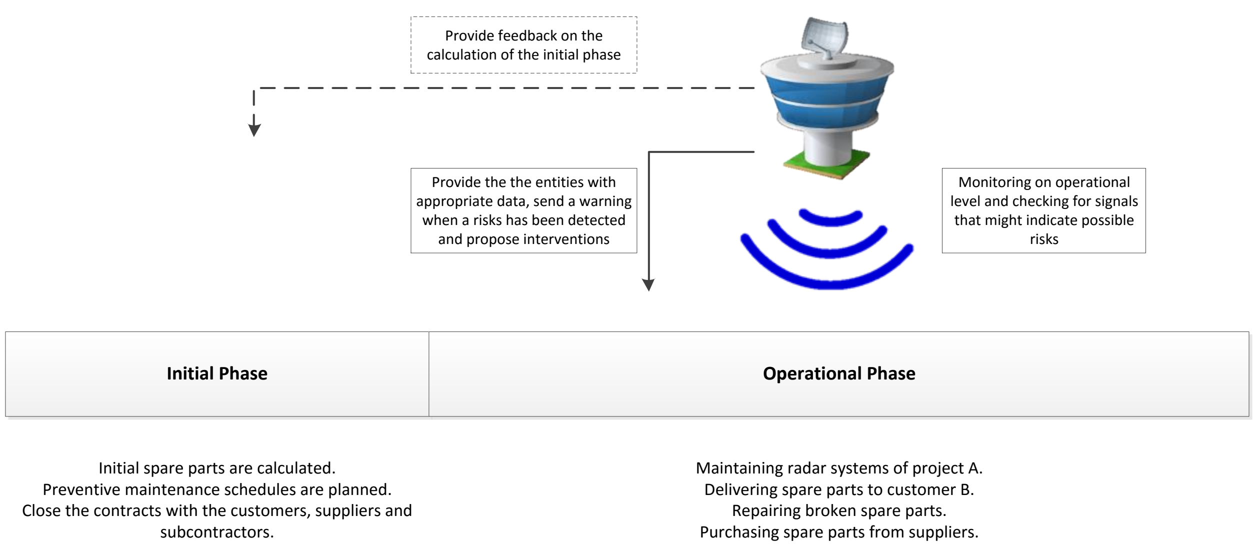


Figure 10: Phases of the project

Initial phase

During the initial phase, the stock levels of the initial spare parts for both project A and B are calculated by the logistic engineers. With these stock levels, Thales should be able to perform all preventive and corrective maintenance. The initial spare part calculations include the preventive maintenance planning, expected MTBF, the location and the mission schedules of the ships. Since the control tower focusses on the operational level for this assignment, the initial stock levels are assumed to be correct. However, to make sure that the logistic engineers get feedback on their calculations, to see if they were correct or should make recalculations, the data about the spare part usage, gathered by the control tower, could be sent to the Logistic Engineers department. This is not part of this assignment however.

Operational phase
During the operational phase, the project will be executed. The radar systems will be operational and Thales has to make sure that they will stay operational. This involves maintaining the radar systems of Project A, repairing defect spare parts, delivering spare parts to customer B and purchasing new spare parts when needed. All of these actions influence the location and stock levels of the spare parts and after every mutation, the status of the supply chain needs to be updated to check whether everything is going well or an actions needs to be performed.

In this assignment, the control tower only monitors the physical flows of the spare parts, STTE's and consumables (these will be summarized as spare parts) and the information flows that are involved with these spare parts (purchasing orders, repair orders, orders of customer B). It will not monitor items like log files or the availability of service engineers for example. The control tower will be functioning in the operational phase and keep track of the operational status of the supply chain

4.2 Key customer requirements

The two most important customer requirements, with respect to the spare parts, are derived directly from the service contracts in Ch. 2.2.2, namely the operational and logistic availability, for project A and B respectively.

For Thales, the most important thing is to fulfill these requirements, since the consequences of not fulfilling them cost a lot of money. However, on the other side, Thales does not want to have an unnecessarily large inventory. Because the costs are not included in this assignment, the focus will lie on the requirements of the customer, not the cost requirement of Thales.

Stakeholder	Key customer requirement	Main situations to prevent
Customer A	> 90% Operational Availability (= the % of time that the radar is functioning properly per year)	Thales is not able to perform preventive/corrective maintenance on the radar of Project A. The radar exceeds the 10% of downtime per year.
Customer B	> 90% Logistic Availability (= the % of time that Thales is able to provide customer B with the spare parts they need to keep the radar functioning properly per time period (mission))	Thales is not able to deliver the spare parts ordered by the customer B, while their system is down. The waiting time for spare parts while the ship's system is down exceeds 10% of the total time (2000 hours per ship per year).

Table 3: Key customer requirements

The key customer requirements form the goals of the control tower. To make sure that these goals are realized, there are situations that need to be prevented, which can be found in the third column of Table 3. These situations could compromise Thales' ability to adhere to the key customer requirements, so it is essential to discover the situations before they actually happen. To do so, the control tower must be able to detect signals that indicate that these situations will happen when there are no interventions.

4.3 Operational activities in the supply chain

So, the control tower needs to indicate signals or risks that indicate a possible failure of the key customer requirements. When these signals are detected, the control tower needs to indicate that an intervention is needed. But how is the control tower able to pick up the signals? Figure 11 shows the causal chain of the how a signal gets generated.
First an action happens in the supply chain. For example a radar system in project A goes down and corrective maintenance is required. The service engineers go to the radar system and replace the broken part with a new spare part. This action causes a mutation in the parameters, a spare part gets used and is taken from a certain inventory and a broken part returns to Thales where they decide what to do with the part repair it or scrap it. These mutations might trigger a signal that says that the inventory gets too low. This signal might require a reaction or intervention, so the control tower needs to notice the appropriate stakeholder that needs to act. After the intervention the parameters might change again, so a new signal might get triggered or the parameters might return to an acceptable state, which would result in a healthy supply chain again.

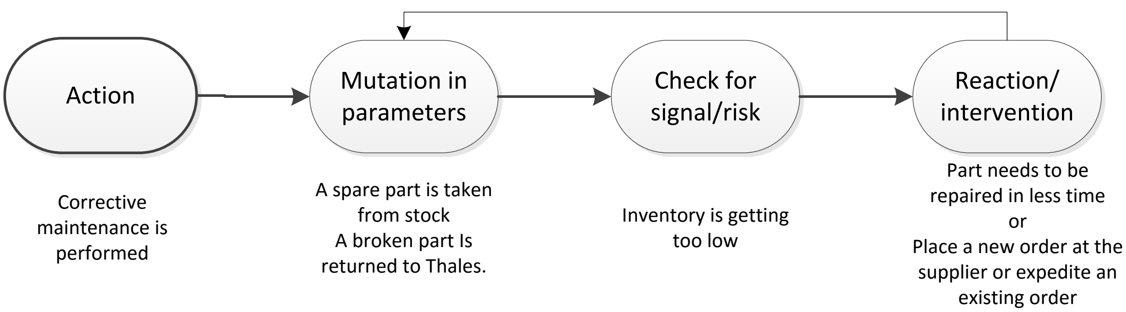


Figure 11: Signal generation chain

4.3.1 Parameters

Chapter 2.3 showed how the supply chain of the after sales service will look like. All of the solid black arrows indicate an action that causes a movement of spare parts, from one location to another. It is also possible that the status of a spare part gets changed due to the action. So, at every solid black arrow, the parameters must be updated. Table 4 (on the next page) shows all the possible movements of spare parts within the supply chain. Actions can also influence the status of a spare part, the different statuses can be found in Table 5. The second column of this table shows the parameters that are important per status. These parameters are chosen with the warning signals of Chapter 4.4 in mind. How they translate into the signals can be found in Chapter 5.2. One problem is that, in the current situation at Thales, not all of these parameters are available in such a state that they can be used right away, but this subject will be handled in Chapter 5 and 6. There will also be discussed where the parameters will come from (their source within the supply chain) and how Thales can improve them.

Type	Movement
Inbound	From supplier
	From repair
	From maintenance
Outbound	To customer (project B)
	To maintenance (project A)
	To repair
	To subcontractor/supplier
	For destruction (scrap)
Transfer	Transfer between warehouses
	Transfer between project inventories
	Transfer between sites
	Form or to blocked stock, stock in quality inspection or stock in quarantine
Return	Return from customer A or B
	Return from maintenance (unused parts)
	Return to supplier
	Return or cancellation / correction movement

Table 4: Movements in the supply chain

Status of spare part	Important parameters	Input for the Control Tower
ON STOCK	Location, quantity	Location of the spare part Quantity on stock
REPAIR IN (INTERNAL)	Repair time	Expected repair time
REPAIR OUT (OUTSOURCED TO SUPPLIER/SUBCONTRACTOR)	Turnaround time	Expected turnaround time
ON ORDER	Lead time	Expected delivery time
DEFECT	Make/buy part	Need to repair, purchase or scrap the part
INSTALLED*	MTBF, amount of installed parts per radar, working hours per year per radar	Expected usage of spare part Return of a broken spare part at break-down

Table 5: Status of a spare part

*(this status is not shown in the control tower, because the part leaves the supply chain as soon as it is installed, however it is important to know when the part is expected to fail / return in the supply chain)

4.3.2 Actions

Within the supply chain there are a lot of actions that influence the parameters, so during these actions there will be some points at which the parameters need to be updated in the control tower. These updates are essential in triggering the signals. In principal, every movement of stock and every order that causes a change in inventory needs to be updated in the control tower.

Preventive maintenance process:

The preventive maintenance process is pretty basic. Thales has made a preventive maintenance planning and taking the lead times in account, they can also make a procurement planning, such that all preventive maintenance can be performed on time. Whenever a preventive maintenance is planned, the expected stock level of the parts that will be used at that date will go down by one. At the same time, a broken part is returned, which will enter either the in-house or outsourced repair process or trigger the purchase process.

Corrective maintenance process:

Corrective maintenance is triggered by a call from customer A, a service engineer will pick the spare parts, that he expects to need, from the inventory at TNL. These parts will be picked from the parts that are marked for corrective on project A. After the service engineer is done with the maintenance he updates the stock level of the parts he actually used and returns the parts that were not necessary. On top of that, he also returns with the defect spare parts that he replaced. These defect spare parts will enter either the in-house or outsourced repair process or trigger the purchase process.

Delivering process:

The delivering process is triggered by an order of customer B and can be considered as a similar process as the corrective maintenance processes. Customer B will also be performing preventive and corrective maintenance and need the necessary parts for this. The exception for Thales is, they only need to deliver the parts and will not return immediately with the used/defect spare parts. Another difference is that it is not certain that a broken spare part will immediately return to Thales.

Reverse logistics of spare parts:

Whether preventive or corrective maintenance has been performed or customer B has replaced a part in their system, all used spare parts will return to Thales, with the status DEFECT. At Thales, the maintenance engineers will decide to repair the part or to scrap it. When it is scrapped, the status of part will become SCRAPPED and the part will be removed from the database. After that, the stock levels will be checked to see if a new part must be ordered instead. When the part can be repaired, the question is whether it must be repaired by Thales or the supplier. After this is decided, it can trigger the corresponding process.

