DSYNE

Towards Digital Requirements for Transformation in the Natural Resources Industries

White Paper from the DSYNE Network Workshop, 9th-10th February 2021

Edited by

David B. Cameron, SIRIUS Centre, University of Oslo

Kristin Falk, University of South-Eastern Norway

Satyanarayana Kokkula, University of South-Eastern Norway

Contents

1 Introduction ... 2
2 Setting the Scene: Industrial Perspectives ... 3
2.1 An Operator Perspective ... 3
2.2 A Supplier Perspective ... 4
2.3 A Survey on the Status of Systems Engineering in Oil and Gas ... 6
2.4 Round-Table on Industrial Needs ... 6
3 Technical Focus for DSYNE ... 7
4 Technical Solutions ... 8
4.1 Introduction to the READI Project ... 8
4.2 The Role of Software Vendors ... 10
5 Overview of the Academic Network ... 10
5.1 University of Oslo. SIRIUS Centre, Norway ... 10
5.2 University of South-Eastern Norway, Norway ... 10
5.3 Federal University of Rio Grande do Sul, Brazil ... 11
5.4 Federal University of Espírito Santo, Brazil ... 11
5.5 Stevens Institute of Technology ... 12
5.6 University of Houston ... 12
6 A Course on Digital Requirements ... 13
7 References ... 14
8 Contributors and Participants ... 14
9 Acknowledgements ... 15
10 Version History ... 15

1 Introduction

The DSYNE network is a collaboration of universities and companies in Norway, Brazil, and the United States. Its aim is to promote adoption and use of digitally represented requirements in engineering and system development. The participants in this network believe that by using digital requirements, the natural resources industries can reduce the capital cost of assets and improve operational performance.

The state-of-the-art in building capital facilities is a process where operating companies, engineering firms and equipment suppliers exchange paper or unstructured documents containing the requirements and their verification methods. This costs money and reduces the quality of engineering. Current research has shown that it is possible to use semantic technologies to describe requirements in a truly digital way, so that they can be shared in databases and used for automated reasoning and validation. This can change the way requirements are managed and transmitted in the natural resources industries. However, if this is to happen, we need to (1) build international awareness of these methods, (2) build knowledge and skills in this technology and methods, both in computer scientists and engineers and (3) bring together domain knowledge in engineering with computer science to build a foundation for creating useable, scalable tools for managing requirements.

The DSYNE project started in autumn 2020. It will run until 2024. Originally, the project planned for face-to-face workshops. However, due to the pandemic, the first workshop has been replaced by shorter workshops and seminars that use videoconferencing. The first of these workshops was held on 9th – 10th of February 2021.

2 Setting the Scene: Industrial Perspectives

The workshop began with two contributions from industrial practitioners. James Haug is General Manager for Systems Engineering in Shell Projects & Technology. Kirsten Helle is Manager for Systems Engineers Subsea Facilities in TechnipFMC. These presentations gave us perspectives from both the customer's and vendor's perspective. These presentations were supplemented by a presentation from industrial PhD candidate Siv Engen, an industrial PhD candidate from TechnipFMC and the University of South-Eastern Norway. She presented the results of a survey on the industrial application of digital requirements.

2.1 An Operator Perspective

The reality in the natural resource industry is that, whereas most money is spent in the construction phase of a project, the amount of money that is spent is determined in the early design and requirements phase. This means that we can expect large reductions in capital cost in return for modest expenditure, if we can simplify the requirements process and ensure that this simplification can be uses effectively in the construction phase.

There remains a contrast in requirements handling between the aerospace and manufacturing industries, on the one hand, and the natural resources industries on the other. It is usually recognized that the former industries are more mature in their approach to requirements. In addition, the natural resource industries use the Engineering, Procurement, and Construction (EPC) project model. This model results in a long, global supply chain, with multiple handovers across international boundaries. The language used in requirements is also a challenge. A requirement written in rich English may be difficult to interpret in China, South Korea or Brazil, due to limited language skills in the supplier company

Furthermore, staff in the natural resources industry are aging. As experienced personnel leave their jobs, companies are at risk of losing the skills needed to interpret requirements.

In view of this, Haug proposed four areas for attention:

1. **Minimizing ambiguity in requirements.** This can be done through adopting object-oriented requirements and writing them in a 3-C way: clean, clear, and concise.
2. **Standardizing.** Then we can see what differences are between different requirements specifications. We can also simplify by agreeing on common digital standards. The IOGP JIP (Joint Industry Project) 33, https://www.iogp-jip33.org, is a typical example of this type of work.
3. **We need new ways of working** around managing requirements. Traceability is needed. We need to know which requirements apply to each sub-system. This is possible if we use digital requirements with attributes. We will also need to implement good ways of tagging requirements. This will allow us to better structure requirements based on tagged criteria such as risk. We also need to move to user-oriented packages of requirements, rather than the existing author-focused requirements. Requirements are organized by the author's technical discipline rather than according to user functionality and use cases.
4. **Digital requirements must enable further digitalization and automation.** Requirements must be computable, which means we must have discrete requirements.

