Development of a tool to improve the traceability between requirements and verification

Master´s thesis in electrical measurements

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Abstract

In the development of a product or system it is important to know that all the requirements are verified and validated in order to maintain a good reputation and standard. Today ThyssenKrupp Marine Systems AB does not have a clear traceability between requirements and verification. In order to improve and create a clear formal traceability for their developing process a traceability examination has to be made. Regarding both how their process is planned and executed, but also how different changes could improve the current situation. How these changes would change the process, both positively and negatively is also discussed.

To get a clearer understanding of their developing process and what developing model they use and how well it actually fits their developing processes, a study and research is conducted. This study results in a recommendation to either continue to use the one they use today, the V-model or to change to either the Agile model or the Waterfall model. This recommendation will be based on the evaluation of three very different developing models.

A benchmark and comparison was also carried out on how other companies in other industries work to maintain and improve traceability, all to get a broader understanding of the verification processes and ways of improving traceability.

ThyssenKrupp Marine Systems AB's developing models, verification tools, documentation tools, ordering tools, developing methods, testing and verification processes where analyzed through ThyssenKrupp Marine Systems AB's intranet and through interviews of employees. The employees were from different departments and had different roles, but in this master thesis the focus were mainly on project leaders. Some computer programs were also investigated first hand, but there were limitations in this process due to security reasons and limited access. This investigation made it possible to develop a new traceability tool.

The result of this master thesis was both a theoretical result and the planning tool, Trace which created a clear traceability between the requirements and the different verification events.

In Trace a requirement can be followed from the start to the end in the verification process, and give the user the answer on if the requirement is completely verified or in what stage in the process it failed a verification test. The program clearly shows the users were the requirement/requirements will be tested, which requirements that are tested at a certain test, if it is finished and if not where it failed, and more information needed to get a good traceability during the whole project. In Trace there is also the possibility to make a verification matrix which contains all of the requirements within a system on one side and all its properties that should be searchable on the other, it will make all the information available and easy to follow at the same place.

The conclusion of the benchmarking and comparison was that ThyssenKrupp Marine Systems AB and most of the other companies interviewed lacked a complete traceability between requirements and verification. These companies are all looking for ways to improve traceability and have mapped out to different extent were traceability is missing. A reason to why they have this mutual problem is that the knowledge and development of technology today is different from 10 years ago. In today's society companies are expected to have a faster production than before, this leads to changes in the developing methods which changes their developing models. And here the traceability got lost in the change.

Preface

This master thesis is written at the Department of Electrical measurement, Faculty of Engineering at Lund University, biomedical engineering. This master thesis is the concluding part of the authors´ Master of Science in Electrical Engineering with a focus on traceability between product requirements and verification. The study was performed in cooperation with ThyssenKrupp Marine System AB. Working with the master thesis has given us an opportunity to implement our theoretical knowledge at a traditional manufacturing company and has been a great learning experience.

We are particularly grateful for the assistance given by our supervisors Johan Granholm, Johan Nilsson and Hans W Persson. They have supported us during the master thesis and have given us constructive feedback that helped us to improve the outcome of this thesis. Further, we would like to take the opportunity to thank the employees at ThyssenKrupp Marine Systems AB, Axis, Sony Mobile and Gambro, for their time and good attitude.

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1 Introduction

1.1 Background

ThyssenKrupp Marine Systems AB design, build and maintain submarines and naval surface ships. These are tailored for the littoral zone and incorporate a highly advanced stealth technology. Their products and technologies enable their customers to counter threats to national security and wellbeing in the littoral zone. Their facilities are based in Malmö, Karlskrona and Muskö in Sweden. [1]

In the development of a product or system, it is important to know that all requirements are verified in order to maintain a good reputation and standard. ThyssenKrupp Marine Systems want to improve traceability between requirements and verification. To have a clear traceability means that a person easily can follow the requirement in the verification process, when, where and how was it verified and if it is not verified where it failed and why. Product or system requirements are the necessary attributes defined for a product or a system before design development. [2] A short presentation is presented below and the subject is discussed further in 3.1.2.

- Requirements are statements that identify the essential needs of a system in order for it to have value and utility.
- Requirements are common derived or based upon interpretation of other stated requirements to assist in providing a common understanding of the desired characteristics of a system.
- Requirements should state what the system or product is to do, but they should not specify how the system is to do it.

The verification process starts in designing the requirement and its attributes and continues in designing the verification events and ends with testing and documenting the results at the verification events. ThyssenKrupp Marine System AB's verification process will be presented in more detail in 4.2.6.[3]

1.2 Problem definition

ThyssenKrupp Marine Systems AB issued this master thesis in collaboration with Lunds Tekniska Högskola. ThyssenKrupp Marine Systems AB needs a complete system for the requirement specifications and their traceability, which they do not have today.

Furthermore this system should propose a clear and simple way to show who's responsible for that the requirements are met, and give a clear view of the requirement from start to finish in the verification process and also give the opportunity to see what requirement are tested in a specific test. The problem is that the information is spread out and not documented in a way so it can be followed easily; information is documented differently and in different programs.

1.3 Purpose

The purpose of this master thesis is to examine and make an improvement of the traceability of requirements at ThyssenKrupp Marine Systems AB. The outcome of this study will give ThyssenKrupp Marine Systems AB a prototype of a tool to help them follow a requirement throughout the whole submarine project, but also investigate if they are working with the right developing model. Additionally the developing model used at ThyssenKrupp Marine Systems AB and other companies will be analyzed. Finally the Master thesis should also analyze and investigate the developing model and carry out a benchmarking and comparison with other industries which is based on interviews with employees at other companies.

1.4 Delimitation and focus area

The focus area of this study is to examine the company's requirements traceability and how they in a project decide the requirement and test them. The focus is also on the documentation of the requirement specification, test specifications and the verification specifications. Furthermore the focus area is also all of the different computer programs that they use during the test processes and the links between them

The delimitation in this master thesis is the sensitive areas for the defense industry, this means that some examination cannot be as thorough as hoped, and not all the requirements can be examined. The companies interviewed are also restricted in what information they want to disclose. The time limitation will also limit the extent in which the other processes at the other companies are examined.

A limitation is also the different information access levels; with a higher access level more information is available. It is important that not all the employees can view and follow all the requirements from a safety prospective; this makes the program more complex.

Furthermore the prototype will not be programmed in a way that is secure to use for confidential material, which is a part that has to be developed by experts on security.

1.5 Disposition

1.5.1 Introduction

The first chapter will introduce the reader to the background, purpose, problem definition and delimitations.

1.5.2 Methodology

The second chapter presents the methods used in the study and how they are carried out.

1.5.3 Theory

The third chapter presents theories that are relevant to the study such as the different developing models.

1.5.4 Company and background

The fourth chapter presents ThyssenKrupp Marine Systems AB's background, developing processes, verification processes and a short presentation of the different programs and tools used at ThyssenKrupp Marine Systems AB regarding verification and traceability.

1.5.5 Benchmarking companies

The fifth chapter presents the background of the different companies that are used to benchmark traceability and verification processes and also compare how they deal with these subjects.

1.5.6 Result

The sixth chapter presents the result of the study, how Trace works and what result the benchmarking and comparison presented.

1.5.7 Analysis

The seventh chapter presents analysis of the tool Trace, the analysis of the benchmark and the analysis of the development model.

1.5.8 Conclusion and recommendations

The eights chapter presents the conclusion of the master thesis results.

1.5.9 References

The ninth chapter presents the references.

1.5.10 Appendix A
Appendix A presents all of the interviews conducted.

1.5.11 Appendix B
Appendix B presents additional information regarding the previews chapters

1.5.12 Appendix C
Appendix C presents the code of the program, Trace and explains the construction in detail.

2 Methodology
In the methodology part, different ways on how to gather information, which the conclusions and the result of the thesis will be based on, is presented and why they were chosen or preferred. The research is based on data collection. Below the research process is presented, however summarized the data collection in this master thesis is divided into three important parts:

- Information about ThyssenKrupp Marine System AB.
- Information about other companies used in the benchmarking and comparison.
- Information about the subjects regarding verification, validation, traceability and verification processes.

The research conducted at ThyssenKrupp Marine System AB was qualitative, since the interviews are few, deep and thorough. Employees at different levels were interviewed to get a broader understanding, however managers were prioritized since they have access to more information. Personal interviews were preferred instead of interviews over the phone or email. The scope was in the author's opinion too complex to do over the phone or based on different surveys, in this way it is easier to get a quick response if something was not clear or not understood correctly. After the interviews the information was written down and then given to the interviewed persons so they could do alterations if there was something misunderstood.

Interviews with employees was important because there are not anybody more fitted to explain what works well and what does not, then the ones working with the system. They have years of knowledge that would be foolish to overlook.

These employees are the ones that will be working with the tool and the developing model later on, without their opinion the same problems can be missed again.

2.1 Research process

The research started with investigating subjects relevant to the master thesis:

- Verification
- Validation
- Verification standards
- ThyssenKrupp Marine System AB's verification programs
- Mapping the current situation at ThyssenKrupp Marine Systems AB
- Product development models
- Benchmarking and comparison

The research phase continued throughout the whole master thesis, from start to finish. The research is based on both literature and interviews with both internal and external sources.

2.2 Data collection

Data are either primary or secondary depending on how it is gathered. Primary data is assembled for a specific study. For an example primary data could in this case be the interviews conducted by the authors in this master thesis for this specific thesis, but the same information would be secondary data if someone else would use it in their report to explain that submarine companies believe that traceability is important.

While reading secondary data the reader must consider that it might be biased and that it is intended for another purpose. Primary data is often composed by questionnaires, interviews and observations. Secondary data is often collected through literature such as books and articles.
In this master thesis the primary data was gathered from interviews with different employees and observations at ThyssenKrupp Marine Systems AB. The secondary data that was used was books and articles collected data. [4]

2.3 Quantitative and qualitative

There are two kinds of studies used in this thesis, quantitative and qualitative study. Quantitative studies are in general aligned with the analytical approach. Data and information that is measured and evaluated numerically it is often quantitative. Qualitative studies are used when deeper understanding for a specific problem is required. [5] In the master thesis the benchmarking and comparison part has been a qualitative research with one to three interviews per company. The research conducted at ThyssenKrupp Marine System AB has been qualitative and not quantitative, since the interviews are few, deep and thorough.

2.4 Interviews

Interviews can be executed in four different ways:

- Personal interviews
- Telephone interviews
- Surveys
- Group surveys

In this master thesis the preferred technique was personal interviews. The scope was in the author's opinion too complex to do over the phone or based on different surveys. Since requirements and requirement testing often is complex and confidential, it was easier to have personal interviews to secure that both parties understood what could be written and what could not. The personal interview was a face to face setup with the researcher and the person being interviewed. The interviews took between 30 minutes to an hour to conduct. [5]

2.5 Problem Identification

The problem identification was determined by discussion and interviews with our supervisor at ThyssenKrupp Marine Systems AB, Johan Granholm. The solution became a verification tool which was implemented in java and which would serve as the basis for future test plans.

2.6 Program implementation

The final version of Trace was a program written in java. The process started with researching what was missing in the traceability at ThyssenKrupp Marine Systems AB, and how it could be improved.

After interviews and a literature research a model was drawn, and after a set of classes was designed to give the program the specific properties, which improves traceability such as linkage between events where the requirements are verified and the information about the requirement. Important properties are for an example easy to use, clear traceability and easy storage of requirements. In programming a class is a set of rules and attributes which makes different functions easier to wright. For an example a programmer could wright the class “Person” which would contain attributes as name, age, education and the functions needed to be able to search and get this information if used in a list with more than one “Person” object.

The model was then showed to ThyssenKrupp Marine Systems AB and some feedback alterations were made to the program. Then a final version was implemented and after a final review it was approved with some few adjustments. The code and comments of the code can be found in Appendix C.

2.7 Product development methodology

There are three important developing models that are researched and discussed in the master thesis, the V model, the Waterfall model and the Agile model. The research is based on articles, literature and interviews with employees at ThyssenKrupp Marine Systems AB, Axis, Sony Mobile and Gambro.

3 Theory

3.1 Verification and Validation

Verification and Validation are independent measures that are used in cooperation for evaluating if a product, service, or system meets the requirements, specifications of the product and that these different are validated. The terms Verification and Validation are commonly used in engineering and focuses on two different types of analysis. Often people have difficulty of separating the two terms, but a way of easily understanding the differences are by asking two different questions:

- *Verification: Are we building the system right?*
- *Validation: Are we building the right system? [6]*

The definition of verification is:

- *Verification. The evaluation of whether or not a product, service, or system complies with regulations, requirements, specifications, or obligatory conditions.*

Verification is intended to ensure that a product, service, or system meets a set of design specifications. Verification procedures involve performing special and specific tests to a model and/or a simulation. The process ends with completing the verification of the development phase, by performing a review and analysis of the results. [6]

In the post-development phase, verification procedures involve repeating and follow up tests to ensure that the product, service, or system continues to meet the initial requirements, specifications, and regulations, as time goes by. [6]

The definition of validation is:

- *Validation. The assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance with external customers.*

Validation is intended to ensure that a product, service, or system meets the operational needs of the user. The user defines a set of validation requirements, specifications, and regulations and these are then used as a basis for qualifying a development or verification flow for a product, service, or system. It is a process of establishing evidence that provides a high degree of assurance that a product, service, or system accomplishes its intended means. This often involves acceptance with end users and other product stakeholders. [7]

Summarized, validation is concerned with ensuring that the system will meet the customer's actual needs and wishes, while verification is concerned with ensuring whether the system is well-engineered, error-free and complete. The verification will verify whether the completion is of high quality, but it will not ensure that the system is useful. [7]

3.1.1 Success Factors

One way to make sure that you are developing a good verification system is to implement a system based on system engineering best practices. A best practice is a method and a technique that has consistently shown results superior to others and that is used as a benchmark.

The best practice can evolve to become better as improvements are developed. Best practice is a feature of accredited management standards which ISO (International Organization for Standardization) provides and ISO will be presented further in the rapport.[8]

Another aspect is to use common and consistent formats and processes for requirement and verification development. This is preferred because it makes it easier to read and write in such a way that others will understand and be familiar with the processes. The requirements should also be *good requirements*, which will be discussed later. The different requirements must also have a person that is accountable and have ownership over that the requirement is verifiable, feasible etc. It is never recommended to proceed without somebody that is accountable, since there is no assurance that someone will take the responsibility and therefore no assurance that it will meet its demands. [9] The requirement owners will define the verification activities, success criteria, develop compliance reports, and start the signature process for verification approval. There should be a requirement owner assigned to all requirements.[10]

- For each requirement there should be a corresponding verification requirement, which answers the question if the requirement is verifiable.

When choosing the requirement owners it is important to have the following rules in mind

– They are not the requirement manager
– They are part of the whole project life cycle
– They are accountable for developing, verifying, and implementing the requirements

- Accountability is not the same as responsibility
- All are responsible, but only one is accountable

Finally having a good requirements management tool is also a success factor, which will make it easier for the management to manage the requirements. Some requirements management tools are able to find defects in the requirements. Some features and characteristics of requirements management tools are [11]:

• To store the requirement statements.
• To store the information about requirement attributes.
• To check consistency of requirements.
• To identify undefined, missing or 'to be defined later' requirements.
• To prioritize requirements for testing purposes.
• To trace the requirements to tests and tests to requirements, functions or features.
• To trace through all the levels of requirements.
• Interfacing to test management tools.
• Coverage of requirements by a set of tests.[10]

3.1.2 Good verifying requirements

Good and well-defined requirements are critical when developing successful verifications as mentioned above. Ways to ensure that the requirements are well written are to use skilled requirement writers and the requirements should all have the attributes as follows: [12]

– Product/System oriented
– Concise
– Single statement
– Measureable
– Feasible
– Verifiable
– Contain rationales
– Traceable

The first phase of verifying system requirements starts with requirements analysis and ends when its customer accepts the system. During the system integration and testing, steps must be taken to verify that the system satisfies every "must" statement in the requirements. These "must" statement requirements are collected in a document called the *Verification Matrix*.

