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A3 Architecture Views – A Project Management Tool?

Tore Boge
University of South-Eastern Norway
toreboge@gmail.com

Kristin Falk
University of South-Eastern Norway
Kristin.falk@usn.no

Abstract. This paper explores the benefits of using A3 Architecture Overviews (A3AO) as a tool for project management and interdisciplinary knowledge sharing in a development project. The goal of the development project was to create an autonomous subsea inspection systems for the oil and gas industry. Sharing of implicit system knowledge early in the systems life cycle is a challenge, yet important for successful development of new technology. Through expert interviews and reverse architecting we made A3AO for two new system that were sequential steps into a fully autonomous solution. Through the research we applied these overviews in meetings with HSEQ, finance, senior management, and engineering. The immediate responses were positive, with comments like, "*now I understand what we are trying to achieve*", and "*Can I please include the A3AO in my document for the management?"* Project personnel, with limited system knowledge, quickly got an enhanced understanding of the project goals by viewing the A3AO. We also experienced that senior management used the illustrative tool as a supplement to support a business case for the board of directors. Clients were happy to see models and schematics as a supplement to textural documents when being presented with new technology. Inclusion of industry terminology and support from management would enhance adoption of A3AO within the oil and gas industry. Overall, our research strongly supports the use of A3 Architectural Overviews as a project management tool when developing new complex systems.

Introduction

Pipeline Inspection. As a response to the demand for safer, more efficient, and low carbon operations, a company has decided to enter the competitive market of pipeline inspections, Figure 1, using autonomous inspection vessels. This paper explores the development of two autonomous, unmanned subsea inspection concepts. The new systems and services will be very different from the current Company offerings. Traditionally the company delivers subsea vessels and subsea services, including light construction, deep sea exploration, and subsea inspection, maintenance and repair.

Figure 1. Illustration of a traditional pipeline inspection with MPV and ROV

There is a marked for the new system as laws and standards require oil and gas companies to have inspection programs for pipelines to validate the integrity of the pipelines throughout its life-time (DNV, 2009), (NORSOK, 2010). Due to the expensive na-

ture of such inspections, the oil and gas companies do inspections as infrequent as possible.

Business Potential. Company believes that it is possible to enter this market, and win jobs by delivering a cost efficient autonomous solution for less than 50% of today's cost. The most common way to perform inspections is by using a Multipurpose Offshore Vessels (MPV), and Remotely Operated Vehicles (ROV), see Figure 1.

A problem is that MPVs are large, thus consuming a lot of fuel, and require a large crew-size. A typical length of an MPV is 90 to 120m. Manning requirements for this type of vessels are 25-45 persons. Average fuel consumption is very high, more than 17 cubic meters per day. This results in a significant carbon footprint and emissions to the environment.

The average inspection interval for pipelines is between two to five years. Depending on the market situation, the typical cost for North Sea pipeline inspection is between 50-100kUSD per day, which typically cover 70km of pipe/day. In Europe alone there is a total of approximately 45000km of pipeline. This equals close to 630 days of operation with a total value of $35,2million, not including weather standby, mobilization and transit costs.

Autonomous Underwater System. Autonomous and remote operation of ships can remove the need for personnel onboard operating the vessels. By replacing remotely operated vehicles (ROVs) with autonomous underwater vehicles (AUVs) it is possible to fully remove the need for personnel offshore during the pipeline inspection. The equipment used for the services will consist of:

- An unmanned ship with capabilities for launch and recovery of an Autonomous Underwater Vehicle (AUV), controlled from an onshore control room.
- A Resident system, where an Autonomous Underwater Vehicle (AUV) is permanently installed subsea, and controlled from an onshore control room.

Project Execution Process. Figure 2 shows the company project execution flowchart. The traditional projects, with vessel and ROV service delivery, have specific deliverables, and requirements for which elements (equipment) to use. Company bases their procedures on the Project Management Institute (Greene and Stellman, 2018) rather than Systems Engineering best practices. This is a natural approach based the characteristics of traditional project deliveries for Company.

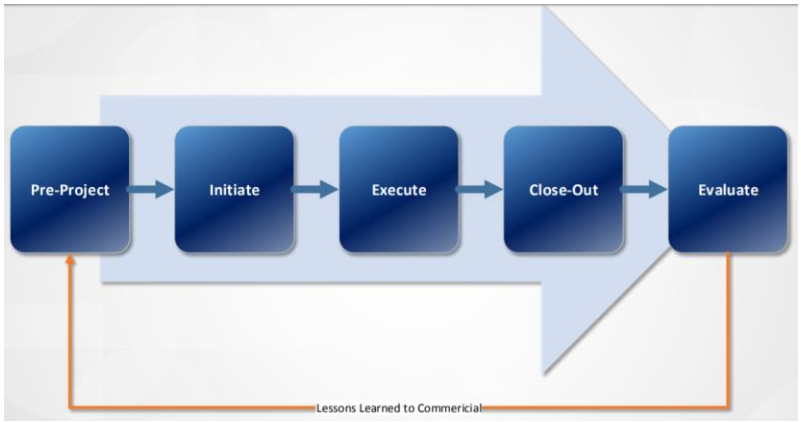

Figure 2. Company project execution workflow

Company also develops new systems and ROV tools for internal and external clients, one to two projects each years. These projects usually entail design, fabrication and testing of new tools, or improvement of existing tools. In these development projects technical experts and designers have to communicate system details to the project manager and other stakeholders. The tools provided by the company project-execution workflow have not been able to handle this type of information. The result has been lack of overview, and focus on details rather than the actual project goals. This is an

important motivation to research the use of more visualization tools to aid the management of development systems.

New Development Project. The new development project had been ongoing for one year when we started the research. The majority of time was used in the pre-project phase, ref Figure 2. Company had spent time on finding a client to sponsor the development, and detailing the set-up of equipment.

