30th Annual INCOSE international symposium
Cape Town, South Africa
July 18 - 23, 2020

Towards Systemic Handling of Requirements in the Oil and Gas Industry – a Case Study

Kirsten Helle
TechnipFMC
P.O Box 1012, NO-3601 Kongsberg, Norway
+47 982 33 875
kirsten.helle@technipfmc.com

Siv Engen
University of South-Eastern Norway
P.O Box 235, NO-3603 Kongsberg, Norway
+47 416 25 503
siv.engen@technipfmc.com

Kristin Falk
University of South-Eastern Norway
P.O Box 235, NO-3603 Kongsberg, Norway
+47 97586909
kristin.falk@usn.no

Abstract. This paper presents valuable insights on implementation of requirement management system in the oil and gas industry. The focus on cost reduction in this industry has led to an urgent need for a more systematic requirement handling.

The paper presents a survey asking international oil and gas actors for status and needs with respect to requirement management. Furthermore, the paper presents experiences from implementing a Requirement Management System at a major supplier in the industry.

The international survey confirms that the oil and gas industry is lagging behind other industries when it comes to implementation of systematic requirement handling. A second result is that the paper shows a clear positive effect when implementing a requirement management system at a single supplier. In conclusion, by implementing such a system, the industry will limit the number of requirement, save cost, and reduce the need for testing and validation. To achieve this, companies will need management support and collaboration across the supply chain. A cross-industry implementation would result in a significant effect, both in terms of reduced cost and increased flexibility.

Introduction

Oil and gas operators and suppliers are striving to improve their work processes. At the start of this millennium, there was a high level of activity in the oil and gas industry, accelerating significant economic growth for all its actors. The focus was on time to first oil. This resulted in tailor-made systems, and an increasing cost level (OG21, 2015). A severe downturn five years ago changed the perspective of the industry, and moved the focus towards low cost. The oil and gas industry is now realizing that other industries are using systems engineering to cope with similar complexity (Muller & Falk, 2018).

In systems engineering, requirements engineering is an essential element. Effective requirements engineering is key in every organization in order to “guide the ship, and to keep pace with the rising tide of complexity” (Hull, Jackson, & Dick, 2005). For large project, implementing require management systems is a necessity for handling and tracing requirements (Hull et al., 2005; NASA, 2007).

The requirement engineering in the oil and gas industry has historically been text based and managed in several word documents and Excel sheets. The requirement specifications provided by the client oil company are typically extensive and detailed, giving a mix of requirements and detailed requirements (Damien Wee & Muller, 2016; Engen, Falk, & Muller, 2019). The use of text-based prose in the industry and company standards makes it difficult for end users to fully understand and verify the requirements (Zager, McKinney, Reed, 2019). The non-stringent formulation of requirements is one of the reasons for cost increases in this industry, as it hinders flexibility(Falk, Ulsvik, Engen, and Syverud 2019).

To improve work processes, the industry has started to adapt requirement management systems. The purpose is to handle the considerable number of requirements and to improve the quality or the requirements. Examples of such implementations are given by (Baker et al., 2016; Zager, McKinney, Reed, 2019). This topic is also a key concern for the INCOSE Oil and Gas Working group. After its creation about five years ago, the group has arranged several workshops and meetings to discuss the topic and share experience and opportunities across the supply chain. The industry sees a clear benefit of adapting requirement management systems, and of moving towards data-centric tools.

However, implementing requirement management systems in large organization is not a straightforward task. In a review, (Kauppinen, Vartiainen, Kontio, Kujala, & Sulonen, 2004) conclude that implementing a requirement process is both challenging and complex. They find that the success is dependent on human, organizational, technological and economic factors. (Beecham & Rainer, 2002) found that the problems that companies experience related to implementing requirement management systems are primarily organizational.

In this paper, we report from the status of the implementation of requirement management tools in the industry. The research questions we aim at answering are:

- *What is the maturity of requirement management in the industry?*
- *What are the benefits and challenges from implementation of requirement management systems in a supplier company?*

The structure of the paper is as follows. This introduction contains a brief literature review on implementation of requirement management in the oil and gas industry. Next, we report from a survey performed in 2019 within the INCOSE oil and gas Work Group with thirty representatives in seventeen different companies. The main part of this paper is a case history from a global supplier of equipment to the oil and gas industry with thirty-two thousand employees in forty-four countries worldwide. We present the stepped implementation of the requirement management system, and the effect of this implementation. Finally, the paper discusses and concludes on the findings.

Requirement management in the industry – an international survey

In April 2019 the INCOSE Oil and Gas Working group hosted a workshop in Paris with 30 representatives from 17 different companies in the oil and gas industry. The topic for the workshop was requirement management, and the companies were sharing their experiences from their respective companies. Following the workshop, we sent out a survey to all participants. In total, we received 13 responses from representatives from 9 companies with different nationalities.

In the survey we used a five-point Likert scale (Likert, 1932), with response alternatives: *Strongly disagree (1)/ disagree (2)/ neither agree nor disagree (3)/ agree (4) / strongly agree (5).* For all questions the respondents had the possibility to answer *not applicable* if they had not been involved or exposed to the given tool or method. The presented survey-results do not include the responses: *not applicable*. To evaluate trends in the results, we looked at the median (Boone & Boone, 2012) of the responds. Were applicable, we have used the Net Promoter Score (NPS), considering *strongly agree* as a promoter, *agree* as neutral and *neither agree or disagree*, *disagree*, and *strongly disagree* as detractor (Reichheld, 2003).

In the following, we present the key result from the survey. Figure 1 shows the distribution of the respondents with respect to company affiliation and company category.

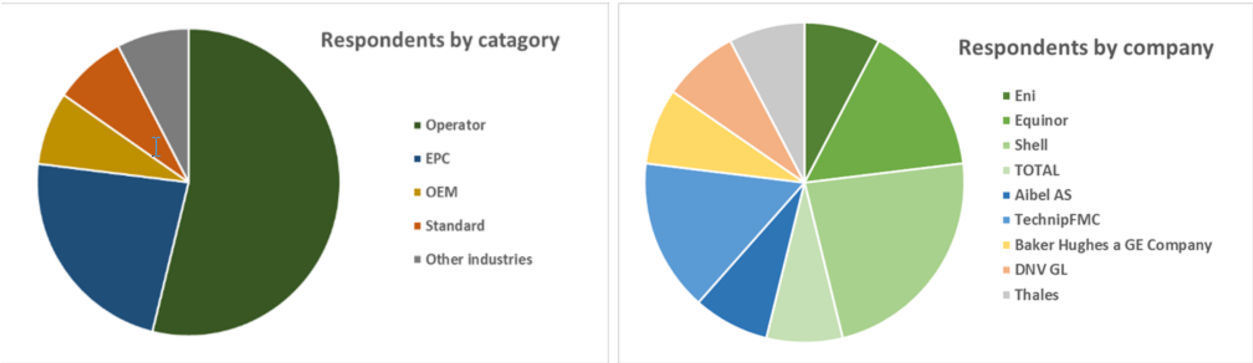

Figure 1. Distributions of respondents in company and company category.

