''Standardization of a visual inspection for radar systems''

Scriptie

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Important

This is a public version of this document. This has as a consequence that some parts are adjusted or left out due to the confidentiality of this research. The system focussed on is referred as Model X.

Management summary

Problem description

Thales Nederland offers a health check service to its clients. With this service, Thales executes an inspection where the state of its products at the client emerges. Thales personnel was seeking for opportunities to make the inspection more unambiguous. The service exists of a functional and visual inspection. This research focuses on the visual part of the inspection. After a short plenary analysis, it became clear that there were improvement opportunities in the corresponding inspection checklist. The following research question arose:

"How can the current visual inspection checklist be improved to increase the quality of the Thales System Health Check Service?"

Method

First we took a look at the current Thales health check. This was done by reading Thales documents and gathering information from Thales personnel by interviewing them. Then three comparable methods were assessed to see whether information from these methods could be useful for improving the Thales health check.

After short assessments of the three comparable methods, one of those methods was chosen to implement on the Thales health check to see whether what advantages this would bring and if it would therefore be an improvement. The chosen method to implement was the NEN 2767, as this method applied the best on the Thales inspection to make the inspection process more unambiguous. The NEN 2767 aims for standardization of inspections, which contributes to unambiguity.

The NEN 2767 works with a condition that is scored on a six-point scale. Condition score 1 represents the new-built condition and condition score 6 represents the worst condition to be found.

The condition measurement is the determination, indication and quantification of defects. The condition scores are based on three elements: the severity, the extent and the intensity of a defect. Within the condition assessment, a three-way division is applied according to the severity of defects: grave, serious and minor defects. For the extent of a defect, an extent score is given based on how often the problem occurs. The intensity of a defect is on the degradation of stages of defects. A three-way division is applied again, a problem can be in an initial, advanced or final stage.

When the three elements are determined, the condition scores can be derived from given matrices in the NEN 2767. The severity of a defect is expressed as minor, serious or grave. There is different matrix for each severity. With these matrices, it is possible for an inspector to determine the condition score for a defect based on severity, extent and intensity.

The visual inspection of the Thales health check has been converted to the NEN 2767 method in an Excel file with VBA codes that automizes some processes. All the items that are normally checked by Thales are now condition based, which means that every inspected item now has a score between 1 and 6. The model can be expanded easily and is easy to use for inspectors as they only have to fill in the found values in the excel file. The file itself does the rest. Also, excel is a commonly used program within Thales so it is not difficult for Thales personnel in general to use this program. Next to that, an explanation on how to expand the model is attached as an appendix to make sure Thales personnel is able to work with this model.

Conclusions and recommendations

The current health check and the modified health check were compared and scored on the five criteria shown in table 1.

Criteria	Current Health check	Modified Health check based on NEN 2767
Speed	--	++
Accuracy	-	+
Clarity	++	+
Simplicity	++	+
Visuality	-	++

Table 1: Criteria table

Working with a six-point scales gives a more refined inspection than before. Also it is possible to apply conditional formatting in Excel because of the quantification. This causes automatic coloring and a better visual overview for the client. Therefore a high score (++) for visuality is given to the modified health check compared to the score of the current health check (-). Next to that it is possible to generate automatic advices because of the quantification. This can save Thales time with processing the information form the inspection. That is why a high score (++) is given to the modified health check and a lower score (--) at the modified health check for the speed criteria. The scores in the table 1 are further explained in appendix C.
Based on the advantages mentioned above, it is advised to Thales to quantify the inspected item by working with a numerical scale. This can be done by implementing the NEN 2767 or a similar method.

1. Thales should now first determine if they see potential in quantifying the current Thales health check. Not only from service, but also from technical perspective. The findings from this research were already presented to both employees from the technical department as well as the service department. After the presentation the reaction from both departments were both mostly enthusiastic. However, there should be a more thorough discussion between both to determine whether to implement the findings of this research.
2. Subsequently, Thales service and technical department should discuss to what extent they will apply this. This research focusses on the visual part of the inspection, while it might also be useful for the functional part of the inspection. The functional part is left out of this research as it would become too technical for me as a researcher. Also, improving the visual part of the inspection is already a big step.

3. Finally the model should be made concrete for one system and tested by personnel who would normally execute a Thales health check. When it work for one system, it should be investigated if this method would be applicable for other systems as well.

Preface

This is my thesis: 'Optimization of a System Health Check Service.' It was written to advise Thales Nederland and to finish my bachelor Industrial Engineering & Management at the University of Twente. The research in this thesis focuses on improving a method to conduct a System Health Check Service by analysing and extracting information from similar methods. The research was conducted at Thales Nederland in Hengelo and took place from September to November 2020.

In this preface I would like to take the opportunity to thank a number of people.

First, thanks to Berend Jongebloed and Pim Cornelissen from Thales Nederland. They provided me with a lot of useful feedback and guided me through my time at Thales Nederland. It was nice that they put so much time into me and my thesis. Next to them, I would like to thank all the other Thales personnel who helped me conducting this research.

Secondly, I would like to thank my supervisors from the University of Twente, Peter Schuur and Jan Braaksma, for the guidance that led to keeping this research academic.

Finally, I want to thank my parents and friends for their support during this time. The interest they showed in me and my graduation assignment kept me motivated.

I hope you enjoy reading my thesis!

Stan van der Wel

Enschede/Hengelo, September – January 2020

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1 Introduction

First a short description about Thales in a general sense is given (1). Then the department where this bachelor assignment will take place is described (1.1). Finally, the process that should be optimized is explained (1.2).

1.1 Thales

With 80.000 talents working in 54 countries, 2000 employees are based in the Netherlands. Thales is one of the biggest high-tech employers in the field of safety and security. Thales helps its customers think smarter and act faster in the fields of transportation, defense, space, aerospace and cyberspace, mastering ever-greater complexity and every decisive moment along the way. Thales is therefore leading the digital transformation, focusing on artificial intelligence, big-data & data analytics, connectivity, mobility and internet of things and cybersecurity.

In the Netherlands, Thales is located in four cities: Huizen, Delft, Eindhoven and Hengelo (HQ). Together with an extensive ecosystem of knowledge partners, customers and suppliers, Thales works on radars for naval vessels, cyber security solutions, transportation systems, communication equipment for land forces, cryogenic cooling solutions, research & development for radar tech (in collaboration with TU Delft) and research & development for Service Logistics (in collaboration with the University of Twente).

1.2 System Health Check Service

Naval ships are equipped with a large number of systems and equipment that have to operate in adverse environments. During their lifetime, systems and equipment need to be supported, maintained and upgraded to minimize the gap between intended and available capabilities and performance. Nowadays, increased system complexity requires well-skilled staff to execute these activities.

As Thales builds and sells a lot of systems for naval ships, they have a lot of knowledge about these systems. Therefore, Thales has well-skilled staff to maintain successful operation, functioning, support and improvement of systems and equipment throughout a ship's operational life.

Thales makes knowledge available to its customers by offering services. In this way, Thales can help customers even further and therefore create extra business. The services are offered in a package where customers can decide their own combination of services based on their own needs. A division is made between core services (baseline) and on demand services, where core services are seen as standard and on demand services can be ordered on a case-by-case basis when required.

The Service Health Check System (SHCS) is one of the eleven baseline services/products. My bachelor assignment will be focused on this service.

The health check is performed at pre-defined time intervals and will be aligned with the ship's maintenance cycle. It ensures high system performance is sustained and/or improved, reduces risks of unforeseen malfunctioning and allows planned preventive maintenance.

Thales-NL has qualified specialists, with extensive experience in inspecting complex systems, who will execute the health check. They have access to the knowledge database, thorough checklists, (built-in) system tests, logging/monitoring facilities and test equipment for support and, in this way, can provide instructions on which measures should be taken. Upon completion of the health check, analysed data is reported and recommendations are provided.

Using the health check as a pro-active service, additional maintenance tasks can be identified at an early stage. This can result in recommendations to the maintenance concept or usage plan (e.g. advised changes) and the logistic support organisation. With appropriate maintenance executed on the right time, the system are more likely to last longer which is an advantage for the customer.

The advantage for the customer is that Thales personnel is very skilled and can there for execute the Health Check relatively fast. The advantage for Thales is that the Health Check enables business by advising other Thales' services based on the Health Check outcome. Also, it creates better communication between Thales and its customers.

2 Problem identification

Thales is constantly trying to improve the quality of their System Health Check Service (SHCS). In reality, over the past years, health checks were designed case by case at Thales. This leads to different processes and outcomes.

