Implementation of A3 architectural overviews in Lean Product Development Teams; A case study in the Subsea Industry

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Abstract. This paper presents a case study investigating the use of A3 Architectural Overviews (A3AOs) in lean product development teams. A3AOs is a tool used in product development and lean manufacturing to increase communication and knowledge sharing across the organization. We studied the implementation in an engineering department of a global oil and gas supplier, by performing a case study and extensive depth interviews. We also studied earlier implementation initiatives of A3s in a thorough literature review. A finding was that, although current and former research have shown clear benefits of utilizing this tool, the company rarely uses it today. We wanted to investigate challenges with creating and implementing A3AO in the organization. Our results show that A3AOs may be a well-suited tool to improve the requirements handover process within the company. We also make an outline of challenges and benefits with using and implementing A3AOs in the researched engineering department, with the goal to successfully implement A3AOs in the future.

Introduction

Domain. Most companies in the Oil and Gas industry are in constant change to stay competitive in the market. Firms are reorganizing and restructuring to become more standardized and implement lean thinking into the project execution. The reduced oil price over the last years puts a high pressure on the companies. The Company is a leading global supplier of Subsea Production Systems(SPS)to the oil and gas industry. SPSs are unmanned oil and gas productions systems installed on the sea bottom (Figure 1).
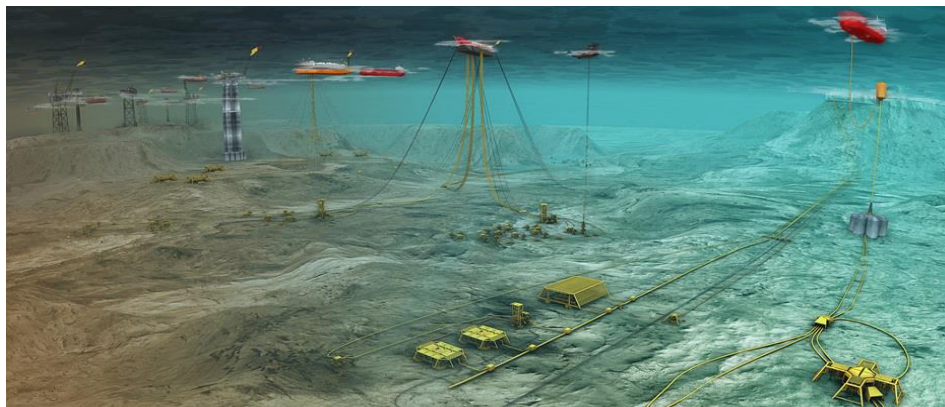

Figure 1: Illustration of Subsea Production System

The Company delivers complex SPS's to customers worldwide. The downturn in the oil industry squeeze projects on lead time and cost. Projects are complex and divided into sub-systems, causing several project teams working in parallel. This is creating critical interfaces that need extra attention and follow-up actions. The importance of focusing on systems engineering (SE) in execution is essential in big complex projects; to mitigate risk, cost overruns and schedule overruns (Haskins, C., ed. 2007). Lean is perhaps the most important concept that has been introduced to increase efficiency in manufacturing in modern times (Welo and Ringen, 2016). Further they state; "Many companies have therefore established strategies for moving the lean concept beyond the factory floor and into Product Development".

Case. In this paper, we will present observations made in a case study at the Company. An initial survey conducted in a product department highlighted the need for improved handover of requirements. We asked designers and product developers about their level of satisfaction with the handover of the design specification. The study showed that designers and product developers lack the understanding of the product in a system context. Information about important interfacing systems and operational requirements were missing. The product design specification defines the requirements for a product, and creates the handover to the development team.

We wanted to meet the recognized handover concerns found in the initial study, and implement A3 architectural overviews (A3AO) in the department. In our case study, we wanted to investigate barriers and thresholds in creating and using A3AOs. We tested the creation process and let the engineers in the organization work with A3AOs.

The proposed solution. In our research, we implemented A3AOs as a supplement to the product design specification in the department. The A3AOs should force easier knowledge sharing by being a supplement on the table in technical discussions and engineering meetings. See the appendix at the last page in this article, of an A3AO created by the author. The end users of the product specification are the designers. The initial study showed that they lacked critical input and that they were not satisfied with the handover process today. The A3AOs should supplement the product specification by giving an overview of the product in a system and project context. The A3AO is a strong visual tool, and it is great for communication of high-level requirements. It should also help the project engineers to gather system knowledge in a structured way, by creating the A3AO. Creating A3 reports help the author to reflect about the problem intended, and the author will gather and investigate what data to reflect in the A3. (John Shook 2008) "Managing to Learn" presents the A3 vision from Toyota, where it was first invented. The focus is just as much on the creation process and that the knowledge gathering happens in the creation process, as the value, A3s give as a communication tool. A3-documenation contributes positively to creating a shared understanding by improving the perceived learning and visualization capabilities (Ulonska and Welo 2014)

Research question. In our study, we have observed the design process and creation of A3AO in the Company. We wanted to research the handover process of requirements to the product developers, and investigate barriers and thresholds in creating A3AO as the proposed solution. The main research questions are:

Is there a need for better handover of requirements to key developers in a product department in the Company? Can we use A3AOs to improve communication of requirements in the Company. What are the main benefits and challenges with using and implementing A3AOs?