3.1.3 Verification Matrix

The verification matrix is documentation that defines all the different requirements, the verification method, the level and type of unit for which the verification is to be performed. It also defines special conditions for the verification.

3.1.4 Verification methods

The verification process provides management tools to coordinate individuals and activities involved in a mission. Verification activities are implemented for the hardware, software, and the integrated system tests. The verification methods shall include the following either separately or in arrangement of a couple:

a. Analysis
b. Test
c. Inspection
d. Demonstration
e. Similarity[12]

Often requirements are verified using a combination of methods, for example analysis and test or analysis and inspection. The verification activities may be, preparation of detailed analysis plans, hardware or software qualification plans, procedures, integrated test plans and procedures [12]

Analysis -Verifies conformance to required performance by the use of analysis based on verified analytical tools, modeling or simulations that predict the performance of the design with calculated data or testing. Analysis must present a verification of unit, subsystem and system performance over expected life and operating environments.

An analysis could be to verify that all the furniture in the submarine fits at the right place by using a design tool; this would be a better way than for an example not test this before the submarine was finished.

Test-Verifies conformance to required performance, physical characteristics, design and construction features by techniques using test equipment and test devices. Tests are intended to be a detailed quantification of performance. Testing includes a clear measure of performance during exposure to an appropriate environment, or it may be a measurement combined with an analysis or a demonstration.

A test could be to verify that all the steals used in the submarine handles the environment at sea by putting the different steel products in that environment a long time before using it in the submarine.

Inspection - Visually verifies form, fit and configuration of the tested item. Often involves verifying those requirements where physical characteristics (e.g. construction features, finish, identification marking and cleanliness) and is usually performed during manufacturing, qualification, acceptance, integration and prelaunch phases.

Inspection could be to verify that the submarine can float by watching it do so.

Demonstration - Verifies that the required operability exists without the aid of test devices. If test devices should be required they should not contribute to the results of the demonstration.

Demonstration could be to verify that the submarine can float by an inspection in front of staff.

Similarity - Verifies requirement satisfaction based on certified usage of similar components under identical or harsher operating conditions. Verification by similarity is used usually in combination with analysis to show that an article is similar to another article that has already been qualified to equivalent or more stringent criteria. This verification method consists of assessment and review of configuration, application and prior test data including a comparison of prior test levels with new specific requirements. Differences in configuration, application or test conditions usually require analyses and additional testing to complete verification by the method of similarity. [13]

Similarity could be to verify that a screw will fit a specific part in the submarine by looking at records of it being used in the same way in a similar submarine with the same properties regarding the screw.

3.2 ISO/IEC 15288- Systems and software engineering — System life cycle processes

The International Organization for Standardization is known as ISO**.** A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. This International Standard establishes a process framework for describing the life cycle of man-made systems. It defines a set of processes and associated terminology for the full life cycle, including conception, development, production, utilization, support and retirement. The standard also supports the definition, control, assessment, and improvement of these processes.

The purpose of this International Standard is to provide a defined set of processes to facilitate communication among acquirers, suppliers and other stakeholders in the life cycle of a system. The life cycle processes of this International Standard can be applied concurrently, iteratively and recursively to a system and its elements. Some limitations with ISO are that the International Standard does not prescribe a specific system life cycle model, development methodology, method or model. It is not either intended to be in conflict with any organization's policies, procedures, and standards or with any national laws and regulations, such conflict should be resolved before using the framework.

This International Standard can be used in one or more of the following modes:

- By an organization — to help establish an environment of desired processes. These processes can be supported by an infrastructure of methods, procedures, techniques, tools and trained personnel. The organization may then employ this environment to perform and manage its projects and progress systems through their life cycle stages.
- By a project — to help select, structure and employ the elements of an established environment to provide products and services.
- By an acquirer and a supplier — to help develop an agreement concerning processes and activities. Via the agreement, the processes and activities in this International Standard are selected, negotiated, agreed to and performed. In this mode this International Standard is used for guidance in developing the agreement.

- By process assessors — to serve as a process reference model for use in the performance of process assessments that may be used to support organizational process improvement. This International Standard contains requirements in two clauses: Clause 6, that defines the requirements for the system life cycle processes and Annex A that provides requirements for tailoring of this International Standard. [14]

There are also several informative annexes contained in the International Standard and they are found in the appendix B:

3.3 Development models

A development model describes a process of creating a new product/system to be sold by a business or enterprise to its customer. It contains activities involved in creating the appearance of the product, deciding on the product's mechanical architecture, selecting materials and processes, and engineering the various components necessary to make the product work. [15]

Development refers collectively to the entire process of creating a product to appeal to the identified market, and testing, modifying and refining the product until it is ready for production. This master thesis is focused on finding a model tailored to be used for submarine development. The three investigated models that will be presented later will also be used in a comparison between industries and their development choices.

A development model should help with fulfilling the tasks below:

- Develop a product that the customer requests
- Develop the product on time
- Develop a product that meets the technical requirements
- The product must be able to evolve and be maintained

3.3.1 V-model

The V-model is a graphical model of a system lifecycle that have been used since 1980 in many different industries. The left side of the "V" represents the requirements, and the creation of the system, whilst the right side of the V represents the validation and how the parts are incorporated. [16]

The basic principle of the model is to break down the requirements to subsystem, which in turn breaks down to smaller sub system until there are only components left. To later on build it up on the right side on a verifying and iterative way. On the way up on the right side of the V there is always a correspondence between the right, verification part, and left, requirement part.

Basically the V-model can be fragmentized in to three levels [17]:

- Process model of the lifecycle: here it is decided what should be done in the specified project, and what conclusion the result should give.
- Method: here it is decided which approaches that should be used in order to get the results that are wanted of the process.
- Tools: here it is decided what kind of tools that will be used, and what role they must have to give the wanted results.

Each of these levels is then divided in to four subsystems:

- Project management
- System development
- Quality assurance
- Configuration management

To go further in to detail of the V-model figure 1 [18] describes the different steps to take. Every step is in turn allocated in the previous mentioned levels and then the previous mentioned subsystems. [18]

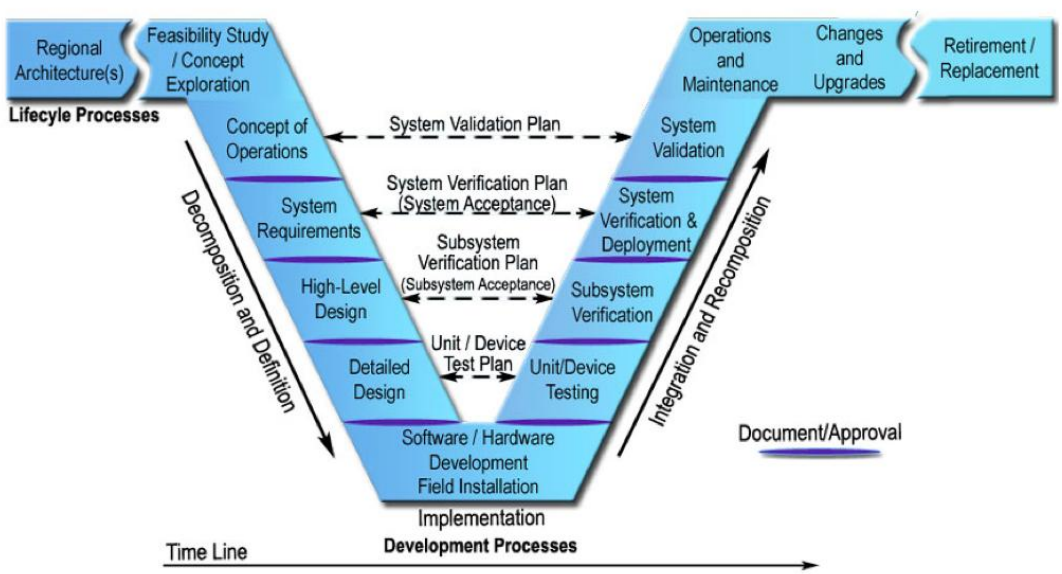

Figure 1- The V-Model

Regional Architecture(s)
The regional architecture is a good starting point; here you gather information related to the project, and overall defining the project. It is also an opportunity for the project leaders to view their projects among the surrounding systems, and to see them as individual projects together and how well they fit.

Feasibility Study/Concept Exploration
In the feasibility study/concept exploration technical, economic and political possibilities are evaluated, the cost and benefits are calculated; a business case is made. At the same time other options are investigated, and the top concept is chosen due to trade study techniques, as in the figure 2. [18]This trade study technique is a way to evaluate and select the top solution by, as seen in figure 2, state the problem, or as mentioned above, do a business case. After the problem has been stated ideas are generated, afterwards candidate solutions are chosen in a quantitative way. Which are then looked upon to choose the ones that follows best practice with the specified constrains and criteria in mind. A study like this should be made when a wide analysis is needed before any final conclusions about the resources are made. In the beginning there is a great amount of information that is unknown and therefore many assumptions have to be made.

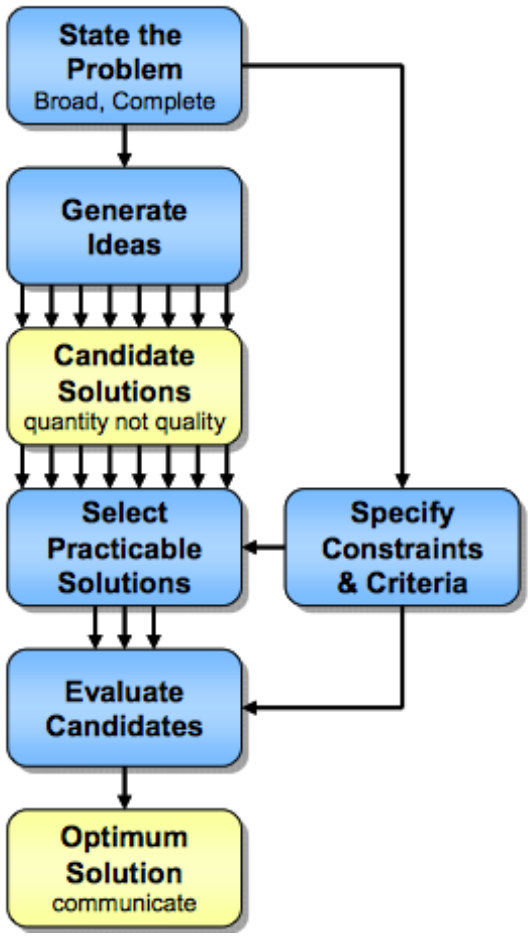

Figure 2-Trade study technique

Concept of Operation

In the concept of operation an understanding should be reached of how the system should run and be maintained, this should be documented in a user-friendly way, and it will be the basic requirements. This document states the overall technical solution to the system in a way that everybody understands. [18]

System Requirements

In the system requirements the need from the concept operation is identified, analyzed and transformed into requirements and define what the system will do, and not how a system will work. This is a significant different.

To be able to get a good traceability the requirements are described in an order (see figure 3), which allow you to work down to the details, and a traceability between the details and the origin needs, is establish in a traceability matrix. Figure 3 [18]is only an example of a system that read tag data, and how it divide the requirement to easier decide how the system will work.

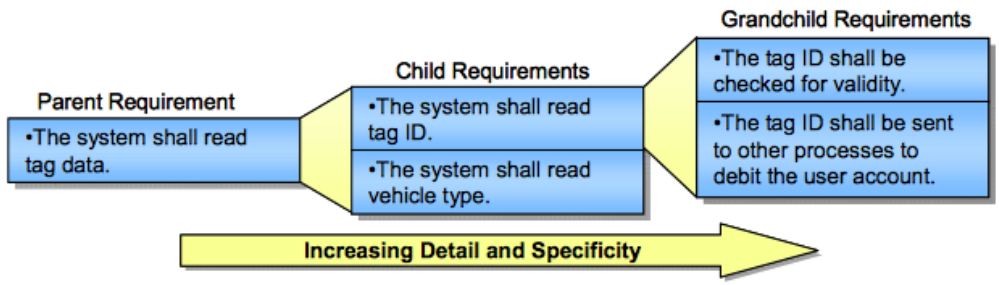

Figure 3-Traceability flow chart

It is important to validate the requirement, where you check for precision, steadiness and completeness, this is an important part since the requirements is defined in the early stages in the V-model. The requirements should be able to pass at the end of the V-model; the requirement should not be unnecessary, too complicated or not doable.

High-Level Design & Detailed Design

In the high-level design and detailed design a design of the system is formed based on the system requirements. This is the first step that focuses on the solution, which is an essential step to link the requirements with the completion in the next step. Where the high-level design is the overall system structure like components, and the detailed design is the specification of how the components work internal.

Software/Hardware Development and Unit Device Testing

In the software/hardware development and unit device testing the components that are identified in the system are tested so they fulfill the requirements, then they are delivered and installed.

Subsystem Verification & System Verification

In the subsystem verification and system verification the components are assembled into a working system and confirmed that it fulfills the requirements. The integration of the components into the system is an iterative process, the components are individually verified before integrated into a subsystem that in turn are verified against the requirement before integrated into a larger subsystem until the whole system is integrated and verified as seen in figure 4. [19]

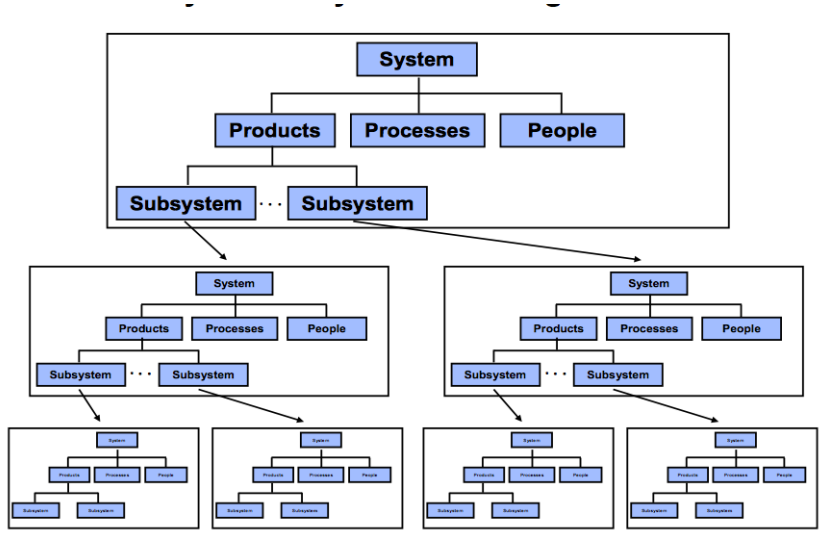

Figure 4-Subsystem description [18]

Every requirement is verified using the test case expressed in the verification method. Some requirements can be tested several times, since the process starts from the bottom and works its way up, but also since there are retests. If a test fails the bug has to be fixed and retested, but if a retest to see if the bug is fixed is not enough, a regression test has to be made. A regression test is a test to make sure that the system that used to work still works after the alterations. If the system still not meets its requirements after the bug is fixed, this procedure is done until it does.

Deployment

In the deployment the system is transferred and installed to the organization that will own and operate it. This transfer includes support equipment, documentation and operator training. After the transformation an acceptance test is preformed to ensure that the system performs as it should in the operating environment. The following tasks are preformed to deliver, install and transition the system into full operation status: [18]

- Plan for system installation and transition
- Deliver the system
- Prepare the facility
- Install the system
- Perform acceptance test
- Transition to operation

System Validation
In the system validation the validation endorses that the product fulfils its intentional use while verification endorses that the product meets its requirements. After installation the operator runs its own tests when the system is in the operational environment. Here it is also a good chance to measure how effective the system is in that environment.

Operation and Maintenance/Change and Upgrades
In the operation and maintenance/change and upgrades the system enters a "steady state" period, which will last to the day when the system needs to be retired or replaced. Throughout this time the operator, maintainers and users of the system may isolate, suggest improvements or recognize likely efficiencies. New releases will be installed and maintains will be executed.

Retirement/Replacement
In the retirement/replacement it is time to replace the existing system when the cost to operate and maintain the system is higher than developing a new system. When this is the case, a system retirement plan will be generated for the existing system.