If we want to be competitive in the sustainable energy field, while being ever more efficient in oil and gas, we must transfer into digital requirements.

Digital requirements is one key foundation or enabler to further the digitalization of our existing design process. Eliminating ambiguity and helping us to standardize is really creating efficiency and safety. How we manage and flow down requirements enables the further visualization of the design process.

2.2 A Supplier Perspective

Kirsten Helle presented her perspective as a discipline manager for systems engineering at TechnipFMC. She described the system that they have implemented for managing customer requirements and linking them to their engineering process. The system has been implemented using the Siemens Polarion tool. As such, it provides an example of state-of-the-art implementation of digital requirements handling.

The procedure for handling external requirements is shown in Figure 1 Requirements handling in the Siemens Polarion Tool.

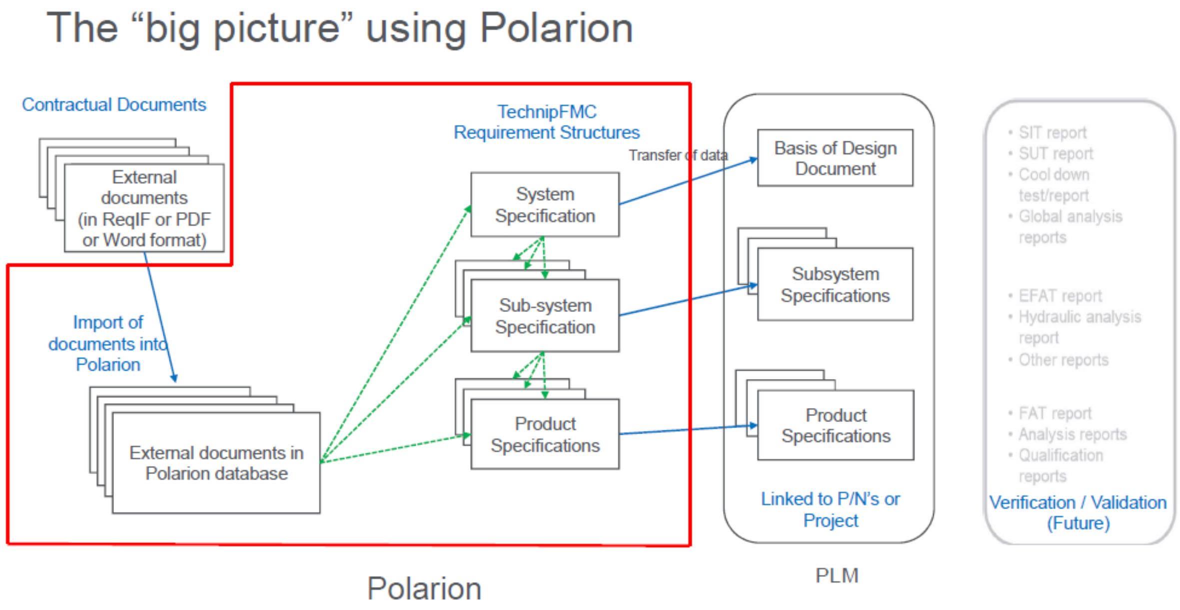

Figure 1. Requirements handling in the Siemens Polarion tool.

The approach is based on importing customer documents into the database and sorting them as either system specifications, sub-system specifications or product specifications. This transfer is simplified if the ReqIF format is used, but documents in PDF and Word formats are also accepted. These records are then used as the basis for formal design documents in the PLM system. Work is planned in future to link further the requirements to verification and validation processes. It is also possible to trace the flow down of requirements from system to sub-system and product level. This is main motivator for this system. It shall be possible to trace a requirement to its source. This is a powerful tool for proving that a system meets its intended use. It supports and simplifies certification and proof of compliance.

Requirements are stored in one place – a global company database. This allows

• Automated comparison between different revisions or versions of external requirements versus internal requirements.

• Traceability between external & internal requirements and the different levels

The system has improved change management and impact analysis and supports a new way of handling exceptions and clarifications. The “Roundtrip” functionality in Polarion tool means that requirements can be sent to persons without Polarion access for review.

It is vital that exceptions and clarifications have their place in the requirements system, as they are essential for compliance and lessons learned.

Engineers have found that Polarion makes searching for information during design reviews and daily project execution is more efficient, as is the creation of compliance reports.

However, the adoption of a new tool requires a change in mindset. A new tool requires training and adaptation. It imposes a more rigid work processes than authoring a prose Word document. Many perceive writing prose requirements to be easier than writing Polarion requirements. The change management involved in implementing the system in a large organization and traditional industry must not be underestimated.

As noted above, requirements supplied in ReqIF format were imported with high quality. It was necessary, but possible, to map fields for different clients. However, it was challenging to reference standards and other external specifications in this format. TechnipFMC has also experimented import of international standards (from organizations like API, ISO, NORSOK) using ReqIF, with varying success. Here we also need to use mapping of fields to cover different standards on the same topic. Challenges here are commercial, involving intellectual property rights and licensing models that are based on purchase of documents.