Purchasing a new part:

The purchasing process can be triggered by multiple sources, like when a spare part is scrapped or the procurement planning for preventive maintenance shows a need to purchase. When a part(s) gets ordered at the supplier, a new part(s) must enter the database with the status ON ORDER and the expected delivery date must be noted.

In-house repair of a defect part:

The internal repair process will be triggered when a defect spare part returns to Thales and is also repairable by Thales. When the part goes to the repair department, the status of the part needs to change to REPAIR IN and the expected repair date must be noted.

Outsourced repair of a defect part:
This process happens when only the supplier of the spare part is able to repair the defect part is. The part needs to be sent back to the customer, the status REPAIR OUT must be given and the expected turnaround time must be noted.

4.4 Signals

All the parameters and processes that provide the input and output for the control tower have been defined, so now the signals that can be extracted from these data can be determined. The signals need to indicate any risks on the key customer requirement (Chapter 4.2). There are proactive and reactive signals. The proactive signals warn Thales when a part needs to be bought or when an order is running late, this way Thales keeps a good overview of their stock levels, so they can handle their maintenance. The reactive signals activate when it is too late to react to the stock mutation with a normal business process, for example, when the stock level is not high enough for all the planned and/or unplanned activities and the purchasing and repair process take too long to replenish the stock. So, these signals indicate that Thales needs to perform an intervention.

So, the signals are determined, based on the key customer requirements that Thales needs to be able to deliver and/or maintain the spare parts. During different meetings, with my supervisors of Thales and my supervisor of the university, signals have been discussed that could be used to warn Thales for possible stock outs and service contract failures. Another important source that formed the inspiration for some of the signals was the ProSeLo Next meeting that I attended on June 13 2016. Here, other companies showed how they designed their control tower and what signals they used.

Proactive signals
These signals are meant to prevent a stock out, where Thales will not have a part when they need to deliver it or maintain a radar system.

Inventory will drop below the safety stock level.
For the corrective maintenance the most important signal the control tower needs to detect is the expected moment when the stock level of a spare part will drop below its minimum acceptable level or safety stock level. When the time until this moment is longer than the expected lead time of the part, it is no problem. However, when the lead- and/or repair time of the part is longer than time until the safety stock is reached, it becomes a risk. The minimum acceptable stock level is the level of inventory Thales needs to hold to prevent stock-outs during the lead time of a part. So, this signal just alerts Thales when they need to purchase a new part to follow the regular supply and demand pattern.

High chance of a stock out
Another way to generate a signal is to show what the probability is that the stock level will drop below zero, which means that there is a backorder, before Thales gets the opportunity to restock. Giving this probability a maximum allowed value allows for a way to generate signals. This value can be dependent on many factors, like the costs of the parts and their storage versus the costs of the stock out occurring. Another factor can be the speed and difficulty of acquiring a new part or the uncertainty of the expected demand. For the model in Chapter 5, the threat of a stock out is considered medium at a stock out probability of 0.5% and high at 1.0%. Why these percentages are chosen is explained in Chapter 5.3.3.

Lead time for preventive maintenance part (almost) exceeds the time until the next preventive maintenance.
For preventive maintenance, a safety stock is not necessary in principle. The maintenance is planned and the required spare parts are known. When the lead time of a required spare part is known, the control tower can generate a signal when spare parts need to be bought for the maintenance. For example, when the total lead time on a part is 5 months and the maintenance is in 6 months, it is useful to check what the current stock level looks like. This way, Thales is able to order a part if necessary. Having two weeks to a month time before the lead time exceed the time till the maintenance should give enough time to discuss actions.

Delivery or repair is late.
The prediction of future stock levels and the related signals are based on the expected dates of deliveries and repairs. When a part is delivered later than expected, it is possible that a maintenance job cannot be executed. Having fewer parts on stock than expected can also increase the risk of a stock out. Noticing when a part will not be available on time, might give Thales enough time to react and get a part from somewhere else. Information about delivery and repair times can also be used to deliver feedback on the parameters from the database, like the expected lead or repair time and its deviation.

The downtime of a radar system is getting relatively high.
The maximum allowed down time per radar is 10% per period. To make sure that Thales is at all times aware whether they are on the right track for this goal, the control tower can indicate whether the down time is relatively high for the time in the period or if they have some breathing room. This way it is possible to prioritize radar systems with a higher risk to break the service contract, for when the inventory runs low. Multiplying the max amount of allowed down time by the portion of the expected uptime that has past gives an image of the max allowed down time per moment of time. So when the total uptime in the service contract is a year and 6 months have passed, the max allowed down time at that point is: 10%*0.5 = 5%. Being above that percentage should trigger a warning that the radar system needs extra attention.

Reactive signals
The reactive signal is when a backorder actually happens, despite the proactive warnings. The proactive warnings are based on uncertain parameters like the expected demand and maybe even an uncertain lead time, so it is possible that they do not predict everything for a hundred percent.

The part will not be available in time with the expected delivery/repair date
When it is certain that there will be demand when the inventory is empty, a signal should be generated in time, so Thales will have the ability to prepare an intervention. Possible interventions will be discussed in the next paragraph.

4.5 Interventions

Check part availability at the production inventory
The spare part warehouse for the after sales and the warehouse for the production of new radar systems will be two separate inventories. When the spare part warehouse is out of stock, Thales could take a spare part form the production warehouse. Of course the type of part must be available in the production warehouse and this intervention must not result in failed delivery deadlines of new radars.

Cannibalize a ship radar of customer B
Between missions, the ships of customer B will be docked in the harbor. Here, they will be maintained or receive an overhaul. During this period, it is possible to cannibalize the radars on the ship. The cannibalization is only possible with permission of customer B and when the part can be reinstalled in time before the next mission. The cannibalized part can be used for other radars of customer B, but also the radars of customer A. This has been stated in the service contracts. The fact that parts from customer B can be used for radar systems of customer A is because both customers ultimately belong to the same organization. When new projects from completely different customers get added to the control tower, it is unlikely that this intervention is useable on every customer.

Move a repair job forwards/ give the repair job a higher priority
When the repair time of the spare parts takes too long in the current schedule, it should be considered to move the repair job forwards at the expense of other repairs.

Reduce lead time (fast delivery)
A supplier often offers the option to purchase a product with a faster delivery. It is more expensive, but can be a viable option when a spare part is needed in short notice.

Increase inventory to prevent further downtime
When the downtime gets relatively high, Thales might want to purchase extra spare parts. The negative of this reaction is that the parts form extra inventory when they were not necessary, so this intervention is mainly applicable for relatively cheap parts, that are easily stored or used for the production of new systems for example.

4.6 Conclusions

The function of the supply chain control tower will be to increase the supply chain visibility on an operational level for the new service contracts. In the first place, it will not be used to check whether the predictions from the initial phase are correct or not, but it will monitor the operational status of the physical parts in the supply chain. This means that it will track the stock levels and the processes that will cause mutations in these stock levels. It will also track different parameters and generate signals related to the stock levels. A summary of all the input parameters, processes, signals and interventions can be found in table 6 on the next page.

Input parameters per part	– Location – Stock level – Repair time – Turnaround time – Lead time – Make/buy part – MTBF
Processes	– Preventive maintenance process – Corrective maintenance process – Delivering process – Reverse logistics of spare parts – Purchasing a new part – In-house repair of a defect part – Outsourced repair of a defect part
Signals	– Inventory will drop below safety stock level. – High chance on a stock out. – Lead time for preventive maintenance part almost exceeds the time until the next preventive maintenance. – Delivery or repair is late. – The downtime of a radar system is getting relatively high. – The part will not be available in time with the expected delivery/repair date
Interventions	– Check part availability at the production inventory – Move a repair job forwards – Cannibalize a ship radar of customer B – Reduce lead time (fast delivery) – Increase inventory to prevent further downtime

Table 6: Chapter 4 summary

5 The model

To illustrate how the control tower could look like and to give a representation of some of the functions it could have, a model of a supply chain control tower has been made. This model is made with the use of excel and VBA programming and uses input parameters that have been provided by the logistic engineers of Thales.

5.1 Approach

This model is only a prototype that will be used to show how a possible control tower could look like, what kind of input is needed and how signal could be generated. To give a proper representation, I tried to use input data that came closest to the real environment the control tower will be functioning in. However, many parameters are still based on predictions and expectation. The parameter values that are finally used in the model are the same values that the logistic engineers use to do their calculations. Because the control tower in this assignment will only focus on the operational level, the given parameters will be assumed to be correct and a reliable representation of the reality. Another important restriction is that there will be no costs included in the model, so no costs of parts or costs of possible consequences or interventions.

5.2 Input of the model

5.2.1 Spare parts

The model simulates the supply chain control tower of the after sales service of project A and B. The system that will be maintained is the Smart-L EWC. Thales has already established a list of the LRU's (Line replaceable units) that are maintainable within the system. This list of parts will be used in the model. When extra spare parts need to be checked, when Thales will start new projects for example, they just can be added to the list, where Thales has to also fill in the rest of the parameters of the added part.

5.2.2 Expected demand per year

5.2.2.1 Corrective maintenance

The expected average demand of a part for the corrective maintenance is the same as the expected amount of failures of a part, since corrective maintenance is only needed when a part fails or breaks down. The amount of failures per unit of time can be expressed in the failure rate. The easiest way to calculate the failure rate is with the formula:

$$Failure\ rate = \frac{Total\ amount\ of\ failures\ of\ part\ 1\ in\ system\ a}{Total\ amount\ of\ uptime\ of\ part\ 1\ in\ system\ a}$$

When part A is installed multiple times in system 1, the failure rates can be added to get the total amount of failures of that part during the uptime. The MTBF stands for the Mean Time Between Failures, which is simply the inverse of the failure rate, however it is not possible to add multiple MTBF's. The value can be used to determine what the average time is a part will fail. It can be obtained with the formula:

$$MTBF = \frac{1}{Failure\ rate} = \frac{Total\ amount\ of\ uptimeof\ part\ 1\ in\ system\ a}{Total\ amount\ of\ failuresof\ part\ 1\ in\ system\ a}$$

The problem with these formulas is that they are based on historical data. It requires data about the amount of failures that have happened in the past and the amount of time the system has been running. As has been pinpointed in Chapter 2.2, Thales gained almost no feedback from their customers in the past, so the required data for the failure rate formula are not available.

That is why the Logistic Engineers of Thales used another method to determine the failure rate. They used a program called Quanterion 217 Plus^{tm}, which is a software tool that can be used for reliability prediction. It uses failure rate models, which are stochastic models that take into account the environments, quality and cycling effects on the reliability of a part. The models give a Poisson distribution with the expected failure rate as the mean. The MTBF's that are used in the model are not the exact values that are calculated by the logistic engineers, but are slightly altered.