When moving into this initiation phase, more people got involved in the project, increasing the internal project team from 2-3 persons to 6-7 persons. This is where we performed all our research, when the project was in the initiation phase. The first pilot-test of an unmanned ship-operation was scheduled, and planning had started. This first pilot was one of several pilots planned in the project. Company uses sequential pilot tests to come to a higher technology readiness level (Equinor, Technology Readiness Level, 2018). In this way, it is possible to get continued support from company owners and keep clients interested in the development as it gradually evolves. To finalize the development, Company estimates a cost of 25 - 30m USD, depending on the final cost of the development of equipment.

Experts on pipeline inspections working in Company believed that existing technology was ready to operate in full scale pipeline inspection projects. An initial analysis of the project, performed by the researcher, uncovered the need for a consistent method for sharing of system knowledge. Most of the information required to successfully develop the project was implicit expert knowledge, and little information was easily available to other project stakeholders. To be able to successfully develop the new services, Company realised that they needed to extract the implicit knowledge from the experts, and make it available for all project stakeholders. Systems engineering best practices within the company is not established. Yet, the company recognize that Systems Engineering best practices can be useful for projects of a development nature.

Knowledge sharing in development projects. Poor visibility of what the project team really knows is a known problem in many companies (Sols, 2014). Almeida & Soares (2016) showed how successful research and development projects rely on effective management of implicit expert knowledge between project stakeholders. Very often professionals have different perceptions of systems, and its system architecture. This is hard to capture in development projects where no finalized systems exists.

Lack of knowledge sharing is identified as a root cause for development problems and poor decisions (Broches, 2010). Effective communication of architectural knowledge allows team members to understand the essential aspects of the architecture, and thus the essentials of the system functions and elements. This can be done by an A3AO. The original intention of the A3AO was to capture and share system knowledge (Shook, 2008). The format is limited to use of two sheets of standard European A3 paper size (297 x 420mm) for presentation of the system. A3AO is a tool built to support communion of high level system architecture and functional flow (Broches, 2010)**.**

The oil and gas industry has performed research on applying A3 Architectural overviews (A3AO) for design and engineering of subsea production systems. Findings showed that the method is well suited to enhance communication between engineering teams. Based on earlier SE research (Broches, 2010), (Løndal & Falk, 2017), (Wee & Muller, 2015) we wanted to address the subject of implicit knowledge sharing by using A3AOs.

Research Questions. In our research we test the use of A3AOs in a different segment of the supplier industry. We also moved away from design and engineering, and used the A3AO in a project management context. This paper addresses the research questions:

- What value can A3AOs add as a project management tool during the development of two new services for subsea pipeline inspections?

- How do different parts of the organization evaluate the A3AO as a tool for communicating implicit expert knowledge?

The researcher was set to manage the development project partly based on his systems engineering knowledge. The project was used as laboratory for the research.

We perform informal interviews to extract expert knowledge. Then, we created the A3AOs and used them as documentation during the project planning phase. During the planning phase we conducted meetings with technical, HSEQ, and commercial departments. We also conducted meetings with senior management to report on the status of the project, and give input to future business development. We applied the A3AO as an addition to other existing project documentation. The purpose of introducing A3AO was to support the departments in their understanding of how system elements and functions are connected.

Research method

Research technique. We performed the research during a "live" project. To verify the suitability of A3AOs we performed research through the industry as laboratory technique. In this type of action research, the researcher combines active participation in the systems engineering activities with the researcher role (Muller, 2013). This gives the researchers the benefit of knowing the system and its context. The academic downside of the method is the risk of having a biased researcher. The researcher had the role of project manager during the research, which enabled the researcher to obtain feedback firsthand. It also enabled the researcher to study the A3AOs in an inter-disciplinary setting, where personnel had different professional backgrounds varying from technical, financial, commercial, and management.

We focused on the internal stakeholders who were accessible on a daily basis, ref Table 1. Due to the hectic nature of the project during the planning phase we did not get to properly introduce the A3AO to the client. However, we got the opportunity to introduce the A3AO to a client representative during the operational phase of the project. We elaborate on the client feedback in the Discussion chapter of this article.

The primary means for collecting results were questionnaires and interviews. Development of new concepts is not a part of the core business for the company. Therefore it was not possible to benchmark the results from this project towards similar projects performed earlier.

Table 1. Company personnel taking part in the research

Role (years in role)	Role (years in role)	Role (years in role)
HSEQ Manager (1)	Senior Surveyor (1)	Engineering manager (1)
HSEQ Advisor (6)	Management Associate (1)	Tendering manager (1)
Senior Advisor (2)	Chief Operations Officer (9)	Project Manager, former (6)

Roadmap. Figure 3 shows the flow of the research, and how we used industry as laboratory for the research. The figure show the industry domain on top of the dotted line, and the systems engineering domain below. It also shows the different challenges and goals for the two domains on each side, and how the research combine input from both to reach the goals described.

We used the technique for reverse architecting described in previous research (Broches, 2010) to create the architectural models for the A3AOs. Then, we used A3AOs in meetings of technical, managerial, and financial character. By doing this, different stakeholders learned about the systems architecture in a consistent manner. Thirdly, we gathered feedback on the A3AOs through a questionnaire. One part of the questionnaire had Likert scale statements, and the second part had open ended questions. Likert Scale is typically a five, seven, or nine point agreement scale used to measure

respondents' agreement with a variety of statements (Pal & Joshi, 2015). Finally we performed an in depth interview.