Paper Outline. This paper introduces domain, case, proposed solution, and research question in the introduction. In Section "Design Process in the Company", we explain the design process in the company. Next, in "Research Methodology", we outline the research methods and the initial study in the research project. Then we present the proposed solution with a literature review of the A3AOs and earlier research of this in Section "A3AO". In the Section, "Results", we present the results from our research study and data from extensive depth interviews with key personnel. At the end follows discussion and conclusion.

Design Process in the Company

Handover challenges. The Company has over the last years implemented a new way of working, introducing Lean Product Development Teams (PDT). One product department drove the first pilot project. Figure 2 shows the new execution model for the Lean PDT. The new structure differs from the old by pulling the product team out of the projects, and putting them in a department. This made the project customers of the product team. The product department became a supplier of components to the different work packages in different projects. The thought behind this was that the product department should deliver standardized components to the projects. The new structure was implemented to drive the Company towards a more standard product based execution, rather than project based and customized every time.
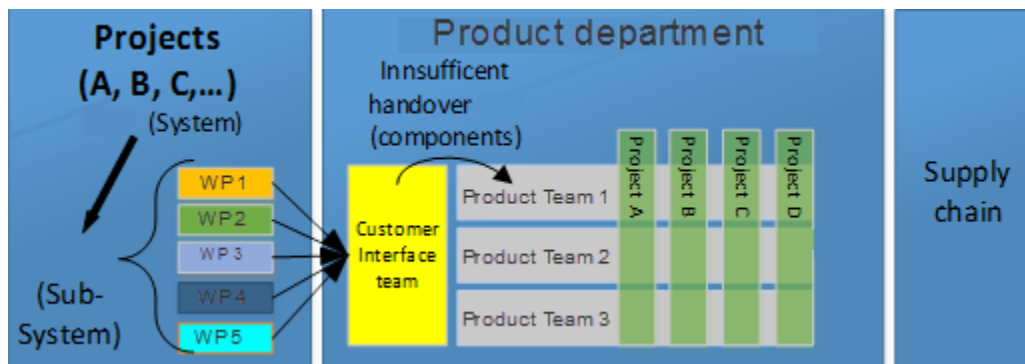
Figure 2: The product department in a project context (Process map)
*Work package (WP).

The Business Process Management System (BPMS) is in the Company described as the single process management tool, and its intention is to map, store and link business processes. This tool is describing the Vee model, "Validation & Verification model" (Sols 2014). The Vee model is well used in large complex projects, where requirements and interfaces will change moderately through the development lifecycle. The model emphasizes requirements-driven design, testing and integration (Sols 2014).

The new execution model has clear connections to the waterfall model, which differs from the Vee model. (Sols 2014) describes; "The waterfall model is a sequential design process in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of Requirements, Design, Implementation (or Construction), Integration and Test, Deployment and Commissioning, and Use and Maintenance". In the Company there are four phases in the engineering execution, and this again creates four handovers of requirements down the chain. The sequences of stages and the "clean start philosophy" require that there are no frequent changes in requirements. Each phase must be completed fully before going further (Sols 2014). The waterfall model differs from the Vee model, where you will have no ability to validate and verify successful integration before the release of design in the end. Large projects in the Company often struggles with freezing the output on scheduled time. There can be a change, either in the requirements or between the interfacing systems. Both of which can be critical, because system integration is essential to end-product quality; "It is crucial to begin the system integration early enough in the project life cycle to ensure good quality" (Muller 2014). The waterfall model is best suited in projects in which the requirements are well known and frozen from the stakeholders, (Sols 2014).

The new execution model met challenges in form of communicating the needed system characteristics to the product designers. The intention was to deliver standardized products from a product portfolio. But, completely standardized products are rather infrequent in the subsea industry today, and therefore, lean product execution is difficult with the new execution model.

The product specification. The product specification is a document that handovers the customer requirements, through the 4 engineering phases and levels, down to the product designers. This means; communication of the perceived project knowledge to the key developers. Typically, in the projects there are experienced engineers, with high technical knowledge and good insight about project characteristics. These engineers are placed at the top in the projects and maintains the systems level of the SPSs. They are responsible of the customer requirements and releases the product specification to the next level. The new structure implies complete handover of validated requirements and gathered knowledge in the product specification, "The Waterfall model" (Sols 2014). This means that it is crucial that the handover is within flawless quality, and able to transfer as much of the gathered knowledge at the top level down to the "lowest level". Knowledge transfer relies on the product specification and additional engineering meetings (meetings, discussions, and emails). Insufficient product specifications cause the need for additional engineering meetings. Engineering meetings are often valuable, but transferred knowledge in these meeting is difficult to store and manage. The product specification is also text heavy and is in A4 format.

Lean Principles. The Company is a project oriented company, but strategic industry goals direct them into becoming more product oriented and to support standardized product portfolios. Lean thinking plays a significant role in this improvement.