For now, expected demand per year is based on the failure rate of the models. To calculate the expected demand per year, the following formula can be used:

$$\text{Expected demand of a part per year per radar} =$$
$$\sum \text{Failure rate per part} * \text{parts per radar} * \text{expected uptime per radar per year}$$

The amount of parts that are installed per radar is known and the working hours of the radar systems will be 8760 hours (the whole year) per radar for project A and 2000 hours per radar for project B. Taking the sum over all radars that need maintenance and contain the part will give the expected demand per year. An example is given in Table 7

Project	A	A	B	B	B	B
Failure rate per part	3.76E-06 / hour	3.76E-06 / hour	3.76E-06 / hour	3.76E-06 / hour	3.76E-06 / hour	3.76E-06 / hour
Parts per radar	8	8	8	8	8	8
Failure rate per radar	3.01E-05 / hour	3.01E-05 / hour	3.01E-05 / hour	3.01E-05 / hour	3.01E-05 / hour	3.01E-05 / hour
Uptime per year (hour)	8760	8760	2000	2000	2000	2000
Expected failures per year	0.263	0.263	0.06	0.06	0.06	0.06
Total expected failures of a part per year over all systems	0.768					

Table 7: Example expected demand per year part 9556 521 0900

So, to determine the expected demand per year, Thales needs to know how many hours the radar systems will be running per year.

5.2.2.2 Preventive maintenance

The demand for preventive maintenance is different from the corrective maintenance. Thales will perform preventive maintenance on their radar systems to prevent break downs. This maintenance will be used to inspect and replace parts that are expected to be worn out after a specific amount of hours. A planning will be made that will determine what part will be maintained at what date, so the demand will be known as soon as the planning is finished. Inserting this planning in the control tower allows it to know when a negative stock mutation will occur and react on that. Because there is no preventive maintenance planning yet, maintenance orders can be inserted manually. The user is able to choose when a part will be used for preventive maintenance and how many.

5.2.3 Stock level

The stock level is the amount of spare parts that are held on stock and are meant to be used for both corrective and preventive maintenance. Since the projects have not yet started, there is also no stock at the moment. However, the logistic engineers did already calculate the initial stock levels. The initial stock level is the amount of stock that Thales should start the projects with, so they will not get in trouble in the foreseeable future.

Because these will probably be the stock levels that Thales will have at the start of the project, they will also form a good starting point for the model.

5.2.4 Lead times and repair times

The lead times per part are known and come from the general supplier database of Thales. These are the lead times that are agreed on with the supplier. The repair times are not known however. These are again the values that the logistic engineers have used in their calculations. The repair time for each part is set at 200 days, which is the expected time a part without any priorities generally takes to repair. The repair time of parts that have a higher priority, or a higher expected demand, has been set at 90 days. The fact that the repair time is very uncertain is not uncommon, since parts often need to be inspected first before an estimated repair time can be given. The way to generate the most reliable repair time has already been discussed in Chapter 3.2.2.

Another important value that is not known is the standard deviation of the lead and repair times. Suppliers do not always deliver on time, which means that the ordered part is not always available on the expected delivery date. This is important for when the purchasing planning is based on the expected use. A higher uncertainty in lead time also means a higher uncertainty in the expected demand during the lead time. However, since the standard deviation of the lead time is not known in this model, the lead time is assumed to be a set value.

5.2.5 Order information

Information about purchasing and repair orders, like the order date and expected delivery date, are being tracked to know when new parts arrive in the system and if they arrive on time. In 4.3.2 is described how and when the information about orders will be updated. Again, there is no relevant order information available, so the model uses improvised orders. These orders can be manually put into the model.

5.2.6 Input summary

All the input parameters and their values per part can be found in the 'Full table' tab of the model. This table also includes a column with the title "Type (critical, normal …). This column can be ignored in this model, but could possibly be used as an extra parameter, to indicate the criticality of parts.

Looking closer to the models full table in the Excel file (figure 12) will reveal that not every cell is filled. Some of the parts do not have any information available about their MTBF or amount of parts per radar, so the demand per year cannot be calculated for these parts. Also, some of the parts do not have an expected repair time, this is because these parts are considered to be non-repairable or are just a lot cheaper to purchase. These open cells will cause for some blank cells later on in the output, but for now they just have to be accepted. What Thales can do to fill the whole table with reliable parameters will be discussed in Chapter 6.3.

Full table

Reference Number	Item Name	Initial Stock Quantities			MTBF (hour) (1 part)	Parts per radar	Expected demand per year	On Order	In Repair	Leadtime	Repair time	Working hours per year
		Project A	Project B	Total								
1	Part 1	2	0	2	1470000	2	0,0347	1	0	108	200	25520
2	Part 2	2	0	2	630000	2	0,0810	0	0	108	200	25520
3	Part 3	2	0	2	840000	2	0,0608	0	0	206	200	25520
4	Part 4	3	4	7	520000	2	0,0982	0	0	108	200	25520
5	Part 5	5	4	9	190000	2	0,2686	0	0	171	200	25520

Figure 12: Full table

5.3 Output of the model

The excel tab 'CT' shows the output of the model. The output exists of general information of the part, a prediction of future stock levels and some signals about possible threats. When there are things that are not yet complete clear in this paragraph, appendix F contains a more detailed manual of the model.

5.3.1 General information

The section "Part specifications" (Figure 13) shows some general information about the part. It gives quick information about the parameters like the lead, repair time and the MTBF. Putting these parameters together creates a sense of overview per part, it becomes easier to see the relationships between them. It shows the background information the signals will be based on, so when a part gets a lot of signals that are not appropriate or when there is a lack of signals, it will be easier to check whether the parameters are correct or have to be adjusted.

Another part of the part specification is the current stock level and how this stock is divided over different stock locations. It is also possible to easily change the stock levels in the model to create different scenarios. This can later on be used to easily check the result of different kinds of safety stock levels or reorder levels. The safety stock level in this model is just an example and is just used to show that the possibility is present.

The part specifications also show information about the planned stock mutation of the part, positive stock mutations like incoming purchase and repair orders, but also negative mutations in the form of planned preventive maintenance. Combining these expected stock mutations with the current stock level gives the expected stock level when the corrective maintenance is not taken into account. This level can later be used as the basis of the stock prediction, including the corrective maintenance, and the risk management of part stock outs.

Part specifications		
Part	119	
Name	Part 119	
		Demand during lead time
Lead time	311 days	0,543610959
Repair time	90 days	0,157315068
MTBF	572,10 days	Expected demand per year
Failure rate	0,0017479 /day	0,638

Current Stock level		
Total		3
TNL	+ -	3
Ships	+ -	0

Service level	Safety stock level
99,50%	1,899158367

On order	1
In repair	0

	Status	QTNY	Starting date	Delivery date	Week nr.	Order nr.
Planned part mutations	Pre Maint	-1		24-10-2016		3
Update Planning	On order	1	24-6-2016	1-5-2017		6

Figure 13: General information per part

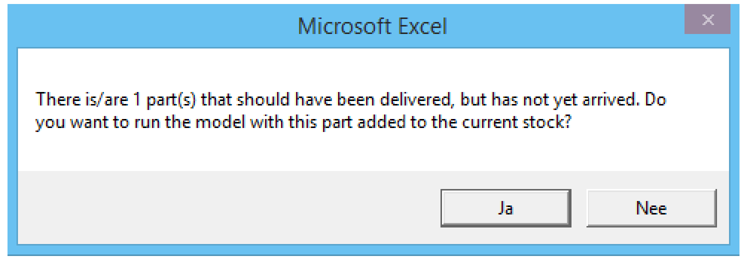
5.3.2 Stock prediction

The stock prediction is based on three parameters: The historic data including the current stock, the planned stock mutations and the expected demand per year. The expected stock is visualized in the graph that can be seen in Figure 14. The green line represents the current moment in time, so everything left of the line shows the historic data and everything right of the line is the prediction of future stock level. The stock is calculated per week.

Normally the historic data would come from the stock database of Thales, but as was mentioned at the input parameters, the historic data is now based on the expected demand per year, which is based on the expected MTBF. These are the same values that are used to predict the upcoming stock levels. As can be seen in the graph in Figure 14, the future stock levels are represented by a continuous descending line. The planned stock mutations can be noticed by the sudden drops or raises in the line, depending on the kind of mutation. The mutations are circled in the graph, where 1 is a usage of a part (preventive maintenance) and 2 is the expected arrival date of an order. The continuous descending of the line in general is based on the expected yearly demand. It is continuous, rather than discreet, because it is based on a (Poisson) probability distribution. Imagine the line without the mutations, then the stock would be expected to drop from 3 to 2 somewhere around 12-01-2018. Using a discreet drop at that date might suggest that it is a certainty. However, it is highly unlikely that the part would be used at exactly that date, since the used Poisson distribution has a high variance, so a continuous line is better at showing this.

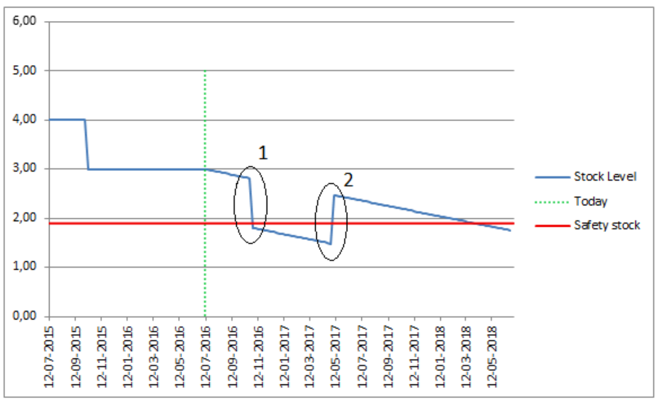
This line can then be used to check when the stock is expected to reach the safety stock and/or the zero. Using this in combination with the lead time, the date at which a part needs to be purchased can be determined. In this example of Figure 14, the preventive maintenance causes the expected stock level to drop below the safety stock level and this date is noticed. However, an expected order arrival fills the stock back up above the safety stock. This gives a somewhat distorted view, so it would be useful to also consider other date it reaches the safety stock and also take into account the information of refills of the stock. Due to a lack of time, this is not in the model however.

An option that has been included in the model is the option to include orders that should have been arrived, but have not arrived yet. An option like this is useful to check how much impact the incoming part has. It could be possible that the absence of the part is generating multiple signals, but that they would be resolved as soon the part arrives.



The probability on backorder that can be seen in Figure 16 will be discussed in the next paragraph.

Stock prediction	52	Weeks in the past (max 104)		104	Weeks in the future					
Week nr	Week 29	Week 30	Week 31	Week 32	Week 33	Week 34	Week 35	Week 36	Week 37	Week 38	Week 39
Date	12-07-2015	19-07-2015	26-07-2015	02-08-2015	09-08-2015	16-08-2015	23-08-2015	30-08-2015	06-09-2015	13-09-2015	20-09-2015
Stock Level	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00



Today	10-7-2016		
Reaches safety stock	30-10-2016	Order needs to be placed at	24-12-2015
Reaches zero	-		-

Pobability on backorder		
With current stock	When a part breaks down	
Probability on backorder before arrival next order	Probability on backorder before arrival next order	Probability on backorder if repaired
0,47%	4,48%	0,06%

Average Stock	2,490166913

Figure 14: Stock prediction

5.3.3 Signals

This model offers three signals, all based on the signals from Chapter 4.4. The first one is discussed in the previous paragraph, namely the expected date it will reach safety stock and the date a new part should be ordered to prevent any negative results. The signal comes in the form of a visual indication when this order date reaches within two weeks of the current date. This way, Thales has enough time to decide whether they think it is necessary to purchase a new part or wait. In the current state of the model, this signal has to be checked per individual part, but the idea is that this signal can be checked for every part at the same time.