Newly employed students lack understanding of the transfer of requirements down in the system hierarchy. At present, this type of system thought needs to be taught to the student by the company after the student is employed.

TechnipFMC is also participating in several Joint Industry Projects. Helle highlighted two projects being run in Norway. The first of these is the READI JIP (which is described below), which looks at classification of requirements and has proposed a Reference Designation Systems (RDS) based on the ISO/IEC81436 standard. The second of these is the KONKRAFT Digital Design Basis project. This is a collaborative project, organized through the SIRIUS centre. This project uses semantics to build a data model for communicating requirements in a design basis for a field.

A valuable capability of the RDS is that a system can be broken down using one or more of four aspects: product, function, location and type. This breakdown is applicable to the subsea systems that TechnipFMC produces and allows a rich naming structure for the objects in an engineering system.

Helle reported that the RDS provides more flexibility due to the different aspects of the classification compared to other standards. It should be possible to classify products automatically using the RDS when creating parts or equipment in the system.

Functional aspects have been challenging to define and agree about the best representation. This requires good engineering knowledge. A possible way is to work by analyzing process flow diagrams and piping & instrumentation diagrams. It is also fruitful to differentiate between horizontal systems – along the process flow stream – and vertical systems, where we drill down from top-level systems to sub-systems.

Adoption of the RDS is going to require creation of guidelines and rules, on how it can be best used. Helle sees a potential to use the RDS and semantic technology at least to be able to release engineers from repetitive work internally and in communication between operators and suppliers. Benefits in searching for information, e.g. for maintenance, can be obtained through new ways of tagging, management of change and life-cycle information management.

2.3 A Survey on the Status of Systems Engineering in Oil and Gas

Siv Engen presented the results of a survey sent to participants at the 2019 INCOSE Oil & Gas Working group meeting. This survey is part of Engen's industrial PhD, and is published in Helle et al., (2020). The survey was sent to 38 participants, of whom 13 responded: seven from operating companies, three from EPC firms, and one each from original equipment manufacturing (OEM), standardization and aerospace companies. This small sample means that it is only possible to make qualitative judgments. However, the experience of the respondents gives their opinions weight. Participants had over 15 years' industrial experience.

Respondents rated systems engineering competence in the oil and gas industry as being fair to poor. They also believed that this competence is worse in oil and gas than in other industries. Most respondents rated the maturity of the implementation of systems engineering in oil and gas as low, although three participants disagreed with this. All but one of the respondents agreed that the industry would benefit from implementing systems engineering methods and requirement management systems.

The survey identified seven reasons why the oil and gas industry is behind in systems engineering and requirements management:

1. The **market situation** does not permit allocation of resources to this work.
2. The work is not seen as being an **economic necessity.**
3. The **tailor-made design** of oil and gas facilities makes system engineering difficult.
4. There is **low regulatory push** for the use of system engineering.
5. The **industry is conservative**.
6. A **lack of competence** in the methods and tools to be used.
7. A **lack of suitable tools**, or that the tools that are available are too complex.

The overall challenge identified by the respondents was to have high-quality requirements that allowed simple collaboration.

2.4 Round-Table on Industrial Needs

The session on industrial background concluded with an open discussion where the other industrial participants commented on the presentations and offered their own perspectives.

DNV GL: noted that adoption of digital requirements can change radically how they do verification work. Explicit linking of verification to requirements will improve efficiency and accuracy.

Equinor has built up experience in the Siemens Polarion tool. Through 35 projects, they have seen improved maintainability, usability and re-use. They are currently working to digitalize workflow. Digital requirements need a new mindset and involve sharing and collaboration along the supply chain. The requirements problem cannot be solved on isolated business islands. This work is being coordinated through the IOGP Requirement Digitalization Task Force (RDTF). This is at present a working group of operators. However, in phase two it will open up to involvement from other actors in the supply chain.

We believe that there is potential for collaboration and synergy between DSYNE and the IOGP RDTF.

The point on change of culture was also emphasized by the participants from Shell. We need to focus on how to write good requirements. We also need to standardize on data and between operators. We must move from a document-centric to a data-centric mindset. This requires us to change culture and the way we do business and interact with supply chain. Digital verification is also an area of interest. Michele Reed has prepared an OTC paper on this topic. This will be published in August 2021. There is a perceived pushback in industry against defining verification criteria up front. Engineers seem to prefer vaguer criteria, perhaps to give them some “wriggle-room”.

3 Technical Focus for DSYNE

The workshop then broke into groups to discuss the following questions:

Can we identify themes and challenges that DSYNE should address?

What do you want in the short-term, i.e. yesterday, if possible?

What do you want in the long-term, i.e. in 2024?

The following topics and priorities arose in the discus sions. The discussions produced a list of points. Here we will try to group the themes under common topics.