In addition to the V-model there are some project management and control activities that are important for a project to be successful. [20]

- Project management
- Project planning
- Project monitoring and control
- Risk management
- Configuration management

Project planning is important to get an overall look at the activities, resources, budget and timeline for the project. A project plan should include the purpose and an overview of the project task description, resources and budget for each task, and a schedule. It should also include a budget plan that estimates annually/monthly costs and identify where funds may come from.

It is important that the project follows the plan after the project has started so if the project starts veering out of track it can be detected in time. Following the plan is done by continuously measure cost, schedule performance and work accomplishment compared with resources. To track this periodically and define this early on is therefore very important.

At the end of a step in the V process a review takes place as a decision point to decide whether or not to move on. The review reviews if the product in the project is used and rightly designed for what it is intended. If it passes successfully the next step in the V process takes place.

The risk in any project can be great, therefore it is important that you can predict the risks, and plan what to do when they occur. It is also important to plan for their presence and monitor the system development so action can be engaged early on. The general risk managing steps are: [18]

- Risk identification
- Risk analysis and priority
- Risk mitigation
- Risk monitoring

To maintain the process integrity it is important to establish the systems criterion or configuration and managing change to that criterion. Throughout the project you should be able to recreate or duplicate the project by looking at the data configuration and documentation.

Summarized, the advantages, disadvantages and when to use the V-model are presented below.

V-Model advantages:

- Proactive defect tracking i.e. defects are found at early stages.
- The model avoids the downward flow of the defect
- The errors occurred in any phase will be corrected in that phase itself.
- Reduces the cost for fixing the defect since defects will be found in early stages[21]

V-Model disadvantages:

- The V model needs a lot of resources and money.
- The model needs an established project to implement.
- It is difficult for smaller companies to implement.
- The model is not proposed for short term projects as it requires reviews at each stage. [15]

When to use the V-model:

- The V-model should be used for projects where requirements are clearly defined and fixed.
- The V-model should be chosen when sufficient technical resources are available with needed technical expertise.[21]
- In projects with high confidence of customer, since, no prototypes are produced, there is a very high risk involved in meeting customer expectations. [22]

3.3.2 Agile and iterative management

Agile management is an iterative and incremental method to design and build activities for engineering, and new products. The projects are often highly flexible and designed in an interactive manner; the most common example is agile software development. Designing in an agile manner requires capable individuals and close collaboration with supplier and customer.

In figure 5 [23] the model is showed and as the reader can see the model is based on iterations. At beginning of a part of the system there is a requirement and how to verify it is then decided by for an example analysis, and after it is executed. If the requirement is verified it moves on to verify another requirement or it starts the circle again with the same requirement. After a part of the system is verified there is a consolidation with the customer, the team or both and the part is given to the customer. This process will continue until the whole product or system is finished.
[24]

Agile techniques are best used in small-scale projects or on projects that are too complex for the customer to understand and specify before testing prototypes. [25]

Agile techniques are variants of iterative life cycles [23] where deliverables are submitted in stages. The main difference between agile and iterative development is that agile methods complete small portions of the deliverables in each delivery cycle while iterative methods evolve the entire set of deliverables over time, completing them near the end of the project. Both iterative and Agile methods were developed as a reaction to various obstacles that developed in more sequential forms of project organization. The end result is meant to be a product or project that best meets current customer needs and is delivered with minimal costs, waste, and time, enabling companies to achieve bottom line gains earlier than via traditional approaches.

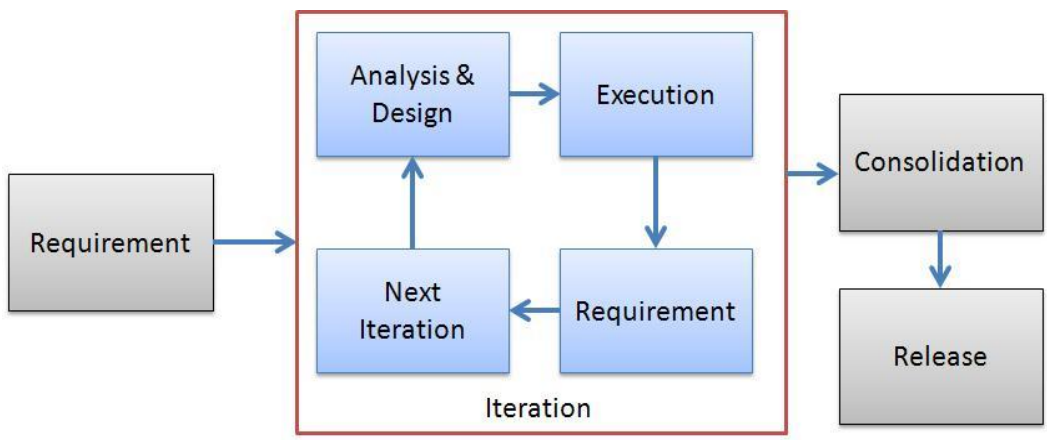

Figure 5- An overlook at the agile method

Manifesto for Agile systems development [26]:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change more important than following a plan

Principles behind the Agile Manifesto

1. The highest priority is to satisfy the customer through early and continuous delivery

2. Welcome changing requirements, even late in the development.

3. Deliver parts frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.

4. Business people and developers must work together daily throughout the project.

5. Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.

6. The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.

7. Working parts are the primary measure of progress.

8. Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.

9. Continuous attention to technical excellence and good design enhances agility.

10. Simplicity, the art of maximizing the amount of work not done is essential.

11. The best architectures, requirements, and designs emerge from self-organizing teams.

12. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly. [26]

Summarized the advantages, disadvantages and when to use the Agile model are presented below.

Advantages of Agile model:

- Customer satisfaction by rapid, continuous delivery.
- People and interactions are emphasized rather than process and tools.
- Customers, developers and testers constantly interact with each other.

- Continuous attention to technical excellence and good design.
- Regular adaptation to changing circumstances.
- Even late changes in requirements are welcomed[27]

Disadvantages of agile model:

- In case of especially the large developments, it is difficult to assess the effort required at the beginning of the development life cycle.
- There is lack of emphasis on necessary designing and documentation.[15]
- The project can easily get taken off track if the customer representative is not clear on what final outcome they want. [25]

When to use agile model:

- In developments where new changes frequently has to be implemented. [15]
- In projects where the planning time is limited.
- In industries where the products and technics used are constantly changed and improved. [28]

3.3.3 Waterfall model

The waterfall model, also referred to as a linear-sequential life cycle model, is a sequential design process in which progress is seen as flowing downwards like a waterfall. The waterfall method main characteristic is that the project relies on a strict plan, often defined by the company or organization's leadership, extensive documentation and has a clear working through project time. [29]
The phases are requirement, design, implementation, verification and maintenance as seen in figure 6 [30]

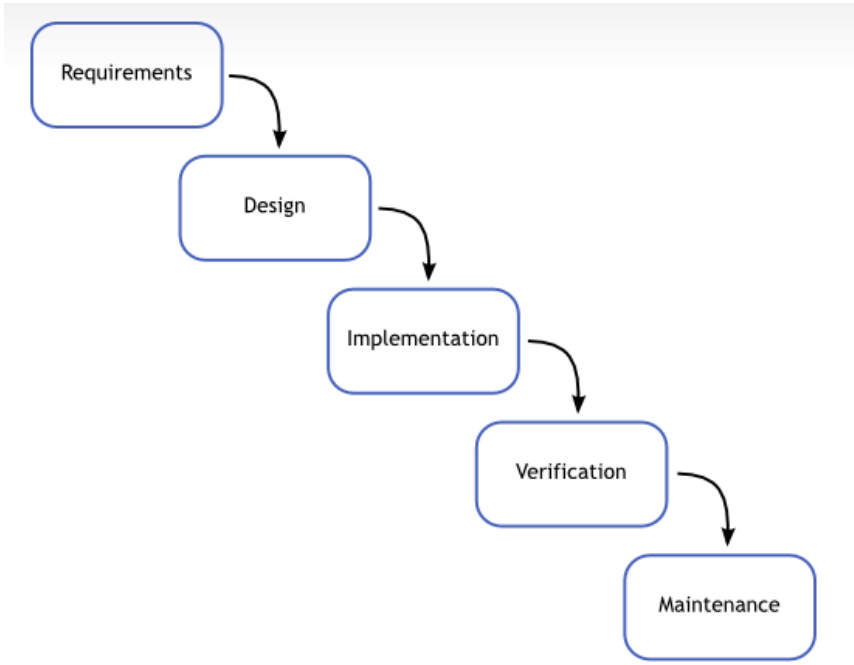

Figure 6 - The waterfall model

In the waterfall model, each phase must be completed before the next phase can begin. After each phase, a review takes place to determine if the project is on the right path or whether it should be discarded. In the waterfall model the different phases does not overlap. The waterfall development model originates in the manufacturing and construction industries. These industries are highly structured and exist in a physical environment in which after-the-fact changes are prohibitively costly or impossible.

The Waterfall model can feel intuitive and clear to use. However it is clear that it can lead to some drawbacks. Some of the criticism directed towards the waterfall method is based on its approach to change and customer interaction. Since much of the product's specifications are written in the first two phases it is not unusual that these occur in the customer contract. The project has difficulty in answering requests on change from the client since it undertook a detailed specification early in developments that delay the adaptation and implementation of new requirements. [31]

The method also lacks a detailed end of the project period of the last phase, because it also includes maintenance, which if not specified in the customer agreement and therefor can proceed indefinitely.

Then phases are directly dependent on each other, a desire for change or increased functionality is difficult to meet. This can thus lead to high costs when process may be repeated, and then lead to less satisfied customers. Some argue that the Waterfall method creates "dead ends ", because the complete phases are considered complete, evolution cannot go back to the example design phase when implementation phase started [28]. The result is that despite identification of needed functionality or improvements the design continues along the original specification.

Advantages of waterfall model:

- Simple and easy to understand and use.
- Easy to manage due to the clear steps.
- Phases are processed and completed one at a time.
- Works well for smaller projects where requirements are very well understood.[32]

Disadvantages of waterfall model

- Unable to make any changes to phases after the process started.[15]
- Waterfall model is not simultaneous.
- Only able to use when the requirements are fixed.[15]
- Unable to move back to the previous phase.
- If any mistake happens, the project should start from the scratch. [32]

When to use the waterfall model:

- Requirements are very well known, clear and fixed.
- Product definition is stable.
- Technology is understood.
- There are no ambiguous requirements.
- Ample resources with required expertise are available freely.
- The project is short. [33]

4 Company and background

4.1 FMV-Defense Materiel Administration

FMV (Försvarets materielverk) provides technology for Sweden's security and defense logistics. In collaboration with key partner, the Armed Forces, they design and provide the military with defense materiel and services. Technology and business expertise are their core competences. FMV is a civil authority under the Ministry of Defense. FMV cooperate with different actors, both nationally and internationally, to meet customers' needs of defense logistics. FMV has been a customer to ThyssenKrupp Marine Systems AB for a long time and was the potential customer to the new designed submarines more described in *submarine projects*. [34]

4.2 ThyssenKrupp Group

ThyssenKrupp is one of the leading industrial groups of Germany and Europe; its head quarter is located in Essen and has hundreds of Member Company in 77 countries. ThyssenKrupp Group is organized in six business areas:

- Components Technology
- Elevator Technology
- Industrial Solutions
- Materials Services
- Steel Europé
- Steel Americas

The business areas are divided into operating units and Group companies operating independently on the market [35]

4.2.1 Group structure

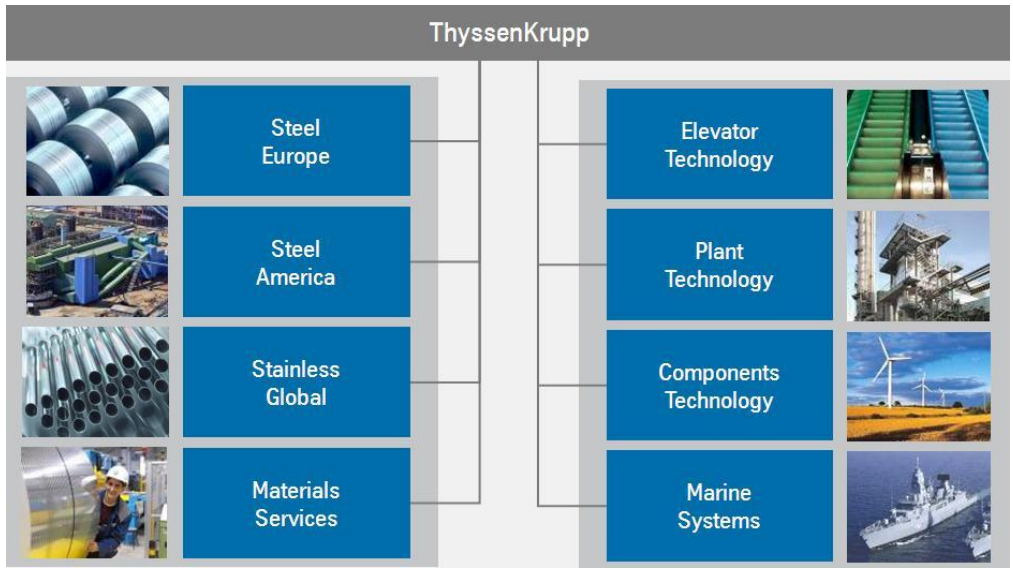

Figure 7-Group structure at ThyssenKrupp Group

4.2.2 ThyssenKrupp Marine Systems AB

Former Kockums

ThyssenKrupp Marine Systems AB is the part of ThyssenKrupp Group seen in figure 7 [29] that will be investigated in this master thesis and their focus area contains maritime and naval technology, both above and below the surface. ThyssenKrupp Marine Systems AB design, build and maintain submarines and naval surface ships. These are tailored for the littoral zone and incorporate a high advanced stealth technology. Their products and technologies enable their customers to counter threats to national security and wellbeing in the littoral zone. Their facilities are based in Malmö, Karlskrona and Muskö in Sweden. [1]

4.2.3 Submarine projects

The main focus and the potentially largest order for ThyssenKrupp Marine Systems AB is an order of two submarines named A26. The Swedish Government approved an initiation of the design phase for a new generation submarines for the Royal Swedish Navy. The new generation of submarines was named, A26 and was mainly designed for littoral operation but would also possess some ocean going capabilities. At the moment the deal is dead due to that FMV and ThyssenKrupp do not agree on the contract terms. [3]

Other projects that are executed at the moment along with designing A26 include the restoration and modification of other submarines and surface ships.[3]

4.2.4 Activity chart

ThyssenKrupp Marine Systems AB's activity chart shows different functions, which together forms the whole function of the company.

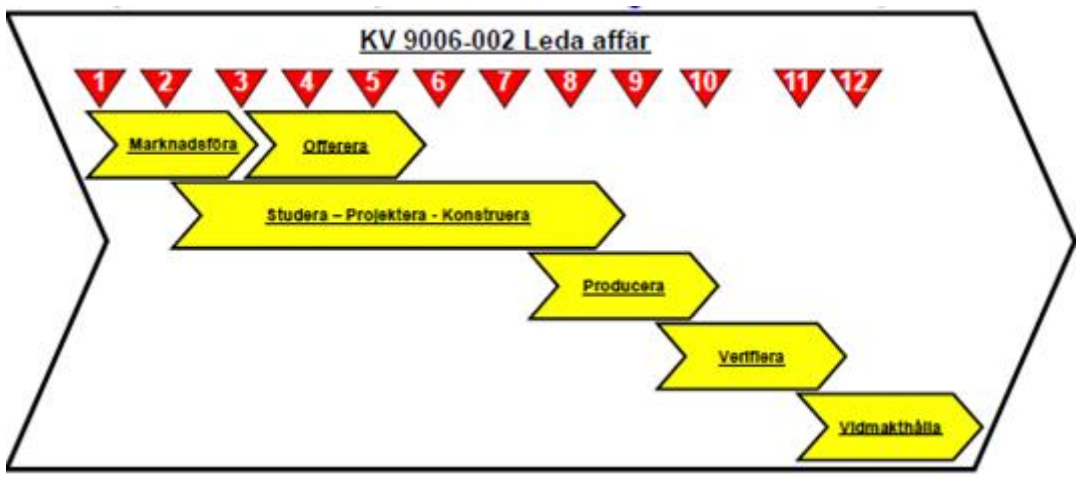

Figure 8-Activity chart

There are six steps showed in figure 8 [3] and in this master thesis the focus will be at verify. Deeper understanding of the different steps can be found in appendix B:

- Market
- Tender
- Study-Define-Design
- Produce
- Verify
- Through life support

4.2.5 Verify

The process describes the part about verification from ICO (Installation check out), which is a verification event until completion of final control and "Ready for delivery". Roles and responsibilities are described for the different events, which will be discussed later in this chapter. The process also describes the requirement management in detail. In this master thesis this part will be evaluated and a verification tool will be developed and motivated. [36]

4.2.6 Verification process

Toll gates, decision gates and milestones build up the different systems and projects seen in figure 9. [3]

Toll Gates- TG
Toll gates are decisions milestones that control the different phases such as start, end and content, steering group level.