By standardizing the System Health Check Service, Thales hopes to increase the quality of their service. Therefore, the norm in this case is a more systematic health check.

2.1 Research motive

In the problem cluster, figure 1, it can be seen that four aspects have an influence on the quality of the System Health Check Service: Non unambiguous asset advice, duration health check, non-unambiguous result and standardization. Also, it can be seen that the checklist used during the health check has a(n) (in)direct on all 4 aspects. Because of that, improving the checklist would be useful for Thales.

During this research we create a new/adjusted checklist by taking a look on other inspection methods. The goal is to give Thales better insights after executing a Health Check without changing the duration of a health check too much. The central research question that arises from this core problem is as follows:

"How can the current checklist be improved to increase the quality of the Thales System Health Check Service?"

2.2 Problem cluster

Out of a several talks with personnel, the following problem cluster (figure 1) came out. The arrows imply causal relations. The problems could also be described as opportunities to improve. In section 3.2 it is further explained why the current checklist is inconclusive, ineffective and inefficient.

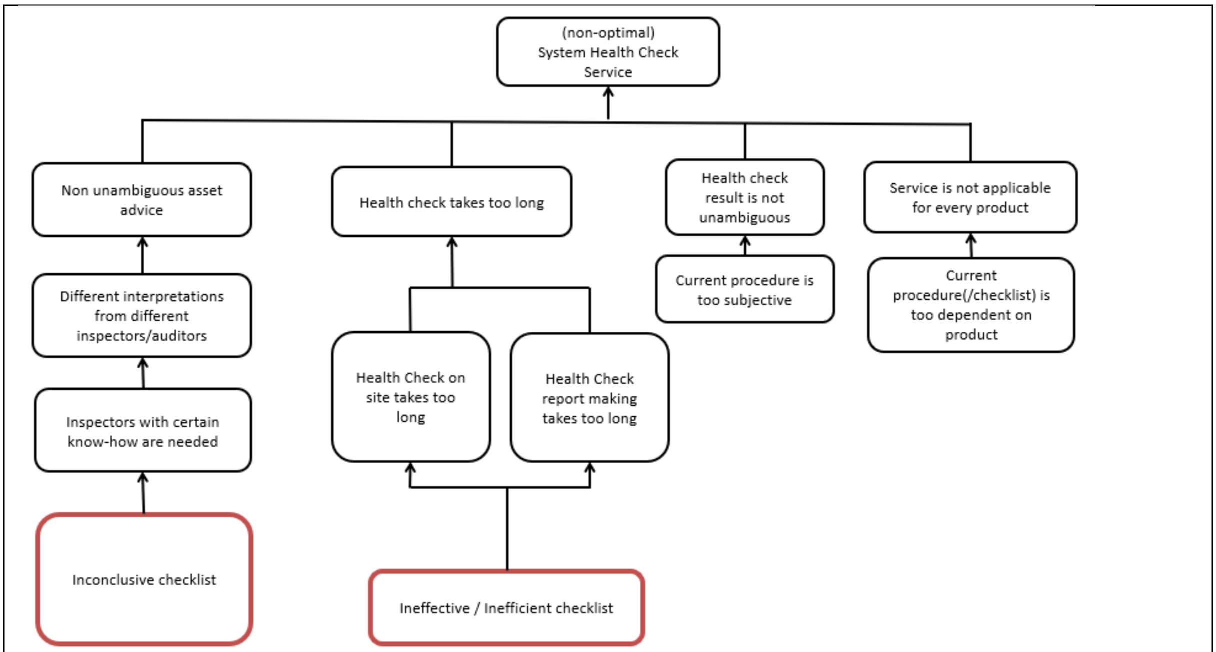

Figure 1: Problem cluster

2.3 Problem approach

1. **Understand the current Thales health check.**
   It is important to find out how the health check is executed currently. From there it is easier to seek for improvements.
2. **See if there are already existing health check methodologies by executing literature research.**
   From the existing methodologies useful information will be arrived that can potentially be used to improve the quality of Thales' current methodology.
3. **Join a health check at another company.**
   By joining a visual inspection from another company, it can be seen how a health check is executed. The knowledge derived from this experience (executor, checklist used, processing of data, etc.) might be used to improve the current health check of Thales. The day will be logged in a logbook, which will be added as an appendix.
4. **Compare Thales' health check with other health checks.**
   After comparing the methods, differences between the Thales health check and other health checks will be searched for. The differences (gaps) are analyzed and used to see if there are opportunities for Thales to improve.
5. **Get in contact with Thales personnel to discuss found gaps/opportunities.**
   Most of the steps above are based on theoretical information. It is important to test the found gaps/opportunities against the experiences from Thales personnel.
6. **Conclusions about the current System Health Check service.**
   After discussing the found gaps/opportunities with Thales' personnel, it is time to conclude whether an alteration is worth taking to bridge the gap/take on the opportunity.
7. **Give recommendations.**
   After drawing conclusions, recommendations will be given to Thales in the form of an altered health check.

2.4 Knowledge problems

The knowledge problems are identified by taking a look at section 2.3.

From step 1 and 2 the following research questions can be derived:

1. **''How is the current Thales health check built up?''**
2. **''What methodologies for executing a system health check do already exist?''**

The methodologies contain qualitative information. As it is the first step in the research, the strategy for this research is broad: gather a lot of information before focusing too much. By creating a new health check methodology for Thales in the end, it is useful to have the knowledge from other existing health checks.

After finding similar methodologies we are having a look at both the Thales' health check and other health checks. From this, differences will become clear. Some of the gaps that exist can be seen as opportunities to improve. With the knowledge found earlier we will start discussions with Thales' personnel to find answers to the questions:

3. **"What can we use from other methodologies to improve the current health check service?"**

After discussing the possible improvement for the Thales health check with the Thales personnel we will implement the potential improvement to see how these improvements will fit for Thales. This will answer the following question:

4. **"How can (parts of) other methodologies be implemented on the Thales health check service?"**

When the implementation is done, it is time to assess whether the alteration actually do improve the Thales health check service. We answer the final knowledge question:

5. **"What advantages does the implementation bring?"**

2.5 Deliverables

In the end, the knowledge gained during the research will be used to improve the current System Health Check Service from Thales. This will be done by improving the current checklist used by Thales for executing the health check.

The improvements will be proposed alterations that are approved by the Thales personnel. The total amount of propositions is generated from knowledge derived from other health check methodologies.

The altered health check will be put in a model that is easy to adjust for Thales. As Microsoft Excel is a common known program and accessible, it is chosen to make this model in Excel. With the use of Excel VBA it is also a tool for a part of the Thales health check. When this Excel is expanded, it could be used during the inspections as the new checklist.

2.6 Research design

The type of research that will be executed is scientific. Everything that is described in this research will be based on facts and found in Thales documents and mostly the experiences from Thales personnel. The goal of the research is to convert the gained knowledge for practical use. In this case that will be an improved methodology to execute a System Health Check.

Qualitative interviews cover a lot of the data gathering in this research. This is largely due to the fact that the System Health Check Service and its checklist are qualitative itself. The checklist does not gather a lot of quantitative data. Most off the data is very specific to the health check. It is not easy to derive any conclusions from this information.
By the mean of qualitative interviews I hope to gain more background information on the System Health Check Service and discover the current flaws.

3 Current Thales health check

Before looking at other methods, we wanted to understand the current Thales health check better. This is done by diving into company files and talking to Thales personnel. The whole process of the health check is described in section 3.1. The inspection itself is explained in section 3.2 using the checklist that is used during the inspections. With both sections we try to explain why the checklist is inconclusive, ineffective and inefficient as stated in section 2.2.

3.1 The process

Customers often do not only have one ship, but fleets that need to be checked now and then. The check can only be executed when the fleet is in harbor. The fleets are often operational and even if they are in harbor, it is important that a fleet can come out at any time. Therefore it is nice if an inspection does not take too much time. To find a moment to execute a health check, the communication between Thales and its customers is very important.

The execution of a Thales health check and the information gathered with it is very confidential. If it is known to enemies when a customer is in harbor or where its weaknesses lie, it makes the customer vulnerable towards its enemies. Therefore the checklist is filled in on paper and not online, to make sure that the information cannot be hacked.

The paper that is filled in, is later on digitalized at the Thales office. The digitalizing costs a lot of time and might also be done directly with a device that cannot connect with the internet. Based on this, the current checklist can be seen as inefficient as there might be faster options to process the found results during the inspection.