The first theme is **foundations**. We need to build on good systems and requirements engineering practice. We must establish a basic terminology of requirements. We need to teach and take account of foundational subjects such as systems thinking, high-level requirements and systems of systems. We also need to look at ontology support for these concepts. The linkages between digital requirements and Model-Based System Engineering (MBSE) need to be explored.

The second theme is **semantics and representation**. We believe that knowledge model and ontologies can be valuable tools for the semantic analysis of requirements. It is, however, doubtful whether we can obtain detailed convergence to one agreed data structure or ontology. Our aim should be pragmatic. In addition, good requirements often use figures. The cliché “a picture is worth a thousand words” is true. How to digitalize this is a challenge.

The third theme is **application**. Digital requirements must offer cost and efficiency benefits. We see possibilities for more re-use of requirements between projects. We can eliminate duplication in documentation. We can standardize internal communications and communication between suppliers and clients. It can also be possible to enhance efficiency and creativity in design. Current systems do not motivate rapid change or transition. Paradoxically, a more rigid framework can give us the security to do things that are more daring. As we move to cloud-based systems for managing requirements, we need better ways of extracting and interpreting requirements.

The next, very important, theme was **verification**. Digital requirements will change how we use requirements in the downstream testing and validation processes. Flow of requirements into a testing environment would be useful. We also need to be able to link systems requirements to client’s needs and then validate the implementation of the needs. Multiple parties are involved in verification including EPC, third party inspection, and clients. Digital requirements can improve this collaboration and remove duplication of work. They could also support use of transaction systems such as a digital passport or block chain. DSYNE links EPC, clients and third-party verification organizations, thus enabling common work on this shared problem.

Finally, we looked at **dissemination, standardization and adoption**. The project needs to consider how to integrate with and leverage commercial tools like Polarion and Doors. We need to work with and communicate with on-going standardization work. In particular, we need to build a collaboration with IOGP, who is looking at the short-term issues in requirements.

- *How do we involve the companies into the project? How do companies want to be involved?*

The second set of questions discussed looked at how companies could participate in the network.

- DSYNE can act as brokerage for collaboration projects.
- DSYNE will be a forum in which suppliers and clients can meet and talk about common challenges and problems.
- DSYNE will develop courses. These can be used for training in companies.
- DSYNE will finance student exchange between industry and academia as well as between the universities.
- DSYNE will invite industry representatives into our course development. They will also be invited to be guest speakers and visiting lecturers.

4 Technical Solutions

The first day of the workshop looked at the problem of digital requirements. The second day started to look at solutions of this problem. This was done through presentations from each of the academic partners in the network. The day started with an overview of READI, a Joint Industry Project on digital requirements. A perspective followed this from a tool vendor, namely IBM. Each of the academic participants then presented their ambitions for the network.

4.1 Introduction to the READI Project

The READI Joint Industry project arose from the Norwegian KONKRAFT (Competitive Power) Strategy for the oil and gas industry. The project focuses on the digital transformation of business processes for field development and operation. This needs a common digital language and framework that enables efficient flow of information between disciplines and work processes. These digital requirements can give large economic benefits, in the order of hundreds of million dollars. Cost savings and increased safety would result from precise requirements and digital control of documentation, re-use of concepts and products, more effective and improved quality in engineering and procurement work processes and reduction of variants and avoiding duplication.

READI aims to develop and demonstrate methods for governance of digital requirements in the oil and gas industry. In the long term, READI should be an open industry platform that translates diverse company practices into shared digital requirements, and helps the industry to improve safety, cut costs and increase efficiency in business critical processes through automation.

This has been proven through the updating and digitalization of the NORSOK standards for Technical Information. Its ambitions are to offer a digital platform to the world industry through engagement with industry (e.g. IOGP) and international (e.g. ISO, IEC) standardization initiatives.

The JIP is supported by leading operators, EPC companies, equipment suppliers and authorities.