Decision Gates -DG
Decision Gates are business decisions milestones which are executed at a lower level of management than TG, management level.

Master milestones - MS
Master milestones are project milestones that manage events, project management. Internal milestones are the lowest level of project milestones.

Master plan
When creating a master plan, the focus is on milestones. Milestones are the usual way of communicating with customers on a global level, and there is often payment connected to the different milestones. [3]. Toll gates and decision gates are connected to the default plan against each phase; adjustments must be an active decision. Milestones are then determined after the toll gates and decision gates as needed in the actual project. [3]

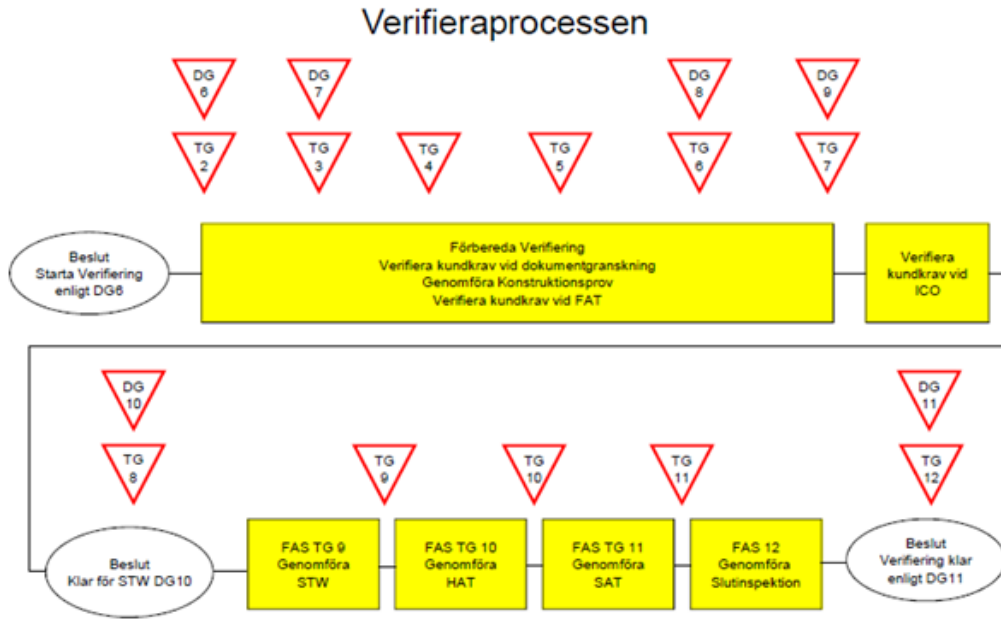

Figure 9- Verification process at ThyssenKrupp Marine System AB

4.2.7 Verification events and participants

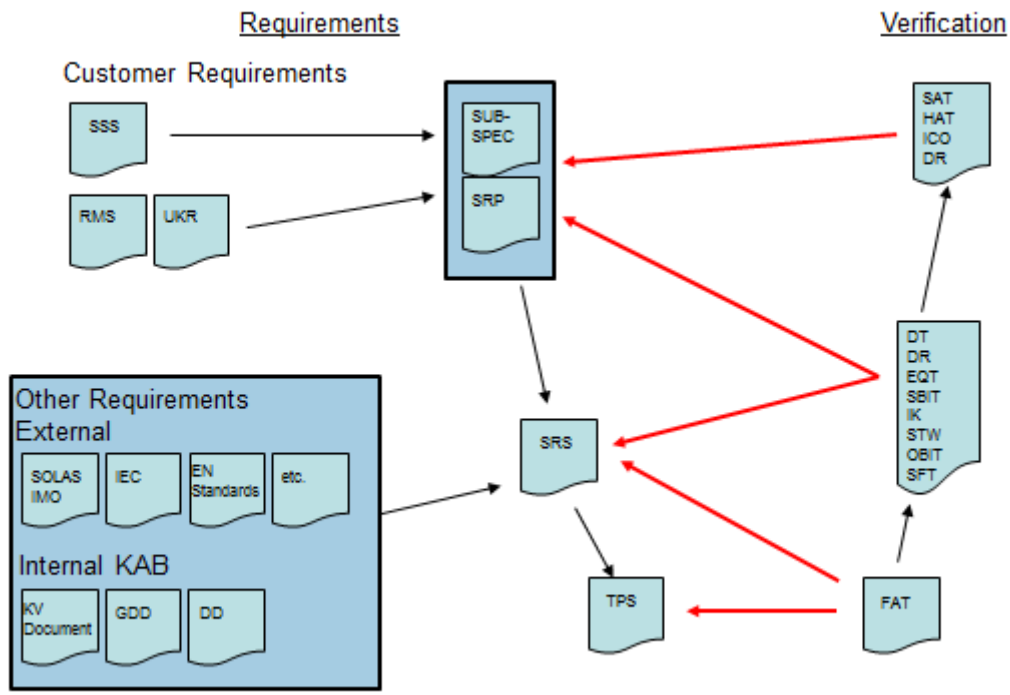

Figure 10- Verification events

As mentioned above the verification process consists of different tollgates and decision gates. But it also consists of different events were the requirements are tested seen in figure 10. [34] If the requirements do not pass at an event, they have to be retested and a residue is filed to the person in charge, in either the residue program Barium or the residue program Veri which will be explained in *Programs and Tools*. The most important events for this master thesis are listed, discussed and presented below. [36]

4.2.8 Verification categories

- Design Test
- Environmental Test
- Design Reviews
- Integration Test
- Factory Acceptance Test (FAT)
- Installation check out (ICO)
- Set to Work (STW)

- Final installation Inception (FII)
- Harbor Acceptance Test (HAT)
- Sea Functional Trials (SFT)
- Sea Acceptance Test (SAT)

Design Test
The purpose of design tests is to verify, in an early stage of the design phase, that a design solution or/and components will be suitable for use onboard the submarine. Design tests are used to minimize future risks onboard the submarine and is not primarily used to verify a specific SUBSPEC requirement.

Environmental Test
The purpose of environmental tests is to verify that a component, unit or system meets certain specific environmental requirements. These types of tests could be e.g. chock tests, noise tests, measurement test, and electromagnetic compatibility verification of testing in a climate chamber.

Design Review
A number of requirements will be possible to verify based on the selected design solution. The formal design review that will be conducted with the customer will be used as a verification category for requirements, which are possible to verify, based on the selected solution.

Integration Test
Integration tests are used to test interfaces and functional integrations between various systems and to eliminate risks of complex systems. Preferably this shall be done before the systems are installed onboard the submarine i.e. Shore Based Integration Test (SBIT), or if more integrated functional testing is required Onboard Integration Test (OBIT) may be required.

FAT
Factory acceptance test is an event before manufacturing, were the requirements are verified at the factory for the specific part. FAT is an acceptance test and shall have a procedure and be documented in a test report. The FAT test report may be as supplementary evidence to other verification categories.

ICO
Installation check out is carried out to ensure that the systems and/or arrangements have been completed and assembled in accordance with installation control document, drawing and building instructions. The ICO includes:

- Onboard installation control (System and room inspection).
- Shock clearance and noise inspections.
- Checks that the FAT's and own control (Egenkontroll) are completed.
- Verification that all specified manufacturing controls, according to inspection plans have been completed and closed.
- Review of applicable certificates and documents.

A completed ICO is a pre-requisite for STW and acceptance testing onboard. ICO is an internal KAB activity. Formal demonstration to the customer is done during FII.

STW
Set to work is an event where all requirements that can be tested on land are tested. This event works as a reference to the other tests. There are more requirements tested at this event in comparison to the HAT and SAT**.** A STW is not a formal demonstration of the system's functions and performance, but may e.g. include functional checks and performance measurements necessary for the designers to verify performance calculations or get the system properly set up prior to formal demonstration to the customer.

STW shall have a test procedure and be documented in a test report. The STW test report may be used as supplementary evidence to other verification categories.

FII
Final installation inspection is the formal inspection with the customer to verify that a system have been installed in accordance with the specifications. During the FII it is also checked that the necessary system documentation and certificates required by the authorities and available. FII shall have an inception protocol.

HAT
Harbor acceptance test, is an event at the harbor were all the requirements that should be tested before testing it out at sea. Hat is performed with a complete system installed onboard to demonstrate compliance with the SUBSPEC. The Hat shall verify that the functional performance of the system meets its specified requirements and demonstrate system serviceability. It also ensures that the interface and integration of the system complies with applicable interface requirement specifications.

The Hat shall demonstrate the functionality and performance under harbor conditions. An approved Hat is a pre-requisite for the start of sea trials. It is an acceptance test and shall have a test procedure and is documented in a test report.

SFT
Sea functional trials are none acceptance trails conducted to verify and/or fine tune system prior to a formal SAT. The use of STF shall be restricted and only used for parameters which cannot be set unless at sea. The SFTs will be integrated in the sea trials program SAT. SFT shall have a test procedure and be documented in a test report.

SAT
Sea acceptance test is an event, which is the last event. At this event the submarine's requirements should all have been tested and verified. SAT is performed to demonstrate full functionality and performance of the complete submarine in an operational environment under dynamic conditions at sea. Verification of requirements during SAT should be limited to requirements, which require the submarine to be at sea for verification. SAT is an acceptance test and shall have a test procedure and is documented in a test report. In appendix B more abbreviations are present and their explanation.[36]

The following verification activities will be conducted prior to installation onboard the submarine:

- Design Test
- Design Review
- FAT
- SBIT

While the following verification activities are conducted onboard the submarine:

- ICO
- STW
- OBIT
- FII
- HAT
- SFT
- SAT

Participants

At the different events there are also different needs from both FMV and ThyssenKrupp Marine System AB showed in figure 11. [34] Some events or parts of the system are more important for FMV to be a part of. This is decided on in a dialog between the producer and the customer, in this case FMV. [3]

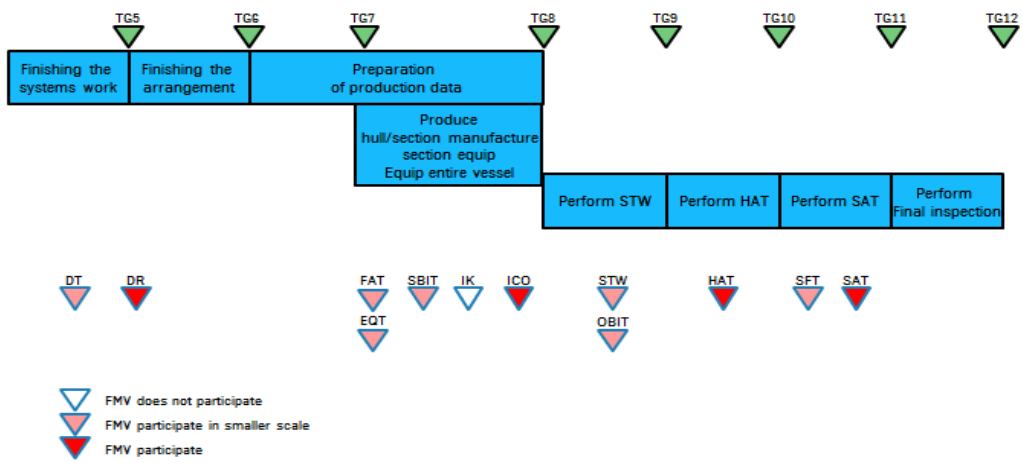

Figure 11- Participants at verification events

4.2.9 Computer programs and tools used by ThyssenKrupp Marine System AB

DOORS
DOORS is a requirements management application developed by IBM for optimizing requirements communication, collaboration and finally verification throughout a company, organization and supply chain. This scalable solution can help the company meet business goals by managing project scope and costs. DOORS lets you capture, trace, analyze and manage changes to information while maintaining compliance to regulations and standards.

DOORS provide:

- Requirements management in a centralized location for better team collaboration.
- Traceability by linking requirements to design items, test plans, test cases and other requirements.
- Scalability to address your changing requirements management needs.
- Test Tracking Toolkit for manual test environments to link requirements to test cases.
- Integrations to help manage changes to requirements with either a simple pre-defined change proposal system or a more thorough, customizable change control workflow with Rational change management solutions.
-

Summarized, DOORS provides requirements management integrated on a common platform with design, change management, or test management capabilities. [37]

Mars Planning
Mars Planning is a computer program and planning tool with a number of different possibilities. At ThyssenKrupp Marine Systems AB there is a specific profession with specific planning responsibilities where you as a planner methodically design different plans. It is vital that everything is entered correctly, and that as much as possible is placed in the Mars Planning program so there can be an economic traceability. Mars Planning is structured so that different projects are divided and then subdivided into smaller systems.

When the engineer is searching for both bigger and smaller parts of the system, information about the system can be shown. Some examples are presented below and there are much more, over hundreds of options.[22]

- When will it be completed
- How many hours will the system take before it is finished
- Budget
- Resources
- Earliest end
- Latest end
- Custom Data
- etc

Mars Planning is also linked to other programs such as MARS and Barium described later, which updates Mars Planning. At the moment Mars Planning is not used by all employees properly, instead they are using other tools such as excel and word. This is something that ThyssenKrupp Marine Systems AB want to change, but it takes time since many are used to working with other methods.

Veri
Veri is a residue program, which is connected to the customer, so it is easy to communicate the status of the requirement threw Veri. However Veri is not connected to Mars Planning or any other of ThyssenKrupp Marine System AB's programs.

Barium
Barium is also amongst other things a residue program. Each time you add a note or change depending on what kind of note/change it is, it creates a deviation note that is linked to Mars Planning. A note or a change can be everything from a request for a new work mobile to a deviation in the production. Barium is not connected to costumers.

Kabanalys
Kabanalys is a program that is linked to Mars Planning, which gives statistics to the project planner/manager. This is used to give workers feedback on their work, residues and to what extent they meet time.

Mars
Mars is a logistics program, were for examples parts and tools can be bought.

PDM
PDM is a document handler, which gets updated continuously throughout the project manufacturing and will be put in KabDoc when it is finished.

KabDoc
KabDoc contains verified documents that are finished.

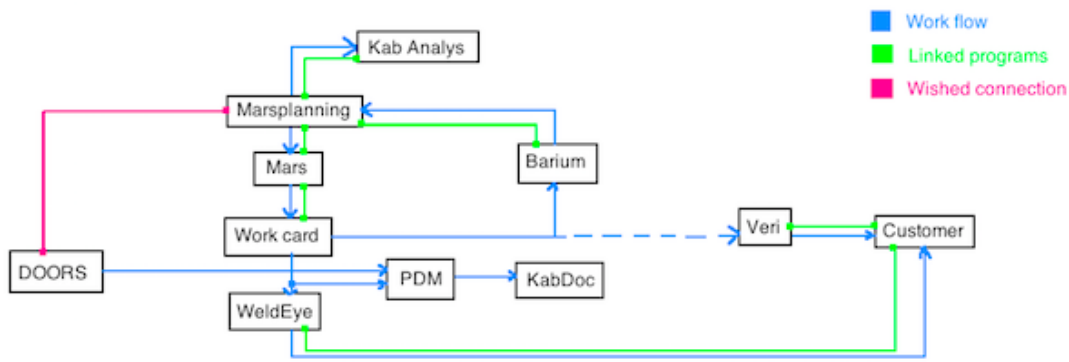

Figure 12-The connections between the different programs

4.3 Companies used in the benchmarking and comparison

The benchmark and comparison part of the master thesis focus on how other companies in other industries work to maintain and improve traceability. Employees who were responsible for testing and verification at the different companies were interviewed. These companies were chosen because they all are well established companies in industries were testing and verification is important. They were also chosen because they work in different industries which may give a broad understanding on if there are common problems in testing and verification processes.