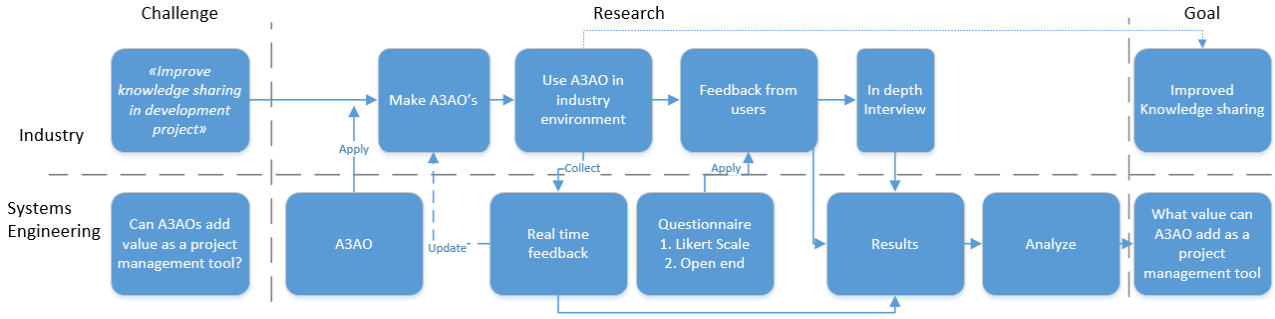

Figure 3. Research method

Collection of results. We collected results in 4 different ways, real time feedback, Likert scale questionnaire, open ended questionnaire, and in depth interview. Figure 3 shows how we collected results during the research stage. The in depth interview of a former project manager in the company gives additional insight in how the A3AO is perceived as a Project Management tool. It also gives valuable information on what is considered to be necessary for more frequent use of the tool within the industry. Through analysis of the collected feedback we validate the suitability of the A3AO format as a tool for project management.

Systems architecture and communication

SE and project management. Methods and processes described in the Systems Engineering Body of Knowledge (SEBoK) have inspired this research (BKCASE Editorial Board 2017). In particular the knowledge from Part 3 of the SEBoK, *"SE and Management",* and Part 6, *"SE and Project Management"* lead the researchers towards the inter-disciplinary study approach. Other work have also concluded that SE efforts could have a significant impact on projects success (Honour, 2004). Tranøy & Muller (2012) showed how early detection of actual needs could improve system quality considerably.

The goal of project management is to plan and coordinate the work activities needed to deliver a satisfactory product, service or enterprise endeavor within the constraints of schedule, budget, resources, and available staffing and technology. (Board, 2017). One of the key skills within project management is communication. Both within the project itself, and to the supporting elements such as management, finance, contractors, etc. (Eisner, 2008). In development projects it is especially important to facilitate this communication.

Systems Architecture applies a framework that enables early visualization of system flow and elements. This provides a common ground for communications among stakeholders. Broches (2010) identified this as one of the key elements for project success. The job of making architectures is the job of the system architect or system engineer. Reverse architecting can be done, similar to reverse engineering. This is a process where the architect have to gather information on a system that exists or gather knowledge of a concept and convert that information to an architecture for the system of interest.

ConOps. In the early phases of systems engineering the ConOps-document facilitates for system understanding without defining any measurable requirements (Sols, 2014). The ConOps allows stakeholders to express their thoughts around a system and see initial design constraints. ConOps are normally long, textual documents owned by the systems architects, while Illustrative ConOps captures the sequence of operations as visualizations (Solli 2016).

The A3AO is another visual tool designed for effective communication of architectural knowledge (Borches 2010), (Wee & Muller, 2015). The original A3 tool, developed by Toyota, is simply based on a piece of paper with the standard European size 297x420 mm. It is sufficient in size for communication purposes, big enough to include both visual and textual information. A number of elements are standard content on A3AOs: physical models, functional models (dynamics), and quantification. An A3AO is normally based on a user story. That is, it has the operational viewpoint, and can thus be compared to a conceptual ConOps. The creation of A3AOs will supplement the ConOps by specifying a "physical", "functional", and "quantification view" presentation (Brussel & Bonnema, 2015). The methods effectively accomplish the system purpose.

The effort creating the architectural overview as well as the novelty of the tool are factors that may prevent people from using and adapting A3AOs in their work. Research have also debated how management had low awareness of A3AOs (Løndal & Falk, 2017).

A selection of benefits by applying A3AOs are given below based on (Solli 2016, Løndal 2018):

- ***Improve decision making*** as it contributes positively in creating a shared understanding by improving the perceived learning and visualization capabilities, and supports the selection of systems in a System of Systems. The tool is also suitable for early validation of operational concepts.
- ***Improve communication*** as it helps the discussions to stay focused, dynamic, and inclusive, and increases cross boundary communication in the organization.
- ***Improve knowledge capturing and knowledge management*** as it is well suited to capture design and system knowledge, share knowledge in an engineering context. In addition it can partially replace heavy text communication of requirements in combination (at least in an early stage of a project), and can make it easy to locate information (save up to 95 % time on finding product and project specific information).

The project manager, as well as the system architect, are normally engaged in decision making, communication, and knowledge management. The traditional project management tools focuses on control and efficiency, and are well suited to manage standard deliveries where the outcome is known prior to starting the project. On the other hand, in new developments project we need tools to support a shared understanding of complex context and systems in order to manage the development.

Results

Selecting A3AO as the method

The process of selecting the A3AO was an iterative process between the author, co-author and the company over a three month period. The initial method suggested was to use ConOps to describe the future system and use this to communicate the different system aspects. However, the ConOps is not as easy to present and use for around the table discussions.

In the project where we performed the research there is already many unknowns, and the introduction of a full ConOps document would probably seem too encompassing for the project team to familiarize with. The "one page format" of the A3AO was therefore considered to be more interesting to use. The possibility to visualize the high-level physical architecture and show how technical success was a criteria for further financial support was also considered to be valuable from a project management point of view.

When we selected the method to use for this research we did also look into existing project management tools that provide similar benefits. Interfaces in a project such as handover from commercial department to the project department typically use a Power Point to describe the overall SOW for the

project. This is probably the closest we get to a similar "tool" in the organization. However, this is not a standardized format, and the content does not describe the same level of detail and dependencies as an A3AO do. As far as the project manager is aware of, there are no similar tools in the Project Management toolbox. The Project Management literature focus more on what should be done, and not so much on how to do it. Therefore the A3AO was considered to be an interesting addition, and a good tool for interfacing between departments and disciplines both internally in the organization and towards external clients or subcontractors.