Figure 2 shows how the respondents perceive the general systems engineering competence in the industry, and how they perceive it compared with other industries. We see a clear trend that the respondents consider the competency in the oil and gas industry as very poor (NPS of -11), and that it is significantly worse than other industries with comparable systems complexity (NPS of -12). We also find that the majority of the respondents agrees that the industry is immature in implementing systems engineering (NPS 1).

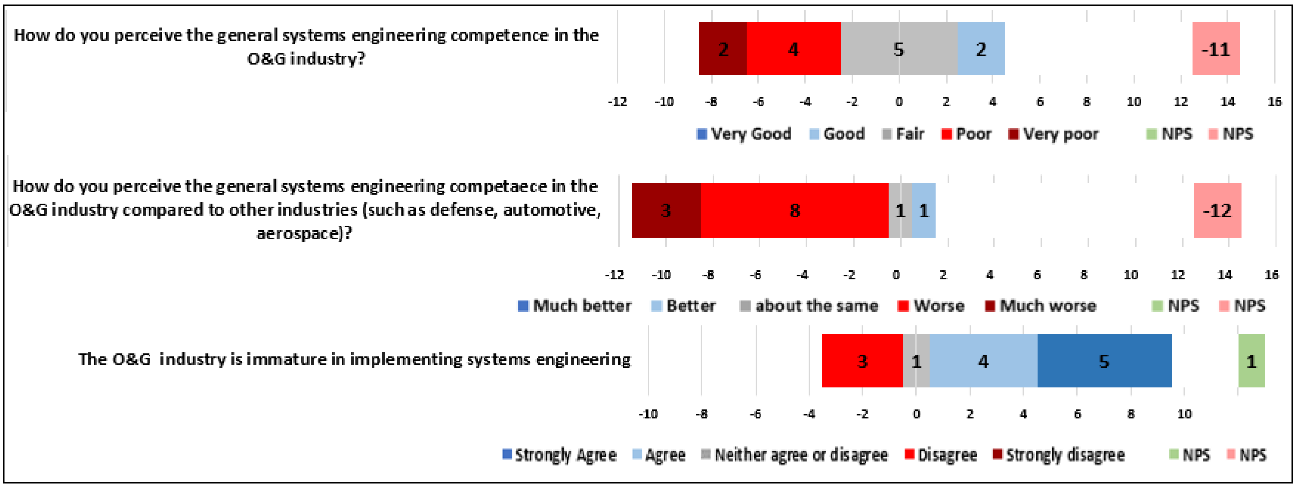

Figure 2. Survey results - systems engineering competency in industry

The survey also opened for comments. Responses to *why the industry is immature when it comes to requirement management* include:

- The market situation has been very good - it has not been an economic necessity
- Low push from regulatory bodies
- Taylor-made designs
- Conservative culture
- Complex contract model
- Lack of multidisciplinary personnel and organizations

We also asked if they believe that the industry would benefit from implementing systems engineering methods, and Figure 3 shows that the percipients clearly see the benefit of such implementation. When asked, "*which systems engineering methods the industry would benefit most of implementing*", eleven out of the respondents highlighted requirement engineering. Other methods that the respondents find attractive includes business and mission analysis, systems architecting, model-based systems engineering, and configuration management. Several of the respondents emphasized that the benefit comes from a full Systems-Engineering implementation in the companies. Following this, the survey asked whether the industry would benefit from implementing a requirement management system. As Figure 3 shows, nine persons *strongly agreed*, two *agreed*, while only one person *disagreed* to this question.

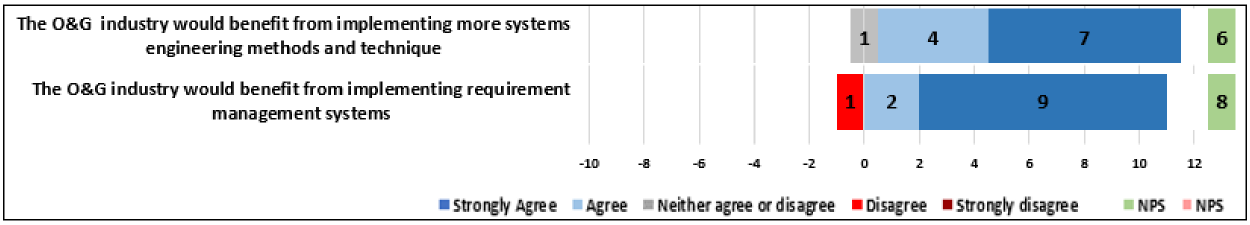

Figure 3. Survey result - implementation of systems engineering and requirement management in the oil and gas industry

In the workshop, it was clear that the participants saw clear benefits of implementing requirement management systems. However, they experienced challenges regarding implementation in their organization. From the survey result, Figure 4, eight of the respondents agree or strongly agree that the culture in the industry challenges the implementation. Five respondents are neutral or disagree. The same trend is seen as responses to the statement: *lack of system engineering competence is a challenge for implementation in the industry*. To the final statement in Figure 4: *the lack of systems engineering competence in my company is challenging the implementation…*, only five respondents agree or strongly agree, while seven disagree or are neutral.

Figure 4. Survey results - challenges of implementation in industry

To sum up; the survey indicates that the industry is lagging behind comparable industries in implementation of systems engineering methodologies. At the same time, the respondents see a clear benefit of implementing such methods, and requirement management is highlighted as a first priority. Furthermore, the companies might have the competence to implement requirement management systems. However, the organization culture and overall systems engineering competency in the industry are challenging this implementation. This is in agreement with the findings in literature that highlights organizational factors as a challenge for implementation (Beecham & Rainer, 2002; Kauppinen et al., 2004).

Implementing a Digital Requirement Management System

This section presents experiences from implementing a requirement management system at a major oil and gas supplier. This implementation was based on inconsistent and text-based client requirements (design basis). The requirements also contained a large number of standards and specifications.

This section is structured into sub-sections. The first sub-section indicates the traditional way of handling requirement in the oil and gas industry. The following three sub-sections describe the three main steps that the Supplier followed when implementing a requirement management system

1. Parsing the Text-based Requirement Documents
2. Select tool, work process and test digital requirement system (database)
3. Implementation of Digital Requirement Management System into organization

The final sub-section shows the status of implementation.