The companies interviewed were:

- ThyssenKrupp Marine System AB
- Axis
- Sony
- Gambro

Axis
Axis is the market leader in network video, and offers network video solutions for professional installations. They are featuring products and solutions that are based on open technical platforms. In comparison to ThyssenKrupp Marine System AB Axis produces less complex products with a smaller time to market. [38]

Sony Mobile Communications AB
Sony Mobile Communications AB is a multinational mobile phone manufacturing company. They also produce music, pictures, computer entertainment and online businesses. In comparison to ThyssenKrupp Marine System AB Sony produces less complex products with a smaller time to market [39]

Gambro
Gambro is a global medical technology company, which specializes in developing, manufacturing and supplying products and therapies for kidney and liver dialysis, myeloma kidney therapy, and other therapies for chronic and acute patients.

Gambro was founded in 1964 and has today 8 000 employees, 13 production facilities in 9 countries, and sales in more than 90 countries. Through innovation and partnership with their customers they provide extracorporeal therapies that save, sustain and improve the lives of patients worldwide. [40]

4.4 Extractions from the interviews
Important information extracted from the interviews, for more detailed information about the interviews see appendix A.

Employees at different levels were interviewed to get a broader understanding of the testing and verification process at the different companies; however managers were prioritized since they have access to more information. The questions asked were regarding testing, verification, verification processes, advantages and disadvantages with their verification and testing methods and questions about their developing models.

4.4.1 Johan Stensson, ThyssenKrupp Marine Systems AB,

Engineer at the Sensor System department at ThyssenKrupp Marine Systems AB

- ThyssenKrupp Marine Systems AB is working on improving specifications for all requirements, not only the ones mentioned in the submarine contracts.
- Wants to build out the functions in DOORS to improve traceability and visibility for requirement information and verification.
- Think that employing a requirement administrator could solve some administrative problems.
- Believes that ThyssenKrupp Marine Systems AB should work more with standardizing documentations.
- Thinks Veri is a great tool since it has a connection to the customers, he prefers Veri over Barium.

4.4.2 Kristian Hultgren, ThyssenKrupp Marine Systems AB

Production leader in Karlskrona at ThyssenKrupp Marine Systems AB
.

- There is a link between Mars, Mars Planning and Barium, and this should be used more.
- Believes Barium is better than Veri due to the connection to Mars Planning.

4.4.3 Mattias Olsson, ThyssenKrupp Marine Systems AB

Quality Assurance Manager at ThyssenKrupp Marine Systems AB

- ThyssenKrupp Marine Systems AB have to prioritize non submarine requirements more, these are not documented as well as the submarine specific.
- All planning should be done in Mars Planning, employees should avoid excel and such programs.

4.4.4 Ola Borgquist, ThyssenKrupp Marine Systems AB

Manager at the Signatures department at ThyssenKrupp Marine Systems AB

- ThyssenKrupp Marine Systems AB needs to improve the education in DOORS if they want the employees to use it more, they employees are avoiding using programs they do not feel that they master.
- He does not believe that activities or functions should be added in DOORS. This is not a good idea since he believes there is a lack of communication, and putting more information in DOORS will only make that situation worse.
- When creating a traceability tool or any tool, it is important to think about the user.
- He thinks that adding access levels to the red environment would make the work easier for many engineers. There are many employees working with information that they cannot reach themselves, this makes their work processes heavy routed.
- He thinks that, if there was more access levels there would not need to be a requirement administrator.

4.4.5 Tommy Ekhdal, ThyssenKrupp Marine Systems AB

Head of the Electric department in Karlskrona at ThyssenKrupp Marine Systems AB

- It is important that all employees follow new directions.
- Using Mars Planning and Barium increases traceability.

4.4.6 Anders Grynge, Sony Mobile

Director at Sony and ultimately responsible for verification at Sony Mobile

- There are a lot of requirement databases with different categories of requirements. It is hard to administrate and update them since they are spread out and have different regulations.
- Different customers and companies have different demands.
- A worldwide company with development and production in many countries. They have a greater problem with standardization of work processes and documentation.

- They are trying to improve traceability by gathering links to the different requirement storages locations in one place.
- In the mobile industry it is a necessity to work with the agile model, since the market needs and technology is changing fast.

4.4.7 Anna Schömer, Sony Mobile

Senior Software Usability Analyst at Sony Mobile

- There is great difficulty in writing soft demands in a way that they can be validated and verified, this is something they are trying to improve.
- Agile is the best model in their industry.
- Having similar and standard ways of documenting improves traceability and makes the documentation easier to understand and follow.

4.4.8 Employee, Axis

Test Team Lead at Axis Communications

- Axis mostly works with the V-model and the agile model; this depending on the part of the product, for an example the software development is agile.
- Axis tries to improve traceability between requirements and test cases, but believe it is very important that the engineer has some freedom in documenting.
- A requirement administrator could be a solution to get rid of some administration from the engineers that usually does not prioritize this as much as their other work duties.

4.4.9 Sabine Alexandersson, Gambro

Test & verification engineer at Gambro

- Gambro are great at traceability due to extremely high pressure from their industry.
- Sabine Alexandersson believes that Gambro priorities education in testing, traceability and documenting more than other companies.

- The projects does not collaborate as in other companies, the different departments designs their product mostly themselves. Sabine believes this is because Gambro is a “rich” company and does not have to optimize in a way as other companies have to.
- The design of the machine must be safety bullet proof, since Gambro cannot take for granted that the people operating their machines are highly educated or working in calm and perfect condition.
- They are using DOORS, HP ALM, HP QC and enterprise architect.

4.4.10 Mikael Kruszewski, Gambro

Verification Team Lead at Gambro

- Gambro is trying to improve traceability by improving the interface between DOORS and HP ALM and HP QC.
- Gambro is working with trying to improve the knowledge of their staff.
- They have a specific Gambro verifying/developing model.
- They do not have access to information about other departments, but have reading access to all information regarding those projects that they are working on.
- They use DOORS, HP ALM and HP QC.

4.4.11 Per Stenqvist, Gambro

Developer at Gambro

- They use different models depending on what part of the project they are working on. Over all, their model is like the V-modell.
- They are using DOORS, HP ALM, HP QC and enterprise architect.
- He believes that the interface between the programs is important.
- Gambro is improving their validation processes which before were more like a verification.
- They are also trying to use exploring testing to find new bugs and difficulties in system.

5 Result

5.1 Trace

The result of the master thesis was a planning tool, Trace which created traceability between the requirements and the different verification events in figure 10. To start Trace the employee has to login with her/his login and password; all the employees have different access levels connected to their account so they only can access the information corresponding to their access level. When the employee is logged in the view of Trace is as in figure 13. Now the employee can choose from different options. The employee can insert a new requirement, which is added to the existing requirement list, to see more on how to insert a requirement look in appendix C. The clearance to add a requirement is something only the administrator should have in the authors' opinion, however this is easily changed depending on how ThyssenKrupp Marine system AB in the future feels fits their work process the best.

The employee can also follow a specific requirement, this means that the employee insert a name or id for a specific requirement and then gets a list with all relevant information, such as which test events this requirement is tested in, but also specific department, date to be finished etc. Then there are three similar choices, *Open requirement view, General requirement view- non-submarine specific* and *Authorized view*. These three leads to the same view but withholds different information. Open requirement view contains requirements that everyone is allowed to see, while Authorized view is connected to the users access level and therefore shows the requirements the user is allowed to see, General requirement are requirement such as environmental and personnel requirements. The view, which the user enters when choosing one of these options, is shown in figure 14.

In figure 14 there is a great amount of options to choose from which are partially decided from figure 10, the different verification events. The idea is that the user can click on chosen verification event and see which requirements are to be tested in that event. There are also other options such as all requirements within a system; system in this case is what ThyssenKrupp Marine System AB calls its departments, where the user can see all requirements within that system that the user specified.

The user can also get all of the customer requirements, and search for a requirement and see all of the information connected to that specific requirement, for an example which test method is used for that specified requirement. All this information comes as lists that the user can save on her/his computer. There is also a function called make matrix, which makes a matrix of all the requirements and their parameters, which are the different searchable options in figure 14.

The results of the program Trace is better traceability at ThyssenKrupp Martine System AB since the program makes it easier for the employee to get access to the information needed due to the changes. The most important change is that for the first time the information regarding a requirement is gathered at the same place. The searchability is also improved due to that the login is connected to the employee's access level, and a better searchability leads to better traceability. It is also easy for the employee during anytime in the project to look up a specific requirement and get all the relevant information in an easy to read list.

Trace also makes traceability easier by the options in figure 14, where the employee can search on different test events to see which requirements are tested, but also get overall information such as a list of all the customer requirements, or a list of all unverified requirements etc. And if the employee wants an overall picture of all the requirements she/he can make a matrix where the requirements are in the row section and all the different options in figure 14 are in the columns.

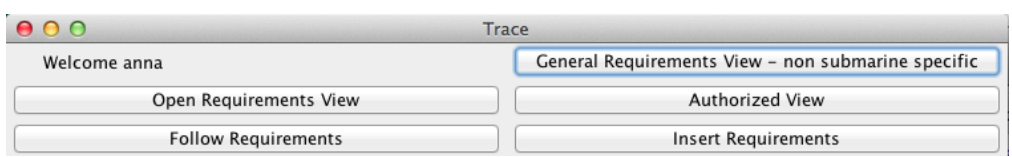

Figure 13-Trace start view

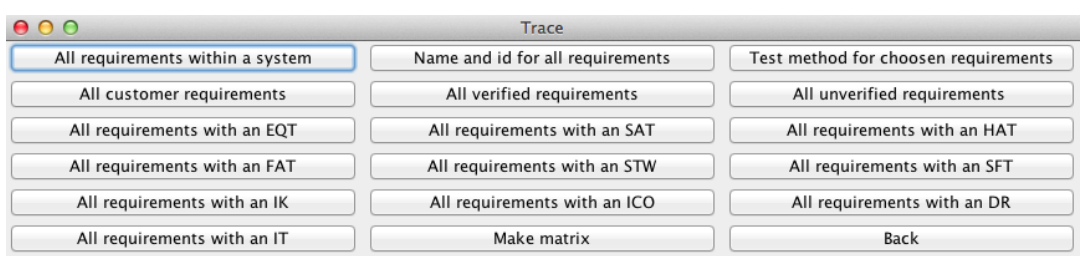

Figure 14-The possibilities of requirement traceability

Advantages with adding Trace into the verification process:

- In Trace a requirement can be followed from the start to the end, which facilitates verification, which makes it easier to trace the requirements in the processes.
- The program clearly shows the users were the requirement/requirements would be tested.
- The program also clearly shows which requirements that are tested at a certain test, if it is finished and if not where it failed.
- Trace can be used both as a planning tool and a traceability tool.

Disadvantages with adding Trace into the verification process:

- Will initially take time to implement.
- Will initially add a cost of development and over time an additional cost for the administrator of the program, since Trace continuously must get updated when requirements get approved or failed in the different verification events.

5.2 Developing model

The result of the developing model evaluation is that, ThyssenKrupp Marine Systems AB uses the V model; this conclusion is reached by the interviews with the staff. This is the perfect match for their kind of industry and the product they are producing.

The V-model is a good match due to:

- The projects requirements are clearly defined and most requirements are fixed over time.
- Building a prototype would be too costly

The Agile model is not a good match due to:

- The development of submarines is not frequently changed and the submarines life cycle are longer then for example other smaller technical products like mobile phones.
- The planning time is relatively long.

The Waterfall model is not a good match due to:

- The project is not short and there is limitation due to the fact that the phases have no overlapping.

5.3 Benchmarking and comparison

The result of the benchmarking and comparison is that ThyssenKrupp Marine Systems AB's development model is more long term due to slower time to market and longer development process in comparison to Axis, Sony and Gambro.

Differences:

- Companies with shorter time to market use the agile development model
- It is more important to be flexible over time for the companies with shorter time to market.
- The defense industry demands a higher security, which makes the development more heavy routed.

Similarities:

- They are all working on improving their traceability.
- They all try to avoid making documentation confidential, if it is not essential. To avoid making the traceability and processes heavy routed.
- All the companies have different ways that they inside the company document tests and results, which can differ from departments in the company and this leads to some traceability problems.

6 Analysis

6.1 Trace

As mentioned before, the purpose of Trace is to provide a complete system for the requirement specifications and their traceability. Furthermore the system will implement a clear and simple way to show the person responsible that the requirements are met, and give a clear view of the requirement from start to finish. Trace is a prototype of a tool to help the company to follow a requirement throughout the whole submarine project.

The analysis of the traceability showed that the difficulty of reaching traceability was that the information was spread out and not linked, the different access levels also contributed to some difficulty, since not all had access to all information even when needed in their job.

Two suggestions by the employees were aimed at extending the documentation in DOORS. These solutions are good ideas, due to the fact that all the requirements are collected there. This is, however not optimal since there is no connection between DOORS and the other programs, and to use DOORS you need a high clearance. In Trace everybody involved in the verifying process can login, but with the limitation in changing and seeing requirements that they are not allowed to see or change. This solution is better than shutting out the engineer all together from the information in DOORS that the engineers are allowed to see.

The idea is that there are initially two views, one with all the secret requirements and one with the open requirements. Here all the relevant information about a requirement is stored, the events that they will be tested in and the possibility to mark them as finished or not. With Trace a requirement can be followed from the start to the end, which facilitates verification, which makes it easier to trace the requirements in the processes. The program clearly shows the users where the requirement/requirements would be tested.

These connections did not exist before; with Trace an engineer can print out all the requirements, their information and also get the requirements that are tested at a specific event. When making this search possible and printable it is easier to see if all the requirements are finished and effortlessly provides the engineer with a verification checklist for an event.

At the moment some legal and work environment requirements are not gathered in DOORS and their traceability has not been prioritized. There will be a specific place in Trace for these requirements so they are easily found and reachable for all engineers. They are gathered separately in the program as general requirements because they do not contain all the additionally information as the submarine specific requirements. These requirements are not linked financially either.

Trace will also improve the traceability in verification since the verification methods such as analysis, test, inspection; demonstration and similarity are searchable in Trace. However Trace will not improve the validation process for the different verification events.

A change often follows by some difficulties in the beginning due to the change in routines. The authors believe that the drawbacks will be that the new program, Trace initially will take time to implement. Trace will also initially add a cost of development and over time an additional cost for the administrator of the program, since Trace continuously must get updated when requirements get approved or failed in the different verification events.

The credibility of the research behind the development of Trace and the advantages of adding Trace into ThyssenKrupp Marine Systems AB's verification process, are good. The research is thorough and takes in many different opinions from different parts of the company. However the credibility decreases due to the fact that the authors could not get access to all information regarding DOORS. There is also a security aspect that has not been investigated as mentioned in the delimitations, since the authors does not have that expertise and the time frame of the master thesis is too short for that type of investigation and implementation.

6.2 Developing model

ThyssenKrupp Marine Systems AB uses the V model in the way that they divide their work process in the three fragmentized levels in the V-model, lifecycle, method and tools. This is the perfect match for their kind of industry because the projects requirements are clearly defined and most requirements are fixed over time. The fact that the requirements are more fixed over time than for a mobile phone makes the process more stable. Therefor the developing process must not be as flexible to changes as in industries, which use agile methods. Building submarines is extremely costly and it is extremely important to know that the different parts of the system work together before starting developing additionally systems to add on. It is more important than for industries with smaller developing costs, since building a prototype would be too expensive and time consuming in the submarine business. Summarized agile methods is more common in business that has a shorter time to market, were the requirements are not as fixed as in the submarine business.