Real time feedback during A3AO creation

During the project execution, as a part of the research, we continuously collected immediate feedback. We did this by observing users and performing informal interviews. This gave us in-depth insight to how professionals of different background respond to the use of A3AO's in a real environment. This section presents a summary of the feedback from 6 individuals with different professional backgrounds. All feedback related to the models or the pictures, no participants commented on the "text sheet". The value of using models close that is close to the mental model of the system have been described in previous research on A3AOs in the subsea industry (Wee & Muller, 2015).

The first feedback came from the senior surveyor/system expert who had the tacit knowledge of the system architecture. We collected this feedback indirectly by observing his attitude and comments during the informal interviews. When working with the A3AO we observed that he remembered things we needed to include in the system. And, in every meeting he asked for a post-it, or wrote notes on the back of his hand or directly on the A3AO.

Figure 4 shows notes on one of the draft versions of the A3AOs. The comments made by the senior systems expert mostly concerned communications between the different parts of the system. If not identified during the A3AO review, these comments and questions would typically be identified during system testing. By identifying system concerns and questions early we avoid trouble shooting and fault finding during the testing period where more personnel and equipment is involved. This save time and cost for the project. We included notes and comments made during the review meetings in the project action tracker. In the action tracker, actions are delegated, and followed up to make sure we meet all project deliverables in due time.

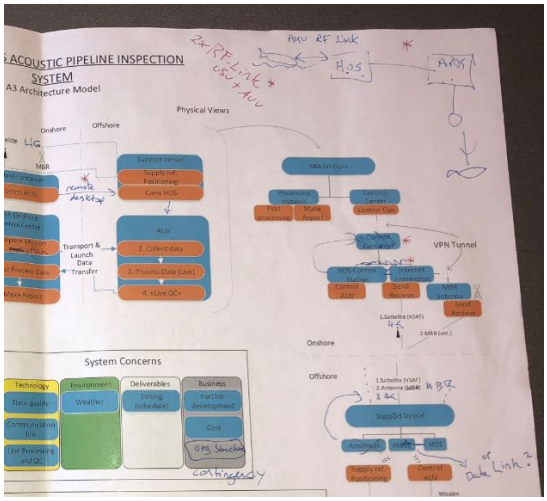

Figure 4. A3AO review notes

Feedback from the second interviewee, the previous project manager of this project was; *this is a very clean and clever way to describe details of the system.* He felt that the already available concept of operations document was suitable for the very high level discussions, but the next level of detail was missing. The A3AO gave the correct detail level to discuss how to further develop the system. He is familiar with functional flow diagrams through his project management background. But combining abstract flow diagrams and physical elements is not something he has used during his six years as a Project Manager in the company.

The third person we interviewed was a management secretary/associate. At the time of the research interview she was working on a document for the board of directors. When familiarized with the A3AOs she immediately responded; *now I understand, this is what I have been writing about the past weeks.* And; *Can I please include the A3AOs in the document for the board of directors?* It was the models showing the connection between the different elements of the system that gave her an enhanced understanding of the system.

This looks very good said the HSE manager who was the fourth interviewee. We discussed how this new services would affect our cyber security. Instead of talking about traditional piracy and safety levels on the vessels, he related it to cyber security since we are controlling the systems via satellite. This was visually displayed through the physical view of the A3AO.

The operations manager was the only person to comment on the "text sheet" of the A3AOs. All other comments related to the "model sheet". *I really like how you present the roadmap with pictures. Maybe you can adjust the picture sizes to show how the new systems are smaller in size?*

The last interviewee, who is the engineering manager came with a lot of questions. *What about changing the name of the functional flow to operational flow? That would make it more similar to how we write our operational procedures. And can you call the physical views, equipment views? Then it would be no doubt that you are showing the equipment needed, and how it is connected. It looks very good, but I would recommend to adopt some of the oil and gas vocabulary.*

Results from questionnaire

Likert Scale. All individuals who was involved in the research filled out a Likert scale questionnaire. In the questionnaire they rated the statements presented on a scale from 1 to 5, where 1 indicated "strongly disagree", and 5 indicated "strongly agree", ref Table 4. In total 9 out of 9 individuals asked delivered a completed questionnaire. The selection of personnel cover the majority of stakeholders that are usually included in projects executed in the company. The individuals are working in different departments of the organisation, ref Table 1.

Average and median results. To get an initial overview of the results we calculated the mean score for each of the questions in the Likert scale questionnaire, see Table 2. We also found the median results, ref Table 3. As there is a limited selection of 9 participants in the research, it is not feasible conclude on the results from Table 2 and Table 3 alone. Researchers also debate ordinal interpretation of Likert Scale results (Jamieson, 2004). Although the values in the Likert Scale are ordinal 1-5, we cannot presume the intervals between the numbers to be equal.

Table 2. Average Likert scale results

No.	Statement	Average score
1	The A3AO is a good tool for sharing technical knowledge.	4,8
2	The A3AO is a new format to me.	4,2
3	The A3AO is easy to understand.	4,3
4	The A3AO provides useful system information that is not captured in traditional documentation.	4,4
5	I believe using A3AO could be beneficial to use in other projects we conduct	4,4
6	The A3AO is challenging to understand as there are too many technical details.	1,7
7	The Summary side (text side) of the A3AO is preferred over the overview side (models)	2,9
8	The A3AO support me or others my job activities	4,0

Table 3. Median Likert Scale resutls

Question No.	Participant #1	Participant #2	Participant #3	Participant #4	Participant #5	Participant #6	Participant #7	Participant #8	Participant #9
1	4	4	5	5	5	5	5	5	5
2	2	3	4	4	5	5	5	5	5
3	4	4	4	4	4	4	5	5	5
4	3	4	4	4	5	5	5	5	5
5	4	4	4	4	4	5	5	5	5
6	1	1	1	1	2	2	2	2	3
7	2	2	2	2	3	3	3	4	5
8	3	3	4	4	4	4	4	5	5

To further validate the results of the Likert Scale we use the Net Promoter Score (NPS) (Muller, 2013). This method separate the promotors from the complainers using the following formula, where # stands for 'number of':

NPS = (#strongly agree – (#neutral+#disagree+#strongly disagree))

The NPS assumes that all respondents answering *"strongly agree"* will promote the method, while respondents answering *"neutral"* or lower will complain about the same idea. Those who "*agree*" is considered natural from a promotion standpoint. An NPS equal to or greater than 1 indicate that there are more promotors then complainers for the method or tool in question. A negative score indicate that there will be an overweight of people complaining about the tool. Neutral means an equal number of promoters and complainers.