As Is – The traditional way of handling requirements in the industry

All contracts between the Customer and the Supplier references a list of specifications the Supplier shall fulfil. A specification, is a document containing requirements for a system or part of a system or a product. The specifications listed in the contract contains the Customer requirements and these requirements are named external requirements and the specifications is named external specifications. An example is the ISO13628-1, that is an external specification with external requirements. The derived requirements from the contract are named internal requirements. In order to describe the features and the behavior of the system, part of the system or a product the Supplier shall deliver, the external requirements are derived into internal requirements. The internal requirements are included in either in a system specification, sub-system specification or a product specification, see Figure 5.

Table 1 lists characteristic numbers for eleven large projects performed in the period 1991-2019. The table shows the number of external requirements specifications included in the contract for the each project. The trend indicates a reduction in the number of external specifications over the last years, but still there is large amount of data to keep track of. A typical industry standard, such as the ISO13628-1, consists of 240 pages with requirements listed.

Table 1: Number of external specifications for different subsea projects in the years 1991-2019 for different customers.

Customer	Project type	Standards	Customer specifications	Governmental specifications	Type of Customer	Total number of specifications	Year started
B	Large	0	24	6	Large	30	1991
B	Large	23	33	6	Large	62	2007
C	Large	22	235	0	Large	257	2011
B	Medium	21	49	6	Large	76	2011
F	Large	70	119	0	Large	189	2012
A	Medium	75	112	4	Small	191	2014
B	Large	11	57	4	Large	72	2015
D	Medium	69	64	6	Small	139	2017

B	Large	15	93	4	Large	112	2018
B	Large	9	45	4	Large	58	2019
E	Large	61	39	6	Small	106	2019

Traditionally, a copy of the external requirements are stored on the Suppliers disk, or found in subscription agreements such as IHS(Information Handling Services). Supplier representatives writes the specifications for the project in Word with manual references to the origin of the requirement. Figure 5 shows the traditional way of working with requirements with no coupling between the different specifications.

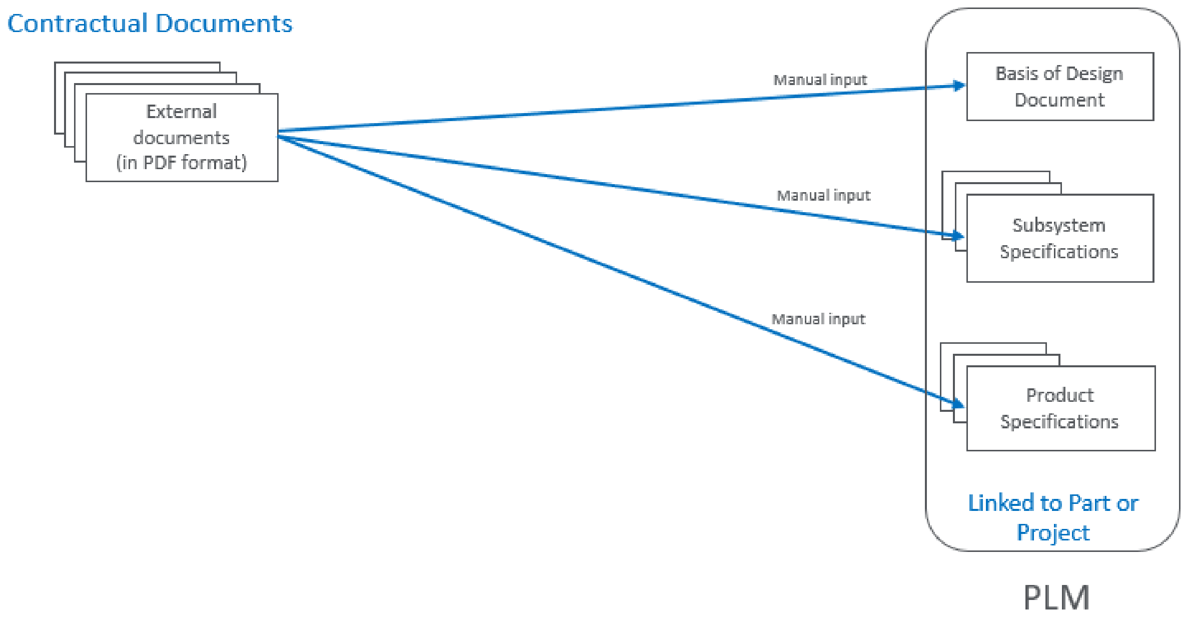

Figure 5. The traditional way of partitioning Customer specifications into Basis of Design, sub-systems requirements and product requirements

First step – Part the Text-based Requirement Documents

Our overall goal was to get control of the requirements. We started by making sense of the text-based requirements. A driver for initiating this work was late delivery of the system requirements specifications in very large projects.

As a first step, the systems engineering department split the Word documents into a spreadsheet. They did this in collaboration with the product lines, and collected *typical requirements* on all levels in this huge Excel spreadsheet. As they did this, they also identified systems requirements based on the following rules; if two or more sub-systems or products used the requirement, they classified it as a systems requirement. Figure 6 shows an example spreadsheet.

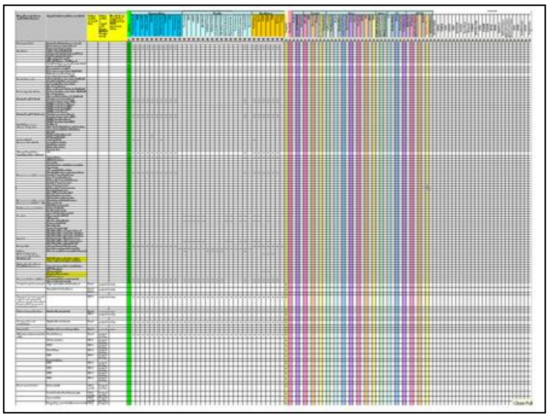

Figure 6. Spreadsheet with requirements

The first Excel spreadsheet contained 1100 requirements. After cleanup, the result was approximately 200+/- system requirements. This “template spreadsheet” should be used for all systems projects. To be able to save properly this new systems specification template, the engineers converted the spreadsheet to a table in a Word template. Finally, they stored this template in the Product Life-cycle Management (PLM) system at the Supplier for re-use purposes.

Second Step –Select Tool, Create Work Process, and Test the Digital Requirements System (database)

Select Tool. Going forward, we wanted more control of the origin of the requirements, better traceability, and an improved way of working with change management than huge excel spreadsheets. We searched for an appropriate tool or database. To select the tool, we used the following requirements; reusability, traceability, handling of exception and clarifications, change management, provide a standard way of working with requirements, and improve quality and end-user satisfaction. After performing a tradeoff study, we ended up choosing a tool from a well-known supplier.