The digitalized results are used for a report that goes to the customer. The report that goes to the customer is composed by other people than those who executed the inspection itself. Non ambiguous advice is therefore very important to prevent irregularities.

The inspectors sent by Thales determine how much and what they will inspect given the time they get from the customer. Most of the time multiple systems on multiple ships need to be checked. In this research we only focused on system X.

3.2 The checklist

The checklist that is used for the inspection is always split up in a visual and functional part. This research is only focussed on the visual part, as the NEN 2767 found in the next chapter is too complex for me to apply on the technical part as I lack technical knowledge.

The visual inspection checklist for the model X consist of 7 (sub)systems that are being checked. The 7 (sub)systems are listed below and can also be found in the excel sheet that is added as an appendix.

1. (4.1 Antenna System)
   - ***A.*** *4.1.1 Antenna assembly*
   - ***B.*** *4.1.2 Drive Assembly*
   - ***C.*** *4.1.3 Junction Box*
   - ***D.*** *4.1.4 Rotary Joint Unit*
2. 4.2 Man Aloft Switch
3. 4.3 Drive Control and Cooling Cabinet
4. 4.4 Filter Unit (if applicable)
5. 4.5 Model X Processing Cabinet
6. 4.6 Air Dryer
7. 4.7 Maintainer Terminal

One of the (sub)systems is called the 'antenna assembly'. The antenna assembly is scored on 10 items as can be seen in figure 2. Every item is checked 'OK' or 'NOT OK' by the inspector.

4.1.1. Antenna Assembly

	Inspection items	OK?	NOT OK?
1	Check for damage of painted surfaces.		
2	Check all covers and hoses for damage.		
3	Check silicone seal of Radome for damage.		
4	Check all electrical cables and connectors.		
5	Check the correct mounting of LRUs.		
6	Check for loose bolts.		
7	Check for missing parts/LRUs.		
8	Check main parts on over pressure.		
9	Check the fixation of the air hose.		
10	Check the mounting of all TR-books.		

Figure 2: Items at the antenna assembly that are inspected during the health check

The inspector first checks the antenna assembly on damage of painted surfaces. If this is ‘NOT OK’, the inspector makes a comment with what is wrong. If it is ‘OK’, the inspector moves on to the next item. This means that every problem will have its own description, independent on how big the problem is. There is not really a gradation when checking the systems in this way. The scoring only says whether the item is good to go or not.

The comments that are put at the items that are ‘NOT OK’ determine the gradation at the inspected items. The comments are influenced by the inspector. With a reference scale and a gradated scoring method, the comments and advices on the inspected items would be less influenced by the inspector. Now the check might lead to different conclusions and the check is therefore inconclusive. This leads to an ambiguous advice to the customers as the same problems might be interpreted differently by different inspectors. As Thales aims for a more unambiguous health check, the current check could be described as ineffective. They want unambiguous results, which is not entirely the case at the moment.

Striving for unambiguous results is useful. For example when personnel retires, it would be nice that the check can be taken over easily by new inspectors. An unambiguous check creates a lower barrier for new personnel to take over.

4 Other health check documents

After analyzing the current Thales System Health Check Service, a look is taken at other methodologies that relate to health checks. This is done to see if it is possible to map parts of these methodologies on the Thales methodology. In every section a methodology is summarized with the findings that will be most useful for Thales. The method summarized in section 4.2 is the most elaborate as this will be implemented on the Thales health check service and is therefore the most important in this research.

4.1 NEN 3140

NEN stands for 'Nederlandse Norm', which means 'Dutch Norm'. This Dutch norm is an operation of low voltage electrical installations. The purpose of this publication is to provide general requirements on the safe operation of electrical installations and electrical work equipment for the Netherlands. Next to that it shortly teaches about determining the time between two successive inspections of electrical systems.

This might be interesting for Thales as the radars that are checked, are electrical systems as well. However, the norm is mostly about setting requirements for a safe operation of electrical installations and of the electrical work equipment. We wanted to focus on the health check process as a whole and specifically more on the checklist that is used during inspection, not the safety in the process regarding electricity. Therefore it is chosen to not elaborate on this method as it seemed less interesting and applicable in the beginning than the norm described in the next section.

4.2 NEN 2767

This Dutch norm is a methodology for a 'condition assessment-built environment'. It is an uniform method to determine the technical state for all objects within a built environment. This is interesting as Thales would like to have a more uniform health check. The norm tells us that the need for such uniform method arises from a number of considerations:

- having access to one method, which can be applied in a multidisciplinary manner within the Real Estate and Infrastructure sectors, offers the desired unambiguity for users of the standard;
- one integrated standard is more efficient for both the user and the standards manager for application within individual business processes and the entire management process;
- to avoid errors and improve consistency, an integrated standard is preferred instead of several complementary parts;
- new results-oriented contracts require an integrated approach. Different assessment methods with their own assessment framework are counterproductive;
- the increasing possibilities of information technology require unambiguous ordering without aspects that can be interpreted in multiple ways;
- lifetime calculations can be made integrally when applying a single condition measurement method. This provides a better interpretation of Life Cycle Management (LCM);

- Integrated elaboration of specific management objects provides more options for application by small asset owners.

The considerations above largely agree with the ambitions on the service department of Thales. Next to ambitions, the NEN 2767 has the following goals:

- NEN 2767 series creates uniformity in the condition score per building part by means of a value that expresses the technical condition of the building part. This value is a combination of the severity, extent and intensity of a defect.
- NEN 2767 provides insight into and unity in the types of defects based on the defect parameters severity, size and intensity.
- NEN 2767 classifies the defects found and can provide support in setting priorities: ranking the need for repair of the defects found.
- NEN 2767 is a tool for testing, steering and implementation for organizational units that focus on management and maintenance.

The NEN 2767 works with a condition that is scored on a six-point scale. Condition score 1 represents the new-build condition and condition score 6 represents the worst condition to be found. Table 2 provides brief descriptions of the condition scores:

Condition score	Description
1	Excellent condition
2	Good condition
3	Reasonable condition
4	Moderate condition
5	Poor condition
6	Very bad condition

Table 2: Explanation condition scores NEN 2767

The condition measurement is the determination, indication and quantification of defects. To this end, three defect parameters are distinguished:

- The severity of a defect
- The extent of a defect
- The intensity of a defect

The severity of a defect can be grave, serious or minor. A grave defect causes impairment of the function of the building part. A serious defect causes degradation of the building part without the functionality directly attack. A minor defect does not affect the functionality of the construction part.

After the severity is determined, the extent of the defect will be determined. The scores is as described in table 3:

Extent score	Percentage	Description
Extent 1	< 2 %	Defect is incidental
Extent 2	2 % - 9 %	Defect is local
Extent 3	10 % - 30 %	Defect is regular
Extent 4	30 % - 70 %	Defect is considerable
Extent 5	>= 70 %	Defect is common

Table 3: Extent scores and explanation NEN 2767

After that, the intensity is determined with a similar table 4:

Intensity score	Designation	Explanation
Intensity 1	Initial stage	The defect is usually barely perceptible and superficially present in the surface
Intensity 2	Advanced stage	The defect is clearly visible and present in the surface
Intensity 3	Final stage	The defect is very clearly perceptible, irreversible and cannot hardly increase

Table 4: Intensity scores and explanation NEN 2767

When all three components are determined, it is possible to derive the condition scores from matrices. There are 3 different matrices, 1 for every severity class:

Minor defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	1	1	2
2 | Advanced	1	1	1	2	3
3 | End	1	1	2	3	4

Table 5: Matrix to determine a condition score for minor defects

Serious defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	1	2	3
2 | Advanced	1	1	2	3	4
3 | End	1	2	3	4	5

Table 6: Matrix to determine a condition score for serious defects

Grave defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	2	3	4
2 | Advanced	1	2	3	4	5
3 | End	2	3	4	5	6

Table 7: Matrix to determine a condition score for grave defects

With the determined condition scores drawn from the matrices above, it is possible to calculate the theoretical lifespan of a part. This is interesting for Thales as a link can be made to financial asset advice. The graph on the next page show how the theoretical lifespan can be determined.