The second one indicates when an order exceeds its expected delivery. This can also be checked per part, but the Contol Tower also shows the total amount of orders that exceeded the delivery date. The user is then able to manually go to the “orders” tab to check which orders create the signal. At this tab all order that exceeded the current date are marked with red. The user is also able to sort the orders on expected delivery date to show the orders with the earliest delivery dates at the top of the table.

Alarms		Amount of stock out chances >1%				Amount of orders that exceeded delivery
		Current stock	In case of corr. Maint. (order)	In case of corr. Maint. (repair)		
		1	10	12		1

Figure 15: Alarms

The final and probably the most useful signal of this model is the probability that a part reaches a stock out and causes a backorder. This means that a radar system breaks down, but Thales has no spare part in their spare parts inventory to repair it or to deliver to Customer B, causing the radar to be down. Since the amount of downtime is the main factor in the contract, it is very important that the risk of increasing this downtime is very low.
The model bases the risk on the probability that Thales has to use more spare parts, in the time until they can acquire new parts, than they have on stock. To give an example, a line from the risk table will be used. This is the same part as is shown in Figure 13 and 14.

					If a part breaks down	
Part	Name	Current stock	Order planned?	Chance of stock out before arrival next order	Chance of stock out before arrival next order	Chance of stock out if repaired
119	Part 119	3	Yes (ETA in 269 days)	0,47%	4,43%	0,06%

Figure 16: Risk of stock outs

The model checks the earliest possible date a new part can be acquired. Figure 13 show that the lead time of the part is 311 days, however there is also an order in the pipeline that is expected to arrive at 1-5-2017, which is in 295 days. This means that the earliest new part arrives in 295 days. The current stock level is 3 parts, so what is the chance that Thales uses more than 3 parts during those 295 days? To make thing more complicated, there is also a preventive maintenance planned during the 295 days, as can be seen in Figure 13 and 14, which will consume one part. To get the risk of a backorder, the chance of using more than 3 parts until the preventive maintenance will be added to the risk of using more than 2 parts after the maintenance. This chance is shown in the fifth column of Figure 16. The chance is calculated using the Poisson distribution, since the calculation of the expected demand used a Poisson distributed MTBF. A more precise description of the calculations can be found in Appendix F.
The sixth and seventh column of Figure 16 show the chances of stock outs when a part breaks down right now. These values are useful to know, so Thales is aware what their options are, even when an unexpected break down occurs. At a break down the stock will go down by one and Thales has the option to either buy a new part to replace it or repair the part. The sixth column shows the chance of a stock out when Thales decides to buy a new part and the seventh column when they decide to repair it. The large difference in percentages in this case, is the result of the difference between the lead and repair time. The sixth column uses the same logic as the fifth column, so it uses the lead time or when there is already an order in the pipeline with an earlier delivery date it uses that date. The seventh column uses the repair time instead of the lead time, since it simulates the choice of Thales to repair the item that has broken down. Because the repair time is much shorter in this case (90 days), the chance of a stock out is also lower. On top of that, there is no preventive maintenance planned within the 90 days, so this does not increase the risk either.

The full table of all the risks per part can be found at the bottom of the control tower (the “CT” tab of the excel model). Parts that have a risk higher than 0,5% are marked with orange and risks higher than 1% are marked red, meaning that these parts should be inspected and maybe it should be considered to purchase an extra part, especially when they occur at the current stock level. At the moment, the 0,5% and 1% are not based on anything other than the fact that the penalties of too much down time are very high, so they should be avoided. A whole new research could be started to determine whether these are appropriate values or not, but that will not be possible in the time frame of this assignment. The 0,5% and 1% will give a good representation of how the warning signals could look like for now. To rank on basis of the stock out risk, it is possible to rank the table per column and filter on the top 10 or 20 values for example.

5.4 **Manual of the model**

A manual of the model can be found in Appendix E. An explanation of the VBA code can be found written next to the code itself.

5.5 **Conclusions**

In this chapter a model has been made to give an illustration of how a possible supply chain control tower could look like for Thales. It shows how the input parameters can be converted to signals that can be used on an operational level.

The required input parameters consist of:

1. The parameters that can be found in the “Full table” tab of the excel model
2. The manually inserted order in the “Orders” tab
3. Historic data of the stock levels, which are currently based on the MTBF’s.

The output of the model consists of three different kind of signals:

1. An indication when to order a new part, such that the stock level is expected to reach the safety stock level when the order arrives.
2. An indication when an order exceeds it expected delivery date.
3. The chance of a stock out before the earliest possible restock.

The goal of the model was to create supply chain visibility, in chapter 3.5 supply chain visibility was described as:
An organization’s ability to collect and analyze available data in the supply chain, generate specific recommendations and making sure that the data and recommendations are provided to the relevant supply chain partners for better decision support.

The focus of this model primarily lies on the first part of that sentence, the ability to collect and analyze available data. The model takes all the important input parameters that will come from the databases of Thales and translates these parameters to signals. These signals can then be used to provide for better decision support.

6 Implementation of the model

In the last chapter, a supply chain control tower has been modeled. However, many input parameters seemed to be not fully reliable or were not available yet. So, in this chapter the last sub question will be answered: *How can Thales implement a supply chain control tower in their after sales services?*

6.1 Validation

Every model needs to be validated before it can be used or be recognized as a proper representation of the reality. However, due to a lack of time and resources, the model will not be validated during this assignment. Instead of that, a method of how to validate the model will be given.

The reliability of a model depends on the integrality of its input, the reliability of processing the input to output and the reliability of the output itself. Because the input parameters are required to generate the output, step one will be finding a complete data set that can be used as input for the model. This means that the data set must contain reliable information of all input parameters per part. This will be the hardest part of the validation, since Thales does not really have a similar service they can acquire the data from. The current after sales could provide the historic data of the stock levels, but his data is not really suitable to distract a MTBF or failure rate from. The data shows when customers order a new part, not when it broke down. This lack of feedback has already been discussed in 2.2.1.

So perhaps it is better to just use the same data set as in Chapter 5, the data set of project A and B, and focus on making sure that the assumptions that have been used are a proper representation of the reality. The MTBF, although not based on historic usage, can be checked with similar parts that do have more information about their break down rate. Repair times could be discussed with the appropriate department to gain better estimation and when a preventive maintenance planning has been made it can be implemented. When all of these things are taken care of and the "Full table" of the model does not contain any unintentional blanks or uncertain cells, the input should be complete and a good representation of the reality.

The processing of the input to output has already been validated during the creation of the model. Every step has been checked to make sure it does what it should do and no problems have been found in the code. The only problem that has been found is that certain parts of the code could be expanded, to add extra functions. An example is the calculation of when the stock level reaches the safety stock. This has been explained in Chapter 5.3.2.

At last, the validation of the output. The way the output is processed has been validated, but does the output give a good representation of what is important for Thales? This is hard to decide at the moment, again because they are coping with a service that is completely new for them. Before validating the output, it should be expanded a bit. At the moment, the part with the highest risk on a stock out will gain the highest priority in the signal, but should they get the highest priority or are there more critical parts that might have a lower stock out risks but should get more attention. A simple way to validate this is by creating a scenario where the stock levels of the parts are lowered, so there are many signals. Then show the whole list of risks to the appropriate employees at Thales, like the logistic engineers who exactly know what parts are more critical than others and which parts deserve more attention. Let them rank the parts from high to low priority, bases on the risk of a stock out and their knowledge of the criticality of parts, and compare it the list from the model. The important part is that the top of the list matches the list of the logistic engineers, since these are the parts that form the biggest risks of causing down time. This is still a validation based on predictions and calculations, but it is probably the best option at the moment.

6.2 Usage of the model

After the model has been validated and confirmed to be a useful tool, Thales could consider implementing this model to help them with their supply chain visibility. In this paragraph, there will be explained how Thales can use the model in their organization and how they can expand the model to gain even more use out of it.

6.2.1 Purpose

As has been mentioned during the design of the control tower, the control tower will be used on the operational level. The model can be used to gain a better overview of the status of spare parts in the after sales supply chain. The signals that are generated on the basis of this status help in the decision making of when to purchase spare parts. Another important feature is that the control tower will be located in a single point in the company, so all data will be collected in one place and from there, the signals will be distributed to the right departments. Instead of having multiple dashboards that all track the important information about their own department, there will be a central hub, giving an overview of all other departments involved in the after sales. With the current model this will only reflect to the handling of the physical spare parts, but in 6.2.4 expansions will be discussed about how to involve other parts of the organization.

6.2.2 Responsibilities

To illustrate how the organization of the after sales service will be organized, the Figure in Appendix E will be used. This Figure shows the “golden triangle”, a depiction of the organizational structure where the control tower will function. In the triangle, different cluster are mentioned, these clusters are the same as the clusters discussed in Chapter 2.1.

Cluster C Project & Service Contact Service

In order to create supply chain visibility, chapter 3.4 and 3.5 explained that an organization needs a single point of contact. One point where the control tower is located, where all the input parameters are received and from where the signals are distributed to the appropriate department. This point should be located at cluster C. This cluster is responsible for the customer service and will be contacted when a customer needs maintenance or when they want to order something. Having the control tower in this cluster makes sure that all of these orders and stock mutations immediately reach the control tower.

Cluster E: Logistic Engineers:

This is the cluster that is responsible for the input parameters of the MTBF, expected failure rate and the preventive maintenance planning. All of these input parameters are stored in the LSAR database, as shown in the triangle. In the triangle can also be seen that cluster E is located in the strategic layer, so they are not the primary beneficiaries of the control tower, but rather are responsible for the input. That does not mean that they gain nothing at all form the control tower. In 6.2.3 will be discussed how a feedback loop can create benefits for cluster E.

Cluster F: Supply chain

Cluster F is the cluster that will handle the spare parts on the operational level and are responsible for the handling most of the stock mutation. This cluster has two roles within this structure, performing the maintenance and the supply and logistics.

Maintenance: The maintenance part of cluster F is responsible for performing both the corrective and preventive maintenance. They are responsible for updating the stock levels as soon as they use a part. In the most optimal situation, the stock levels will be update in real time, but another alternative would be to update them on a weekly basis.

Supply and Logistics: This part of cluster F is responsible for the purchasing, material planning, warehousing, shipping and reverse logistics of the parts. They will receive the signals when it is time to purchase a new part, but are also responsible to update all the stock mutations they are responsible for. When a part is ordered, an order needs to be created and the expected delivery date must be received by the control tower. The same count for repairable items that enter the reverse logistics and the shipping of parts to the customer or between warehouses. All of these stock mutations need to be recorded and end up in the control tower.