The waterfall model is mainly used in projects that are short and therefor this model is not a great match for the submarine business, since a submarine project may last up to 25years.

The credibility of the development model research is limited, since the interviewed at other companies are not always that educated in that area.

6.3 Benchmarking and comparison

The interviews demonstrate that ThyssenKrupp Marine Systems AB and all other companies interviewed, except Gambro, lack a complete traceability between requirements and verification. They are all looking for ways to improve traceability and have mapped out in different extent were traceability is missing. A reason to why they have this mutual problem is that the consumption and technology today is different from 10 years ago. In today's society companies are expected to produce faster than before, this leads to changes in the developing methods. And here the traceability gets lost in the change.

All companies have some confidential information regarding testing and results. There are importantly two different levels:

- Confidential for people outside the company.
- Confidential for employees and people outside the company without a specific clearance.

These levels are created to protect the company from leaking information, but will make the work around the confidential requirements more complex due more administration since not everybody has access to all the information. This also makes traceability harder. Therefor higher levels are avoided if not needed.

When documenting results and tests all companies believe that a common way of documenting result and test improves the traceability and interpretation of results and tests. However since the companies are divided in departments with different minds and preferences it is harder to implement in practice, in a way which will fit all the departments. Implementing a common way may add more documentation than needed, and limit the engineer from wanting to improve the documentation process. This could be a result due to the fact that the change must be approved before changed.

ThyssenKrupp Marine Systems AB has different ways of documenting results of testing. They have all information but spread out, and they are currently researching ways of improving the traceability. They are doing this by giving different people at different departments the task of researching ways of improving the traceability and finding a more standardized documentation.

Axis works with making the test case documentation more similar written, but feel that the engineer should have freedom to change documentation if there is a reason to why it should be documented differently. This makes a total standardization unwanted and impossible. Sony is a large company located in different countries all over the world. The results and requirements are stored on different locations, today it is too time consuming and costly to put them all in one database. The solution that they are working on is developing a common place, which contains links to all the different places were the information is located, so everybody knows where to start looking.

At Gambro the documentation is more strictly handled. This is very important due to that they are in an extremely regulated business, the medical business, where patient security is a driving factor. The high regulations of their business area put more pressure on them to have a perfect traceability. Since an external inspector can come in at any time and shut down the project if there is a lack in traceability.

When analyzing different companies it is important to take into account that their companies and businesses have different demands on traceability and that their requirements are based on different standards for an example different ISO standards.

The credibility of the benchmarking and comparison research is limited, since the interviewed at other companies are restricted in telling us everything. There is also a time limitation that also limits the extent in which the other processes at the other companies are examined.

7 Conclusion and recommendation

7.1 Trace

Conclusions:

- Improves traceability.
- Gives a clearer overview of where different requirements are tested.
- Improves planning for verifying requirements.
- Improves the search ability, since people at every access level has access to more than before.
- Gives an easier way of getting relevant requirement information printed and gathered.

Recommendations:

- Implement Trace into the verification process.
- Develop a security login fitted for the defense business.
- Link Kabdoc to Trace.
- Educate staff in how to use Trace.
- Create an interface between DOORS and Trace to get synchronization for the requirement information.

7.2 Developing model

Conclusions:

- Different developing models fit different projects and business.
- At a company and in projects there can be different parts that are developed with different developing models.

Recommendations:

- Continue to use the V model.

7.3 Benchmarking and comparison

Conclusions:

- DOORS is used at all the companies, but used in different ways.

- ThyssenKrupp Marine System AB could solve some of their problems by educating more staff in how to use DOORS and its possibilities.
- Different developing models fit different projects and business.
- Traceability is important for all companies and they all try to improve traceability.
- There are different demands on traceability depending on customers, time frame, and regulatory requirements and depending on the industry.
- There is a difference in how many different departments collaborate.

Recommendations:

- Educate the staff in DOORS, Trace and the other programs needed.
- Continue to have collaboration with other departments.
- Standardizes the test cases so they can be reused more frequent.
- Standardizes the reports.

7.4 Further recommendations:

- Stop using Veri and implement a customer connection in Barium.

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8 Appendix A

8.1 Interviews at ThyssenKrupp AB

Interviews with employees at ThyssenKrupp Marine Systems AB. some wishes to be anonyms and the other ones are named.

8.1.1 Interview with Johan Stensson 26/2-14

Who is Johan Stensson, and what role does he have at ThyssenKrupp Marine Systems AB?

Johan Stensson works within the Sensor System department at ThyssenKrupp Marine Systems AB, Johan has been trying to create traceability between requirements and verification. He worked closely with the NOLI Singapore project. The methods and approaches used in that project is a base for his ideas. Johan is now working on HTM Gotland and tries to implements his new ideas to create the traceability between requirements and verification.

Has the verification process developed and improved during your employment?

During the Singapore project, During the Singapore project, there were contractual costumer and sub-supplier requirements, as well as internal requirements. However, the verification was traceable only on system level and not on the level of each individual requirement. Now in HTM Gotland there are specific individually identified requirements, which makes it easier to have a clearer verification process. So now the priority is to improve the traceability.

What does Johan want to develop and how?

At ThyssenKrupp Marine Systems AB they have a specification of the requirement for each project, one for the customer and one internal, Johan wants to improve the existing requirements and create a concept for verification. He wishes to do this in the program DOORS, and he believes that this also will be applicable to A26 and future submarines.

ThyssenKrupp Marine Systems AB has for the moment a submarine specification that contains time, method and testing, but you can't see in detail how the requirement shall be tested. Johan wants to solve this by making an extra module in DOORS with the name Verification, where the verification should have a link to the requirement. Johan also wants one module with the name Deviations for the residue test that also should have a link to the verification module.

DOORS is a database in the red environment which has limited access for different employees, therefore for this solution to work a position as requirement administrator has to be created. The requirement administrator should have the responsibility and be in charge of making the connection between the different modules. This solution would lead to a common structure for a project.

Can you standardize the work process?
Since ThyssenKrupp Marine Systems AB is not a mass producing company and its projects are different from each other, he feels that it can be hard to do a standardization of how the projects is handled, since the projects are so different from each other. However Johan does think it is important that the same methods are used throughout the same project.

VERI is a database that ThyssenKrupp Marine Systems AB uses for deviation today; this database is not linked together with DOORS since VERI is in the yellow environment.

8.1.2 Interview with Kristian Hultgren 5/3-14

Who is Kristian Hulgren, and what role does he have at ThyssenKrupp Marine Systems AB?
Kristian Hultgren works as a production leader in Karlskrona.

How does the work process look like?
When they get a job, in the form of a work card, they get a KV-document that is the same as an installation regulation from the technician department.

When the installation is made according to the regulation, they have to ask someone else to also verify that it is correct done. Finally Kristian checks the work that has been done, and document it and report to the control department. They also verify that everything is made according to the regulations, in order to go further in the testing.

How do you plan your work?
In addition to the work cards that they get for the different jobs, there is also a program called Mars Planning. Mars Planning is a planning program where the planner planes the projects time plan. In this program you can get your work card, if there is a residue, that becomes a new work card and the project does not get closed before every residue is finished.

How do you handle the residues?
The residues can be handled in different ways; VERI has no connection to Mars Planning. Barium is a program for all kinds of deviations and not only residues but it is linked to Mars Planning, which can give traceability in the project. According to Kristian not everyone likes Barium since if a deviation is noted and the project has to be revised a cost is created.

8.1.3 Interview with employee at Kockums 6/3-14

Who is this person?
This person works with Quality Management & process development

How does the work process look like?
In his work the first thing he does is to look at what requirements there are and how to break them down in sub requirements. His opinion is that ThyssenKrupp Marine Systems AB is good at fulfilling the customer requirement, but not as good to handle other requirements in the business, such as restrictions in the construction, working environment and law requirements as requirements, they are fulfilled but not in the most efficient way. This requirement is expected just to be dealt with.

His thoughts about not everyone using Mars Planning
All planning should be handled in Mars Planning, He thinks that the reason why we haven't heard about it in Malmö yet, is because the work there is on a higher level and they don not have to work through Mars Planning, to get work cards for what they should do.

The reason why we have not heard about Barium until we got to Karlskrona, is because Barium is used during the construction whilst VERI is used during the commissioning with the customer, since the customer has access to VERI.

8.1.4 Interview with Ola Borgquist 28/2-14

Who is Ola Borgquist?
Ola work with signatures in NOLI

How does the work process look like?
In the beginning of a project a techno-economic study is made, and a thorough dialog with the customer takes place. This is an important step otherwise the project can become too expensive without a plan from the beginning.

What they do is to divide the requirements into sub requirements, which in turn creates the conditions to how the submarine will be made and what the different department will do. The reason why the requirements is divided into sub requirements, is that there is so many requirements which are secret, and ThyssenKrupp Marine Systems AB works with a need to know basis, so when the requirement is divided it is easier to divide them in to secret and non-secret requirements.

Then the products that have been bought from another company have to be tested. Either you test them at ThyssenKrupp Marine Systems AB, or you can by a test from another company, or the company from whom you bought the product. When all this is done the building of the submarine can begin.

Do they use DOORS?
In this department they do not use DOORS, they can see the positive with the program, but do not all have the skills within the program to get the most out of using it, and therefore they use word instead.

Ola reason about why not to develop DOORS even more is that it would decrease the communication, which already is a problem. But if a program like that should be developed it is important that it is created with the user in mind and not the creator, as the program is developed today. Ola also thinks that everyone that needs information from the red environment for his or her work should have access to red environment.

How do they respond to Johans proposal of an administrator to the requirements?
The question whether or not there should be an administrator to DOORS he reasoned: Since you cannot change requirements on a signed contract without communicating it with FMV, there already is an administrator against the customer requirements, but not the internal. The engineer must have the authority to change the internal requirements, so to have an administrator to the internal requirements would just take unnecessary administration time. Instead he thinks that they should focus on improving what they have, and not change something that works.

How does the writing of the reports work, is it in need for a standardization?
When the reports are to be written they cannot look however the writer pleases, even though many departments have various layouts. When a report is almost done there are many different people that shall approve it, after that a presentation is held for the customer before the report is completely done.

8.1.5 Interview with Peter Eriksson 5/3-14

Who is Peter Eriksson?
Peter Eriksson work as a production leader within testing in Karlskrona

How does the work procedure look like?
Peter gets a test procedure that has been approved by the customer, from a system engineer. After that, he does a STW with different tests and verifications, if it is all ok, he tells the system engineer to proceed.

What is Peters opinion on the different programs?
KabDoc - Has a really bad search engine, unless you can all the different id's.

WeldEye - When Peter worked with NOLI he was forced to work in this program; it had a better traceability with functions such as checking. Unfortunately it was difficult to enter all the information.

How does Peter decide how to test and which program to use?
It is the contract that controls completely the practices and programs to use in testing. Even though it was good to use WeldEye during NOLI due to the traceability, it took longer time and more costs, since it had to be extra inspectors during the tests.

Peter also points out the different between the smaller and larger projects, the smaller projects have a good routine it is the larger projects that have more problems. In the smaller project you get your work card and check Barium(what have been done, how many work hours are taken). You can also attach documents in Barium with smaller maintenance. Then it is also a difference between Swedish projects and foreign project, we have generally more trust against each other in Swedish projects.

Have they tried to develop new work methods?
They have tried to work with the document electronically, the positive was that they did not have to deal with all the papers, and the version was always updated to the latest one. But unfortunately it was not a success, since the employees thought it was difficult to find all the documents, and sometimes the employees wanted their old documents with their doodles on. And the document is still at the department server, but the problem there is that they can't take them on the boat for safety reasons.

8.1.6 Interview with Tommy Ekhdal 5/3-14

Who is Tommy Ekhdal?
Tommy Ekhdal works as head of the electric department in Karlskrona

Which programs does he use?
Tommy uses the program DashBoard to get an overlook of the statistics of his department; the statistics are extracted from Mars Planning and KabAnalys.

How does he feel that not everyone uses Mars Planning?
He thinks that it is important that everyone follows the new directions of the use of Mars Planning, since excel isn't a good program, due to the lack of transparency.

What is KabAnalys?
KabAnalys is a program that produces reports with data from Mars Planning, so what you get is measurement data.

8.2 Benchmarking Interviews

Interviews with employees at the benchmarking companies

8.2.1 Interview with Anders Grynge, Sony 10/4-14

Who is Anders Grynge and what is his role at Sony Mobil?
Anders is ultimately responsible that all of the requirements are met at Sony mobile. He is responsible both in Sweden and the big part of the company in Japan and all the five locations were Sony Mobile has offices.

How does their verification and test procedure look like?
He points out that there are many different tests for the different requirements, customer, regular requirements, SAR requirements and that the different clients' requirements. There are over 18500 requirements that must be verified in 25 different areas.
They have different places that they are saving requirements and they sometimes have trouble finding the requirements and if they are satisfied. None of the important requirements have been forgotten, but smaller requirements have been.

Does Sony Mobile work to improve the procedures?
They are continuously working on improving traceability and in a current improvement project; they have made a page that is linked to all the different places that the requirements are described and where they are met. This is important for Anders because now anyone looking for a requirement knows where to look.

When asked why they do not have them all at the same place or program Anders says “that they think it is too heavy routed if everything should be in a system and that they do not have the resources to do the switch right now”. However they are open to it in the future and are continuously working on the improvement. One difficulty is that their industry is changing so rapidly and that the time to market is so short for their products. Their requirements are updated four times a year and it requires resources. Anders feels it is really important to have a common way of working and describing test methods and their results even though they are submitted to various places.

What developing method does Sony Mobile work with?
They follow different development methods, but use primarily the Agile method and scrum. They always have to be open to change and be flexible, so they can improve and change depending on the technology development, new customer requirements and preferences.

They avoid the Waterfall model and Anders means that using the Waterfall method would reduce their competitiveness since their industry is changing so

8.2.2 Interview with Anna Schömer, Sony 10/4-14

Who is Anna Schrömer and what is her role at Sony Mobile?
Anna is responsible for the usability requirements at Sony mobile. She works with different ways of testing, and claims that it is hard to judge user satisfaction and describing the levels of customer satisfaction, since people reacts differently to different situations and products.

How does their verification and test procedure look like?
She agrees with Anders Grynge, that Sony mobile works at a fast pace and that they have to be open to change. A great difficulty for their department is that the time to market is so short for the mobiles, and therefore the demand on feedback of the usability has to be fast and solid. The different departments come to them and want them to test both almost finished applications and some in the early developing phase.

When working with testing and verification, what is most important to your department?
Anna feels it is really important to have a common way of working and describing test methods. They can work quite freely in describing and documenting requirements, even though they in many cases have predetermined document, which has advantages and disadvantages.

What developing method does Sony Mobile work with?
They follow different development methods, but use primarily the Agile method. Anna also stretches that Sony Mobile always have to be open to change and be flexible. So Sony Mobile can improve and change their products if the customer preferences changes or if new technology is developed either in house or in the industry. She also feels that the Waterfall model does not fit the mobile industry at all.

8.2.3 Interview with Employee, Axis 26/3-14

In this interview the reader has to take in consideration that interviewed can only answer the questions from her point of view.

How does the work process look like?

New products start with a requirement specification, how this look like is different for different projects but often in excel or HTML. The requirement specification consists of functional, quality and customer requirements. The project leader is the one who writes the requirement specification, but everyone review it. The test is based on the requirement specification; they often reuse old test case, sometimes some new test cases are added. They do not have traceability between requirements and verification, but the test cases is based on the information in the PRS and the test leader have the responsibility to make sure that all the requirements are tested.

How does you look upon a requirement database?

A requirement database is desirable but it will take a lot of administration therefore it can be good to use the test cases as a traceability to the requirements as long as the results is documented and stored well, so you can reuse them.

How does Axis try to get some traceability?

Today they have different numbering on the same requirement in different projects. But instead of the numbering here you could use test cases instead, it would take, as mentioned above, better documentation.

Do you test everything?