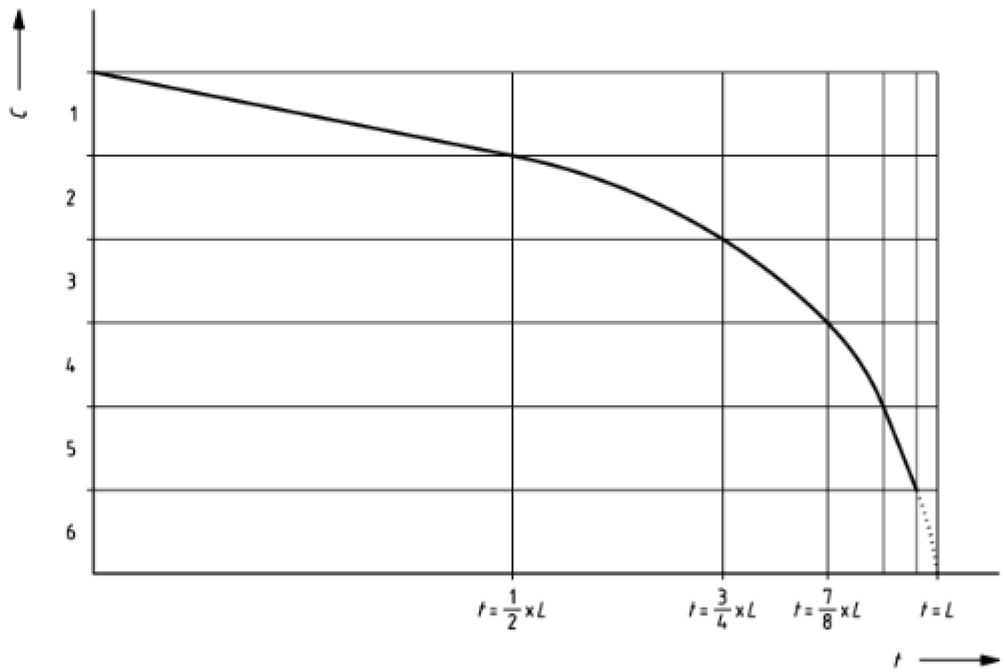

Figure 3: Graph for determining the past lifetime based on a given condition score

The variables in figure 3 stand for the following:

- C = condition score of the part
- t = the past lifetime of the part
- L = the theoretical lifespan of the part

From the graph we can calculate the theoretical lifespan 't' of a part. For example, a condition score between 3 and 4 gives t = 7/8 x L. This theoretical lifespan value can be used for calculations in asset advice. The NEN 2767 norm tells us that other norms elaborate on this and that this is not part of the NEN 2767 itself. Unfortunately the NEN 2767 does not tell us which norms elaborate on this. The condition scores and its theoretical lifespan only functions as an indicator that can be used for asset management.

We do not dive deeper into this as it is not totally a part of the NEN 2767. However, we wanted to highlight this potential shortly as Thales personnel told us to be interested in improving asset advice. Also, this graph is made for buildings. The radar systems from Thales are different than buildings. Therefore this graph is probably not optimal for the radar systems and the formulas might be different for radar systems. We just wanted to show the concept here, to let Thales know this exists. It could be interesting for Thales to investigate whether they can use this concept for their radars as well.

4.3 BPR Solar

It was not possible to experience an inspection at Thales. So to experience an inspection, I experienced a day at BPR Solar commissioned by Thales. BPR Solar does, among other things, quality management at solar parks. This means that they inspect large series of solar panels to check whether they meet prescribed requirements. I wondered how the inspections at BPR Solar were prepared, executed and processed. The experience at BPR Solar did not directly match the research, but interesting observations were made. The most interesting findings are listed below and the whole experience is summarized in a logbook of the day which can be found in appendix A.

The first interesting finding was the use of a tablet when the inspection was executed. When an item was inspected the inspector made comments which could be uploaded directly. Also, pictures were made with the same tablet and uploaded as well. This showed direct digitalization and a fast processing process. This is interesting for Thales as Thales is now executing their check on paper and digitalize it later at the office, which takes quite some time.

The second interesting finding was the use of PlanGrid. PlanGrid is a construction productivity software. The platform provides real-time updates and seamless file synchronization over Wi-Fi and cellular networks. PlanGrid replaces paper blueprints, brings the benefits of version control to construction teams, and is a collaborative platform for sharing construction information like field markups, progress photos and issues tracking.

After the inspector uploaded the comments and corresponding pictures, it was possible to print out an automatically generated document. PlanGrid cannot be used at Thales as it is an online program, but this aspect is interesting for Thales as Thales spends much time generating the same looking report every time. With a process like this, the pictures from the visual inspection could be automatically combined with the corresponding comments and advice.

The third and last interesting finding was the use of torque wrenches. A torque wrench is a tool used to apply a specific torque to a fastener such as a nut, bolt, or lag screw. It is usually in the form of a socket wrench with special internal mechanisms. This might be interesting for Thales as well as Thales is checking on loose bolts as well. A torque wrench gives more information than the naked eye. This leads to a less subjective outcome when checking on loose bolts during the visual inspection. This contributes to a more unambiguous inspection.

5 Towards the design of an useful tool

From chapter 3 we learned that a lot is inspected during the Thales health check. To show the power of using the NEN 2767 in the Thales health check, it is not necessary to map the method on the whole Thales health check. To save time, we chose a several problems that we zoomed in on. These problems were selected based on that they are often checked on different systems. With zooming in on problems that are inspected multiple times, we hope to discover relations when analysing the results. The problems are described and given a severity in section 5.1. Then in section 5.2 it is explained how these problems are given a condition score on a scale of six. This scoring leads to a more refined review of the problems and with that to standardisation.

5.1 Scoping

Problems

This section explains the problems that will be focused on in this thesis. During the Thales Health Check different subsystems are checked on several aspects. Aspects that are described as problems in table 8. We picked the most occurring problems for this analysis, as some aspects are too specific for one subsystem. Also, picking every problem would be more time-consuming whilst the results would not improve. The severity for each problem is determined and shown in the table as well.

Problem number	Problem	Severity
A	Damage painted surfaces	Minor
B	Electrical cables and connectors	Grave
C	Loose bolts	Minor
D	Corrosion	Serious

Table 8: Allocation of severities to chosen problems

The allocated severities in table 8 are based on common sense and the severity descriptions in the NEN 2767. The descriptions from the NEN 2767 can probably not be copied directly, as the NEN 2767 is made for buildings. Thales should discuss in what extent these descriptions can be used and what adjustments should be made for every problem when allocating a severity. The descriptions for severities from the NEN 2767 are shown in table 9.

Severity	Explanation	Example
Grave	Causes impairment of function of the building part	Wood rot, burst in a flue gas discharge from a boiler
Serious	Causes degradation of a building part without directly disturbing the functionality	Weathering, erosion, defect that leads to leaks in installations
Minor	Does not affect the functionality of the building part	Discoloration due to aging, improper attachment of components

Table 9: Allocating severities NEN 2767

A. Damage painted surfaces

From the 7 systems that are visually inspected, 4 are checked on the damage of painted surfaces. From the antenna assembly, all the 4 subsystems are inspected on this problem as well. A painted surface is important as it functions as a protection layer. Without a layer of paint, the layer beneath is more vulnerable for corrosion.

B. Electrical cables and connectors

All the electrical cables its connectors should be as they were in the beginning. This means that the cables should be fixated in the right way and that they are not damaged. This way problems like short circuits will be prevented and safety can be guaranteed better.

C. Loose bolts

Loose bolts might cause parts to vibrate more than they should. Not all parts are strong enough to handle these vibrations. It might weaken and eventually cause parts to break down. This will lead to unnecessary high costs.

D. Corrosion

Corrosion leads to a loss of strength, due to the fact that the corrosion products (oxides and salts) are much weaker than the metal. The corrosion products crumble and the metal parts become thinner. In this way, even holes can fall in metal plates.
An additional problem is that the corrosion products occupy a larger volume than the metal. Expansion of the material can disrupt a structure.

5.2 Key performance indicators (KPI)

The severity of the problems is already determined in the previous section. To determine the condition score for every problem, the extent and the intensity score for the problem are needed. When we have the scores for severity, extent and intensity we can make a more objective description of the problems found at the inspection. Problem description will be based more on scale than on interpretation.

The inspector should be able to determine the extent of each of the selected problems by the use of the table 10:

Extent score	**Percentage**	**Description**
Extent 1	< 2 %	Defect is incidental
Extent 2	2 % - 9 %	Defect is local
Extent 3	10 % - 30 %	Defect is regular
Extent 4	30 % - 70 %	Defect is considerable
Extent 5	>= 70 %	Defect is common

Table 10: Extent scores and explanation NEN 2767

That leaves only the intensity score. The intensity score is different for every problem. Below the it is explained how the intensity score can be determined per problem. For every problem intensity 1 is the starter stadium, intensity 2 is the advanced stadium and intensity 3 is the end stadium.