6.3 Implementation of the input parameters

To make sure that Thales is able to the model reliable, all of the input parameters need to be complete and reliable. Figure 12 in Chapter 5.2.6 showed all the needed input parameters. Here, per input parameter will be discussed how to make it complete and reliable and what the source of the parameter will be.

Reference number and Item name

In the model the reference numbers and item names were changed to 1,2,3,… and part 1,2,3,… but in reality every part has its own number and name. The only challenge is to make sure that these values are the same in different databases. So that a part has the same number in the ERP system and the logistic engineer database (LSAR) for example. If this is the case, it should cause no problems. When new parts are added to the control tower, their numbers and names can just be added to the 'full table'.

Initial stock quantities (current stock levels)

In the model, the current stock levels are the same as the initial stock quantities that are calculated by the logistic engineers, simply because the project is in the initial phase, but when the project is in progress these stock levels will change. In the model, the current stock levels are located at the 'stock' tab, but this was just to simulate a stock. To implement this model, it needs to use real time stock levels of all used spare parts. This means that the control tower (model) needs to be connected with the ERP system of Thales, so real time stock levels of the Thales warehouse can be used. However it is also important to know how much stock is located at customer B. The best solution would be to also have a direct connection to the ERP system of customer B, at least to the stock levels of the spare parts. To make sure that the control tower can generate signals as soon as possible, all stock mutations should be adjusted directly when they happen. For the stock at Thales, this should be no problem, however for the stock at customer B this requires very good communication. Again, the best solution would be a direct connection to the stock levels in their ERP system. It would also be sensible to monthly check the stock in the warehouse and make sure it matches the amount stated in the ERP system. This way there will be no surprises.

MTBF

As has been mentioned multiple times in the assignment, the MTBF in the model is based on a predictive model instead of historic data, making it less reliable. However, before there is any historic data, the values cannot be validated. As soon as the radar systems are running, Thales needs to keep track of the amount of running hours and the amount of break downs. Since many parts have an expected MTBF of more a than a year, this validation period can take rather long, because a single break down is often not

enough to reliably validate a calculated value. But when Thales has gathered enough data, for example multiple break downs have occurred, they can check whether the predictions are correct or not and adjust them. Because it can take a long time between break down, I suggest that the data will be checked every three month, more often would be unnecessarily.
So, the initial MTBF is based purely on the predictions of the logistic engineers and gradually during the project this value can be tested and adjusted with the collected data.

Parts per radar
The parts per radar should cause no troubles. There are still some blanks in this column of the full table, but it is easy to check how often a part is installed in a system and write down this value. When new radars are added they may contain a different amount of a certain part, so that is something to keep in mind.

Expected demand per year
The expected demand is based on the MTBF of a part, parts per radar and the amount of working hours per radar per year, so when all of these parameter are known, the expected demand per year can be calculated without any problems. It is important to calculate the expected demand per radar and then add these values, instead of adding all of the parts in the database and then calculate the expected demand, since some radar systems may contain fewer parts or have less expected running hours.

On order and In repair
The repair and purchase orders are now simulated in the tab 'Orders', but when the model gets implemented, these orders need to come from the ERP system. When an order is placed in the ERP system, it should also be updated automatically in the control tower.

The same counts for the preventive maintenance planning. As soon as this planning is known, it should be updated in the control tower. This planning needs to come from database of the logistic engineers, either from the LSAR or the POK.

Lead and repair time
The lead time of most parts is known and it should be no problem finding the lead time of the remaining and of new parts. These can be discussed with the suppliers. However, it will also be useful to know the reliability of a supplier and the standard deviation of their lead times. These values can be used to rank the parts, giving parts with a higher uncertainty a higher priority to look after. The standard deviation of the lead times can only be determined from historic data, so maybe some suppliers have delivered similar parts in the past. When this is the case, these data can be used to check the reliability of their lead times.

The repair times are now set at either 200 or 90 days, depending on the priority the spare part gets in the repair shop. It would be useful to discuss with the repair department to gain a better approximation of all the repair times. It is unlikely that every low priority part takes the same time to repair. The repair time also gets used in calculating the stock out risks, so it is an important parameter.

Working hours per year
The expected amount of working hours per radar is needed to calculate the expected demand, so it is important that it is known per radar system. For the two projects that are included in the model, these hours were known, so the calculations are no problem. This should also be the case when new service

contracts are added. When signing a new contract, one of the demands on the side of Thales should be that the customer makes clear how many hours the radar system will be running per year.

6.4 Expansions of the model

To further improve the model and the general supply chain visibility, some recommendation are made to expand the model

Linking data sources to the model
Every input parameter has to be manually inserted in the model at the moment. For now, this is no problem, because the amount of project and spare parts that are involved are not that large. But when more and more spare parts will be included, manually inserting all the input parameters, preventive maintenance plans and purchase/repair orders will compromise the gained overview. Mistakes are made more easily and it takes a lot of time.
Directly linking the ERP system Oracle to the control tower will provide data about the stock levels including their locations, purchase orders and repair orders. It will also provide information about the lead, repair and turnaround times. Also linking the LSAR data base, will provide the MTBF, the amount of spare parts per radar and the amount of expected working hours per radar.
Having all systems linked to the control tower makes it also able to generate signals as soon as an update has been made in another system.
Another important data source is the ERP system of customer B. Thales needs to know when customer B uses a spare part on their ships. This way they can update their own stock levels and prepare for the delivery that customer B will likely make, since they just used a spare part. There needs to be some sort of link between the ERP system of Thales and customer B, so stock mutations are noticed right away.

Standard deviation of lead and repair times.
The risk calculation of a stock out during the lead time is only based on the expected demand per year and the standard deviation of this demand, the lead and repair times are assumed to be set values. However, a lead time is almost never completely reliable; suppliers often deliver either too soon or too late. This variance in lead times causes extra uncertainty in the demand during the lead time, so the risks of stock outs will increase.

Feedback loop to the initial parameters
When the project is running and the control tower is doing its job on the operational level, it also stores the information about the stock levels. After a while, the project will be running long enough to provide feedback on the reliability of the input parameters. Are repair time correctly assumed, has a part failed more often than expected or less? The last question is difficult to provide feedback on, since the expected MTBF of many parts is at least several years. For these parts, the project should probably be running at least a couple of years before a reliable feedback on the parameters could be given. Even when a part with an expected MTBF of 3 years fails after 3 months, it could be only one extreme deviation. This changes when the part breaks down every 3 months. At that moment, an alarm should ring that indicates that the input parameters should be revisited. When exactly such an alarm should ring and how the parameter could be changed could be an interesting follow-up study.

Adding extra priority factors to the risk signals
As was mentioned earlier, the priorities of the signals are only based on the risk of a stock out during the lead time, which is only based on the expected demand per year and its probability distribution. Adding

extra factors that influence the priority of a signal can be useful to tackle the signals in the right order. Those extra factors could be:

- The criticality of parts: How critical is the part for the radar system? Is the breakdown of one part worse than the other?
- Ability to replenish the part: The risks are based on the inventory of the after sales service, however Thales also has a regular warehouse where parts are stored for production. It might be easy to 'borrow' a part from this warehouse and replenish it when a new order arrives. This way, even a stock out might not be that bad and the priority of the signal could be lower.
- Expediting costs: Maybe the expediting costs of a part are extremely high, so Thales wants to make sure that this part never reaches a stock out. Then, this could add up to the priority to handle a signal of this part first.
- Obsolescence risk: Parts that have a higher chance to become obsolete should be looked after more carefully. Looking at these parts when there risk is still low give Thales the opportunity to check at the supplier for the risk on obsolescence. Looking at these parts too late means that Thales has to find a new source, while they already need to act fast on the risk.

Interventions

When the control tower is functioning properly and generating signals with the right priorities and Thales acts appropriately on these signals, by repairing and buying the parts on time, it is still possible that a part reaches a stock out when Thales needs that part. Another situation could be that Thales is not able to restock in time to prevent an expected stock out. In these situations Thales needs to perform an intervention. These interventions happen on the operational level, so it could be an option to include them in the control tower. In Chapter 4.5 some different kinds of interventions have been discussed. Having standardized interventions per scenario will increase the supply chain visibility even more. It will help in the decision making and prevention of increasing down time. To create standardized interventions, the costs of an intervention could be weight against the benefits or prevented costs, but this could also be an interesting follow-up study.

6.5 **Conclusions**

This chapter the sub question: *How can Thales implement a supply chain control tower in their after sales services?* has been answered.

There are some big obstacles that need to be conquered before Thales would be able to implement this model in their after sales. The model needs to be validated before it should be used as competent tool. The big problem is that the validation requires reliable and complete input parameters. These parameters are not easily obtainable, so the validation will still be partly based on assumptions. There is also no proper way to check whether the output signals are ranked in the right priority, but it could be tested with the help of the professional expertise of the logistic engineers for example, instead of historic data.

The control tower model will have the purpose of increasing the supply chain visibility on operational level, by providing an overview of the input parameters of the spare parts and generate signals that can be used to aid in the decision making. These signals show the risk that a part reaches a stock out before it can be restocked. Thales can use these signals to decide whether they need to buy extra parts or accept the risk when it is small enough.

The responsibilities that come with the control tower are divided over the different cluster of the organization. The control tower will be located in Cluster C. Here all the data of the input parameters will be collected and the signals will be distributed to the right clusters. Cluster E and F will provide all of the input of the control tower.

At the implementation of the input parameters, the current stock level and the MTBF will probably cause the biggest problems. For the current stock levels a connection with ERP systems of Thales and customer B is needed. It is also important that stock mutations get updated as soon as they happen, so this requires an extra level of connection between the control tower and the stock database of customer B.
The MTBF can only be properly validated when break downs have actually occurred; this could mean that the radar systems are running for more than a year, since most parts are expected to last (much) longer than that.

To further improve the model, some expansions of the model have been recommended:

- *Add standardized interventions*
- *Add extra priority factors to the risk signals*
- *Feedback loop to the initial parameters*
- *Add Standard deviation of lead and repair times.*
- *Linking data sources to the model*

7 Conclusions and recommendations

In this final chapter, the conclusions and recommendations for follow-up studies will be discussed. This will be done by answering the main question of this research.

7.1 Conclusions

This assignment was set up because Thales wanted better supply chain visibility of their after sales supply chain and have a better overview of the status of the supply chain.. They want to shift from their ad hoc after sales service, where the customer pays only when they need service, to a performance based service, where the customer pays for a service contract that makes Thales (partly) responsibly for the system uptime. This change means that certain aspects of the supply chain become much more important, like the availability of spare parts. A discussion with Thales has concluded that the best way to track the status of the supply chain is with a supply chain control tower. This conclusion has led to the main question:

> ***What information is needed to create a functioning control tower for the after sales supply chain of Thales and how will it help to create a better overview of the supply chain?***

To answer this main question, five sub questions are answered 2 to 6.