READI vision & framework

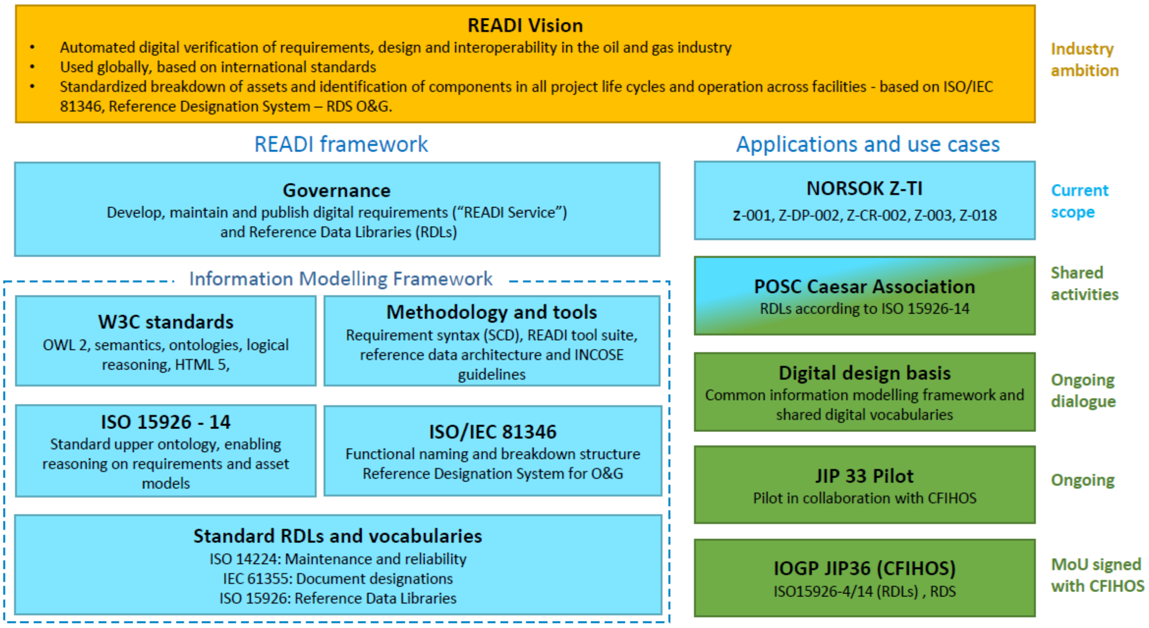

Figure 2. READI vision and framework.

The vision and framework is described in Figure 2. In DSYNE, we see two aspects as being especially relevant: the Scope, Condition, and Demand (SCD) requirements syntax and the ISO/IEC 81346 for functional naming and breakdown structures for complex systems.

Figure 3 summarizes the SCD syntax .

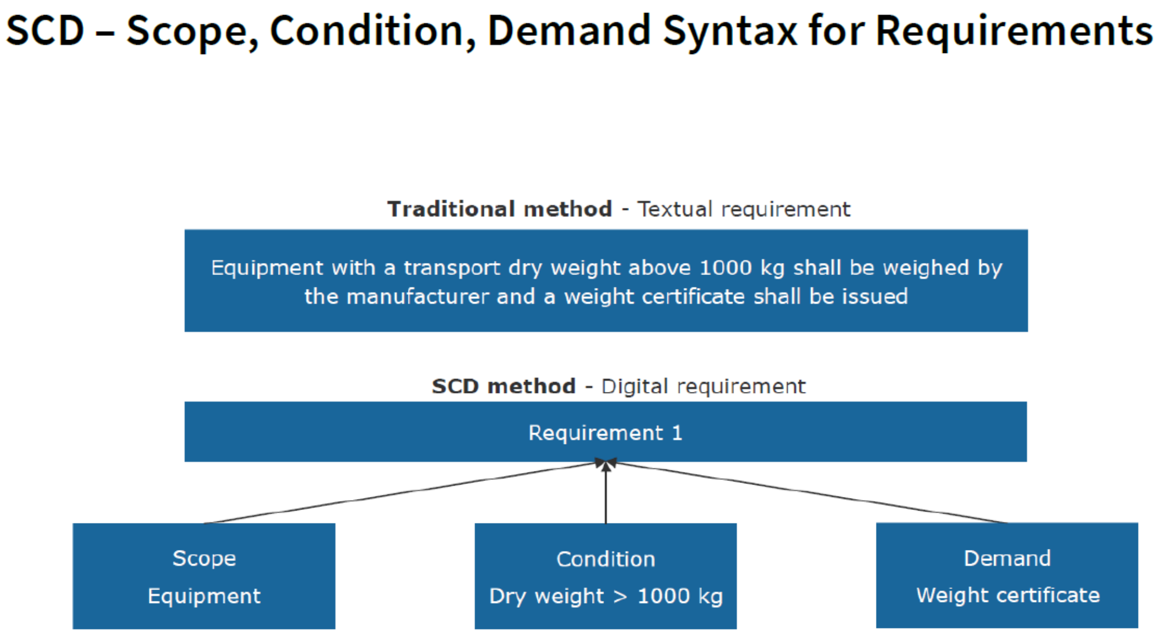

Figure 3. Scope, Condition, Demand syntax requirements.

Here we see a requirement as a triple of Scope – what the requirement applies to – Condition – when the requirement applies – and Demand – what is required.

This type of representation also requires a flexible, informative and standard way of referring to Scope. For this reason, READI has also developed a Reference Designation System for Oil & Gas, based on ISO/IEC 81346. This is called the READI Information Modelling Framework. More information on this can be found at https://readi-jip.org/reference-designation-system-for-oil-and-gas/ .

4.2 The Role of Software Vendors

Ben Amaba from IBM presented a perspective from a software vendor. IBM delivers DOORS, a leading commercial system for managing requirements in systems engineering. Amaba discussed some of the product plans for DOORS, namely a move to cloud and hybrid cloud hosting. He also is enthusiastic about the opportunities of using tools as a basis for using artificial intelligence

Interaction with leading software vendors will be an essential part of the DSYNE activities. We will be working together to ensure that our research and teaching activities take account of the commercial state-of-the-art tools.