The average results in Table 2 indicate the validity of the A3AO as a project management tool. The participants in the survey agree that the A3AO is a good tool for knowledge sharing. (No. 1) It is clear that the A3AO format is new to the organization (No.2), this is as expected as the level of SE practices in the company are low. Still, the participants don't prefer the textural summary over the models (No.7). Average results on question 8 indicate that the participants see the A3AO tool as a tool that will support them or others when performing their job.

Table 4. NPS (Net promoter scores)

No.	Statement	1: Strongly disagree	2: Disagree	3: Neutral	4: Agree	5: Strongly Agree	NPS
		1	2	3	4	5	
1	The A3AO is a good tool for sharing technical knowledge.				2	7	7
2	The A3AO is a new format to me.		1	1	2	5	3
3	The A3AO is easy to understand.				6	3	3
4	The A3AO provides useful system information that is not captured in traditional documentation.			1	3	5	4
5	I believe using A3AO could be beneficial to use in other projects we conduct				5	4	4
6	The A3AO is challenging to understand as there are too many technical details.	4	4	1			-9
7	The Summary side (text side) of the A3AO is preferred over the overview side (models)		4	3	1	1	-5
8	The A3AO support me or others my job activities			2	5	2	0

The results in Table 4, show that there will be an overweight of promoters for question 1 through 6. Question 2 is not relevant for the promotion of A3AO, but it indicates that most of the persons involved in this research had not used A3AOs before. Question 7 debates whether it is the textural or the model side of the A3AO which is best. This is also hard to evaluate through NPS. Question 8 has got a neutral NPS result.

We can see from Table 5 that the results from Table 2 and Table 4 follow the same trends. Questions 1 through Question 5 has got positive results in both tables. Question 6 and Question 7 has got a neutral to negative score in both tables. Question 8 has got a positive result in Table 2, but a neutral result in Table 4. The weighting of the answers in the NPS method moves this from a positive (4.0 score) in Table 2 to a neutral (0 score) in Table 4.

Table 5. Scores comparison

Scores comaprison - from high to low								
Rank	1	2	3	4	5	6	7	8
	Question #1	**Question # 4/5**		**Question # 3**	**Question # 2**	**Question #8**	**Question # 7**	**Question # 6**
Average score (table 1)	4.8	4.4		4.3	4.2	4.0	2.9	1.7
NPS score (table 2)	7	4		3		0	-5	-9

Results from open ended questionnaire

All personnel received a written open-ended questionnaire with 5 questions. We wanted to find out what they consider to be the main benefits of the format. And what factors could impact further use of A3AOs within the company. Earlier research show that mangers have low awareness of the use of A3AOs (Løndal & Falk, 2017). Therefore it is interesting to see how managers consider the use of A3AOs in this particular domain. The questions asked were:

1. How much time would you estimate/budget for making one A3 report (including reviews)?
2. Which factors need to be in place for the A3AO format to be accepted in the Oil and Gas industry?
3. Which factors may block the use of A3AOs?
4. What do you see as the main benefits of the A3 format?
5. What do you see as the main challenges of the A3 format?

The mean answer for time required to create A3AOs was 27 hrs. Actual recorded time was 28hrs.

In the remaining questions the participants answered with two to three factors, benefits, or challenges on each question.

The top two factors mentioned under Question 2 was support from top management and implementation in Company procedures and processes. 5 of 9 participants suggested that one of or both these factors needs to be in place. A third suggestion was the need for a "paying customer". I.e. client need to define A3AO as a deliverable.

7 out of 9 participants gave an answer related to time consumption as a factor that may block the use of A3AOs. (Question 3) This is interesting as the questionnaire reveals that the participants had the right perception of what time it takes to make the A3AO.

All participants answered very similar on question 4. Although with different wording, everyone replied that the main benefit of the A3AO is the strong capabilities for communication of system aspects. This is noticeable since the feedback was individual, without the researcher present.

5 out of 9 saw the format size, and fitting all information on two pages as the main challenge. (Question 5).

Results from in depth interview

To further investigate the use of A3AOs as a Project Management tool we performed an in depth interview with the former project manager of this project. He managed the project for eight months during the pre-project phase (see Figure 2). He has been a project manager in the company for more than six years, managing both vessel delivery projects and small scale internal development projects. In total he has fifteen years of experience from the subsea industry. The researcher performed the interview in person.

The first question is regarding use of A3AO in the company in general. Do you consider it a good tool, and will it add value to the company?

He replied that he could see benefits both when describing processes and products. He made an example of a specific project where timing between many different operations was crucial. "*A tool like this could have helped us optimize our operational set-up in less time. Especially when there are several companies involved in the operations"*

Further he mentioned that he would like to use the A3AO to perform Risk Assessments and Hazard Operational Studies (HAZOP).

Secondly we asked about other small scale development projects that Company has performed. Do you see any benefits of using A3AO in these type of projects?

The former project manager answered that in most projects we are dependent on internal and external experts that have to communicate. We have seen information get lost in E-mail trails. If we could base the discussions around an A3AO we could potentially avoid this. "*But most of all it would help the experts get a holistic view and see the bigger picture."*

The combination of functional and physical views would be useful when discussing potential improvement suggestions with management. *The ability to show the correlation between function and equipment can be translated into time and cost of operations".*

Finally we talked about the future of the subsea industry, and how things are changing towards autonomous or remotely controlled operations.

How do you consider the use of A3AOs when developing subsea services further?