Configure: We realized that the RMS tool was not ready to use. We had to configure to fit the Supplier’s way of working. The industry still requires a document as an output. This required both development and configuration of the tool. To configure the tool was straightforward. For example, our discussions related to design of the layout (i.e. Word or PDF files) included:

- how shall the layout of the output report/document from the tool look like (the tool is a database)?
- shall the requirements ID be shown on the layout?
- what about the size and the layout of the traceability information?
- how to handle and show revision control of the requirement itself ?

Figure 7 shows an example of a Word output format as communicated to the Customer.

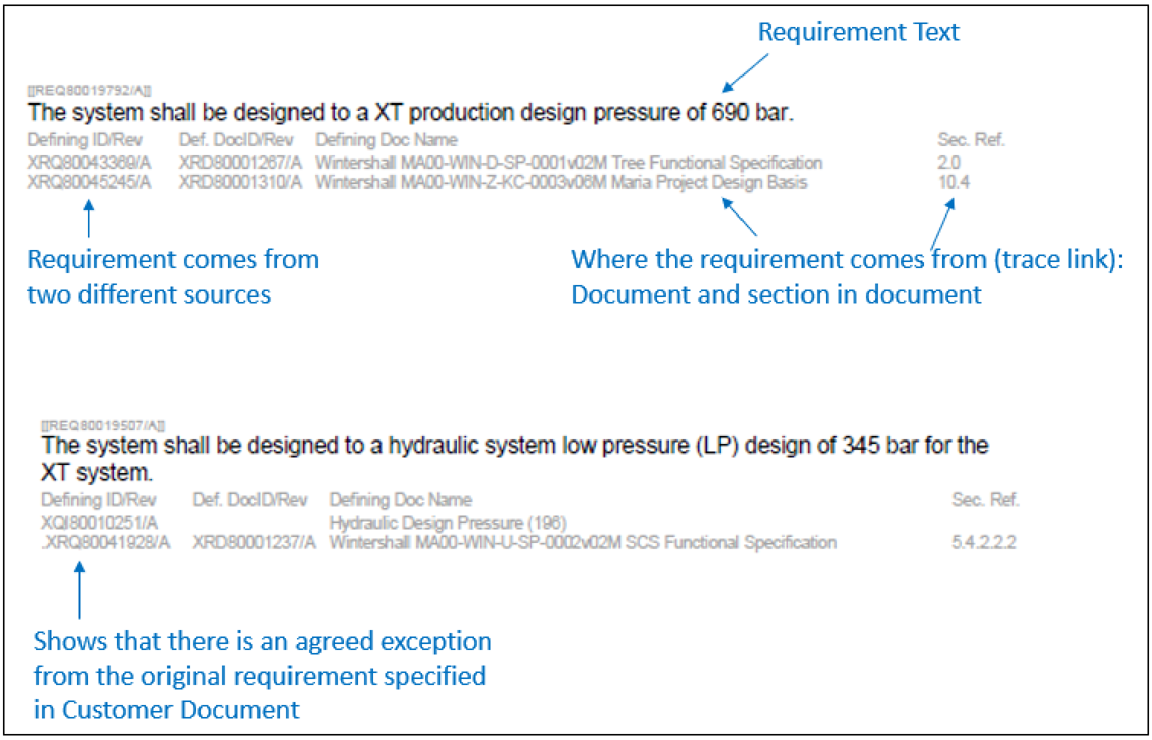

Figure 7. Example of Word output layout. Blue text is explanations in this figure and not sent to the Customers.

Testing the Tool. We performed initial testing, and then created three levels of requirement specifications; a system, sub-system and a product specification. By then we had gained enough practices to use the tool on a real project. We started by creating a shadow of a systems specification for a specific project. The purpose was to see whether we were able to replicate the content of the systems specification by the tool. The RMS has a functionality denoted “duplicate”. We created templates for different levels of requirements specifications, and then applied the duplicate functionality to create new specifications. We experienced that, using this functionality, we were able to reuse information such as the actual requirement text and its traceability.

Third step: Implement a Digital Requirement Management System

Implementation of such a big system implies changes to the work processes. For a successful implementation, it was important to illustrate and communicate how the tool is helping the process of writing specifications. Figure 8 illustrates how we structure the requirements handling using RMS at present.

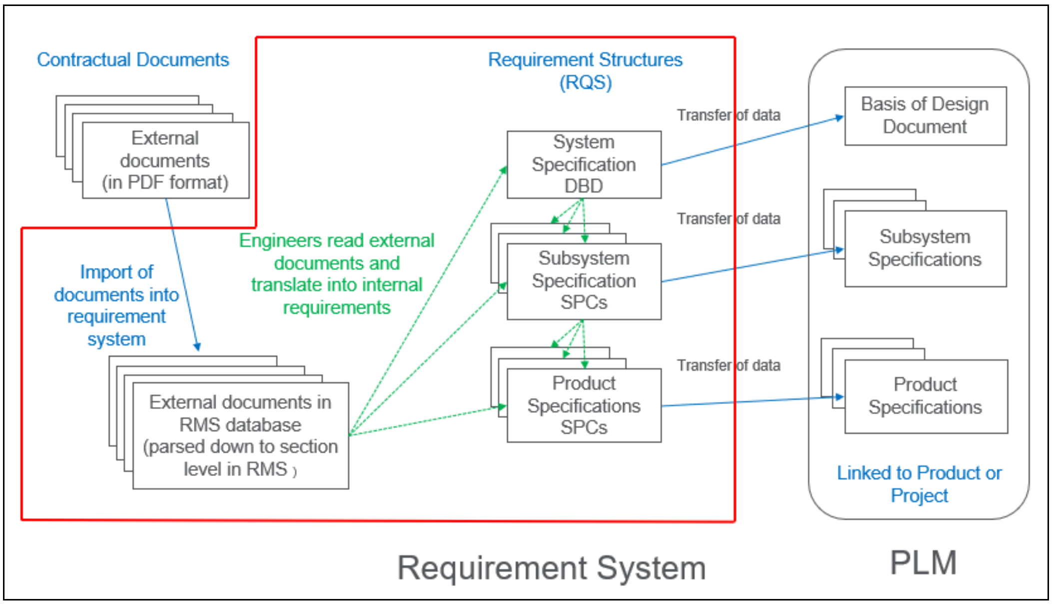

Figure 8. The "big picture" for requirements handling as per today

The data structure inherent in the tool gives us the flexibility to have several levels of requirements, including system, sub-system and product levels. Hence, the requirements can be defined on the appropriate level. We were able to allocate the right requirements to the right level of the system. The tool is set up to be able to handle exceptions and clarifications agreed in contracts with different clients. Figure 9 shows the internal structure of the tool. XRD is the external requirement specification. It can be an ISO or a client specification. XRQ is the actual requirement in an external specification, RQS is the internal specification, PGH is section heading, REQ is the actual requirement and XQI is used for including an exception or a clarification to a requirement.