5 Overview of the Academic Network

5.1 University of Oslo. SIRIUS Centre, Norway

The University of Oslo is participating in the DSYNE project through the SIRIUS Centre for Scalable Data Access in the Oil and Gas Domain. David Cameron, the project manager, presented the centre's work in the context of the READI project. SIRIUS is a centre for research-based innovation, financed by the Research Council of Norway. DNV, TechnipFMC and Equinor are partners in SIRIUS and are working on projects that are relevant to DSYNE. These include:

- Development of templates for easy building and maintenance of ontologies and knowledge models.
- Ontology-based data access for operational data and sub-surface data in oil and gas.
- Natural language processing for extracting semantic models from text documents.
- Knowledge models for digital twins of process facilities and petroleum production.
- Formal verification of simulations and complex cyber-physical systems.

5.2 University of South-Eastern Norway, Norway

Satya Kokkula, Associate Professor of Systems Engineering, presented the DSYNE team from the University of South-Eastern Norway (USN). The other participant from USN is Kristin Falk, Professor of Systems Engineering. The Systems Engineering centre is located in Kongsberg, a town near Oslo with a strong cluster of engineering and manufacturing companies.

Kokkula sketched out the USN understanding of requirements and their role in the system engineering process. They are interested in digital requirements because the companies they collaborate with are working with digital tools. Requirements are a key element in the effective use of these tools. However, all companies are struggling with the processes of requirements engineering and management.

He referred back to the work of Siv Engen, presented above, and presented two sets of results.

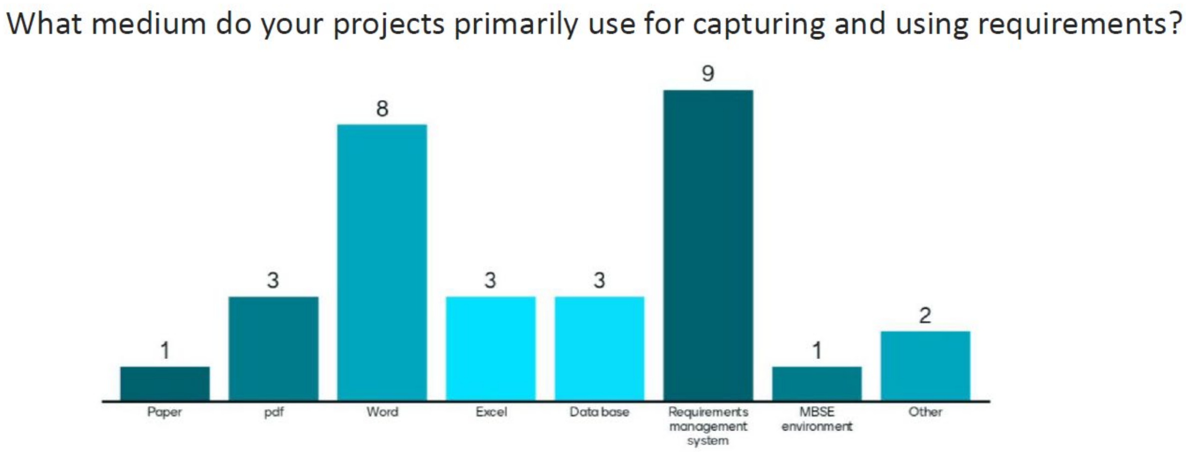

Figure 4. Survey results on medium for capturing and using requirements.

Here we see that, Figure 4, while 60% of respondents use structured methods of storing requirements (Excel, Database, RMS, MBSE), 40% still use unstructured methods (Word, PDF and paper).

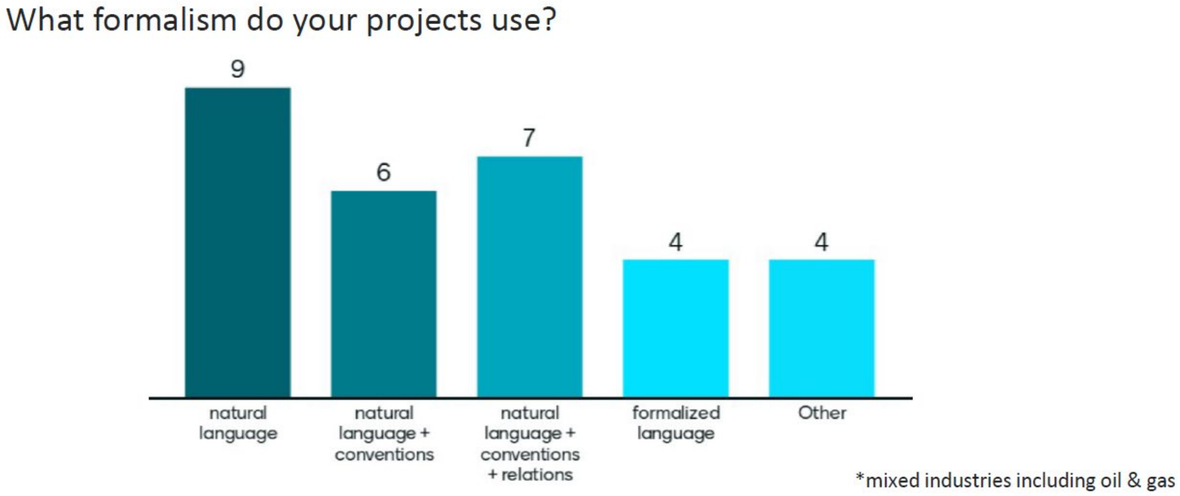

Figure 5. Survey results on formalism for requirements capturing.