No, the test leaders together with the rest of the project have a risk mindset; they will test one selected part of a product and risk that the other will work, this is dependent on which project. They also have different priorities on the tests (High, Medium, Low) and if they do a risk they sometimes only test the high priority tests, but this is different from case to case.

Do Axis work after a development model?

A lot of the development is following the V-model, but the test and verification can be problematic so in some cases they follow agile methods.

How does you feel about a new employment for a requirement administrator?

It would be a good idea to get a common gathering point and a view over all the work and requirement at Axis. Though it is hard to get away from that some parts has to be handled by the project group. The employee thinks that you should be careful to introduce new documentation; specific when it is the requirement database the pros and cons must be considered. But if you should introduce a database for the requirements the employee think that a new employee had to take the position as administrator.

Does everyone have the same work process?
No, they work with different methods. Since they do have history of test, but many with only pass or failed as a result. This can lead to double measurements that take unnecessary time that could have been prevented if the history was more informative, the test department is doing a lot of improvement in gathering results and hopefully they do not have to make double measurement in the future. A positive is that the information is very open almost everyone has access to everything.

What is the strength in testing in Axis?
The strength is in that they have good tools to execute the test cases and that it exist some traceability due to the test specification, and a good bug system. They have a good combination of relying on knowledge and experience. Though they could always get a better traceability between requirement and verification.

8.2.4 Interview with Sabine Alexandersson Gambro 6/5-14

Who is Sabine Alexandersson?
Sabine has worked at Gambro since January 2014; she works in the department test and verification in the NextGen project. Before she started to work at Gambro she worked at ThyssenKrupp Marine System AB.

How do they work with requirements?
At Gambro there are a lot of regulatory requirements, since the customer is not decided in advanced the product has to be able to fit most markets. Since some customers has requirements that is too different from other (this can depend on different countries and laws), there might be products that are not designed to meet these markets requirements in order to get a product out on the market at a reasonable price.

Were do they keep all the information?
They keep all their requirements in DOORS in different levels such as system requirements and component requirements.

How do they work in the different projects?
The different projects are divided and have no contact with each other. It is not like in ThyssenKrupp Marine System AB where for an example the engineer that works with sonar, works with sonar on all the different boats. In the case of ThyssenKrupp Marine System AB the engineer can take his knowledge from a submarine to another. This can be used in a time saving manner at ThyssenKrupp Marine System AB since the project is long and you can work parallel with the projects. This has historically not been the way they work at Gambro even though many engineers work at Gambro for many years and therefore experiences different projects – but only one project at a time.

How does the traceability and information handling works at Gambro?
First of all they have a good education for the employees in the different programs that they use. Then in the production every machine has a serial number so there is quite easy to follow. In the overall project there is high demands on a perfect traceability since the machines are created for saving peoples life. The documentation handling is also very strict; all information has to be documented in DOORS and Enterprise Architect.

At Gambro every employee have reading rights in their project, and sometimes in other projects if they have to. Overall the information is on a relatively need to know basis.

What do Sabine thinks is better at Gambro than ThyssenKrupp Marine Systems AB?
At Gambro there is more pressure from the outside and the employees takes it more seriously, since there is important life savings machines. It is also important to have in mind that you cannot trust that the final customer will know how to use the product well. At ThyssenKrupp Marine System AB to the employees know that the customer is trained in the area of submarines.

8.2.5 Interview with Mikael Kruszewski, Gambro 7/5-14

Who is Mikael Kruszewski, and what role does he have at Gambro?
Michael is responsible for that all of the requirements are met for his team at Gambro. He is working on projects that are improving and maintain the already designed dialysis machines. His title is Verification Team Lead at Gambro.

How does the verifying and validation process look like?
They use a verification model that they have specially designed at Gambro. They have different requirements in different categories, all of these requirements then have different numbers of features that has to be tested. The requirements all have test cases with test runs. These requirements are both tested when designed but also when put together with other requirements. To clarify, the requirements are tested in both when developed and in the test cases. Therefor they get doubled checked internally. Before getting approved they are also tested formally.

Is there any specific difference between the internal and the external verifying process?
In the internal there is a regulation saying that inspectors from another company must approve there verifying process, if there is something missing or the process lacks in traceability, the inspector can shut down the project until the situation is fixed.

What programs are you using?
At Gambro they use DOORS and HP- ALM/HP-QC. These programs are linked and information can automatically transfer between the two. However this transfer does not work perfectly yet.

How does different levels of access work at Gambro, are all employees in your team allowed to see all requirements?
In Mikael's team everybody has reading access, but it is also Mikael that can change the information surrounding the requirements in DOORS. They have different clearance for different projects, but cannot read everything. The information at the department working on the future dialysis machines is not available for him to read.

Does Gambro work to improve traceability and verification?

- Michael believes education surrounding testing is very important, so he is looking for ways and opportunities to update his team's knowledge, he believe this is a success factor.
- They are working to get the updates in regulations faster.

What are the biggest differences between testing and verifying at Gambro in comparison with the other companies that you have worked at?

- There is much more regulative requirements, since the medical industry in different countries are different. A dialysis machine in Sweden can have a whole other view on patient security than other countries in Europe and for an example USA.
- The traceability and documentation is much more detailed and thorough due to patient security.

8.2.6 Interview with Per Stenqvist, Gambro 7/5-14

Who is Per Stenqvist, and what role does he have at Gambro?
Per is a System Engineer at Gambro and has worked with requirement management before starting at Gambro. He is working on the future dialysis machine.

How does the verifying and validation process look like?
They are in the beginning of the project and are working on gathering requirements and completing the designing of the machine. At earlier projects at Gambro they have different requirements in different categories. The requirements all have test cases with test runs and after internal tests there is a formal testing and verifying.

Are you working with a specific developing model in addition to the Gambro model?
They are working with different developing models in different parts of the project. The software development are more agile but the

mechanical and platform development are more working after the Waterfall, but not as strict as the ideal Waterfall model. Overall he feels that the V-model is more representative of their process.

What programs are you using?
They use DOORS since it is the "King of traceability" and they are also using HP- ALM/HP-QC. They are using enterprise architect were they are saving rapports.

How does different levels of access work at Gambro, are all employees in your team allowed to see all requirements?
They do not have access to all of the different departments, but the reading rights to all information in the project that they are working on.

Does Gambro work to improve traceability, verification and validation?
They are working to improve the interface between DOORS and HP-ALM/HP-QC.
They are also working on improving the validation processes. They are taking in more opinions from people working with the machines and patients. There also trying to find better ways of writing soft requirements, "how to wright a god requirement". They are also using "explore testing" to find new problems. Explore testing means to test a requirement in a different way, or by testing other parameters than before.

What are the biggest differences between testing and verifying at Gambro in comparison with the other companies that you have worked at?
There are much more regulative demands in the medical industry. The machines have to be really safe since the machines are not always operated by highly educated people or in perfects conditions. The patient security is really important; it is hard to compare that risk with other risks in for an example the mobile industry.

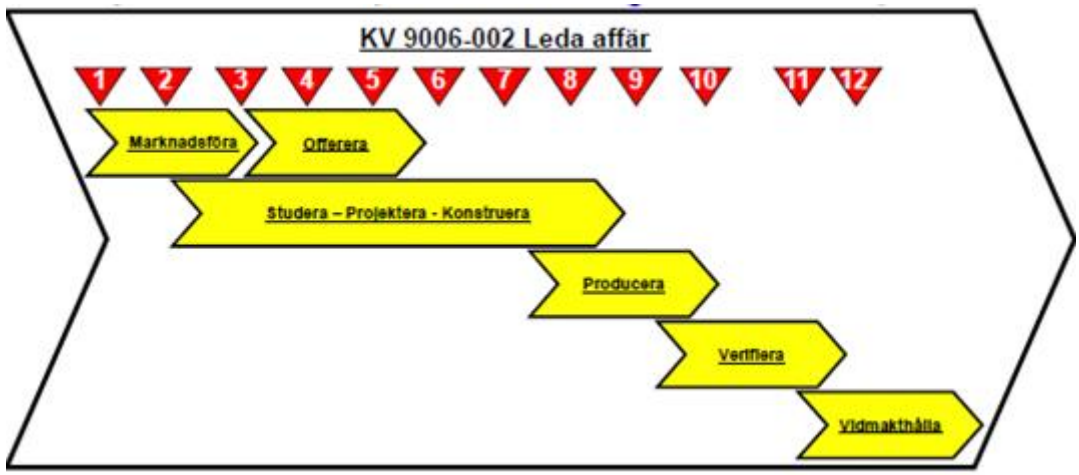
9 Appendix B

9.1 Abbreviations

CMS	Combat Management System
DD	Design Description
DOORS	Dynamic Object Oriented Requirements System
EN	European Standard
FAT	Factory Acceptance Test
FII	Final installation inspection
FM	Försvarsmakten
FMV	Försvarsmaktens materialverk
GDD	General definition Description
HAT	Harbor Acceptance Test
KAB	Kockums AB
KV	Kockums Verksamheter
ICO	Installation Check Out
IEC	International Electrotechnical Commission
IMO	International Maritime Organisation
OBIT	On board Integration Tests
RMS	Regler för militär sjöfart
RTS	Reference Test Site
SAT	Sea Acceptance Test
SBIT	Shore Based Integration Tests
SCMS	Ships Control and Monitoring System
SFT	Sea Functional Trials
SMS	Selected Major System
SOLAS	International Convention for the safety of Life at Sea
SRP	Safety Requirements Proposed
SRS	System Requirements Specification
SSS	Submarine System Specification
STW	Set to Work
SUBSPEC	Submarine Specification
TPS	Technical Procurement Specification
UKR	Ubåtssäkerhet

9.2 Extended activity chart

ThyssenKrupp Marine Systems AB's activity chart show different functions which together forms the whole function of the company.



There are six steps and in this process:

- Market
- Tender
- Study-Define-Design
- Produce
- Verify
- Through life support

Market
The Market process shall ensure that the products and services of Kockums are effectively marketed in order to generate profitable and good prospects caring for the KAB trade mark.

Tender
The Tender process shall strengthen the KAB ability to submit attractive tenders to customers and to increase sales. The process also clarifies how orders and contracts shall be handled, to improve the *handover* to the future project.

Study – Define - Design
The process shall ensure that the product development process is logically connected, from initial design ideas to a complete design that can be manufactured.

The three sub-processes Study, Define and Design may appear separate in time, and under different types of contracts, and therefore it is necessary to logically couple them. The Design sub-process is divided into phases following the Toll Gates of the Project Process.

Produce
This process ensures that all needed preparations are taken before start, to obtain an effective production and to secure the manufacturing/mounting during production. It shall also perform control according to manufacturing specifications in order to fulfill the work order requirements.

Verify
The process describes the part about verification from ICO until completion of final control and "Ready for delivery". Roles and responsibilities is described for ICO, STW, HAT, SAT and for completion of final control. The process also describes the requirement management in detail. In this master thesis this part will be evaluated and a verification tool will be developed and motivated.

Through Life Support
The process describes the services for products in the operational phase. It clarifies the steps in the maintenance projects from maintenance planning until delivery. The process also describes Mission support for military units with the different levels of support which can be provide by ThyssenKrupp Marine Systems AB . Spare parts supply is an important part in the operational phase and this is part of the process description. The process also covers the handling of material phase out, training and documentation.

Verification methods
The verification process provides management tools to coordinate individuals and activities involved in a mission. Verification activities are implemented for the hardware, software, and the integrated system tests. The verification methods shall include the following either separately or in arrangement of a couple:
a. Analysis
b. Test
c. Inspection
d. Demonstration
e. Similarity

Often requirements are verified using a combination of methods for an example analysis and test or analysis and inspection. The verification activities may be, preparation of detailed analysis plans, hardware or software qualification plans and procedures and integrated test plans and procedures [8]

Analysis -Verifies conformance to required performance by the use of analysis based on verified analytical tools, modelling or simulations that predict the performance of the design with calculated data or testing. Analysis must present a verification of unit, subsystem and system performance over expected life and operating environments.

Test-Verifies conformance to required performance, physical characteristics, design and construction features by techniques using test equipment and test devices. Tests are intended to be a detailed quantification of performance. Testing includes a clear measure of performance during exposure to an appropriate environment, or it may be a measurement combined with an analysis or a demonstration.

Inspection - Visually verifies form, fit and configuration of the tested item. Often involves verifying those requirements where physical characteristics (e.g. construction features, finish, identification marking and cleanliness) and is usually performed during manufacturing, qualification, acceptance, integration and prelaunch phases.

Demonstration - Verifies the required operability exists without the aid of test devices. If test devices should be required they should not contribute to the results of the demonstration.

Similarity - Verifies requirement satisfaction based on certified usage of similar components under identical or harsher operating conditions. Verification by similarity is used usually in combination with analysis to show that an article is similar to another article that has already been qualified to equivalent or more stringent criteria. This verification method consists of assessment and review of configuration, application and prior test data including a comparison of prior test levels with new specific requirements. Differences in configuration, application or test conditions usually require analyses and additional testing to complete verification by the method of similarity.

9.3 ISO

ISO/IEC 15288- Systems and software engineering — System life cycle processes

There are also several informative annexes contained in the International Standard and they are:

- Annex B provides information about use of the system life cycle processes as a process reference model to support process assessment.
- Annex C provides a description of the process constructs used in this standard.
- Annex D provides an example of a process view for Specialty Engineering, intended to illustrate how a project might assemble processes, activities and tasks of ISO/IEC 15288 to provide focused attention to the achievement of product characteristics that have been selected as being of special interest.
- Annex E describes the alignment of the processes of ISO/IEC 15288 and ISO/IEC 12207.
- Annex F describes relationships to other IEEE standards.

10 Appendix C

10.1 Login

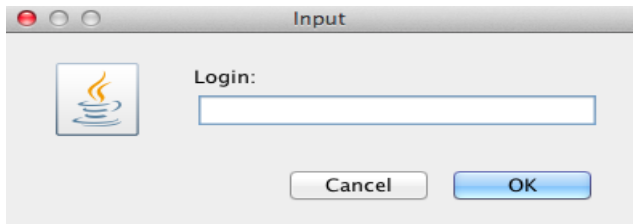


Figure C-1 Insert login

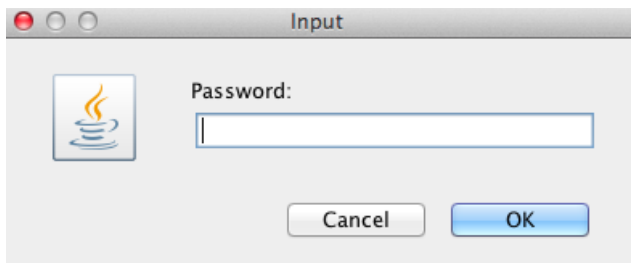


Figure C-2 Insert password

10.2 Different choices

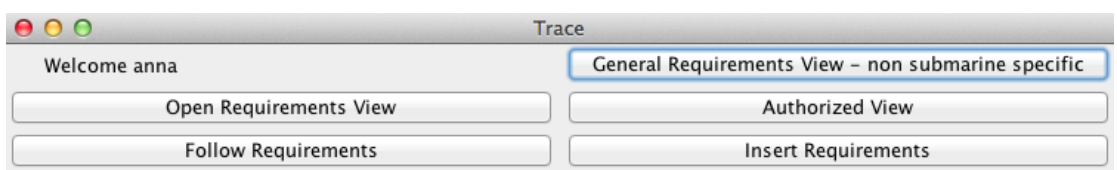


Figure C-3 Choose option

As showed in figure C-3 Trace starts with some options. Open requirement view will only present the requirements that are not confidential and therefor a list made in this view can be shown to all of the employees. The Authorized view will show all the requirements that the one in logged are allowed to see, a list her cannot be showed to all. The General requirement view-non submarine specific will create list of the requirements that are not submarine specific, these could be personal safety requirement or work environmental requirements