A. <u>Damage painted surfaces</u>

<u>Figure 3:</u> Reference scale paint damage

As can be seen, an inspector should give an intensity score of 1 when the paint slightly starting to degrade or when it is less worse. If the painted surface is worse, for example when the paint layer begins to loosen, an intensity score of 2 should be given. If it is even worse, an intensity score of 3 should be given.

From section 4.1 we see that this problem is has a minor severity. Therefore we use the following matrix, table 11, from the NEN 2767 to determine the condition scores:

Minor defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	1	1	2
2 | Advanced	1	1	1	2	3
3 | End	1	1	2	3	4

Table 11: Matrix to determine condition scores for minor defects

B. Electrical cables and connectors

This problem is more difficult to visualize than the other problems. Therefore table 12 is made instead of a scale with pictures. The examples of problems are based on problems found in executed Thales health checks.

Intensity	Examples of problems
1	A cable is not maintained anymore.
2	A connector and/or cable is damaged but does not cause a dangerous problem yet.
3	The protective layer of a connector and/or cable is broken and may cause dangerous problems. Or a connector and/or cable is not connected anymore.

Table 12: Intensity description for the problem 'electric cables and connectors'

From section 4.1 we see that this problem is has a grave severity. Therefore we use the following matrix, table 13, to determine the condition scores:

Grave defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	2	3	4
2 | Advanced	1	2	3	4	5
3 | End	2	3	4	5	6

Table 13: Matrix to determine condition scores for grave defects

C. Loose bolts

The amount of loose bolts would not be a good measurement for the intensity score, as this would be more related to the extent score. It is possible to use a torque wrench, as done by BPR Solar (section 3.3). The idealistic torque could be determined by Thales beforehand. The intensity scores could then be based on a maximum deviation. An example is shown in the table 14.

Intensity	Maximum deviation of idealistic torque
1	0% - 1%
2	1% - 2%
3	2% or more

Table 14: Intensity description for the problem 'Loose bolts'

From section 4.1 we see that this problem is has a minor severity. Therefore we use the following matrix, table 15, again to determine the condition scores:

Minor defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	1	1	2
2 | Advanced	1	1	1	2	3
3 | End	1	1	2	3	4

Table 15: Matrix to determine condition scores for minor defects

D. Corrosion

This problem is comparable to the problem damage on painted surfaces. Again a visual scale is made. Important to note is that the intensity score does not stand for the extent of the corrosion, but on the intensity. So the inspector should score on how deep the corrosion is, instead of the amount of surface that is covered in corrosion.

Figure 4: Reference scale corrosion

From section 4.1 we see that this problem is has a serious severity. Therefore we use the following matrix, table 16, again to determine the condition scores:

Serious defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	1	2	3
2 | Advanced	1	1	2	3	4
3 | End	1	2	3	4	5

Table 16: Matrix to determine the condition scores for serious defects

6 The resulting tool

Now that we have scoped our research in chapter 5, it is time to process all the findings and imply them on the Thales health check. This is done in an excel file. This excel file is a tool that Thales can later use for its health checks. An excel model is made to have concrete way to show Thales the implementations that we have made. This way it becomes clearer to Thales how the findings will be useful for their health check. First we explain how all the defects are scored in section 6.1. Then we show how automatic advice can be generated per subsystem and per problem in sections 6.2 and 6.3 respectively. Finally we explain the strength of conditional formatting in section 6.4

6.1 KPI Values

Based on a worked out report of an executed inspection, the problems (KPI's) from chapter 5 could be scored quite correct. The report has sufficient pictures and comments on the problems to determine a score for every problem. However, the information in this report is sensitive and therefore confidential. Due to that, the KPI's are score with pseudo scores. A disadvantage of this is of course that it will probably come to different outcomes in advice than the report did. Nevertheless, it is still possible to see whether the NEN 2767 method is applicable on the Thales health check.

In total, for the Model X, 10 subsystems are visually inspected. One of these systems is the antenna assembly. The antenna assembly is inspected on 10 items, as shown in figure 5.

4.1.1. Antenna Assembly

Inspection items	4
Check for damage of painted surfaces.	1
Check all covers and hoses for damage.	1
Check silicone seal of Radome for damage.	2
Check all electrical cables and connectors.	1
Check the correct mounting of LRUs.	1
Check for loose bolts.	1
Check for missing parts/LRUs.	4
Check main parts on over pressure.	2
Check the fixation of the air hose.	1
Check the mounting of all TR-books.	1

Figure 5: Items that are inspected on the subsystem 'Antenna Assembly'

As can be seen in figure 5, the antenna assembly is checked on all problems mentioned in chapter 5 except corrosion.

In the current Thales health check, the inspector has to mention whether the inspected item is ''OK'' or ''NOT OK''. If an inspected item is ''OK'', the inspector moves on to the next item. If an inspected Item is "NOT OK", the inspector has to note what is wrong and add a picture when possible.
Now, every item has a condition score. The scores can be seen in figure 5 as well. The score at the

top is the condition score for the subsystem as a whole. From the NEN 2767 it is known that total condition score is equal to the lowest score given to an item. In this case, the antenna assembly gets an condition score of 4 due to the condition score given to the item ‘Check for missing parts/LRUs’. If this item was not part of the antenna assembly inspection, the overall condition score for the antenna assembly would have been 2 in this case.

The condition score for damage of painted surfaces at the antenna assembly is 1. When taking a look at the condition score for minor defects, table 17, it shows that there are 9 possible combinations to come to this condition score. The possible combinations are marked green.

Minor defects					
Extent **Intensity**	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	1	1	2
2 | Advanced	1	1	1	2	3
3 | End	1	1	2	3	4

Table 17: Matrix to determine the condition scores for minor defects

In the attached excel file it becomes clear that the inspector in this case would have classified the intensity as advanced and the extent to be smaller than 2% (see figure 6). The condition score selected in the matrix is automatically adopted in the table with inspection items for the antenna assembly.

Check for damage of painted surfaces. Run

Minor defects					
Extent Intensity	1 | < 2%	2 | 2% - 10%	3 | 10% - 30 %	4 | 30% - 70%	5 | >70%
1 | Starter	1	1	1	1	2
2 | Advanced	1	1	1	2	3
3 | End	1	1	2	3	4

Figure 6: Filled in condition matrix for the problem ‘damage of painted surfaces’

A linked matrix is made in the excel file for the antenna assembly for every problem described in section 5.1. Condition scores are given for all the visual inspected subsystems. These can also be found in the attached excel file or in the screenshots at the end of this document.

6.2 KPI-based advice per subsystem

In the excel file, all the final condition scores for the (sub)systems are listed together:

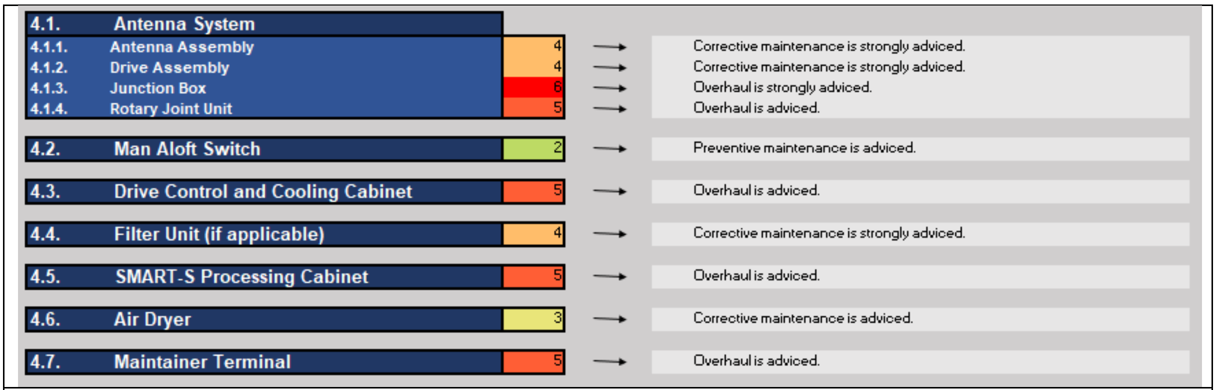

Figure 7: Generation of automatic advice

Due to that every inspected (sub)system now has a score in terms of a number, it is possible to program an automatic advice that is linked with a specific number. In this case, a condition score of 6 is linked to ''Overhaul is advice'' as a score of 6 means that the system is in a really bad condition. Other way around a condition score of 1 is linked to "Is in good condition. No further action advised" as the system is in an almost 'new' condition. Table 18 gives an overview of the advice that each number is linked to. Of course it is possible to alter the automatic generated advices, as well as differentiation between (sub)systems. These advices are generically based on advices in existing health check reports. Text can always be added to automatically generated advice.