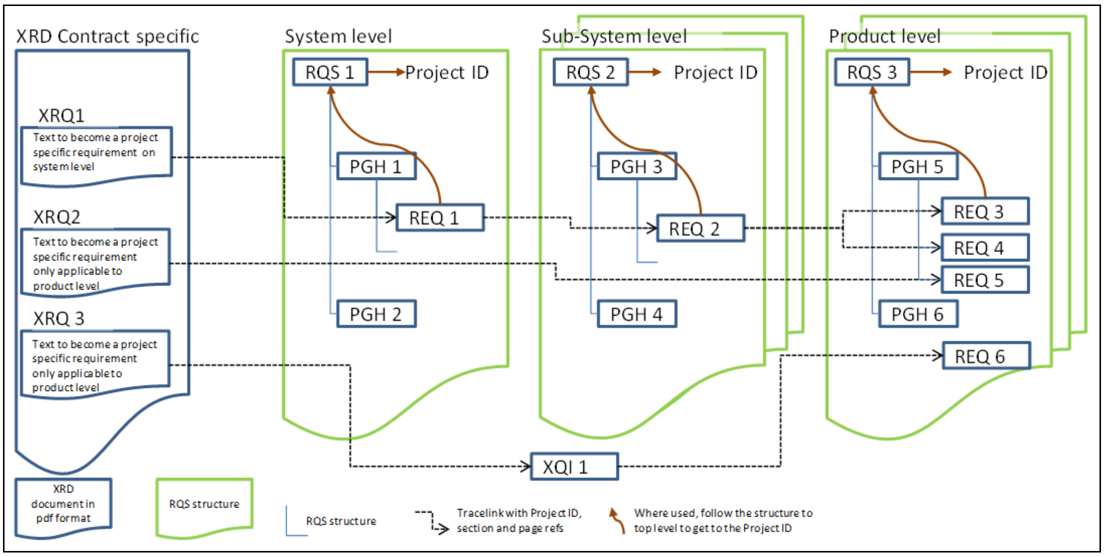

Figure 9. Flowdown/Relationship between Requirements

External specifications changes over the years and from contract to contract. Today these are normally communicated as a pdf file with no revision lines included in the margins. This makes it challenging to grasp all the changes to the external specification.

The Supplier is importing each external requirement specification in a certain pattern; each section is "one" requirement, it is easier and less time consuming to understand. To highlight what have been changed, the tool uses red to indicate addition/deletion, yellow indicates changes and green indicates no change. Figure 10 shows an example of a comparison-report. This information can also be used for knowledge purposes. New tenders/studies can easily run the report that compares and highlights changes. We need to pay special attention to such changes in the next contract or solution we deliver.

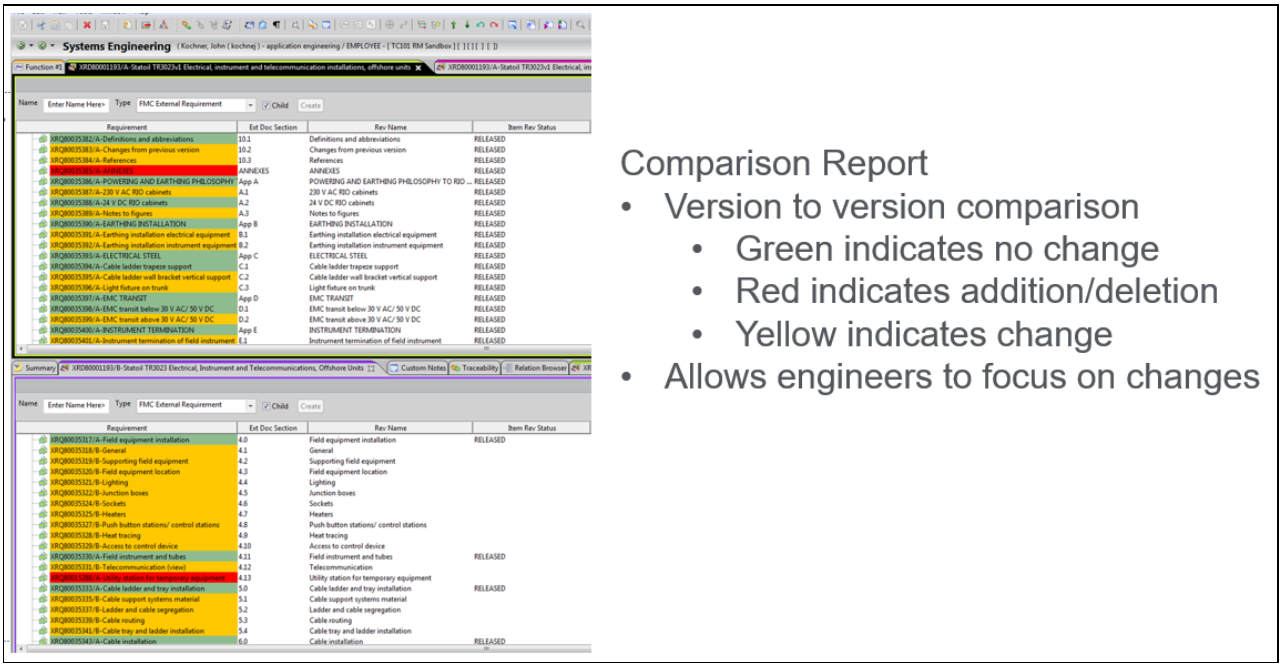

Figure 10. Example of comparison reports

When we used a tool to help structuring how requirements relate to each other, we got a better understanding of how a requirement can affect the whole system. The traceability report includes a tree structure. This report makes it easy to see how a requirement is linked to/fulfil or is derived from a requirement on a higher level. We use this information for preparing a design review on a lower level of the system or on a product. This enables us to see whether the design has taken into account a requirement from the systems level, hence check expectation to the design on a lower level. Figure 11 shows the traceability report and the tree structure of the requirements for a project.