10.3 Insert Requirement

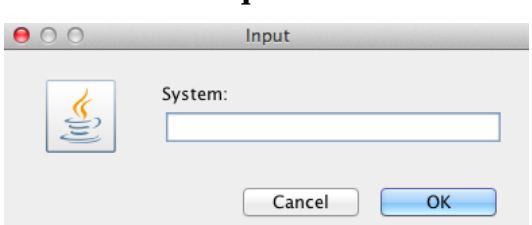


Figure C-4 Insert the system for the requirement

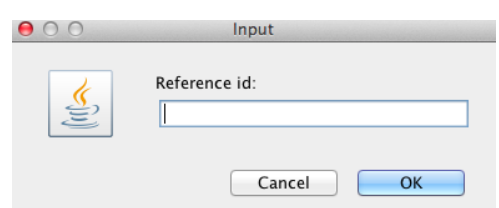


Figure C-5 Insert the reference id for the requirement

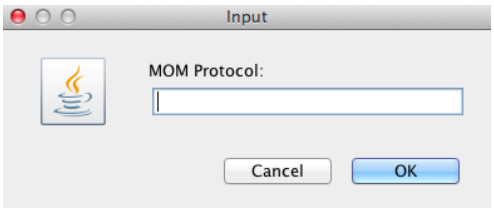


Figure C-6 Insert the MOM protocol for the requirement

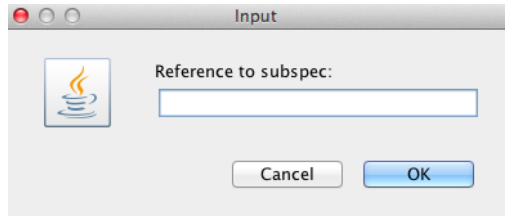


Figure C-7 Insert the reference to the submarine specification for the requirement

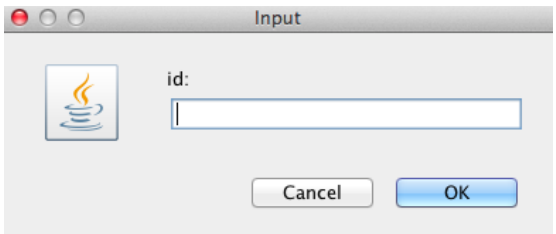


Figure C-8 Insert the id for the requirement

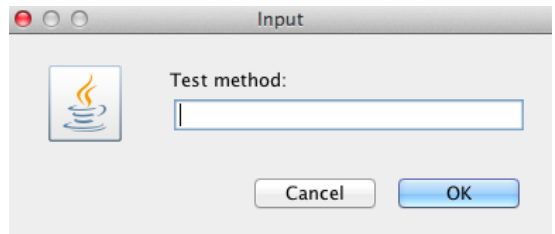


Figure C-9 Insert the test method for the requirement

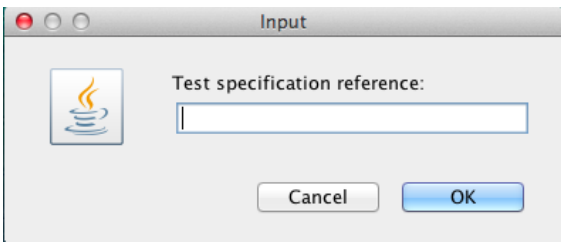


Figure C-10 Insert the test specification reference for the requirement

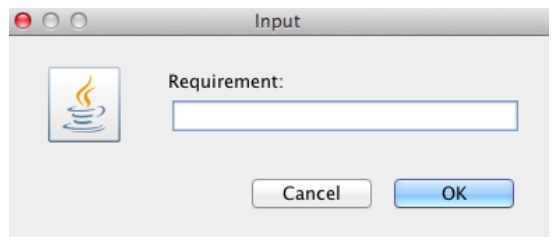


Figure C-11 Insert the name of the requirement

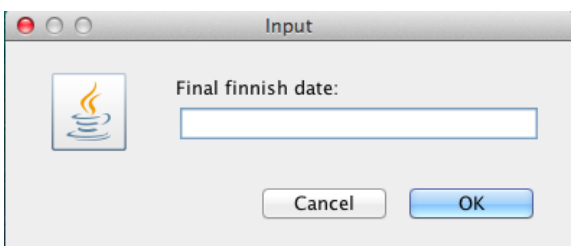


Figure C-12 Insert the final finish date for the requirement

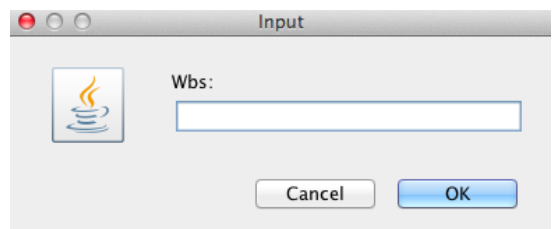


Figure C-13 Insert the wbs for the requirement

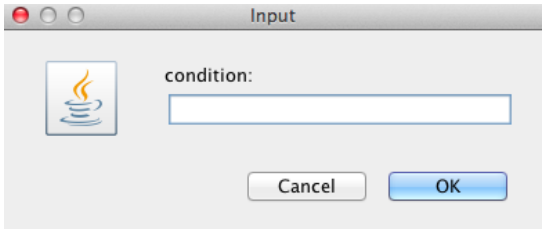


Figure C-13 Insert the condition for the requirement

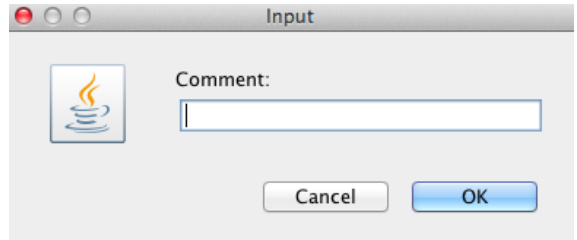


Figure C-14 Insert a comment for the requirement

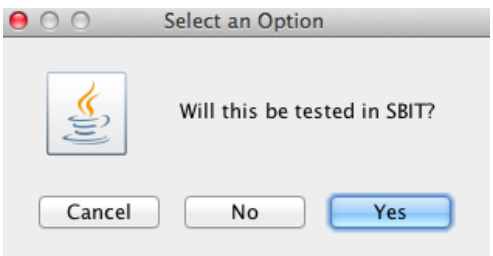


Figure C-15 Answer if it will be tested in the SBIT

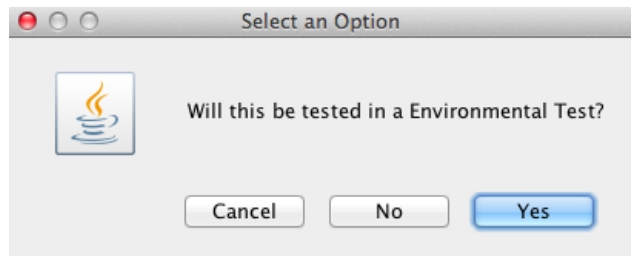


Figure C-16 Answer if it will be tested in an environmental test

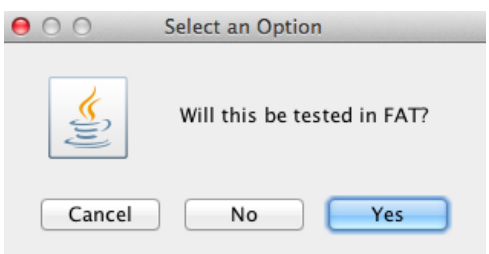


Figure C-17 Answer if it will be tested in a FAT

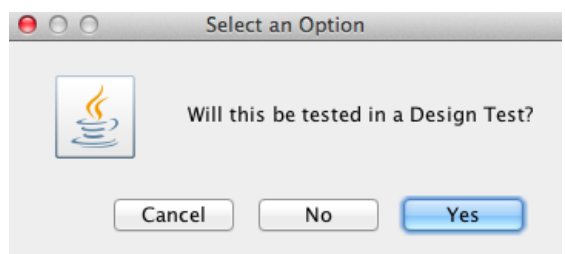


Figure C-18 Answer if it will be tested in a design test

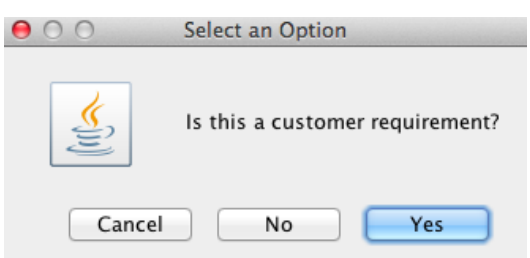


Figure C-19 Answer if it is a customer requirement

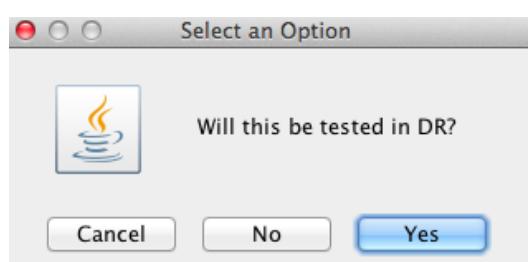


Figure C-20 Answer if it will be tested in a DR

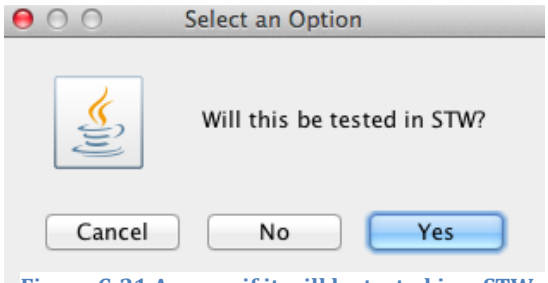


Figure C-21 Answer if it will be tested in a STW

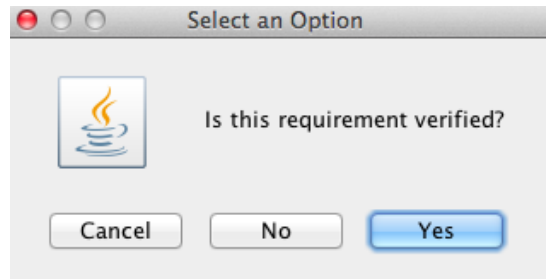


Figure C-22 Answer if it is verified

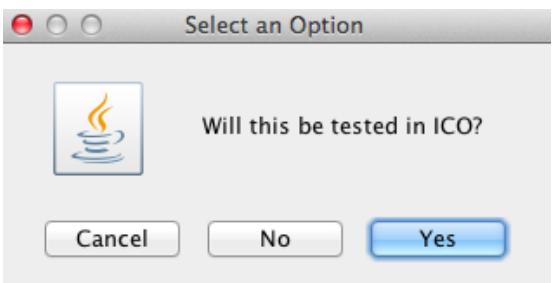


Figure C-23 Answer if it will be tested in a ICO

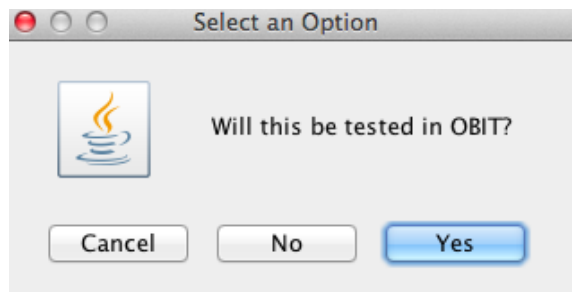


Figure C-24 Answer if it will be tested in the OBIT

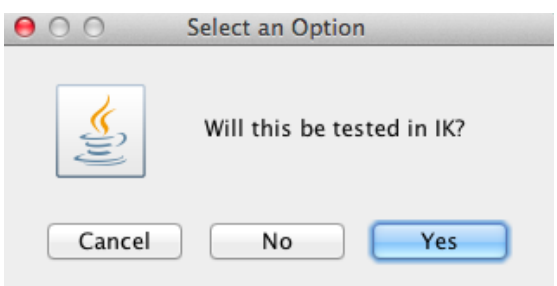


Figure C-25 Answer if it will be tested in a IK

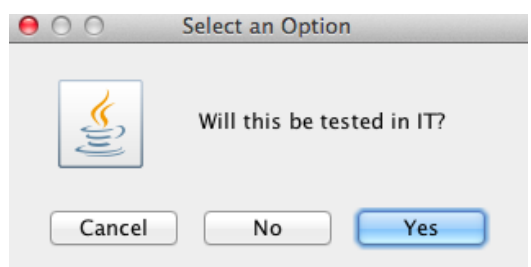


Figure C-26 Answer if it will be tested in a IT

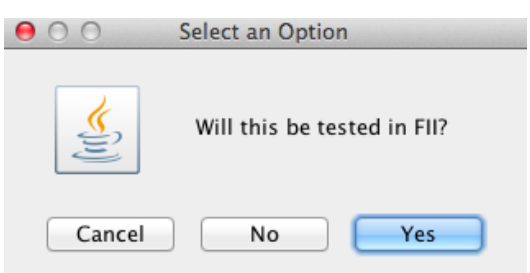


Figure C-27 Answer if it will be tested in a FII

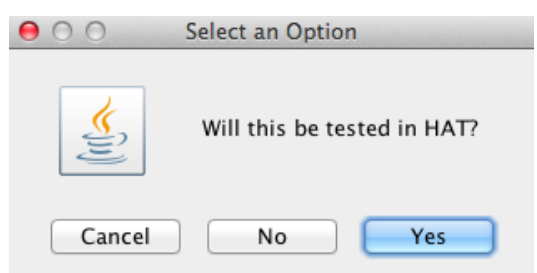


Figure C-28 Answer if it will be tested in a HAT

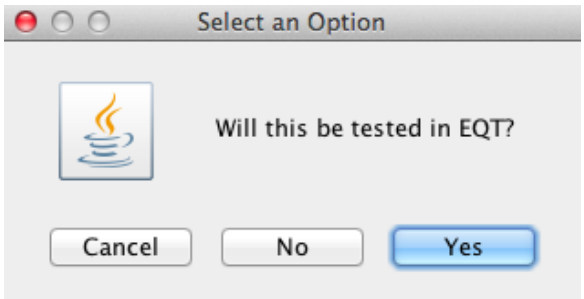


Figure C-29 Answer if it will be tested in a EQT

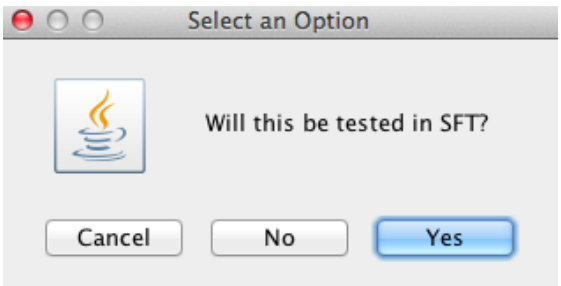


Figure C-30 Answer if it will be tested in a SFT

10.4 Searchable options

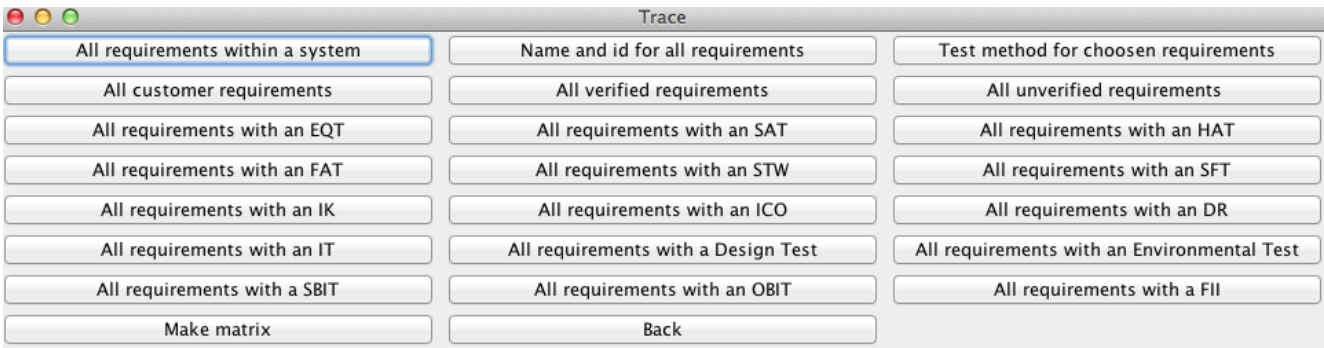


Figure C-31 Searchable options