Condition score	Advice
1	"Is in good condition. No further action advised."
2	"Preventive maintenance is advised."
3	"Corrective maintenance is advised."
4	"Corrective maintenance is strongly advised."
5	"Overhaul is advised."
6	"Overhaul is strongly advised."

Table 18: Automatic generated advice per condition score

6.3 KPI-based advice per problem

Due to that now every item has a score in terms of number, it is possible to give a score per problem as well. On the sheet ''Advice per problem'' in the excel file the problems described in section 5.1 are listed.
Now the thickened number above in each table is not the highest number, but a rounded number. Again an automatic advice can be generated. These advices tell the client something about the problems in general instead of per system. Advice are based on advices from existing health check reports and common sense.

With the earlier determined condition scores, we come to a rounded score of 2 for the 'Damage of painted surfaces. That gives the following advice: 'In general there is some degrading in the painted surfaces. Preventive maintenance would be wise.'

The problem 'Corrosion' has a rounded score of 3. This gives the following advice: 'In general corrosion is taking place. Preventive maintenance is strongly advised. See handbook X.'

''Loose Bolts'' has a rounded score of 2. The advice that follows is: 'Overall there are some loose bolts. This should be checked more often.'

Finally, the problem 'Cables & Connectors' has a rounded score of 1. This gives the following advice: 'Overall, there are no or close to no damaged cables and/or connectors.'

All the programmed advices can be found within the VBA code that is written for this excel file. Of course it is possible again to alter the generated advices.

6.4 Conditional formatting

As can be seen in all the examples above and the excel file that is attached, all condition scores are conditional formatted. This means that when the an item is has a condition score of one that it becomes green. When an item has a condition score of 6 it becomes red. In between the color is yellow.

The colors that arise by the use of conditional formatting give a clear overview to the client. At a glance the client can see what systems are in a good or bad condition. Moreover, when the client sees that a system is not in perfect condition, it is easy to see what subsystem causes this. For example the antenna assembly. It has a total condition score of 4, while almost everything is colored green. Almost everything, except the score for ''Check missing parts/LRU's". It becomes directly clear for the client that only this problem should be fixed to give the antenna assembly a good condition score again.

7 Conclusions

This chapter concludes the thesis *Optimization of a System Health Check Service.* We summarize the most important findings and answer the main question of this thesis. (6.1) Also, we discuss the scientific relevance of this research.

7.1 Conclusion

This research was started because of Thales personnel that had feeling their health check service could be improved. They wanted someone to take a fresh look at it and seek for improvement opportunities. This led to the following research question.

"How can the current checklist be improved to increase the quality of the Thales System Health Check Service?"

We took a look at three methods that were comparable with the Thales health check: 2 NEN norms and 1 inspection from another company. The most important findings and experience were summarized.
The conclusion was drawn that the NEN 3140 was not too interesting for this research as it focusses on a safe operation of electrical installations, while we wanted to look more at the process as a whole and focus on the checklist that is used during the inspection.
The experienced inspection at BPR Solar was interesting but did not directly match the Thales health check. It was still interesting as some observations might be useful for Thales to think about. For example the use of tablet instead of pen and paper during the inspection.
The NEN 2767 norm was found to be interesting and used extensively further in the research by implementing it. It was applicable on the current Thales health check. Conclusions about this are described below.

By implementing the conditions assessment method, we gave condition scores to problems that are inspected during the Thales health check service. This provided a refinement of the scoring of the inspected problems.

The implementation was done in an excel file that is attached to this thesis. Using excel was not necessary to implement the NEN 2767, but it gives a concrete view of the implementation and leaves opportunities for improving the Thales health check. For example, by using excel we made a model that could automatically redirect the determined condition scores. This gives the opportunity to generate advises based on these condition scores. Also, by the means of conditional formatting it becomes more visual to the client where the problem are within the (sub)systems. Lastly we see that, by giving condition scores, it is possible to take average scores per problem. In that way, it is possible for Thales to take conclusions easily per problem. We highlighted only four problems, due to that highlighting all problem would be too time-consuming for this research. The model is made in such way that it is easy to expand.

We can conclude that a condition scoring method for inspection has many advantages:

- A more refined review, which contributes to the quality of the check.
- Automated condition score based advice per subsystem, which can speed up the whole process in the Thales health check service.
- Automated overall advice per inspected item/problem, which can speed up the whole process in the Thales health check service as well.
- A conditional-formatted interview, which gives the client clarity at a glance. This gives the client a better overview.

Because of these advantages, we recommend that Thales should put time in investigating to what extent implementing the NEN 2767 can be useful. Chapter 8 goes more into detail about recommendations for Thales.

7.2 Scientific relevance

The NEN 2767 that is used during this research was developed by a well-known standardization committee: the royal Netherlands standardization institute. In this thesis it is shown how this method can be applied on an inspection for radar systems. The application shows the effects of a condition assessment method and how it influences certain risks. We found that a condition assessment method like the NEN 2767 helps Thales with improving their health check service.

8 Recommendations

8.1 Implementing condition scores

From the results in chapter 5 and the conclusions drawn in chapter 6 we see that using condition scores has many advantages. This is mainly because of the fact that giving condition scores quantify the problems that are inspected. Whether it is using by the NEN 2767 method or not method at all, quantifying the problems is therefore recommended.

Quantifying can be made more objective when using scales as described in chapter 4. When quantifying, I would recommend Thales to make us of these kind of scales for every possible problem that will be inspected during the Thales health check. The biggest challenge here is to find a solution for each inspected item. Service and technical department should get in discussion to come with fair scales. This would take some time from the Thales personnel, but this time can be reclaimed later on as the modified health check is executed faster than the current health check.

8.2 Automizing

By talking to Thales personnel I understood that there is much time invested in making the report that goes to the client. The reason for this is that the inspector that does the inspection has to fill in the inspection results on paper. This is due to that the gathered information is sensitive and therefore confidential. If the information would be gathered digital the risk would be higher that the gathered information leaks. When the inspection is finished, the gathered information is later digitalized at the office.

Although the argument of confidentiality, I would recommend Thales to take look at this again. The model I made in this thesis is not too complicated and it should be possible to use this digital but offline. If this is done, you would take away the digitalization step at the office which saves time. Saving time here contributes to handing over the report to the customer in time. The inspection could be executed with some sort of tablet as done by BPR Solar at their inspection.

If such device could be used, there is also the potential advantage that it can take pictures as well. If we take a look again at BPR Solar, Thales could then use a similar program that BPR Solar uses. However the similar program should be an offline variant. BPR Solar makes use of a program called PlanGrid. This program can merge advice with corresponding picture into one format. This could also save Thales time with processing the found information from the inspection.

8.3 Further research

Based on this research, we figured that there are two big challenges for Thales.
When Thales is enthusiastic about implementing a condition assessment method like the NEN 2767 and/or quantifying the inspected items, it should find out which method fits the best for their service. In this research I was explicitly asked to test the NEN 2767. Therefore I did not look at other standards (i.e. ISO standards) that might contain quite the same information. Before starting such a huge implementation I think it is wise to check whether there a similar option and compare them. There might be a norm that is even better applicable then the NEN 2767.
When the method is definitively chosen, Thales should investigate to what extent and how they will implement the chosen method. For example, the NEN 2767 is a norm for buildings. Although there are quite some similarities with radar systems. Not everything can be just taken over.

As said , the NEN 2767 is not the only condition assessment method. There are more existing methods. For example internationally recognized methods. In general, they come down to the same solution. However there are small differences. For instance the scales that are used for the condition scores or the factors where the condition scores are based on. Thales should do research to what other similar methods exist and choose the method that fits best for their health check service.

When the method is selected, investigation should be done to in what extent the method can be implemented. For example, in this research the implementation is only done on the visual part of the Thales health check. Moreover, only four problems that are inspected during this health check are highlighted in this research. It should be investigated if the same possibilities apply for all the checked item during the Thales health check. Based on that investigation, Thales needs to decide whether wants to implement the method totally, partly or not at all.