(Welo and Ringen 2015) have created a framework for the use of Lean in Product Development (PD). "The application of lean concept in New PD (NPD) is far from straightforward since the work product in NPD is information, rather than a physical product to which value (and waste) can be assigned." Further, they explained the Lean Framework to consist of six components; customer value, knowledge transfer, continuous improvement, standardization and stabilization and culture. The handover process of the product specification goes directly under the "knowledge transfer" component of the six lean components (Welo and Ringen 2015). (Saad et al. 2013) found in an industrial field study that the A3 thinking approach is sufficient for knowledge capture and knowledge transfer. They used A3 thinking approach of problem solving to support the Lean Product and Process Development in a knowledge-based environment.

Research Methodology

We used the research method industry-as-laboratory in this case study (Heemels and Muller 2007). The means for measuring in the case study was surveys, open interviews and a log sheet used in a real case study. Early, in the research project we conducted an initial study to map the need for change in the design process. Based on the results we asked selected engineers to test a new working method in a real case study and log in a log sheet. We also used depth interviews with several engineers with different experiences and background.

(Muller 2013) described the challenges with researching systems engineering, including both "soft" human factors and hard engineering. The measurements in this study included a large degree of "soft factors". We needed to be aware of this when planning for the measurements, and when analyzing the results. There was also a limited amount of test personnel available for the case study, which are common in Systems Engineering research (Muller 2013, Martin and Davidz 2007).

Initial study. We set up a survey using interval questions and the Likert Scale. The Likert scale principle is a survey where you ask participants a series of questions and assertions and they have five different response alternatives ranging from 1 =strongly disagree to 5= strongly agree (Boone & Boone 2012). We asked the designer engineers in the department to participate in the survey. All available designers in the product department got the survey.

Real case logging. We chose the proposed solution based on the initial study, and wanted to meet the recognized communication issues mentioned in section 1. We asked 4 engineers to participate in an A3AO creation process. We wanted to log the frustration, needed effort and barriers with creating the A3AOs. We also wanted to investigate challenges with integrating such tool in the organization. The participants were engineers working in different projects in the Company and they used real cases from the projects when creating the A3s. The data collection in the case was intended to measure peoples attitude and perception of the A3 creation process and internal company processes. We chose the "case study" as the main research method to collect data for the research question. (Martin and Davidz 2007) described the use of research case studies in a systems engineering context. "The case study is useful when the research objective is to study a phenomenon of interest that is only observable in a small number of samples" (Martin and Davidz 2007).

We provided the participants with a template in the computer program Visio and a log sheet to fill out during the creation. Earlier research performed by (Østheim and Gerrit 2016) and (Frøvold and Gerrit 2011) inspired the A3 template provided to the engineers in the study. The researcher gave the participants a thorough explanation of the A3 concept and how they should use the template and software. The participants started the tasks and logged in the log sheet before, during and after the creation.

The intention of the measurements was to investigate what the needed effort to create an A3AO in a typical work task is. Observables of interest are; *time needed, tools needed, contacted personnel, sources of frustration, successful attributes, and attitude from the participants (before, during and after creation).*

We wanted to observe the attitude by the participants before, during, and after the creation exercise. One interesting theme was whether we could measure any change in attitude towards the A3 tool. The tool was new and unknown, and we expected some critical attitude.

Depth interviews. The researcher conducted several depth interviews with key personnel, to investigate further. "Interviewing is a powerful way to get information from other people", (Muller 2013). The

interviews were free and unstructured and the researcher prepared threads and bullet points of interest to lead the "free" conversation in the wanted direction. We conducted the interviews after the case study. The analysis of the case study data lead to some themes of interest. Interviewing key personnel gave the possibility to dig deeper in those areas and touch themes we were not able to in the real case logging.

Initial survey findings

The initial study (presented in Table 1) intended to map the need and satisfactions from the end consumers of the product specification. The study indicated that there was a need for better handover of the project requirements to the product designers and product engineers. The product specification which is an A4 sized document report is the only document that specify the customer requirement of a needed product, at this level.

We asked a selection of the designers and product engineers in the department to answer some questions in a survey. Sixteen engineers with various experience answered the survey. We conducted the survey to gather the attitude and level of satisfaction with the product specification in the department. The Likert scale is common to use when measuring attitude and is an essential tool in psychology and in social surveys (Boone and Boone 2012). To assess the results collected in the survey we used the Net Promoter Score (NPS) (Keiningham, et al. 2008). This analysis method collects the promotors, the neutral and the detractors of the statement. The promotors are those who totally agree with the statement. The ones that mark for agree are passive and classified as "neutral" while those who are neutral, disagree or totally disagree are the detractors. We analyzed a positive NPS score as a valid statement.