On this question the former project manager suggested to look at other industries as well as the oil and gas industry. The format is universal, which is allows for use in a wide range of industries. The oil and Gas industry is conservative, and has got an established set of rules and regulations to follow. Terminology has developed over time, and text documents is the most common format. *I believe the A3AOs could improve communications within the subsea industry. However, I think other industries are more susceptible to change, and new ways of working. Therefore it may be easier to implement the A3AOs in a less regulated industry.*

The later statement must be seen in a context where the industry traditionally have used 10 to 15 years to introduce new technology. Whether this is due to regulated industry is not a scope of this paper. But it opens up to the idea that the A3AO will be perceived differently in different industries.

Client feedback

Due to limited time and heavy workload during the project and research execution we were not able to include the client from an oil and gas company in the formal research process (Figure 3). Nevertheless, during the operation they requested system schematics, and we forwarded the A3AO. They needed a better understanding of the system internally in the organization. We spent approximately 5 minutes with one of the client reps, introducing the A3AO. This was his first encounter with this format.

During the brief introduction, he commented that it was a lot of information to process, especially on the text sheet. After an hour he came back with specific questions regarding the communication links shown on the model side. We could answer the question by showing the detailed physical view of the system combined with the A3AO legend. The Client representative forwarded the A3AO internally, and other client representatives commented it in a phone conference held after the operation was completed. They claimed that it was too much text and information for them to understand. However, they would like to see the system presented in this type of way with schematics and models. We did not given any introduction to how the A3AO is set up, and its purpose to these client representatives.

Analysis

The initial results shows that participants in the study were positive to the use of A3AOs in the project. The score of Question 1 (is the A3AO a good tool for sharing technical knowledge?) is particularly high, both on average results and NPS. The average score on question 8, which is: *the A3AO supports me or others in my job activities*, is slightly lower than on question 1, ref Table 5. Question 8 gets a neutral result from on the NPS, ref Table 4

Further analysis of Question 8 shows that the managers are giving this an average score of 4.5, while the technical experts give an average score of 3.5 on this question. Other non-technical personnel have an average score of 4.0 on the same question. Mangers have a positive NPS on question 8, while technical and non-technical achieve a negative, and neutral NPS on the same question. These results support the findings from (Løndal & Falk, 2017), where participants indicate that the A3AO is a "kind" way of handing over information. The persons on the receiving end appreciate the format

more than the experts that spend time with the systems engineer during the reverse architecting of the A3AOs.

The positive response from the managers are interesting as earlier research have found that managers have low awareness of the A3AOs (Løndal & Falk, 2017). Table 6 shows that it is only management that give a positive NPS score on Question 8 regarding the A3AO supporting them in their job activities. Not only are the non-technical personnel and the managers more positive towards the A3AO than the technical experts, in addition, the technical experts budget only half the time for making the A3AOs compared to managers and non-technical personnel combined.

Comparison of average results and NPS shows that the results from both methods of analysis follow the same pattern, ref Table 5. The majority of the questions receive a positive response by the project team. Question 8 achieves a neutral score on the NPS, ref Table 4. We believe that this is connected with the type of Projects Company is performing today. And that the need for A3AOs are not the same for projects with routine deliveries as it is in development projects. Question 8 also implies that the interviewees will have to change their working routines, and start using the A3AOs. Most humans have an inherent resistance towards change, and several studies and articles discuss the top factors triggering this resistance (Kanter, 2012), (Oreg, 2003).

Table 6. Comparison of technical vs. non technical and management personnel

		Average Scores			NPS Scores		
		Tech	**Non Tech**	**Managem**	**Tech**	**Non Tech**	**Managem**
Q1	The A3AO is a good tool for sharing technical knowledge.	4.5	5	5	1	3	4
Q2	The A3AO is a new format to me.	4	4	3.67	0	2	1
Q3	The A3AO is easy to understand.	4	4.33	4.67	0	1	2
Q4	The A3AO provides useful system information that is not captured in traditional documentation.	3.5	4.67	4.67	-1	2	3
Q5	I believe using A3AO could be beneficial to use in other projects we conduct	4	4.67	4.67	0	2	3
Q6	The A3AO is challenging to understand as there are too many technical details.	1.5	2	1.33	-2	-4	-4
Q7	The Summary side (text side) of the A3AO is preferred over the overview side (models)	2.5	3	2.33	-2	-1	-4
Q8	The A3AO support me or others my job activities	3.5	4	4.50	-1	-1	2

In the open question section of the questionnaire one of the experts mention that A3AO functional flow section give a good easy to read overview of the key processes. This correlates well with the results collected from the non-technical personnel and the managers. One of the experts also specifically mention that A3AO has the benefit of giving top management in depth knowledge. The results from the Likert scale questions confirm this. Further, the submission of the A3AO as an attachment to the business case document intended for the board of directors further supports this view.

From a Project management perspective it is also interesting to see the reaction of the company expert during the creation of the A3AO. Although the score on the Likert scale is lower than for the other groups, the creation forced him to describe connections between elements, which again reminded him of things we needed to investigate or take care of. To have a tool that trigger this kind of thinking is useful for project management.

The in depth interview with the former project manager gave useful insights. He can see several application areas for the A3AO format in the subsea domain. Similar to the results from (Wee & Muller, 2015), he commented that A3AO could have prevented problems seen in the past, and optimized the operational flow in less time. He also pointed at how the A3AO can bridge the gap between technology and business by connecting elements to operational flow, which in turn can be translated into time and cost. As pointed out by (Wee & Muller, 2015) former research has also highlighted that A3AOs can be valuable describing functional flows and connecting this to time and cost.

Discussion

This paper addresses the two research questions: “What value can A3AOs add as a project management tool during the development of two new services for subsea pipeline inspections?”, and “How do different parts of the organization evaluate the A3AO as a tool for communicating implicit expert knowledge?”

Through the research we have found answers to these questions by implementing the A3AO in a development project, and collecting feedback from the project personnel. Results from the study shows that the added value comes in form of improved communication of system knowledge. And, that non-technical personnel such as HSEQ, and management are the stakeholders who benefits most from the use of A3AOs.