We see, Figure 5, also that natural language remains the dominant form to represent requirements.

USN has a well-established research program on requirements and improving engineering processes. They have a student mass embedded in industrial organizations in the energy, defence, maritime, manufacturing and automotive sectors.

USN will be contributing to DSYNE as co-ordinator of the project's Work Package 2, Course Development. They also bring in their academic background in systems engineering, requirements management and requirements engineering.

5.3 Federal University of Rio Grande do Sul, Brazil

Karin Becker, Professor of Informatics, presented the participants from UFRGS. There will be three professors from UFRGS participating in the work. Mara Abel leads the oil and gas informatics and semantic technologies work at the institute. Karin Becker works with software engineering and Marcelo Pimenta works on software requirements.

5.4 Federal University of Espírito Santo, Brazil

João Paulo Almeida presented the NEMO group at UFES. Additional participants from UFES are Giancarlo Guizzardi, Monalessa Perini Barcellos, Renata Guizzardi and Vítor Silva Souza. The vision of their group is that requirements and systems engineering require advanced conceptual modelling techniques and that there is no digitalization without an underlying ontology. There is never no ontology, only a bad or unexpressed ontology. In their opinion, too many standards and formats developed without proper care for ontological foundations and adequate representation. This is particularly the case when we consider abstract nouns like "requirement" and "goal". They therefore have worked on ontologies for software engineering that can be used to harmonize the concepts in standard software engineering and architecture methods. These ontologies build on the UFO foundational ontology.

Tools and methods relevant to DSYNE are:

- The OntoUML language and tool for building ontologies. This is available as a plugin to the Visual Paradigm tool. The features of this tool are syntax verification, model transformation. Work is being done on simulation and detection of anti-patterns
- An OWL implementation of UFO foundational ontology (e.g., in Protégé) http://purl.org/nemo/doc/gufo.
- Ontological foundations for Software Requirements https://nemo.inf.ufes.br/en/projetos/rose/ and https://nemo.inf.ufes.br/en/projetos/seon/.
- Semantic Documentation in Requirements Engineering and Project Management https://nemo.inf.ufes.br/en/projetos/semantic-documentation/.

The NEMO group also teaches course on Conceptual Modeling, Ontology Engineering, Model-Driven Development, Software Engineering, Semantic Web and Goal-Oriented Requirements Engineering.

5.5 Stevens Institute of Technology

Mo Mansouri, the Director of System Engineering Programs, presented Stevens Institute of Technology. His group is the US Department of Defense National Centre of Excellence in Systems Engineering Research. It runs one of largest graduate systems engineering programs in the world. It led a global systems engineering knowledge initiative - Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE), which is now co-led by SERC, INCOSE and IEEE-CS. They were also co-founder of the CSER (Conference on Systems Engineering Research), the most prestigious worldwide research conference for industry, academia and government.

Stevens has experience in running industry programs that focus on impact: talent development and retention, performance and problem solving. They are developed jointly with companies and the lead executive in a sponsoring company works closely with Stevens faculty.

The faculty has broad experience in systems, software, engineering management and analytics/data science. At present, there are 31 full time faculty and 42 adjunct positions.

The systems engineering program has the following areas of emphasis:

- Focus across **system types** – space, software, cyber-physical, socio-technical, other.
- Focus across **system life cycle** – from concept to support
- Focus on **systems engineering capabilities**: model based practices, systems security, risk management and decision making, complex project management and technical leadership.
- Systems engineering is a **practice-oriented discipline**, rather than a theoretical discipline. This drives collaboration across industry and academia.
- **Teamwork** is valued.

5.6 University of Houston

Gino Lim, Chairman of the Department of Industrial Engineering at the University of Houston, introduced his department. The Industrial Engineering department collaborates closely with the Subsea

Engineering program. This program is linked tightly to industrial and operating companies in the Houston region and offers Masters' and Certificate courses in Subsea Engineering.

The Department of Industrial Engineering offers a BSc course in Systems Engineering and a Masters in Engineering Management. These programs would host a DSYNE-developed course. The BSc course is offered at a suburban campus in Katy. Its purpose is to develop a skilled future workforce in the Houston area.

The University of Houston is participating in DSYNE because of the importance of requirements in Systems Engineering. They bring knowledge and resources in course development and teaching in requirements for systems engineering, petroleum engineering, subsea engineering, and certificate programs. They will participate in student exchange programs and in brokerage for joint research projects.