Table 1: Initial survey results

#	Initial study: Master Thesis	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		NPS
#	Description							
1	The specification is the only document to give project specific design input.		3	1	7	5		1
2	The specifications are easy to read and I feel that I understand the needed product that should be designed.		3	5	7	1		-7
3	The specs are often consistent and have all the info and data that is needed to design and develop the detailed manufacturing drawings.		11	3	2			-14
4	Additional design meetings (actual meetings, email and oral discussions) are often required between design reviews.				10	6		6
5	The new structure (Product teams and CIT) is challenging regarding knowledge sharing of project characteristics.			6	3	7		1
6	Specs are good for communicating customer requirements and key performance parameters.			2	12	2		0
7	The spec is often lacking important information of dynamic behavior and operational aspect requirements for the needed product.			4	11	1		-3
Legend	Design review (DR), Product Team (PT), Customer Interface Team (CIT).							

Results from the survey show that the consumers of the product specification are unsatisfied. The NPS for statement 2. is -7, which is a strong negative. This gives an indication of bad readability and that the design problem is difficult to understand. There is also a strong negative NPS for statement nr.3 which have a strong connection to statement 4. Additional design meetings are often required in the design process. The design engineers need to understand and verify the content of the product specification. There is a need for further clarification of the content after handover. This may be caused by inconsistency, low readability, and that the structure includes a lot of handovers. This leads to increased spending of resources and may impact the lead time of critical products. Additional meetings often include several engineers to clarify and understand the lacking design specification. Example; if there

are a need for five engineers, with different knowledge in a one hour meeting. This will extend engineering hours by five, and disrupt the lead time for other tasks.

There is a positive NPS in statement nr.5; The new structure with different product teams is challenging regarding knowledge sharing of project characteristics. We see this statement as valid. There are some concerns with the organization structure and the processes of how they work in the Company. Statement 6. has a passive NPS score, and the group is not promoting statement.

The results show that there is a need for improving the handover of requirements. This motivated the researcher to use A3AOs to supplement the product specification and study the implementation of these overviews in the department. In the main research case, we studied the implementation of A3AOs in the department. In the proceeding sections, we make an outline of A3AOs theory and earlier research.

A3 architectural overviews (A3AO)

The A3 tool, developed by Toyota, is simply a piece of paper with the standard European size 297x420 mm. (Borches 2010) described A3AOs, and the intention is to capture design and system knowledge for shared understanding and better decision making. "Managing to learn" (Shook 2008) presents that Toyota focus just as much on the process of creating the A3, as the value the A3 gives when it is finished and can be used for communicating. The tool is not just about communicating, but also learning about the chosen problem throughout the creation process of A3AOs. The A3AO is a tool designed for effective communication of architectural knowledge (Borches 2010). It is sufficient in size for communication purposes, big enough to include both visual and textual information. The paper sheet may include different application views, showing several aspects of a system, and connecting these views together. Including all information on just one sheet makes it easy for the reader to keep an overview of all the information at once, while also being able to "zoom" in on details on the sheet. While the A3-format is larger than the traditional A4-format, it is sufficiently big to handle for engineers in work tasks. The sheet will fit nice on an office desk, and it is easy to bring in to meetings and other office desks for discussions.

Earlier A3 research. Earlier research investigating the use of the A3 architectural overviews in product development, intended to improve the communication and system overview across the organization. (Singh and Muller 2013) and (Frøvold and Muller 2011) successfully used A3 for cross boundary communication and early validation.

(Polanscak and Muller 2011) presented that the A3 was a great tool in discussions, by helping the discussions to stay focused, dynamic, and inclusive. A statement in their "further research" (Polanscak and Muller 2011) was; "Findings from our research and feedback from System Engineering Study Group indicates that the Novelty of tool/method seems to be factor that may prevent people from using and adapting A3s in their work". This statement was in high interest for our research and helped us create the research questions in this study.

(Ulonska and Welo 2014) researched the A3-reports as tools for supporting organizational learning and knowledge reuse. They proved that A3-documentation contributes positively in creating a shared understanding by improving the perceived learning and visualization capabilities (Ulonska and Welo 2014).

(Wiulsrød and Muller 2011) used the A3AO approach developed by (Borches 2010). They used the approach in reversed architecting to learn about a complex system. They learned that the A3AO is more usable than traditional documents.

Systems Engineering (SE) awareness is a relatively new direction within engineering execution in Norway. Several Master's students that did systems engineering research in the Company, experimented with the A3 approach. The A3 approach has mostly been communication of models and knowledge management (KM) initiatives, to show different system models and overviews in engineering.

(Østheim and Muller 2016, Bøhn and Bechina 2015, Andersen and Bergsjö 2015 and Moen and Falk 2015) used the A3 sheets successfully to improve and increase cross boundary communication in the organization. (Østheim and Muller 2016) got positive feedback from the study group on A3AOs as a systems overview, easiness to locate information, readability, and the well presentation of knowledge. (Bøhn and Bechina 2015) studied the use of A3 hybrid framework for knowledge sharing in an engineering context. They successfully used the KM tool to support the selection of needed systems in bigger systems. (Moen and Falk 2016) used the A3 approach together with model based systems engineering to replace text heavy communication of requirements. (Andersen and Bergsjö 2015) used an interactive dynamic A3AO to increase the R&D product system knowledge. This by making the knowledge more available with the use of the A3 approach. They found in practical experiment, that it can be presumed and expected that the users of the A3AOs save up to 95 % time on finding product and project specific information.