A simple reason to why the more technical employees rate the A3AO lower than the non-technical can be that they already has the knowledge conceived in the A3AO. They do not see the value of bringing the knowledge to others; either because they believe it is trivial, or because they do not understand how it is relevant for the others. The fact that the project manager received very useful info from the technical expert seems to support both these points.

The research topic is a result of close collaboration with the company. Over the past 6 years the researcher has gathered much experience with how Company execute their projects. Discussions with the Chief of Operations and Engineering Manager led to the selected topic. Company put the researcher in the role as Project Manager partly based on his Systems Engineering knowledge. Company recognized that the implemented routines for project execution would not be suitable for this project, and a different approach would be beneficial. Using the industry as laboratory has been a major success criteria for our research.

Another important fundament for this research has been former research. We have based our research on former research of A3AO applied in the subsea industry, primarily conducted by suppliers of subsea production systems. With this as a fundament, we tested the use of A3AO in a different segment of the supplier industry, and moved the application from requirements, design and engineering to project management.

The Oil and gas industry is a conservative industry when it comes to implementing changes. However, the downturn over the past three to four years has forced the industry to change in an effort to cut costs. One way of cutting cost is to make operations more efficient. Technology enhancements is important to enable more efficient operations. As discussed by Wee & Muller (2015), a good time for creating an A3AO is when a topic is hot. This has certainly been the case for this research, which resulted in the A3AO being used as an attachment to a business case document. We believe that this is a direct reflection of the ongoing change in the industry, and Company’s effort to find more efficient ways of operating.

A3AO is a tool that facilitate sharing of implicit expert knowledge, making it available for management and decision makers as well as other project stakeholders. Going forward, suppliers in the oil and gas industry will have to make changes to deliver more competitive products. Managers and decision makers will benefit from having a tool for sharing of system knowledge. Therefore, we believe that tools like A3AOs will play an important role for the suppliers to the oil and gas industry over the years to come.

Used effectively systems architecture methods, such as A3AO, accomplish the products *purpose*. This is why such methods are good tools in the hand of a project manager, especially in the early phase of a project where the product purpose is still under consideration by the project, company and client.

Former project activities within Company consist of vessel deliveries and subsea ROV services. These are well defined service deliveries for the company. Benchmarking of results are difficult, as the nature of the development project is very different from traditional projects within the company. This gives us a challenge in terms of researching measurable added value. On the other hand, the A3AOs are not replacing any existing documents or processes. It is rather a supplement to typical formats such as A4 text documents and power point presentations. This is aligned with the suggestion for future research by described in the article by Wee and Muller (Wee & Muller, 2015).

Resistance towards organizational change is a repeated research topic. Researchers within psychology have made a scale for an individual's dispositional inclination to resist change (Oreg, 2003). During this study we observed resistance in terms of the experts seeing the A3AO as additional work, not adding immediate value for them. Management also resisted the introduction of A3AO to the client, as it could lead to loss of control in terms of client communication. Non-technical personnel expressed concern in relation to creating A3AOs. These types of resistance are not unique for Company. They are all part of common reasons for resistance towards change (Kanter, 2012). The resistance towards change may have an impact on the results in this research.

The initial analysis of the development project was supported by the former project manager and the system expert. Through an extensive handover, between the former project manager and the researcher, it became clear that system knowledge beyond ConOps and power point presentations was not formalized. The ConOps and the Power point presentations had attracted a Client and a center of expertise that were willing to invest in the project. However, detailed technical descriptions beyond the ConOps were missing, and a clear statement of goals for the project was missing. To mitigate this, the A3AO format was considered to be a suitable tool.

When creating the A3AOs input was mainly gathered from the mind of one system expert. In addition, the ConOps document and power point presentations were used to support the creation. After creating the A3AO drafts, we presented them to a wider group of people with system knowledge for them to give input. Four iterations was required to finalize the first A3AO. The second and third A3AO required fewer iterations, as they build on the same architecture. The researcher created all the A3AOs, according to methods described in earlier research (Broches, 2010). We chose this approach to focus the research on the application of A3AOs in a new environment rather than focusing on the creation process, and optimization of the format itself.

After the creation of the A3AOs we had documents to use when presenting the project to internal stakeholders, who had deliverables to the project. This gave the team a common ground for understanding what the project goals where, and how we designed the system to meet these goals.

Not surprisingly, based on the current state of systems engineering in the company, the results show that the A3AO is a new format to the project team. We believe that the lack of knowledge of model based systems engineering (MBSE) or other SE methods makes the members unbiased, with no preferred SE tool. This is positive in one way, but it also presents the challenge of not being able to compare A3AO to other SE tools. This is also the case for the nature of the project. This is the first development project of multi-million dollar size within the company. The lack of grounds for comparison is a drawback when it comes to benchmarking the impact of SE on the project. On the contrary, there is a positive attitude and willingness to test new tools for communication and knowledge sharing. Senior management supported the research approach, and allowed for this research to take place. Still, there were some resistance to involve the end client in the research.

The end client was not formally involved in the research. Ideally we would like to get more client feedback, as client feedback plays a vital role when evaluating further use of new tools such as the A3AO. Fortunately, we were given the opportunity to share the A3AOs with the client, and received some feedback. The feedback on the A3AO confirms that it is a format that is new to the industry. Therefore, a proper introduction is needed to get an understanding of how it works. The feedback on

the A3AO and the requests for more schematics and models also confirm that model based systems engineering (MBSE) is welcomed in the oil and gas industry.

Based on feedback we see that use of the format described in other research (Broches, 2010) may have resulted in an increased number of questions from the participants in the study. By adopting standard terms and expressions used in the oil and gas industry, and reduce the number of views, we could have made it easier for the users to follow the logic of the A3AO format. In particular we learn that the "equipment interface overview" (see attachment), adds little value when the "detailed equipment overview" is available.