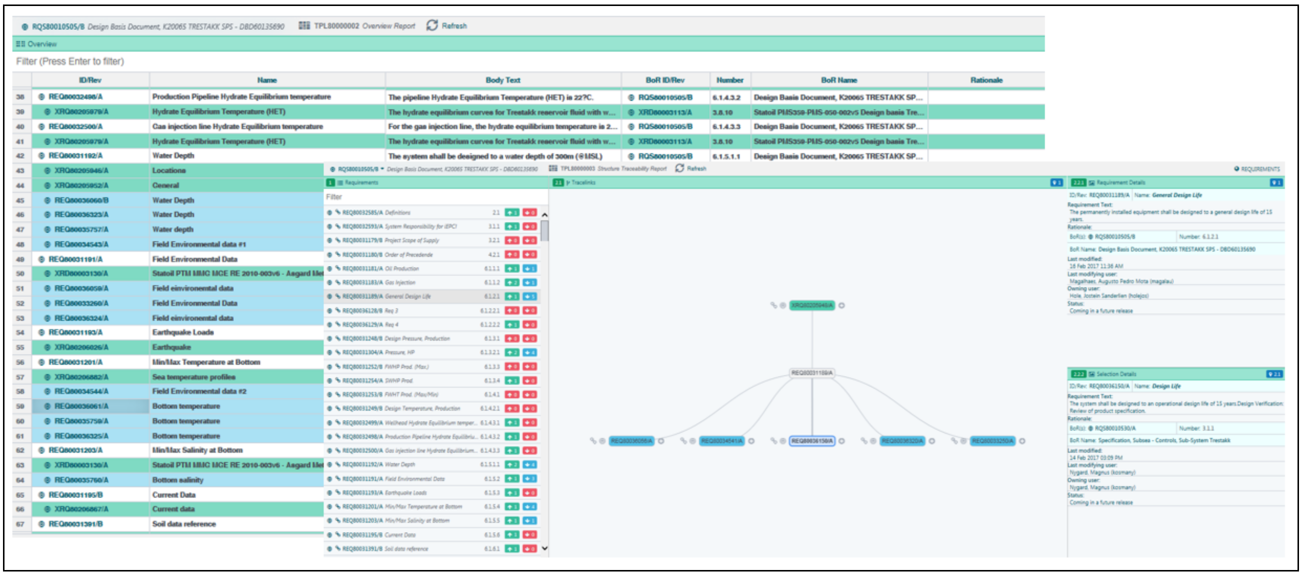

Figure 11. Report with tree showing traceability and conformance to requirements

Experiences from Using a Requirement Management Systems

The requirement management system (RMS) is now in operation with at the Supplier. The first sub-section shows the status of implementation, that is where the Supplier has used RMS.

The preceding sub-sections present two Cases where the Supplier used RMS at Product level and at Systems level, respectively. We have measured how the RMS can save time used on searching for compliance, time used to answer questions related to conformance to requirements, and time used for change management. More generally, we have investigated how a requirement management tool can help the engineers in their daily work. Customers, sub-suppliers or colleagues, often ask the systems engineers: “Is this product fulfilling the requirements of the Clients or Governments,” or “what is the actual requirement for this product or solution?” To answer this, we have counted additional work related to not having RMS. Our results show that such a RMS-tool for organizing and handling requirements will results in cost savings. However, the organization has to invest in work upfront.

Status of implementation

Table 2 shows where the Supplier has used the RMS, and at which levels of the system they have included. The Supplier does not use RMS in the whole organization. There are several reasons for this. The most common feedback we have heard from the engineers at the Supplier is that:

- timing between study and execution is very short,
- not able to start early enough to capture the requirements into the tool,
- mindset for new way of working is challenging,
- it’s a new tool,
- it is a more rigid working process than using «Word»,
- writing requirements specifications in “prose” is perceived as easier.

We conclude that implementing a new way of working in a huge organization in a mature industry is not straight forward.

Table 2: Status of RMS used in different projects

	System DBD	Safety	Sub-system 1	Sub-system 2	Sub-system 3	Sub-system 4	Sub-system 5	Product 1	Product 2	Product 3	Product 4	Product 5
Project 1												
Project 2	x		x		x	x		x				
Project 3	x						x					
Project 4	x		x									
Project 5	x											
Project 6	x											
Project 7	x		x		x	x	x	x		x	x	
Project 8	x											
Project 9	x	x	x	x	x	incl in DBD		x		x	x	x
Project 10	x											
Project 11	x				X							
Project 12	x	x				x				x		
Project 13	x		x		x	x						

Collaboration Some customers have already invested in a RM tool. The Supplier has tested import of external specifications from two Customers and one specification from a Standardization Organization. The format communicating on is ReqIF (Requirements Interchange Format). This is a XML file format that can be used to exchange requirements (Wikipedia, 2019) along with its associated metadata, between software tools from different vendors. Each Customer and Supplier need to map the format to its internal schema. When working systematic with requirements we will probably save time when we import the data in a known format instead of partitioning each pdf file into a RM tool.

Another thing is that starting to exchange requirements on a more digital format we question whether it will be easier to limit number of requirements specifications and requirements knowing that AI (Artificial Intelligence) or machine reading can be used on big data to recognize patterns.

Case 1: Product Level

This first case presents experience from a medium sized project run by the Supplier. The case is limited to a specific product that the Supplier designed and delivered. Since the industry aim at offering standardized equipment, this example is valid for more products. Contracts usually include exceptions & clarifications that the Supplier has to evaluate for different products.

For this specific case, the product proposed by the Supplier was a copy from a previous project. The tender team at the Supplier did not properly review the product specifications related to the customer specifications prior to contract award.

We have estimated the number of hours spent for writing emails and attending meetings to clarifying the requirements for the product in early phase of a project, Figure 12. We have done this both with RMS when the Supplier had product requirements stored in RMS, and without RMS when the requirements were captured the "old way". The “old way” implies writing specifications as prose without digital traceability.

In Figure 12, the first set of bars denoted "E-mails" show the number of hours used by the Supplier to clarify the requirements for the product. The engineers working without RMS estimate that they sent approximately 20 emails to get confirmation of the design and compliance. We have estimated half an hour for each e-mail, including writing, reading and answering the e-mails. The second set of bars in Figure 12 shows time spent for “Meetings”. The engineer called for two more meetings of one hour each with four attendees to be sure that they used the correct standards to verify compliance. Only after the emails and meetings, the engineer decided that this product was fit for purpose.

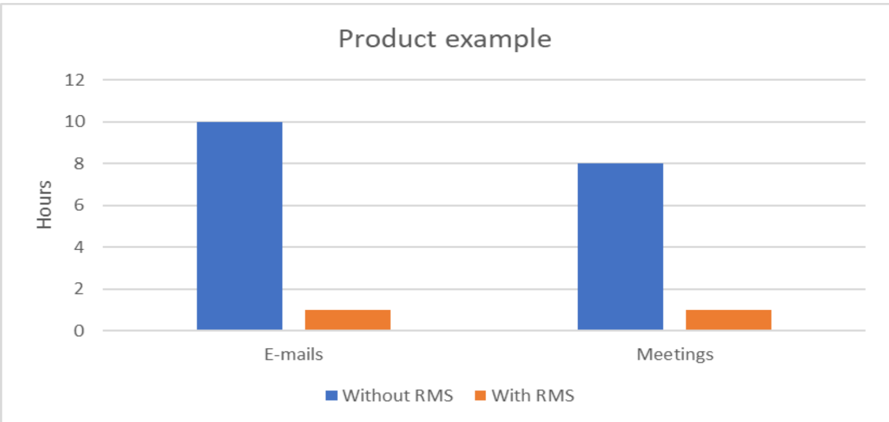

Figure 12. Number of hours spent for emails and meetings to clarifying the requirements for an existing product with (orange) and without (blue) RMS.