Chapter 2 has answered the sub question: *What is the current situation of the after sales supply chain?* As was mentioned, Thales uses an ad hoc type of after sales service. The demand is order-driven, which means that Thales only knows how many parts a customer orders in a certain time period. The customer provides no further feedback. The amount of parts a customer orders does not even have to be the same as the usage, since customer may have other ways to obtain parts. Also the amount of uptime of the radar system is often not known, so there is also no feedback on MTBF calculation. All of this results in a service, that provides little to no useful feedback. Thales does use some dashboards to track their performance in the supply chain, but these dashboards are spread out over multiple clusters and are mainly meant to look back on the performance over the last time period.
The supply chain of the after sales service for the new service contracts has also been determined, giving an overview of all the entities and stakeholders, which can later be used to in the design phase of the control tower.

With the literature study, I tried to get a better understanding of the different kinds of after sales services and how to cope with them. Chapter 3 also answers the question: *How can a supply chain control tower help to improve supply chain visibility?* This is answered with the definition of a control tower is *"A supply chain control tower is a central hub with the required technology, organization and processes to capture and use supply chain data to provide enhanced visibility for short and long term decision making that is aligned with strategic objectives"*.
On top of that, there are three phases in which a control tower gets introduced in an organization. For this assignment, the first phase will be the main focus, with phase two as an extra addition. The objective in phase one is to achieve operational level visibility on supply chain data such as shipment and inventory status. In phase two this status will be used to generate signals that can assist in the decision making in the supply chain.

Chapter 4 answers the sub question: *What are important input parameters for the control tower?* and is best summarized by table 6 as was used in Chapter 4.6. This table shows all input parameters, processes and signals that are included in the control tower and the interventions that can be used in case of a signal.

In chapter 5 the results of chapter 4 have been used to create a model of a supply chain control tower that could be used in the after sales service of project A and B. It will also be possible to add extra project. The model uses the input parameters from Table 8 and adds the expected working hours per part as parameter. It also keeps track of the processes of Table 8. Preventive maintenance, purchase orders and repair orders are all being tracked to get an overview of the planned stock mutations. The MTBF and expected working hours per year are used to calculate the expected demand per year for the corrective maintenance.
The output of the model consists of three different kind of signals:

- An indication when to order a new part, such that the stock level is expected to reach the safety stock level when the order arrives.
- An indication when an order exceeds it expected delivery date.
- The chance of a stock out before the earliest possible restock.

The focus of the model primarily lays on the ability to collect and analyze available data. The model takes all the important input parameters that will come from the databases of Thales and translates these parameters to signals. These signals can then be used to provide for better decision support related to the purchase of spare parts and prevention of stock outs.

The final step of this assignment was to describe how to validate and implement the model in the organization of Thales. A problem with the validation is that it requires reliable and complete input parameters. These parameters are not easily obtainable, so the validation will still be partly based on assumptions. There is also no proper way to check whether the output signals are ranked in the right priority, but it could be tested with the help of the professional expertise of the logistic engineers for example, instead of historic data.

The control tower model will have the purpose of increasing the supply chain visibility on operational level, by providing an overview of the input parameters of the spare parts and generate signals that can be used to aid in the decision making. These signals show the risk that a part reaches a stock out before it can be restocked. Thales can use these signals to decide whether they need to buy extra parts or accept the risk when it is small enough.

The responsibilities that come with the control tower are divided over the different cluster of the organization. The control tower will be located in Cluster C. Here all the data of the input parameters will come together and the signals will be distributed to the right clusters. Cluster E and F will provide all of the input of the control tower.

7.2 Recommendations

To further improve the model and the general supply chain visibility, some recommendations are made to expand the model. These recommendations are further worked out in Chapter 6.2.3

- *Add standardized interventions*
- *Add extra priority factors to the risk signals*
- *Feedback loop to the initial parameters*
- *Add Standard deviation of lead and repair times.*
- *Linking data sources to the model*

8 Bibliography

Bhosle, G., Kumar, P., Belinda, G.-C., Rob, v., MarieAnne, S., & Adrian, P. (2011, May). *Global Supply Chain Control Towers.* London: Capgemini Consulting.

Cohen, M. A., Agrawal, N., & Agrawal, V. (2006). Winning in the aftermarket. *Harvard Business Review*, 129-138.

Dam, M. (2016, May 31). Interview with Mark Dam - Test & Integration Thales. (E. Keppels, Interviewer)

Dinalog. (2015). *Logistics and Supply Chain Innovation.* Dortmund: Springer.

Driessen, M., Rustenburg, J., van Houtum, G., & Wiers, V. (2014). *Connecting Inventory and Repair Shop Control for Repairable Items.* Eindhoven: Eindhoven University of Technology.

Driessen, M., Wiers, V., van Houtum, G., & Rustenburg, W. (2013). *Typology of Repair Shops for Maintenance Spare Parts.* Eindhoven: Eindhoven University of Technology.

Goh, M., De Souza, R., Zhang, A., Wei He, & Tan, P. (2009). *Supply Chain Visibility: A Decision Making Perspective.* Singapore: ICIEA.

Harperink, C. (2016, June 3). Interview with Clemens Harperink - Supportability Engineering Thales. (E. Keppels, Interviewer)

Hausman, W., & Scudder, G. (1982). *Priority scheduling rules for repairable inventory systems.* Manag Sci.

Kothamasu, R., Huang, S., & VerDuin, W. (2006). *System health monitoring and prognostics: a review of current paradigms and practices.* London: Springer-Verlag.

Thales. (2016). *One Naval*. Retrieved April 26, 2016, from Intranet Thales NL: http://intranet.peopleonline.corp.thales/nl/onenaval/pub/index.cfm

Tohamy, N., Orlov, L., & Herbert, L. (2003). *Supply chain visibility defined.* Cambridge: Forrester Research.

Yan, W., Tan, P., Koh, N., Tan, Y., & Zhang, A. (2012). *Towards better supply chain visibility - the Design and Implementation of a Supply Chain System S-ConTrol to Support an Operational HQ in Singapore.* Singapore: Planning and Operations Management Group, Singapore Institute of Manufacturing Technology.

9 Appendix

Appendix A: Tasks per cluster

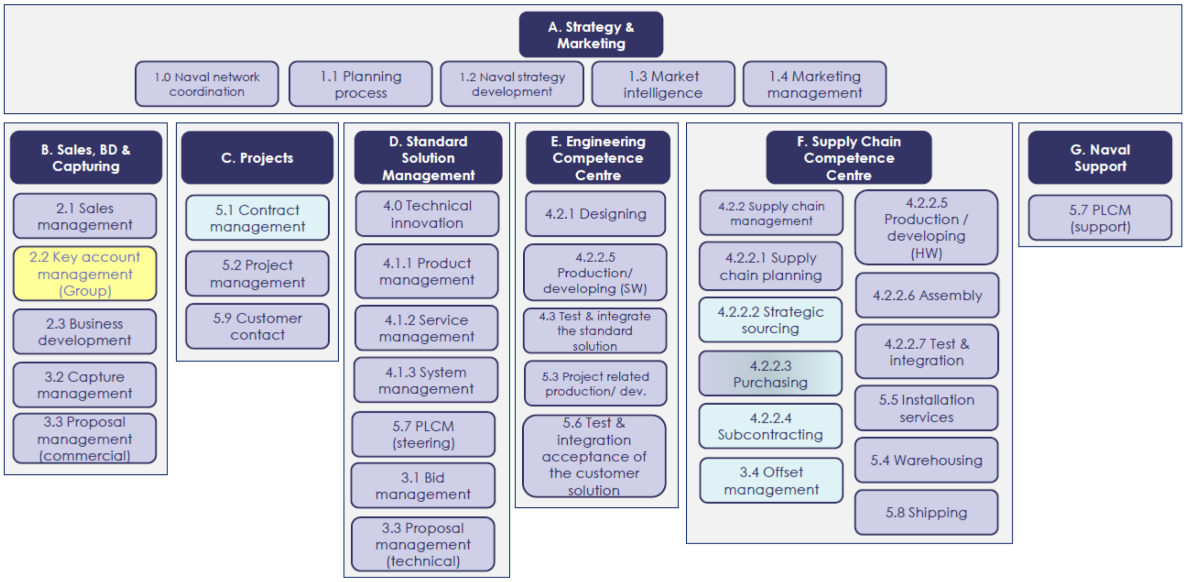


Figure 17: One Naval organizational design

Appendix B: Penalty schemes project A and B

Penalty scheme Project A		
Beschikbaarheid (*OA*) over afgelopen Beschikbaarheidsperiode	**Prestatiekortingsbedrag per Subsysteem over afgelopen Beschikbaarheidsperiode gedurende Inwerkperiode**	**Prestatiekortingsbedrag per Subsysteem over afgelopen Beschikbaarheidsperiode na afloop Inwerkperiode**
95 tot 100 %	tegoed € 225.000,00*	-
90 tot 95 %	tegoed € 150.000,00*	-
85 tot 90 %	-	€ 300.000,00
80 tot 85 %	-	€ 450.000,00
75 tot 80 %	€ 300.000,00	€ 600.000,00
70 tot 75 %	€ 450.000,00	€ 600.000,00
0 tot 70 %	€ 600.000,00	€ 600.000,00

Table 8: Penalty scheme Project A

Penalty scheme Project B	
Logistieke beschikbaarheid van Spares/STTE aan boord per schip over afgelopen Vaarperiode	**Prestatiekortingsbedrag per Radarsysteem over afgelopen Vaarperiode**
< 90 %	€ 75.000,00