Although several successful studies in using the A3 approach, the researcher recognized that the Company rarely use the approach. We investigated in this research study, if we could use the A3AOs to handle the communication challenges in the Lean product development teams, in the Company. We wanted to investigate the needed effort to create A3AOs and highlight benefits and challenges with creating, using, and implementing them in engineering product development.

Results and analysis

Real case logging. In this section, we present the results from the case study. We asked 4 participants to create A3AOs for real work tasks. Out of 4 engineers asked to participate, 3 answered back in the log sheet and tested the creation process.

Before A3AO creation. 2 of the participants estimated they would use above 5 hours, and one participant answered above 1,5 days, to create the A3AOs. Actual spent time by all 3 participants was between 4 - 6 hours, which was less than estimated. All the participants created the A3AOs either in parallel or before creating the product specification. We also set up a Likert scale survey in the log sheet. Then we could measure the attitude towards the task of creating the A3AO. See Table 2 for results.

Table 2: Before creation of the A3AO

#	Before the A3 Creation — Description	N/A	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		NPS
1	I am overall positive to create this A3				1	1	1		0
2	I see the value in creating the A3					2	1		1
3	I have a good understanding of the "design problem" that I want to reflect in this A3	1			1	1			-1
4	I am familiar with the project characteristics				1	2			-1
5	I have a good system overview to support me when creating this A3				1	2			-1
6	I think I will increase my knowledge about the "design problem" by creating this A3 Architectural Overview					3			0
7	I think the designer/product engineer will have great value in the A3 supplementing the specification.					1	2		2

The NPS score indicates the validity of the statement. We see that the participants are passive to the creation of the A3s, but that they are positive and see the value in creating the A3s (#1 and #2). We also recognize a negative score for the questions regarding knowledge of project characteristics and the design problem which will be presented in their A3AOs (#3 and 4#). They are passive in their belief that the creation of the A3AO will help them increase the knowledge of the design problem (#6). But there is a possitive score that they belief designers, which are the consumers, will find great value in their A3AOs (#7).

Logging frustration during creation. One interesting obsereable was to see what the participants experienced as the most frustrating part in the creation process of the A3AOs. Most of the frustration was connected to the computer tools and the time spent creating the A3AOs. Another source of frustration was the lack of available personell and data at the time when creating the A3AOs. See Table 4 for results, the participants marked a coss each time they felt frustration.

Table 3. Logged frustration during the creation.

Sources of frustration	Participant #1	Participant #2	Participant #3	Total:
Computer tools	3	2	1	6
Availability of data	2	1	1	4
Stuck			1	1
Non-available personell	2			2
Time consuming	3		3	6
Template		1		1
Lack of knowledge			1	1

We also had some open questions, where the participants were able to log possitive thoughts during the creation. *"The A3AO with informative figures and info is a suitable tool for discussion."* The participant with this statement used the A3 in an iterative process and brought it to meetings and discussions before it was completed. The A3 was the center of attention in the meeting and the sheets were pointed at and notes where taken consecutively.

After A3AO creation. After the participants had created the A3AOs, they filled out one more survey. We wanted to measure their attitude, when they knew the process. See Table 3 for the results.

Table 4: After creation of the A3AOs.

#	After A3 creation / Description	N/A	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		NPS
1	It was difficult to create and visualize what I had intended.			2	1				-3
2	It was difficult to gather the models/drawings/figures that I used in the views.	1		1	1				-2
3	I feel that my creativity is limited because of the tools that I use to create the A3. Example: trouble expressing through drawing.				3				-3
4	It was easy to create the A3AO.				1	2			-1
5	The creation of the A3AO helped me gather information and knowledge about the problem in a structured way.					2	1		1
6	I see the value in creating A3AOs.					1	2		2
7	Creating the A3AO helped me improve my system overview and knowledge about the project.					3			0
8	I think the designer will find great value in my A3AO.					1	2		2
9	I am overall positive to create A3AOs in the future.					2	1		1

None of the participants agrees that it is difficult creating and visualizing or gathering models, drawings, and figures to include in the sheet (#1 and 2#). They also feel that the creation help them gather knowledge about the problem in a structured way (#5). Results show that they are positive to create and use the approach again, and that they think the consumers will benefit in their sheets (#6, #8 and #9).

We recognized one of the participant to be the more positive and self-involving in the case study, than the two others. This participant also used the sheet further and found value in using it. The participant used the sheet in a concept discussion meeting with the customer. The participant also sent the sheet as info to the customers, as info about the product and progress. We present a depth interview conducted with this participant later in the paper.

Summary of case study results. The log sheet results showed that the engineers were overall positive to the concept of the A3AO and they found value in creating them, both for them self and for the consumers. The research indicated that some of the engineers were more resistant to the task before start, than after getting to know the process. They estimated that the task would take more time before, and used less time than estimated creating the views. The participants increased knowledge of the chosen problem and were positive to use the A3-apporach in the future. Most of the frustration in the creation process was connected to the computer tool and the time spent creating the sheets.