RMS can digitally trace information to the origin of the requirements specified in the Customer contract. The organization could have avoided both e-mails and meetings if they had properly captured the requirement for the product in RMS.

Adding up, the Supplier could save 16 hours on one single product for one single project. A medium-sized project delivers approximately 300 main pieces of equipment. Say that each equipment consists of in average 10 components or products and some products need clarifications. Then the Supplier can save 16 hours x 30(10%) main equipment + 16 hours x 20 components(<1%) = 800 hours on clarifications by not having to handle emails and participate in meetings related to clarifying the product requirements for existing products.

RMS allows for including information about exceptions and clarification (E&C) from previous projects for each single product requirement, as Figure 9 illustrates. For the product in Case 1, if RMS had contained E&C information, the timesaving of introducing RMS could have been even higher than what we show below. Furthermore, the team could have avoided the manual work of reading the E&C's in the contract, as well as avoided searching and comparing the actual requirements written in prose specifications for each product.

If the Supplier had implemented all the product specification through RMS, and linked to the industry standards, the Supplier could have saved even more hours. This includes both looking up the traced requirements in RMS for the product during project execution, as well as building knowledge and more visibility on actual product requirements for use in the tender phase.

During project execution, engineers were searching for information to explore whether the product fulfilled a specific requirement. This was a cumbersome job. The first hurdle was to find the correct number of specifications for the product, and then, it was to find the correct information in the document written in prose with no traceability. During our research, we received feedback from users of RMS. They claimed that, if the Supplier had linked requirements for a product to the system and product structure in RMS, they were able to searching for information related to specific requirements in "two minutes", hence immediately, just clicking the buttons.

Case 2: Saving engineering hours at Systems level

The Supplier has used RMS for the systems specification in 14 projects. Here, we zoom in to the Systems level of two complex projects lasting for two years. One of these incorporated the requirements through RMS and the other did not. The case illustrates how RMS affected the workload related to requirements and saved engineering hours in project execution.

Figure 13 shows the number of hours spent performing tasks related to requirements. We have identified four such main tasks: write specifications, discuss origin of the requirements, handling Variation Order Requests (VOR), and demonstrate conformance to the requirements. The blue bars in the figure show the number of hours without RMS, and the orange bars show with RMS. These numbers are assuming that the organization used RMS for all the specifications in the project.

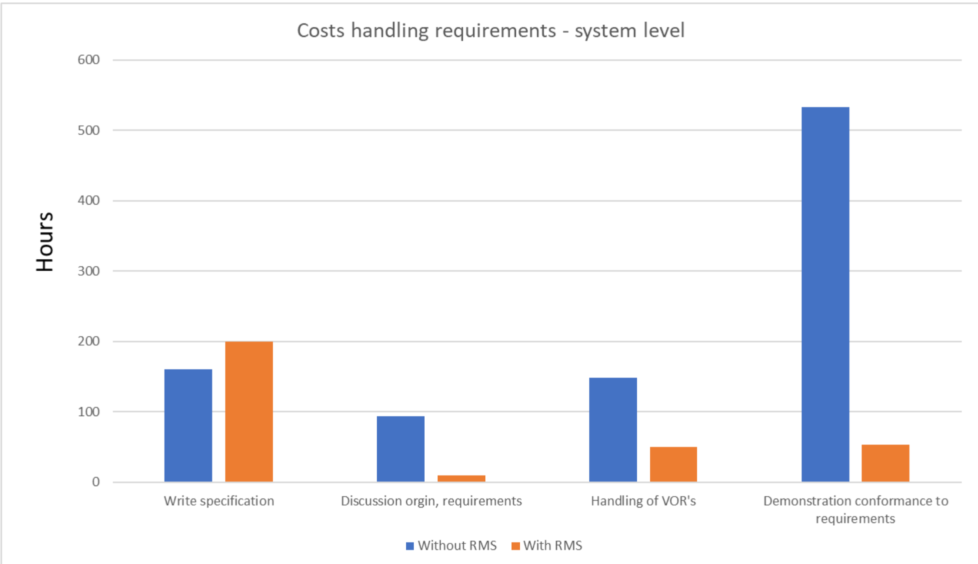

Figure 13. Number of hours spent on requirement-related issues in a two-year delivery project with and without RMS

Our experience shows that writing the system specification in RMS takes approximately 15% more time than writing the specification in Word. The RMS forces the user to trace each requirement to its origin, an external specification, in order to create traceability. When the user had done this effort once, the discussions about the origin of the requirement were stored and easy to re-find.

When project resources were changing, the knowledge related to requirements was difficult to hand over to others without RMS. A result was regular discussions related to the origin of the actual requirements for approximately 90 specifications created in a project. This refers to the second set of bars in Figure 13.

RMS also simplified change management. Changes in specifications from Customer were the reasons for such changes and other variation orders(VOR's). Demonstrating conformance to requirements was quicker and significantly easier to facilitate with RMS. The project teams estimate that a person typically answered one question per week for two years related to the requirements. Moreover, the person spent in average 60 % less time searching for answers if they had requirements stored in RMS. See the third set of bars in Figure 13. The same trend occurred for demonstrating conformance to requirements required by the Customer. The fourth set of bars showing amount of hours used for this effort on one project using a lot of hours searching for the origin of the requirements, when it could have been stored in RMS from the start. Looking at first bar in Figure 13 shows that there has to be an effort done upfront to gain that level of maturity for handling requirements in a digital tool to achieve these savings.

Summing up the numbers from Figure 13, the Supplier could save more than 60 % of the engineering hours related to requirement if they used an RM tool. For our Case this could counts for a saving of more than 600 hours during project execution. In addition, there are savings in other phases of the life cycle as shown in Case 1.

Discussion

Effective requirement engineering is a key to cope with systems complexity, and it is a necessity to implement a requirement management systems for large projects (Hull et al., 2005). Although the benefits of effective requirement engineering have been evident for decades, the oil and gas industry are lagging behind in implementation of requirement systems. However, lately the industry has recognized the need for systems engineering methodology to cope with their system complexity, and is implementing systematic requirements handling.