Table 9: Penalty scheme Project B

Appendix C: Business models of the after sales service

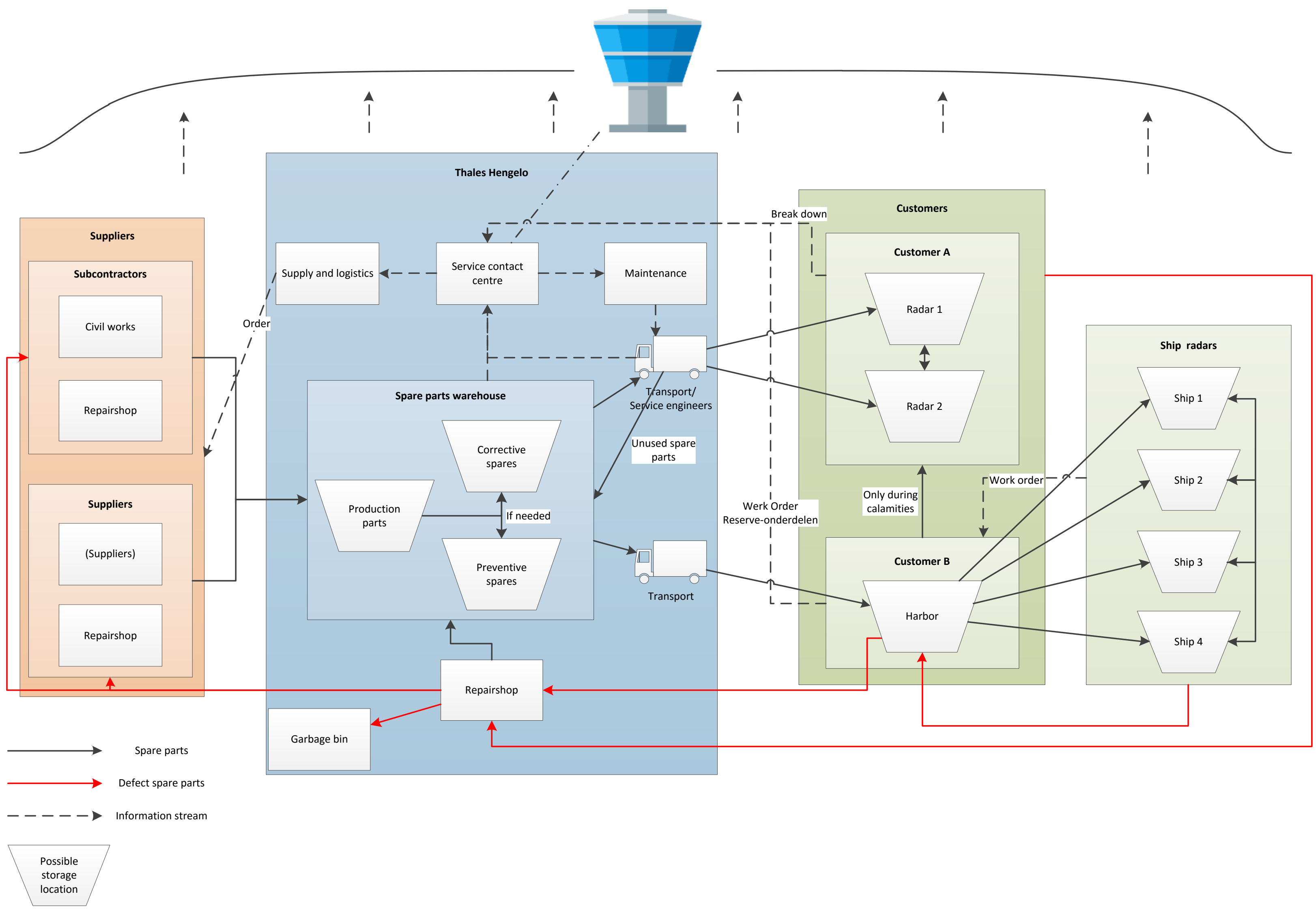
Models of
After-Sales Services

The value companies place on after-sales services will determine the business models that firms can use to deliver them. When services are all-important, manufacturers may choose to sell services rather than the products that generate them.

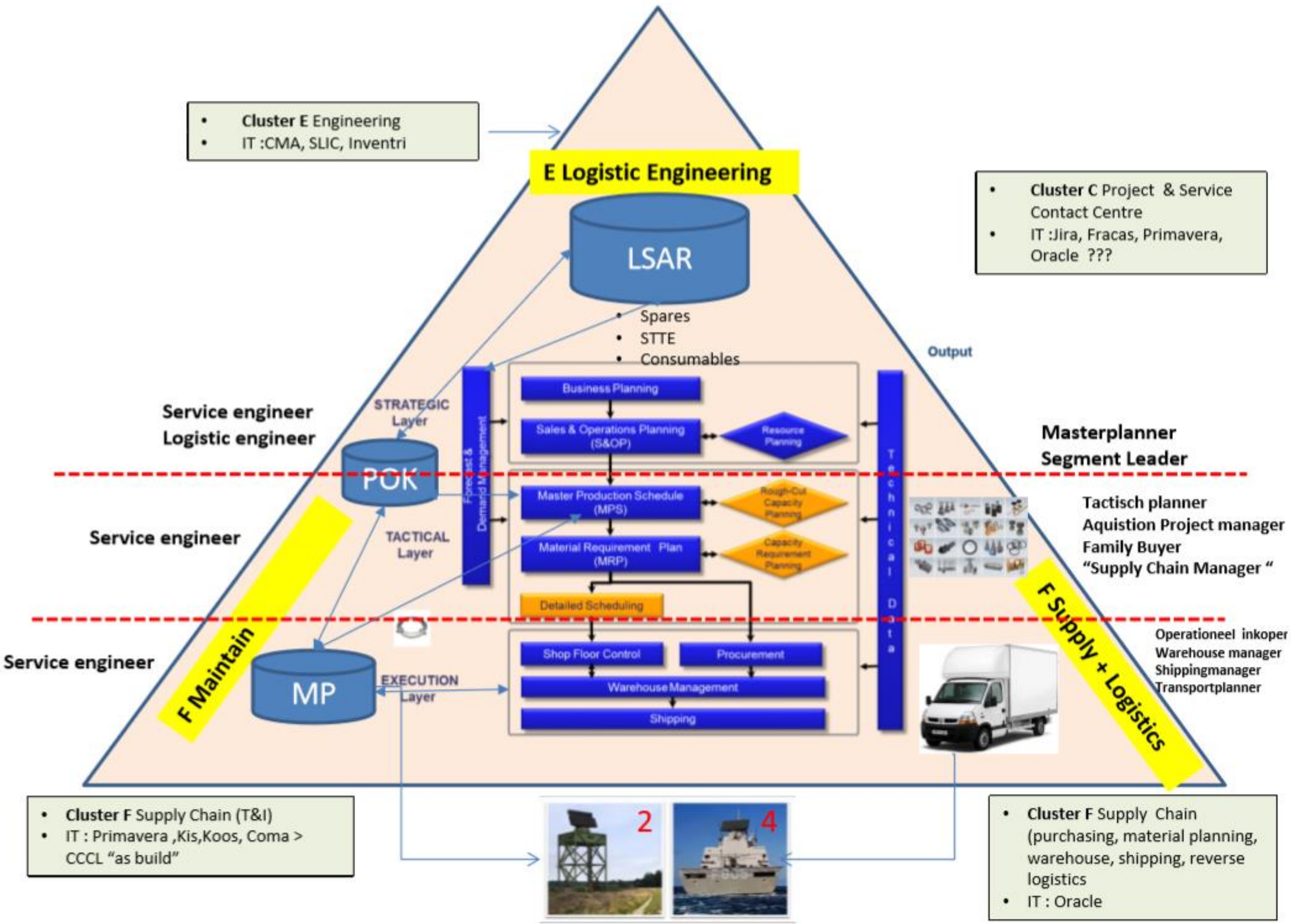
SERVICE PRIORITY	BUSINESS MODEL	TERMS	EXAMPLE	PRODUCT OWNER
None	Disposal	Dispose of products when they fail or need to be upgraded	Razor blades	Consumer
Low	Ad hoc	Pay for support as needed	TVs	Consumer
Medium-high	Warranty	Pay fixed price as needed	PCs	Consumer
Medium-high	Lease	Pay fixed price for a fixed time; option to buy product	Vehicles	Manufacturer; leasing company
High	Cost-plus	Pay fixed price based on cost and prenegotiated margin	Construction	Customer
Very high	Performance based	Pay based on product's performance	Aircraft	Customer
Very high	Power by the hour	Pay for services used	Aircraft engines	Manufacturer; service provider

Figure 18: Business Models After Sales Service (Cohen, Agrawal, & Agrawal, 2006)

Appendix D: The supply chain



Appendix E: “Golden triangle”



Appendix F: Manual of the model

Here a manual of the model will be given. The manual will explain the model per excel sheet

Excel sheet “CT”, the main control tower dashboard pt. 1

This part of the dashboard (top left) shows the part specifications. In the cell next to “Part”, the cell with the part number in it, a part can be selected with a drop down list. When the part is selected, all the information will change immediately, except for the planned part mutations. These need to be updated manually by pressing the “Update Planning” button. Planned orders that have exceeded their delivery date are highlighted in red. As can be seen, the order with order nr. 5 had to be delivered in 2015, but has not yet arrived. In this overview, the current stock level can also be adjusted with the “+” and “-“ buttons. This option can be used to quickly change the current stock level to simulate different scenarios. The stock levels are taken from the sheet “Stock”, the planned stock mutations from “Orders” and the rest of the information from the sheet “Full table”.

CONTROL TOWER

Update Stock

Part specifications	
Part	136505
Name	TRANSFORMER

		Demand during lead time
Lead time	108 days	0,010068164
Repair time	200 days	0,018644749
MTBF	10726,88 days	Expected demand per year
Failure rate	0,0000932 /day	0,034026667

Current Stock level	
Total	3
TNL + -	3
Ships + -	0
On order	3
In repair	0

Service level	Safety stock level
99,50%	0,258459338

	Status	QTNY	Starting date	Delivery date	Week nr.	Order nr.
Planned part mutations	On order	1	4-7-2014	20-8-2015		5
Update Planning	Pre Maint	-1		24-10-2016		4
	On order	2	1-9-2016	18-3-2017	Week 11	10

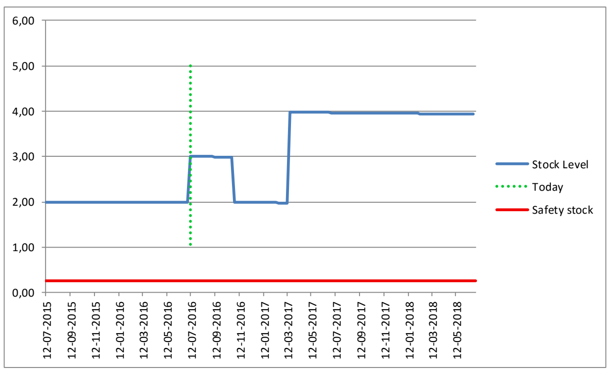
Excel sheet “CT”, the main control tower dashboard pt. 2

This is the top right part of the dashboard and shows the stock prediction. When the part is selected in the previous section, you can press “Update stock” to generate the stock prediction. The time period of the prediction and the amount of historic data you want to show can be changed by entering the amount of weeks you want to look in the past and in the future. Right now they are set at 52 and 104. The max weeks in the past are 104 weeks and in the future 520. The graph show the predicted stock level (blue), the safety stock level (red) and the current date (green).On the right it gives the information about when the stock is expected to reach the safety stock and the zero and when to place an order to prevent this. When the order date is closer than two weeks from now, it will be highlighted with red. Underneath that table is the table that shows the probabilities on stock outs/backorders. And the average expected stock is shown.

Update Stock

Stock prediction	52	Weeks in the past (max 104)		104	Weeks in the future						
Week nr	Week 29	Week 30	Week 31	Week 32	Week 33	Week 34	Week 35	Week 36	Week 37	Week 38	Week 39
Date	12-07-2015	19-07-2015	26-07-2015	02-08-2015	09-08-2015	16-08-2015	23-08-2015	30-08-2015	06-09-2015	13-09-2015	20-09-2015
Stock Level	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00
							On order				

Order nr.
5
4
10



Today	11-7-2016		
Reaches safety stock	-	Order needs to be placed at	-
Reaches zero	-		-

Pobability on backorder		
With current stock	When a part breaks down	
Probability on backorder before arrival next order	Probability on backorder before arrival next order	Probability on backorder if repaired
0,00%	0,00%	0,00%

Average Stock	2,951954201

Excel sheet “CT”, the main control tower dashboard pt. 3

The bottom left of the sheet. This shows the table with the probabilities on stock outs. Right now, the table shows the top ten probabilities when a part would break down at this moment and be restocked with an purchase order. The columns can be ranked with filter button in the headings of the table. When you want to zoom in on one of the parts, you have to select the part number from the table and press the button “Update Worksheet”. This will immediately update the previous two parts with the selected one.