Depth interviews. We conducted interviews with several key personnel; internal, external, in different domains, in various positions and with different level of experience. All interviewed persons have some knowledge about the A3 approach. We chose the personnel to be interviewed based on their experience and domain, as well as their results from the case study. The researcher interviewed; earlier SE students, participant from the real case logging and we interviewed one with a key role in the management of another company in the area, which have used the A3 approach in the last decade. We also interviewed a manager in a systems engineering department in the Company. This with interest in; what is the awareness of the A3 tool by management in the company.

Earlier SE students. An interview with an earlier SE student that has worked on a project implementing the A3 approach stated: *"It is difficult to implement A3s in the organization. The A3 approach is more common knowledge by typical SE students, but managers and elder employees does not know what the*

A3 concept is. It can be difficult to amaze them with this kind of tool." He also stated that the A4 reports and typical PowerPoint presentations stands strong in the engineering environment, and that this is the preferred way of documenting.

Another interview with an earlier SE Student working in another company in the area. *"Creating A3s is for those engineers who cares about other people!"* With this statement, the earlier SE student meant that A3s are a more preferred way of communicating information, than traditional text heavy A4 reports with several pages. In a sender and receiver relationship, the sender has a responsibility of the information quality. A3s are a better way of communicating and in that way a more "kind" way of handing over information.

Case study participant. We set up a depth interview with one of the participants in the case study. This participant tested the use of A3AOs in a real engineering task. We wanted to dig deeper in concerns and thoughts around the creation process and implementation concerns.

Stated concerns: "*I don't feel that I have the time to do additional work, I like the approach, but in our organization, this may feel just like another document to complete!"* It was also mentioned that they need designer resources that can help create visual 3D models in an effective way. It can be difficult to get these resources on short notice. *"The A3AOs working file should be an "alive" file so that it can be revised actively throughout the design process. But the Visio file is not fully adaptive with the product management lifecycle management (PLM) system as it is today, we need an appropriate solution for this in the future. "*

"I liked Visio after some time. It was a good program to use, and easy to learn. But we needed to download the software and get an approval to install it. Power point is also suitable for the task, and this program is already integrated into the PLM system and the organization."

Manager interview. Findings from this interview clarify the awareness of A3-approach by the management in the Company. The interviewed manager has some knowledge of the approach and knows the basic concepts. There was no routine or trend of using the A3 approach at this level in the management. *"There was one attempt of using the A3-approach last year. We got a template with no further explanation and we were asked to fill it out and create an A3 of some processes in the company. Most of us felt unsure about the use of the A3-approach."*

Manager in another local company: This company have used the A3 approach for the last decade. *"One customer asked us to do all documentation in A3 format and skip the traditional A4 reports"* The manager identified the importance of good mentoring when learning the A3 approach. *"It is important to ask the right questions. It is not the A3 format that is brilliant, but that the approach forces the user through a process in use of Lean principles. The A3 approach is very appropriate to use for juniors getting information from experienced seniors, where the senior takes the typical mentoring role."*

Discussion

Design process in the Company. The company has moved from a customized business to become more standardized and deliver products from a portfolio, this with a lean approach. In the review of the design processes in the Company, we saw that the company struggles in using the waterfall model when executing non-standardized products. The product designers were unsatisfied with the current handover of the requirements, in this way, the knowledge transfer could be seen as insufficient. In lean principles, knowledge transfer is one of the six components (Welo and Ringen 2016) and therefore an important component to focus on, for successful implementation of lean in product development. We have

proposed A3AOs as a tool supporting good knowledge transfer in the lean environment. (Raudberget and Bjursell 2014) focuses on the A3-report as a knowledge management tool to support good knowledge transfer in Lean PD. A3AOs may be an appropriate lean tool to deal with the handover problems in the researched engineering department in the Company.

Challenges using A3AOs. We recognized some challenges with implementing the tool in this big Company. Depth interviews indicated that the management has a low awareness of the A3 approach. The A4 report and PowerPoint presentations stand strong as the preferred way of sharing knowledge today. Interviews with earlier SE-students showed that it is a mutual understanding that there is a low awareness of the A3 approach outside the SE domain. The fact that the A3 approach is simple makes it difficult for persons unknown to the tool to see its benefits.

The PLM system in the Company supports the execution processes of all engineering documents, and we believe that also the A3AOs need to be successfully integrated in the system. The PLM system does not support the computer program Visio today. One of the participants stated the importance that the A3AO was an alive "file" through the whole design phase, supporting continuous revising. The computer program PowerPoint may be a better computer program to use, when arguing about the integration into the PLM system. We propose to investigate this further.

The engineers creating the A3AOs stated that the creation felt as added work. Thus, they felt that they use more time than just creating the product specification. To motivate them, it is important to focus on the value this tool gives, by providing good knowledge transfer. By investing more time creating better knowledge input for the product developers, they save time in the next step and are also more likely to work on the correct input.

Neither of the three participants had ever used the computer tool Visio. They logged some frustration connected to the computer tools used. PowerPoint is more commonly practiced in the company, and it would probably have been the better choice to use this tool instead. Visio also needs additional approval and licenses on the work computers.