In this paper, we have investigated the implementation of requirement management systems in the industry. We did this by attempting to answer the two questions: *What is the maturity of requirement management in the industry? What are the benefits and challenges from implementation of requirement management systems in a supplier company?*

The maturity of requirement management in the industry. In the survey at the INCOSE oil and gas work group, the systems-engineering competency in the industry is perceived as poor, and worse than in industries with comparable system complexity. The oil and gas industry is immature in implementing systems engineering. Reasons why the industry are lagging behind include the conservative culture, the good market situation, and low push form regulatory bodies. The lack of systems engineering competence and culture are amongst the factors challenging the implementation systematic requirements handling. The survey also shows that the industry would benefit from implementing systems engineering methods, and in particular implementing requirement engineering management.

The case study from the supplier company shows clear benefits of implementing a requirement management system. Traditionally the Supplier has been handling requirements through several word documents. Unfortunately, with the considerable number of requirements in the industry, requirement management in Word is time consuming, and it becomes challenging to keep requirement specification consistent. The main benefit from the implementation at the Supplier is that it gives a systematic handling of requirements that improves traceability, consistency and ensures quality of the origin of the requirement. The case examples show that implementation of requirement management system at the Supplier, saves the resources time in searching for information during project execution. Experience also supports identification of conflicting requirements.

Implementation of new tool in an organization is challenging. Even if we see clear benefits from the implementation of the requirement management system in the company, it is still a challenge to get everyone in the organization onboard. We experience that many resources are skeptic to new tools, and perceive the use of tools more rigid and time consuming. The benefits of the implementation are more visible on a company level than on a personal level. Thus, the key to successful implementation throughout the organization is management support.

Next step - enabling verification and validation. The next step for implementation in the company is linking the requirements to verification and testing. A pilot in Shell have showed a great potential of time and cost saving by introducing this linkage, by reducing clarification cycles and reduce design errors and late design changes pf non-conformance (Zager, McKinney, Reed, 2019).

Requirement management as the starting point for the digital thread. Digitization is identified as one of the key trends in the oil and gas industry moving forward (Eriksen, 2016). An expedient requirement system, properly implemented in the organization is a sensible step accompanying digitization, and the perfect starting point of digital twins.

Conclusion

The oil and gas industry are increasingly implementing requirement management systems to improve their work processes and ensure quality of the system deliveries. However, implementing requirement management in large organizations is a complex and challenging task, and even harder in a whole industry. This paper provides insights and experience from the industry. A survey base on input from participants at an INCOSE Oil and Gas Work Group, shows that the industry is far behind in implementing systematic requirement handling. We find that the culture and lack of systems engineering competence in the industry are factors limiting the implementation. The case study from a supplier company shows that the industry has a great potential from implementing requirement management systems. Key benefits include improved traceability, improved quality of requirement and reduced engineering hours. However, we find that it is challenging to get the system integrated throughout the organization. To succeed with implementation, it is crucial to have support from management, and to collaborate across the supply chain. We find that the industry sees the need towards a data centric requirement management, and that this is an important factor to enable the digital twin as the industry moves forward.

References

Baker, J., Ferraioli, P., Pereira, L. R., Hudson, A., Barton, G., Bhatt, S., … Odegard, R. (2016). Requirements Engineering for Retrofittable Subsea Equipment. Proceedings - 2016 IEEE 24th International Requirements Engineering Conference, RE 2016, 226–235. https://doi.org/10.1109/RE.2016.44

Beecham, S., & Rainer, A. (2002). Requirements problems in twelve software companies: An empirical analysis Article in IEE Proceedings-Software ·. https://doi.org/10.1049/ip-sen:20020694

Boone, H. N., & Boone, D. A. (2012). Analyzing Likert Data. Journal of Extension, 50(2), 1–5. https://doi.org/10.1111/j.1365-2929.2004.02012.x

Damien Wee, K. Y., & Muller, G. (2016). Evaluating the effectiveness of applying a Requirements Management System for a Subsea Oil and Gas Workover System. INCOSE International Symposium, 26(1), 2346–2360. https://doi.org/10.1002/j.2334-5837.2016.00299.x

Engen, S., Falk, K., & Muller, G. (2019). Architectural reasoning in the conceptual phase - a case study in the oil and gas industry. Systems of Systems Enginginеering (SOSE), 87–92.

https://doi.org/10.1109/SYSOSE.2019.8753863

Eriksen, R. (2016). DNV GL Technology Outlook 2025. Dnv Gl, 1–88. https://doi.org/DNV GL 02/2016

Falk, K., Ulsvik, O. K., Engen, S., & Syverud, E. (2019). Systems Engineering Principles To Enable Supplier-led Solutions. Offshore Technology Conference, “Unpuplished.”

Hull, E., Jackson, K., & Dick, J. (2005). Requirements Engineering.

Kauppinen, M., Vartiainen, M., Kontio, J., Kujala, S., & Sulonen, R. (2004). Implementing requirements engineering processes throughout organizations: Success factors and challenges. Information and Software Technology, 46(14), 937–953. https://doi.org/10.1016/j.infsof.2004.04.002

Likert, R. (1932). A Techniqe for the Measurement of Attittides. Archives of Psychology, 22(140), 1–55. https://doi.org/2731047

Muller, G., & Falk, K. (2018). What can (Systems of) Systems Engineering contribute to Oil and Gas ? An illustration with case studies from subsea . 13th Annual Conference on System of Systems Engineering (SoSE), 629–635. IEEE.

NASA. (2007). Systems Engineering Handbook. Retrieved from www.sti.nasa.gov

OG21. (2015). G21 TTA4 Report Subsea Cost Reduction.

Reichheld, F. F. (2003). The One Number You Need to Grow. Harvard Business Review. https://doi.org/10.1111/j.1467-8616.2008.00516.x

Wikipedia. (2019). Requirements Interchange Format. Retrieved November 15, 2019, from https://en.wikipedia.org/wiki/Requirements_Interchange_Format

Zager, McKinney, Reed, O. (2019). Verifying Process Safety Requirements: Similarities between aerospace and Oil & Gas Industries. 1–16.

Biography

Kirsten Helle. Kirsten Helle is a manager for System Engineers in the Front-End & Systems Engineering department in TechnipFMC. Kirsten holds a Bachelor degree in Machine/Graphic from Gjøvik College of Engineering, a Bachelor degree in Computer Science from University of Oslo and a Master Degree in Systems Engineering from Steven University of Technology. She has more than 20 years' experience from a major supplier company in the oil & gas industry working as a Computer Scientist in Measurement of oil & gas, System Engineer and Engineering Manager in oil & gas projects and present as a Manager for System Engineers working in international projects.

Siv Engen. Siv Engen is an Industrial PhD candidate at University of South-Eastern Norway. Siv holds a Master of Technology in Engineering Science and ICT, with specialization in Marine Constructions from NTNU, Trondheim. She has more than 10 years of experience from a major supplier company in the oil and gas industry and is doing her PhD research within the company. The focus of her research is on system architecture and conceptual modeling in early phases.

Kristin Falk. Professor 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. 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'.