6 A Course on Digital Requirements

The workshop then broke into groups to start discussing what a course in digital requirements would look like. The groups were asked to think about three following questions.

What do you need from a course in digital requirements?

First, we need to present a consensus concept of what digital requirements are. We then need to build an understanding of what this means for practice in engineering projects. There will be different types of digital requirements, depending on the industry and system we are working with. The course should also present why we want to use digital requirements. We should teach the importance of really going digital and relying less on text-based requirements (less MS Word), i.e. emphasizing data-centric instead of document-centric requirements engineering.

One of the groups proposed a "Requirements 101". This could cover requirements management, risk management (cost-risk tradeoff at the conceptual design stage, safety & maintenance, reliability, economic analysis with life cycle consideration), systems engineering process (process for driving requirements at the functional level), interface management and digital software ontology.

Foundational aspects need to be addressed. Understanding functional breakdown, in the systems engineering point of view. Understanding what to do and then being able to breaking it down (function decomposition is essential).

Content is needed on how to express requirements well, taking account of aspects such as non-ambiguity, cross-company interoperability, standards and integration (in opposition to knowledge silos). This requires knowledge of standards and what can be standardized.

Tools, modelling languages and notations must also be introduced, with best practices for using them. However, the course should attempt to stay agnostic to specific solutions. Tools that should be considered are IBM DOORS, Siemens Polarion and the IOGP JAMA database.

Use cases will be an important part of the course, as a bridge between theory and practice. They provide a context for trying out tools, discussing lessons learned and motivating applications. Work practices should be examined.

Digital requirements need also to be located in a context of requirements management and requirements engineering. This means we will need to address practices such as verification and validation, traceability, elicitation, expression, management, reuse and evolution.

We wish also to develop students' analytic abilities, such as reasoning about functional and non-functional requirements, analysis of alternatives. This can be helped by teaching a template to give structure to analysis.

Which types of students? MSc? Lifelong learning?

The course should address MSc students as an elective in their program. It should also be packaged as a module in lifelong learning aimed at industrial practitioners and reskilling workers.

The course should be accessible to general engineers, i.e. with little computer science background.

A pre-requisite of prior work experience in projects and requirements would be helpful.

Shell already offers an internal program on Digital Requirements Management Systems at the graduate level.

How should the course be built up? Modules? Single course?

A modular concept is preferred, because of the flexibility that it offers. We should be able to reuse modules in different configurations and contexts. Courses can then be tailored according to the type of course and skills of the student group. This is important as we are looking at system engineers and computer scientists as possible students.

We could then offer basic, medium and advanced modules.

The course should support a hybrid virtual and face-to-face training model.

7 References

Helle, Kirsten, Siv Engen, and Kristin Falk. (2020), "Towards Systemic Handling of Requirements in the Oil and Gas Industry–a Case Study." INCOSE International Symposium. Vol. 30. No. 1. 2020.

Lu, H., Guo, L., Azimi, M., Huang, K., 2019. Oil and Gas 4.0 era: A systematic review and outlook. Computers in Industry 111, 68–90. https://doi.org/10.1016/j.compind.2019.06.007

8 Contributors and Participants

Contributors in **bold**.

University of Oslo: **David Cameron**, Martin Giese, Evgeny Kharmalov, Yuanwei Qu, Adnan Latif, Dimitrios Kyritsis, Ole Magnus Holter.

University of South Eastern Norway: **Kristin Falk**, **Satyanarayana (Satya) Kokkula**

Stevens Institute of Technology: **Mo Mansouri**

University of Houston: **Gino Lim**.

UFES: Federal University of Espirito Santo: **João Paulo Almeida**, Renata Guizzardi, Giancarlo Guizzardi, Vítor E. Silva Souza, Monalessa Barcellos.

UFRGS: Federal University of Rio Grande do Sul: **Karin Becker**, **Marcelo Pimenta**, Mara Abel, Nicolau Oyhenard dos Santos.

DNV GL: **Astri Haukerud**, Pål Rylandsholm, Christoffer Grette.

Equinor: **Steinar Mollan**, Andreas Rønning.

Shell: **James Haug**, Jeroen Veen, Irfaan Khalid, Tasha Penner, Michele Reed, Kiran Krishna. Chang Li Ee.

TechnipFMC: **Kirsten Helle**, **Siv Engen**.

9 Acknowledgements

The DSYNE network is financed through the Norwegian INTPART program, Research Council of Norway project number 309404. INTPART is jointly financed by the Research Council of Norway and DIKU, the Norwegian Agency for International Cooperation and Quality Enhancement in Higher Education.

Diku Norwegian Agency for International Cooperation and Quality Enhancement in Higher Education

With funding from The Research Council of Norway

10 Version History

Version	Date	Author(s)	Content
0.1	15.03.2021	DBC, KF, SK	First draft
0.2	15.04.2021	DBC, KF, SK	Comments from USN
0.3	21.04.2021	DBC, KF, SK	Comments from UFES and TechnipFMC