An interesting method that could help with this is the Failure Mode and Effect Analysis (FMEA). This is probably already executed by Thales to decide what items should be checked for every (sub)system. As one of the factors of this method is severity as well, it should be easier to determine the severity class for each problem with the use of the FMEA.

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A Logbook BPR Solar

To see how inspections went at other companies, I joined BPR Solar for a day on executing a quality inspection. Here an inspector checks whether the prescribed standard are met for a good solar panel system. This is of course not the same as an inspection for a radar system from Thales, but the inspection itself shows similarities and therefore walking along for a day may lead to inspiration. The activities of that day are listed below:

- Arrival at site in Goeree-Overflakee
- Introduction to inspector
- Introduction to the office
- Every part that has to be inspected has its own error description, date of check, verification, code, name of inspector and name of company that inspects it
- Preparing for inspection by gathering needed items: safety helmet, safety glasses, safety vest, safety shoes, torque wrenches and tablet
- Determine the most efficient route to walk when inspecting all the part that should be inspected during that day
- Walk to the solar systems that need to be inspected
- Inspect an alleged problem
- Make a comment on the tablet when the inspected part is still not okay, but also when it is okay
- Make a picture with the tablet and add it to the corresponding comments
- Upload both comment and picture to PlanGrid with the tablet
- Repeat the 4 steps above for every part that needs to be checked
- When all the parts are checked head back to the office
- Check off the parts that are inspected and now okay
- Make a notion of the parts that are still not okay

B Explanation on how to expand the model

In total there are 5 sheets in the Excel model:

- Sheet 1: Scales
- Sheet 2: Task Colouring
- Sheet 3: Condition score determination
- Sheet 4: Visual inspection
- Sheet 5: Advice per problem

The sheet 'Scales' is not that interesting for the model itself and can be left out. They are also described in section 5.2 of this thesis.

The sheet 'Task Colouring' can also be left out for the model. It only shows the problem/items checked that different (sub)systems have in common.

Sheet 3, 'Condition score determination', shows how the condition scores for items for a subsystem can be determined from corresponding matrices. In this case the subsystem '4.1.1 Antenna Assembly'. By colouring a cell red in a matrix, the inspector select this the condition score given in the cell. This process is created by a VBA code, which can be seen in the VBA sheets. When expanding a matrix should be given for each item that should be given a condition score. Also other (sub)systems should be added, preferably in different sheets. The scores generated are linked to the next sheet.

In sheet 4 the gathered condition scores for the antenna assembly from sheet 3 can be found again. Together with made-up scores for other (sub) systems. When expanding sheet 3, all the values should be linked to sheet 4 as done for the antenna assembly. You can see how this is done by selecting a condition score cell from the antenna assembly in sheet 4. The table with 'KPI Values' can be deleted.
At the bottom of the sheet, the condition scores for all the (sub)systems are summarized. By clicking on the button 'RUN', advices for every system will be generated on the left. This can be found too in the VBA sheets. The advices can be easily adjusted in these codes.

Sheet 5, 'Advice per problem', does kind of the same as the part at the bottom of the page on sheet 4. However, now the condition scores are listed per inspected item instead of the per (sub)system. Again it is possible to generate automatic advice, by clicking the 'Advices' button. The code written for this can be found in the VBA sheets again.

C Criteria table

Criteria	Current Health check	Modified Health check based on NEN 2767
Speed	--	++
Accuracy	-	+
Clarity	++	+
Simplicity	++	+
Visuality	-	++

Table 19: Criteria table

We scored both health checks, the current and the modified health check, on five criteria shown in table 19. Speed indicates how fast the health check is done. Here we are not only talking about the time the inspection itself takes, but also the time the processing of the inspection takes after the inspection. The accuracy score is based on how the impact of the found results are noted down. The clarity score is based on how explicit the problem and the corresponding advices are written down. The simplicity score arises from the difficulty to execute the health check. Finally, the visuality is based on the visual strength of the report that is based on the inspection results.

They can be scored bad (--), moderate (-), good (+) and excellent (++). Together with my supervisor I determined the given scores in table 19. We work with these somewhat inaccurate scores, as it is difficult to give a precise score in this situation. There is no quantitative data to measure these criteria and compare both health checks. The scores are based on quantitative data and experiences. We will now explain the scores per criterium.

The time in which the current health check can be executed will be relatively much more than the modified health check. Therefore the current health check has been given a bad (--) score and the modified health check an excellent (++) score at the speed criterium. This is due to two reasons. The first reason is that the modified health check is digitalized, this saves the post processing time that the current health check has to deal with. The inspection itself might take a bit longer, but the inspection time is relatively small to the post processing time. The modified health check is more unambiguous and therefore leads to unambiguous decisions. As there is more unambiguity, there is less post processing time needed to make an unambiguous report for the client. The second reason is the possibility of automizing at the modified health check. Because of the six point scale it is possible to link a score to a certain advice.

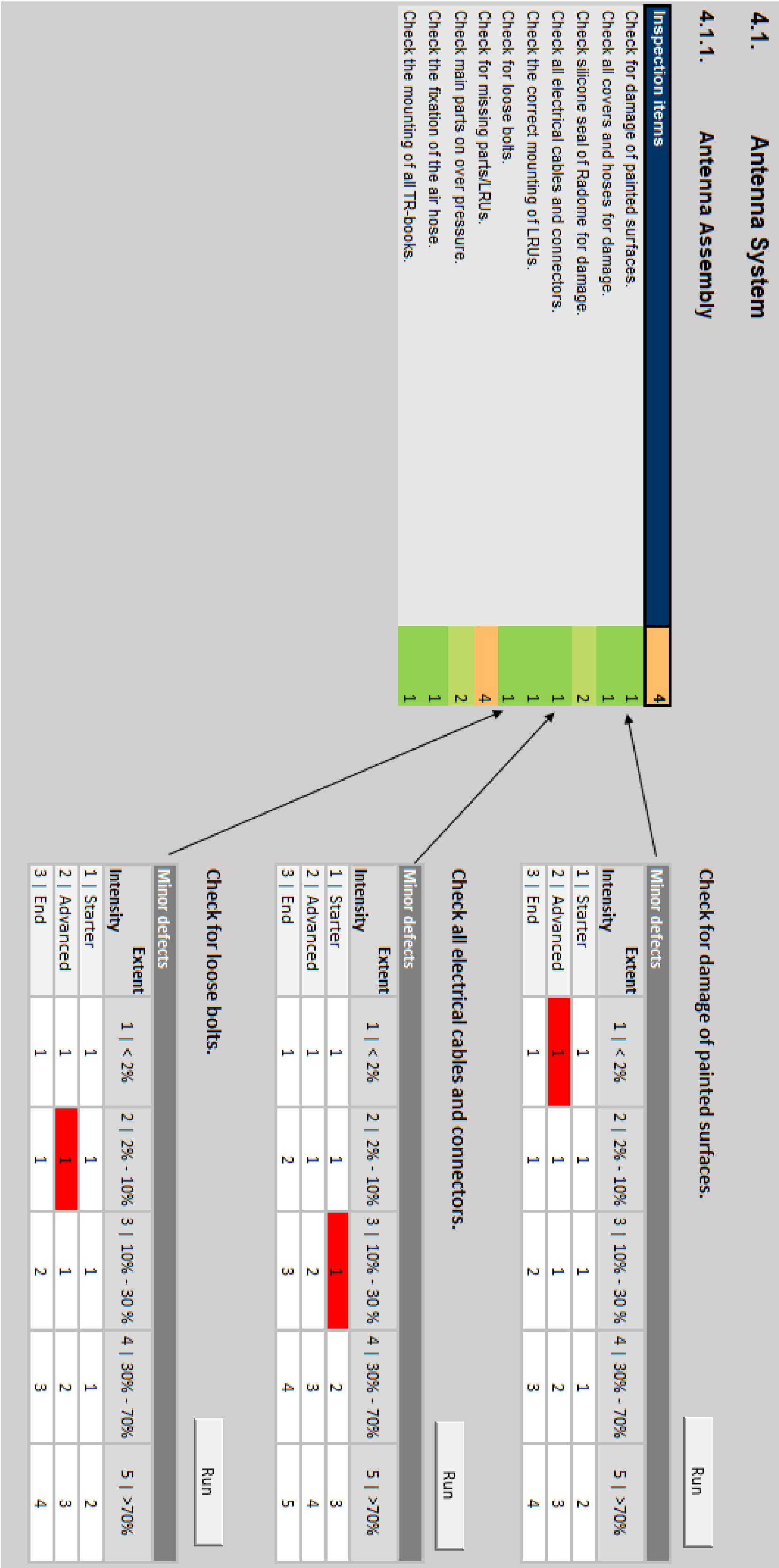
The difference in accuracy between both checks is not too big. A good (+) score for the modified health check and a moderate (-) score for the current health check. Both can be quite descriptive if there is a problem at a system. However, the modified works with a six point scale and therefore better indicates the gradation of a problem.