Organization in change. Our study recognized that the participants got more positive to the A3 approach after they had spent some time getting to know it. This research took place in an organization and environment in change. The researcher was aware of the symptoms of employees going through change. Resistance is a natural part of the change process and is to be expected (Wayne and Hede 2001). We must expect that there will be noise, and that employees will be resistant towards the "new" tool because of all recent changes. In addition, this touches the "soft human factors" which are very hard to measure and may impact the measurements (Muller 2013). Therefore, when we analyzed the results, we were aware of some level of noise and bias.

Benefits using A3AOs. We have investigated earlier implementation initiatives of A3AOs as a lean knowledge sharing tool for cross boundary communication between development teams, during the last seven years. And we have presented results from several successful studies on the use of A3AOs in similar environments. The proposed solution is based on earlier work and we believe that the A3AOs will improve the requirements handover in the researched department. We tested the creation process and found benefits and challenges creating the A3AOs. The engineers did not think it was difficult to create the A3s. They used less time than expected, the creation helped them gather knowledge about the problem, they thought the consumers would find value in their A3s, and they were positive to creating A3s in the future. In a depth interview, it was stated that the A3s are a better way of communicating and in that way a more "kind" way of handing over information.

Method & Quality of research. The initial survey, as presented earlier in this paper, investigated the satisfaction by the designers in the department. A high percentage of the designers answered the survey, and we used the Likert scale and the NPS score to analyze the results. We believe that this survey gives valid indications about the satisfaction of the product specification handover in the department.

The real case logging in the case study was based on the research case studies in a system engineering context (Martin and Davidz 2007). We only had three participants available for the real case logging, therefore we need to conclude upon the results with moderation. The results will still give us some indication of benefits and challenges with creating and implementing A3AOs in engineering product development.

The depth interviews gave interesting insight into the attitude from key personnel towards the A3 approach. We interviewed both internal (management and engineers) and external (management and engineers). This made it possible to investigate the awareness of the tool at different levels in the company, and in other industries.

Reflections. This research study started as an initiative by the researcher to improve the handover process of requirements in an engineering department in the Company. We chose the A3 approach as the proposed solution based on knowledge and experience from the SE domain. After initial research, it was clear that several similar studies had been conducted both internal and external by other SE students over the last seven years. Therefore, we chose to investigate new aspects with A3AOs. We wanted to look at the creation process and see what was difficult and needs extra attention when implementing the A3 approach. We also looked into the benefits of using and implementing A3AOs and will use these as arguments to the management.

Conclusion

To conclude upon the results, there is a need for better handover of the requirements to key developers in the researched department in the Company. The designers are unsatisfied with the handover process of the specification as is today.

Results from the survey analysis, research review and depth interviews indicate that A3AO is a well-suited tool to improve communication and collaboration within the Company.

We have seen benefits with using A3AOs. The results show that it is an easy and low effort tool with potential value in engineering. The case participants were satisfied with the creation process of A3AO. They thought the creation process helped gathering information and knowledge. They also thought the A3AOs are valuable for the product developers.

Challenges with using A3AOs in engineering are; The tool is relatively new and unknown by the industry. Furthermore, management have low awareness in the use of the A3 approach. Traditional A4 reports and PowerPoint presentations have strong roots as the preferred communication tool in the industry today. Another challenge is that the PLM system does not support sufficient handling of the A3AO working file as is today. We also found that the creation process of A3AOs also puts additional work and needed time on already busy engineers. The other companies that have successfully implemented A3AO uses software that is good for creating A3AOs and easy to integrate in the PLM system.

Our results show that A3AOs are a useful tool supporting knowledge transfer in lean product development. The challenges and benefits we have highlighted can be used to better understand aspects about the A3 approach when implementing in new organizations. We conducted our research in the

subsea domain, but our findings are relevant in all industries working with product development, especially those implementing lean thinking in their execution.

Appendix

The appendix shows an example of a A3AO created as an example and used in the research work to instruct the case participants. The researcher used a real case when creating the A3AO example.

References

Andersen, S., Bersjö, D. (2015) *"Exploring Interactive Dynamic A3 Architecture Overviews to Increase R&D Product System Knowledge"* Confidential master project paper at HSN, Norway

Boone, H. N., & Boone, D. A. (2012). *"Analyzing Likert scale data. Journal of Extension, 50(2), 1-5."* & *"Jamieson, Susan. Likert scales: how to (ab)use them."* Blackwell Publishing Ltd, 2004

Borches Juzgado, Pedro Daniel (2010) *"A3 architecture overviews: a tool for effective communication in product evolution."* thesis. PhD thesis Twente University

Bovey, W. H., Hede, A., (2001) *"Resistance to organizational change: the role of defence mechanisms"* Journal of Managerial Psychology; 2001; 16, 7/8; Proquest

Bøhn, A., Bechina, A. (2015) *"A generic A3 framework for sharing knowledge in engineering context"* Society for Design and Process Science

Haskins, C., ed. 2007. *Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities.* Version 3.1. Revised by K. Forsberg and M. Krueger. San Diego, CA (US): INCOSE.

Heemels, M., Muller, G. (2007) *"Five years of Multi-disciplinary academic and industrial research lessons learned".* Hoboken, NJ: CSER, 2007.