Conclusion

The main goal with this paper was to investigate how A3-Architectural Overviews (A3AO) can add value as a project management tool during early-phase systems development. We looked into development of two new services for autonomous subsea pipeline-inspections. The autonomous systems were still in the initial development phase when business plans were made and clients requested information on future systems. The project manager created two A3AOs prior to an initial field trial where they should test challenging systems features. We can conclude that the A3AO added value as a communication tool. It helped to obtain tacit information about the system from the technical experts, to communicate the overall system to the project participants, and not the least to communicate technical content to management and customers.

Different parts of the organization evaluated the A3AO differently. Project personnel with limited system knowledge got an enhanced and quick understanding of the project goals. Top management appreciated the format as a tool for communicating a future business case. The A3AOs made in this research were even included in a business plan made for Company's board of directors. Clients emphasized that the use of models and schematics is needed as an addition to textural documents. Non-technical and management personnel rate the value of A3AOs higher than the technical experts when it comes to communication of implicit system knowledge. On the other hand, the same technical experts transferred significant technical knowledge to the project manager as they discussed over the A3AO. This was tacit knowledge that the project manager might not have received otherwise.

Future research should investigate how A3AO adds it value and by how much, and also how to implement A3AOs in the initial stages of system development. Participants in our study believed that promotion of A3AOs from top management was required to ensure continued use of this tool within Company. They also suggested that the application of A3AOs will benefit from adapting vocabulary from the subsea industry. With the ongoing change towards more autonomous operations we find the A3AOs to have a wide range of application areas. There is a need for a visual communication tool involves the experts early in the development, and forces structured documentation of systems aspects which in turn enable knowledge sharing between experts, business developers, clients and decision makers.

References

Almeida, MV, & Soares, AL 2016, 'Knowledge sharing in project-based organizations: Overcoming the informational limbo', *International Journal of Information Management Vol. 34, Issue 6*, 770-779.

BKCASE Editorial Board 2017, *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*, v. 1.9.1 Cloutier, RJ (Editor in Chief). Hoboken, NJ: The Trustees of the Stevens Institute of Technology. Accessed October 2019. www.sebokwiki.org.

Borches, PD 2010, 'A3 Archtecture overviews - A tool for effective communication in product evolution', PhD thesis, University of Twente (The Netherlands).

Brussel, FF and Bonnema, GM 2015, 'Interactive A3 architecture overviews: intuitive functionalities for effective communication,' *Procedia computer science*, *44*, 204-213.
DNV 2009, *Reccommended Practice DNV-RP-F116 - Integrity Management of Submarine Pipeline systems.* DNV (Norway).
Eisner, H. (2008). *Essentials of Project and Systems Engineering Management.* New Jersey: John Wiley & Sons.
Equinor 2018a, *Technology Readiness Level.* Acquired from Equinor (Norway).
——— 2018b. Technology Roadmap for Underwater Intervention Drones. *Subsea Operations Conference,* Haugesund (Norway).
Honour, EC 2004, 6.2. 3 'Understanding the value of systems engineering,' In *INCOSE International Symposium*, Vol. 14, No. 1, pp. 1207-1222.
ISO 2015, *Quality Management systems Requirements (ISO 9001:2015).*
Jamieson, S 2004, 'Likert scales: how to (ab) use them,' *Medical education*, *38*(12), 1217-1218.
Kanter, RM 2012, Ten reasons people resist change. *Harvard Business Review*, *74*.
Løndal, S and Falk, K 2018, 'Implementation of A3 architectural overviews in Lean Product Development Teams; A case study in the Subsea Industry,' In *INCOSE International Symposium*, Vol. 28, No. 1, pp. 1737-1752.
Muller, G 2013, 'Systems engineering research methods', *Procedia Computer Science*, *16*, 1092-1101.
NORSOK 2010, *Life extension for transportation systems*, Norsok standard Y002, December (Norway).
Oreg, S 2003, 'Resistance to change: Developing an individual differences measure', *Journal of applied psychology*, *88*(4), 680.
Joshi, A, Kale, S, Chandel, S, & Pal, DK 2015, 'Likert scale: Explored and explained', *British Journal of Applied Science & Technology*, *7*(4), 396.
Greene, J and Stellman, A 2018, *Head First PMP: A Learner's Companion to Passing the Project Management Professional Exam*, O'Reilly Media.
Shook, J 2008, *Managing to learn: using the A3 management process to solve problems, gain agreement, mentor and lead*, Lean Enterprise Institute.
Solli, H and Muller, G 2016, 'Evaluation of illustrative ConOps and Decision Matrix as tools in concept selection,' in *INCOSE International Symposium*, Vol. 26, No. 1, pp. 2361-2375.
Sols, A 2014, *Systems Engineering Theory and Practice.* Madrid, Spain.
Tranøy, E and Muller, G 2014, 'Reduction of Late Design Changes Through Early Phase Need Analysis,' *INCOSE International Symposium*, Vol 24, No 1.
Muller, G, Wee, D, and Moberg, M 2015, 'Creating an A3 Architecture Overview; a Case Study in SubSea Systems,' In *INCOSE International Symposium*, Vol. 25, No. 1, pp. 448-462.

Biography

Tore Boge has been working in the oil and gas industry for 8 years. In 2010 he received his bachelor's degree in subsea engineering from the University College in Bergen. He has been working as a project engineer in Aker Solutions for 2.5 years. And as a project engineer, offshore manager and project manager in Company since 2012. He has got experience from onshore refurbishment, light subsea construction, deep-water salvage, and subsea inspection projects. In November 2018 he received his Master's degree in systems engineering from the University in Southeast Norway.

Kristin Falk. Dr. Kristin Falk has lead technology teams in start-ups, SME and large corporations primarily in the energy industry. She has been in the industry for more than twenty years, where she has introduced complex systems for integrated operations, subsea processing, and automated drilling. She is teaching Systems Engineering at the University of South-Eastern Norway. Her research focus is 'how to create systems fit for purpose in a volatile, uncertain, complex, and ambiguous world'.