The current health check scores a bit better on clarity than the modified health check: excellent (++) versus good (+) respectively. At the current health check every problem gets assessed its own problem description with advice. That possibility is also there at the modified health check, but a lot of advice will be probably automized. This automized advice will be more generic and therefore a bit less explicit.

The simplicity has been scored excellent (++) as well for the current health check. The modified is score good (+). The reason that the modified health check is less simple, is that the current health check works with condition matrices and the program Excel. As an inspector you should be able to work with both. That makes it a little bit more difficult.

The visuality of the modified health check has been scored a lot better than the current health check: excellent (++) versus moderate (-) respectively. The current health check is visually already quite clear, there is a good overview but very textual. The modified health check works with conditional formatting in Excel. This means that a good condition score is coloured green and a bad condition score is coloured red. The colours make sure that the client can see at a glance in what state the systems are.

D Excel screenshots



4.1. Antenna System

4.1.1. Antenna Assembly

Inspection items	4
Check for damage of painted surfaces.	1
Check all covers and hoses for damage.	1
Check silicone seal of Radome for damage.	2
Check all electrical cables and connectors.	1
Check the correct mounting of LRUs.	1
Check for loose bolts.	1
Check for missing parts/LRUs.	4
Check main parts on over pressure.	2
Check the fixation of the air hose.	1
Check the mounting of all TR-books.	1

4.1.2. Drive Assembly

Inspection items	4
Check for damage of painted surfaces.	2
Check all electrical cables and connectors.	2
Check for loose bolts.	1
Check the base ring of the SAF.	4
Check the ball bearings of the SAF.	2
Check the shock absorbers of the SAF.	3
Check the Drive Assembly and the SAF on corrosion.	1

4.2. Man Aloft Switch

Inspection items	2
Check for damage of painted surfaces.	1
Check for any visual/mechanical damage.	1
Check the external cabling on damage.	1
Check the sealing condition.	2

4.3. Drive Control and Cooling Cabinet

Inspection items	5
Check for damage of painted surfaces.	1
Check the cabling connections on damage.	1
Check the cooling connections on damage.	1
Check for loose bolts.	2
Check the DCCC on corrosion.	1
Check the DCCC dry air inlet.	1
Check if the door seals are in good condition.	3
Check if the doors open, close and lock properly.	4
Check for cooling leakage (pay extra attention below the Amplifier).	5
Check if ESD wristband is checked regularly.	1

4.6. Air Dryer

Inspection items	3
Check for damage of painted surfaces.	1
Check the Air Dryer on corrosion.	3
Check for loose bolts.	2
Check the cabling connections on damage.	2
Check the air connections on damage.	2
Check the operating pressure.	2
Open the Air Dryer and check if all tubes and pipes are in proper condition.	1

4.7. Maintainer Terminal

Inspection items	5
Check for any visual/mechanical damage.	2
Check the cabling connections on damage.	1
Check all Software carriers (CD/DVD and MT store) related to the VDD (ref [8]).	1
Check if the required software is installed (ref [7]).	5

4.1.3. Junction Box

Inspection items	6
Check for damage of painted surfaces.	1
Check the Junction Box on over pressure.	2
Check all covers and hoses.	3
Check all cooling and air hoses.	4
Check for loose bolts.	2
Check the Junction Box on corrosion.	6
Remove cover and check electrical cables and connectors.	1

4.1.4. Rotary Joint Unit

Inspection items	5
Check for damage of painted surfaces.	1
Remove the covers and check the electrical cables and connectors.	1
Check for air or cooling leakage.	1
Check the RJU on corrosion.	5

4.4. Filter Unit (if applicable)

Inspection items	4
Check for damage of painted surfaces.	3
Check cooling connections on damage.	2
Check for loose bolts.	4
Check the Filter Unit on corrosion.	1
Check for cooling leakage.	2

4.5. SMART-S Processing Cabinet

Inspection items	5
Check for damage of painted surfaces.	3
Check the cabling connections on damage.	2
Check the cooling connections on damage.	1
Check for loose bolts.	1
Check SPC on corrosion.	1
Check if the door opens, closes and locks properly.	2
Check if the door seal is in good condition.	5
Check the SPC dry air inlet.	2
Check all cables and connectors.	5
Check the correct mounting of LRUs.	4
Check for missing parts/LRUs.	1

KPI Values	
Check for damage of painted surfaces.	2
Check all electrical cables and connectors.	2
Corrosion	3
Loose bolts	2

4.1.	Antenna System		
4.1.1.	Antenna Assembly	4	Corrective maintenance is strongly adviced.
4.1.2.	Drive Assembly	4	Corrective maintenance is strongly adviced.
4.1.3.	Junction Box	6	Overhaul is strongly adviced.
4.1.4.	Rotary Joint Unit	5	Overhaul is adviced.
4.2.	Man Aloft Switch	2	Preventive maintenance is adviced.
4.3.	Drive Control and Cooling Cabinet	5	Overhaul is adviced.
4.4.	Filter Unit (if applicable)	4	Corrective maintenance is strongly adviced.
4.5.	SMART-S Processing Cabinet	5	Overhaul is adviced.
4.6.	Air Dryer	3	Corrective maintenance is adviced.
4.7.	Maintainer Terminal	5	Overhaul is adviced.

Damage of painted surfaces	2	>	Overall, there appears to be quite some corrosion. It is adviced to carry out maintenance to prevent the corrosion from spreading.
4.1.1. Antenna Assembly	1		Is in good condition. No further action adviced.
4.1.2. Drive Assembly	2		Preventive maintenance is adviced.
4.1.3. Junction Box	1		Is in good condition. No further action adviced.
4.1.4. Rotary Joint Unit	1		Is in good condition. No further action adviced.
4.2. Man Aloft Switch	1		Is in good condition. No further action adviced.
4.3. Drive Control and Cooling Cabinet	1		Is in good condition. No further action adviced.
4.4. Filter Unit	3		Corrective maintenance is adviced.
4.5. SMART-S Processing Cabinet	3		Corrective maintenance is adviced.
4.6. Air Dryer	1		Is in good condition. No further action adviced.

Corrosion	3	>	Overall, based on corrosion, the system is in good condition. No maintenace needed.
4.1.2. Drive Assembly	1		Is in good condition. No further action adviced.
4.1.3. Junction Box	6		Overhaul is strongly adviced.
4.1.4. Rotary Joint Unit	5		Overhaul is adviced.
4.3. Drive Control and Cooling Cabinet	1		Is in good condition. No further action adviced.
4.4. Filter Unit	1		Is in good condition. No further action adviced.
4.5. SMART-S Processing Cabinet	1		Is in good condition. No further action adviced.
4.6. Air Dryer	3		Corrective maintenance is adviced.

Loose Bolts	2	>	Overall, based on corrosion, the system is in good condition. No maintenace needed.
4.1.1. Antenna Assembly	1		Is in good condition. No further action adviced.
4.1.2. Drive Assembly	1		Is in good condition. No further action adviced.
4.1.3. Junction Box	2		Preventive maintenance is adviced.
4.3. Drive Control and Cooling Cabinet	2		Preventive maintenance is adviced.
4.4. Filter Unit	4		Corrective maintenance is strongly adviced.
4.5. SMART-S Processing Cabinet	1		Is in good condition. No further action adviced.
4.6. Air Dryer	2		Preventive maintenance is adviced.

Cables & Connectors	1	>	Overall, based on corrosion, the system is in good condition. No maintenace needed.
4.1.1. Antenna Assembly	1		Is in good condition. No further action adviced.
4.1.2. Drive Assembly	2		Preventive maintenance is adviced.
4.1.3. Junction Box	1		Is in good condition. No further action adviced.
4.1.4. Rotary Joint Unit	1		Is in good condition. No further action adviced.
4.2. Man Aloft Switch	1		Is in good condition. No further action adviced.
4.4. Filter Unit	2		Preventive maintenance is adviced.
4.5. SMART-S Processing Cabinet	2		Preventive maintenance is adviced.
4.6. Air Dryer	2		Preventive maintenance is adviced.
4.7 Maintainer Terminal	1		Is in good condition. No further action adviced.