Keiningham, Timothy L., Lerzan Aksoy, Bruce Cooil, and Tor Wallin Andreassen. "*Net Promoter, Recommendations, and Business Performance: A Clarification on Morgan and Rego.*" *Marketing Science, 2008: 531-532.*

Martin J.N., Davidz H.L, (2007) *"Systems Engineering Case Study Development"* in the 5th annual conference on Systems Engineering research 2007 (CSER2007), Hoboken, New Jersey.

Moen, K., Falk, K. (2016) *"Model-based specifications as a tool for improving communications in development projects"* *Confidential master project paper at HSN, Norway*

Muller, G. 2013*"Systems Engineering Research Methods"* Paper presented at Conference on Systems Engineering Research (CSER'13)

Polanscak, E., Muller, G. (2011) "Supporting Product Development, A3-assisted Communication and Documentation."

Raudberget, D., Bjursell,C. "A3 reports for knowledge codification, transfer and creation in research and development organisations" Int. J. Product Development, Vol. 19, Nos. 5/6, 2014

Saad, N. Mohd, Al-Ashaab, A., Shehab, E., Maksimovic, M., "A3 Thinking Approach to Support Problem Solving in Lean Product and Process Development". Springer-Verlag London 2013

Shook, J (2008), " Managing to Learn: Using the A3 management process" Cambridge: Lean org.

Singh, V., Muller, G. (2013) *"Knowledge Capture, Cross Boundary Communication and Early Validation with Dynamic A3 Architectures"* Paper presented at the INCOSE Symposium, Philadelphia, PA.

Sols, A., ed. 2014. "Systems Engineering Theory and Practice" Universidad Pontificia Comillas

Ulonska, S., Welo, T. (2014) *"A3-reports as tools for supporting organizational learning and knowledge reuse: A comparative survey-based study"*

Welo, T., Ringen, G. (2015) *"Investigating Lean development practices in SE companies: A comparative study between sectors"* © 2015 Published by Elsevier B.V.

Welo, T., Ringen, G. (2016) *"Beyond waste elimination: Assessing lean practices in product Development".* Procedia CIRP 50 (2016) 179 – 185

Wiulsrød, B., & Muller, G. (2011) *"Architecting Diesel Engine Control System using A3 Architecture Overview."* INCOSE

Østheim, F., Muller, G. (2016) *"Using A3 Architecture Overviews to Improve Accessibility to Systems Knowledge; a Case study in Subsea Production Systems."* Confidential master project paper at HSN, Norway

Biography

Sindre Løndal received his Bachelor's degree in mechanical engineering from the University College in Sør-Trøndelag in 2014. He has been working as a project engineer in the Subsea Components department in TechnipFMC since 2014 and received his Master's degree in systems engineering from the University College in Southeast Norway in 2017. In July 2017 he started as a Mechanical Engineer in EAB Engineering at Gjøvik.

Kristin Falk is employed as Associate Professor at University College of Southeast Norway, where she is responsible for the Subsea track and fronting research on systems engineering. Kristin holds a PhD in Petroleum Production and a Master in Industrial Mathematics, both from NTNU. She has worked with research, development and management in the oil and gas industry for 20 years, both with major subsea suppliers and with small start-ups.

A3 - Installation Cap of Pump module

Author: Sindre Løndal
Review:
Approve:
Scope: Installation cap
Released: No

Context diagram

Function Goal:
Avoid debree from getting into the pump unit during installation, and keeping the preservation fluid inside the unit.

Concideartions & abbrevations:
Inst.cap = Low pressure installation cap.

Legend

Topside
Subsea

Operations

Vessel

Manifold - Boosting Station

Suction Anchor

*Safe Zone

*Remove installation cap with the ROV

Pump module

ROV

*Safe Zone

The module will move due to heave from vessel in the waves

ROV

Main Objectives
- Prevent debree from getting in to the Pump unit under
- deployment of pump module.
- Keep the preservation fluid inside the pump module
- Be fully operated by a ROV (weight in water below 50 kg)
- Topside installability shall be considered

SSC Scope
Low pressure installation cap for the pump module installation

Key Personell
CLT Engineers:
Sindre Løndal
Product Engineers:

PRE:

Chief Project Engineer:

Project Engineer (Pump module):

Relevant Documents
Spec
GA xxxxx
ASSY xxxx
ICP xxxxx

Operation Comments
- The installation cap shall be fully operateable by a ROV.
- The pump module will hang on the crane in the safe zone while the rov will operate and remove the installation cap.

Flow Diagram
*(Pump module perspective)

1. Install caps
2. Fill Pump unit with preservation fluid
3. Pump module ready for deployment
4. Deploy pump module (by crane)
5. Hold Pump module in safe zone
6. Operate cap in safe zone by ROV
7. Release cap
8. Bring cap to basket

Pump Module Physical View

* red crossed area to be filled with preservation fluid

Illustration: A typical low pressure cap is shown just for illustrative purpose.

The bottom of the insulation box has a foam sealing wich is of poor quality and may be damage if the ROV touches it.