Select a part from the table and press "Update Worksheet" to get information about the part

Update Worksheet

Part	Name	Current stock	Order planned?	Chance of stock out before arrival next order	If a part breaks down: Chance of stock out before arrival next order	Chance of stock out if repaired
9556 002 06000	ROTARY JOINT	3	Yes (ETA in 294 days)	0,47%	4,48%	0,06%
9556 210 57300	RADHAZ BOX	1		0,03%	2,32%	1,39%
3522 500 61788	CPCI-CPU4	1		0,03%	2,30%	2,49%
9556 001 50900	MAIN GEAR	1		0,01%	1,42%	0,70%
3522 500 60651	PSU	2	Yes (ETA in 204 days)	0,04%	1,35%	1,08%
9556 002 09900	BEARING	1		0,01%	1,23%	
9556 002 144XX	BEARING	1		0,01%	1,23%	
3522 500 61822	SSD-120GB	1		0,01%	1,21%	2,76%
3522 441 43000	GEARBOX B	1	Yes (ETA in 316 days)	0,01%	1,10%	0,70%
3522 406 71000	EMP FILTER	1		0,01%	1,04%	1,39%

Excel sheet “CT”, the main control tower dashboard pt. 4

The bottom right of the sheet. This is just a quick overview that shows how many signals there are.

Alarms	Amount of stock out chances >1%			Amount of orders that exceeded delivery
	Current stock	In case of corr. Maint.	In case of corr. Maint. (repair)	
	1	10	12	1

Excel sheet “Orders”, the manually inserted order and preventive maintenance list

The bottom left shows all the purchase order, repair order and preventive maintenance jobs. These have been manually inserted on the right of the sheet. The top “table” can be used to select a part, choose whether it is a purchase or repair order, select a quantity to order and select the date the order was placed on. To quickly choose today, you can press the button “today”. Choosing a date the order the placed on will automatically generate the expected delivery date with the help of the lead or repair time. When all the information is filled in, press the button “Insert Order” and the order will be placed at the first row of the order list. This will also automatically increase the order nr. for the next order by one.

The same principal works for the preventive maintenance jobs, but you do not have to insert a placement date, just the date the preventive maintenance will take place.

ORDER LIST

	Order nr.	Part	Status	Quantity	Date ordered (today)	Planned delivery date	
					Lead time (days)		
					200		
NEW ORDER	34	136505	On order	1	5-7-2016	21-1-2017	Insert order
		TRANSFORMER					

	Part		Quantity		Planned maintenance	
PREVENTIVE MAINTENANCE	3522 500 60651	Pre Maint	1		24-1-2017	Insert maint. job
	PSU					

Order nr.	Part	Status	Quantity	Date ordered/started	Planned delivery date
5	136505	On order	1	4-7-2014	**20-8-2015**
7	9556 754 17800	Repair in	1	24-6-2016	22-9-2016
4	136505	Pre Maint	1		24-10-2016
3	9556 002 06000	Pre Maint	1		24-10-2016
33	3522 500 56231	On order	2	24-9-2016	22-11-2016
32	3522 500 59365	On order	2	24-9-2016	22-11-2016
31	3522 500 19598	On order	2	24-9-2016	26-11-2016
30	3522 500 61448	On order	2	24-9-2016	29-11-2016
29	3522 500 54868	On order	2	24-9-2016	20-12-2016
28	9556 754 17800	Repair in	5	24-9-2016	23-12-2016
27	143565	On order	2	24-9-2016	10-1-2017

Excel sheet "Orders", shows the current stock levels

This sheet contains the current stock levels on the left and ways to mutate these stock levels on the right. How it works it quite obvious, choose a part that you want to remove from the stock at the maintenance sections, choose how many and from what location you want to take them and press "Update" next to maintenance. When there is no stock at the location you want to take the part from, a warning will be generated that says: There is no stock available at this location.

Current stock

Part	Stock level TNL	Ships	Total
136505	3	0	3
143565	2	0	2
263369	2	0	2
266133	3	4	7
266141	5	4	9
266143	2	0	2
266163	3	4	7
266172	3	4	7
266606	3	4	7
291129	2	0	2
503131	1	0	1
61369392	4	0	4
61739572	3	4	7
61739836	4	0	4
61739837	4	0	4
61739838	6	4	10
61739839	4	0	4
61992370	13	4	17
61993155	6	4	10

reset

MAINTENANCE — Update

	Corrective maintenance	QNTY	Taken from location
Part	136505	1	Ships

TRANFSER OF STOCK — Update

		QNTY	Taken from:	To:
Part	136505	1	TNL	Ships

ORDER ARRIVES — Update

	Part has arrived	QNTY	Added to location
Part	136505	1	Ships

Excel sheet "Risk per part"

This is the sheet where all of the stock-out risks are calculated. The table on the left is an summary of the other tables.

Risk per part

Part		With the current stock: Chance of stock out before arrival next order	When a part breaks down: Chance of stock out before arrival next order	Chance of stock out if repaired
TRANSFORMER	136505	0,00%	0,00%	0,00%
INDICATOR	143565	0,00%	0,05%	0,06%
GASKET	263369	0,00%	0,07%	0,04%
FAN MODUL.	266133	0,00%	0,00%	0,00%
COMPRESSOR MOD	266141	0,00%	0,00%	0,00%
ADSORBER	266143			
REG. MOD.	266163	0,00%	0,00%	0,00%
LUCHT MOD.	266172	0,00%	0,00%	0,00%
FILTER	266606	0,00%	0,00%	0,00%
DIG.CONTR.	291129	0,00%	0,03%	0,89%
BELLOWS	503131	0,00%	0,05%	0,06%
CCC	61369392	0,00%	0,00%	0,00%
CONBO_SM	61739572	0,00%	0,00%	0,00%
OTB	61739836	0,00%	0,00%	0,00%
TL_ENC_UN	61739837	0,00%	0,00%	0,00%
UW_GEN	61739838	0,00%	0,00%	0,00%
LO1_SYNTH	61739839	0,00%	0,02%	0,00%

The second table is the risk calculation with the current stock. I will explain the table per column.
I and J are just part name and nr. K is the current stock level
L tells you if there is a upcoming order in the pipeline and M show at what date it is expected to arrive.
When there is no order planned, the soonest arrival date will be today plus the lead time of the part, this is the date in column N
O checks whether M or N is shorter and calculates the amount of day until the earliest order arrives.
P checks if there is a preventive maintenance job planned during before the part arrives, if so then the date of this maintenance job is noted in Q and the days until the job in R
S contains a very long formula but to summarize it: It checks if there is a maintenance job planned between now and the earliest arrival of a part.

If not, then it uses
1-POISSON.DIST('Risk per part'!K4;(('Full table'!H4)/365*'Risk per part'!O4);TRUE)
1 - X=current stock; mean = expected demand per day * days; cumulative prob.
Which gives the probability, based on the Poisson distribution, that the demand is more that the current stock in the time until the next order.

If there is a preventive maintenance in between it does:
1-POISSON.DIST('Risk per part'!K4;(('Full table'!H4)/365*'Risk per part'!R4);TRUE))+
(1-POISSON.DIST('Risk per part'!K4-P4;(('Full table'!H4)/365*(O4-'Risk per part'!R4));TRUE)

It looks much more complicated, but it does the same thing. The first part of the function is the probability of demand higher than the current stock until the prev. maint. And the second part calculates the probability of demand higher than the current stock – the amount of part that have been used during maintenance in the time from the pre. maint. until the earliest arrival of the order.

I	J	K	L	M	N	O	P	Q	R	S
				Already ordered	No order yet, but ordered today					
Part		Current total stock level	Upcoming order?	Arrival date	Arrival date	Days until arrival of order	Parts used for preventive maintenance before arrival	First preventive maint.	Days until maint.	Chance of stock out before arrival
TRANSFORMER	136505	3	Yes	20-8-2015	28-10-2016	0	0	24-10-2016	104	0,00%
INDICATOR	143565	2	Yes	10-1-2017	28-10-2016	182	0			0,00%
GASKET	263369	2	Yes	12-4-2017	3-2-2017	274	0			0,00%
FAN MODUL.	266133	7	Yes	10-1-2017	28-10-2016	182	0			0,00%
COMPRESSOR MOD	266141	9	Yes	14-3-2017	30-12-2016	245	0			0,00%
ADSORBER	266143	2					0			
REG. MOD.	266163	7	Yes	10-1-2017	28-10-2016	182	0			0,00%
LUCHT MOD.	266172	7			28-10-2016	108	0			0,00%
FILTER	266606	7			28-10-2016	108	0			0,00%
DIG.CONTR.	291129	2			16-8-2016	35	0			0,00%
BELLOWS	503131	1			30-12-2016	171	0			0,00%
CCC	61369392	4			9-3-2018	605	0			0,00%
CONBO_SM	61739572	7			23-1-2018	560	0			0,00%

The third table does the same thing as the second one, but with a stock level that is one lower and it uses the repair time instead of the lead time in the corresponding column.

Excel sheet “Stock database”

This sheet has been used to calculate the historic demand, based on the expected demand per year. The current date is located in column DD. In every column before DD contains the formula:

=ROUND($DD4+(COLUMN($DD:$DD)-COLUMN(DC:DC))*(('Full table'!$H4)*7/365);0)
=Current stock + (Week difference with today * Week demand) rounded of on integers

This causes the stock level to increase more the further it is away from the current date. Because the historic data would only contain whole parts, not half or quarter parts, the values are rounded to integers.

If a part breaks down today			Chance on stock out	
New stock	Repair time	Date repaired	If repaired	If ordered /upcoming order
2	200	28-1-2017	0,00%	0,00%
1	200	28-1-2017	0,06%	0,05%
1	200	28-1-2017	0,04%	0,07%
6	200	28-1-2017	0,00%	0,00%
8	200	28-1-2017	0,00%	0,00%
1				
6	200	28-1-2017	0,00%	0,00%
6	200	28-1-2017	0,00%	0,00%
6	200	28-1-2017	0,00%	0,00%
1	200	28-1-2017	0,89%	0,03%
0	200	28-1-2017	0,06%	0,05%
3	200	28-1-2017	0,00%	0,00%
6	200	28-1-2017	0,00%	0,00%

Excel sheet “Full table”

Contains a summary of all the input variables

Full table												
Reference Number	Item Name	Initial Stock Quantities			MTBF (hour) (1 part)	Parts per radar	Expected demand per year	On Order	In Repair	Leadtime	Repair time	Working hours per year
		Project A	Project B	Total								
1	Part 1	2	0	2	1470000	2	0,0347	1	0	108	200	25520
2	Part 2	2	0	2	630000	2	0,0810	0	0	108	200	25520
3	Part 3	2	0	2	840000	2	0,0608	0	0	206	200	25520
4	Part 4	3	4	7	520000	2	0,0982	0	0	108	200	25520
5	Part 5	5	4	9	190000	2	0,2686	0	0	171	200	25520

The sheets “MTBF” “Leadtimes” and “Repair times” (these are only included in the classified version for Thales) formed the input for the full table