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# A Context-Enabled Systems Development Method: The Case of Semi-Autonomous Remotely Operated Vehicles in an Arctic Environment

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**Abstract.** The Arctic areas are the new point of focus for the oil and gas industry, due to its large reserves of hydrocarbons. However, the extreme climate makes direct operation of existing systems hazardous. Aiding the need to redesign the ROV (Remotely Operated Vehicle) for the Arctic scene, this study aims to create a systemic method to enable system requirements development for an extreme and unfamiliar situation. This study jointly employs the system of systems thinking, contextual architecting, ConOps and hazard identification method to derive the systemic method to address the system of interest, and applies it in the case of battery requirements of a semi-autonomous ROV for Arctic applications. In this way, based on expert interviews and second-hand data, the field-layout for a potential oilfield in the artic is firstly crafted; the working scenarios are created; finally, the power range of the ROV can be calculated. It is found that this method can enable an analytical way of determining the contexts impact on the system and thus may allow for the successful determination of system requirements in unknown contexts.

## Introduction

**Background.** The hydrocarbon resources on the earth are not infinite, and the occurrences of new hydrocarbon production fields are getting rarer. Simultaneously, the world´s demand for hydrocarbons are increasing rapidly. Despite the recent price drop, the growing population of the emerging industrialized countries, have increased the global demand for oil and gas. EIA (2016) predicted that the global consumption of oil would surpass 100 million barrels of oil and liquid fuels per day. This increase in demand cannot be met with more efficient production solutions and increased oil recovery from already existing fields, alone.

The US Geological Survey (2008) has estimated that 30% of the world´s undiscovered gas, and 13% of the undiscovered oil, can be found within the Arctic areas. The Arctic areas are defined as the polar region located north of the Arctic Circle (66 degrees, 34 minutes North Latitude), which has extreme operating conditions. Due to the large amount of natural resources believed to reside in the Arctic, subsea equipment developments have become critical for the industry.

**Company.** This study was performed within a global supplier of subsea production equipment and IMR services. The Company X is one of the global market leaders of Engineering, Procurement and Construction projects for the subsea oil and gas industry. The Norwegian branch of the Company X had over 3000 employees at the end of 2014. This number has decreased substantially since then as a result of the tough market situation.

**Domain.** Although the global subsea equipment suppliers have acquired extensive experience and knowledge over the past decades, the harsh and unhospitable environment of the Arctic areas poses new unknowns and unexplored challenges for the industry. This study is conducted together with the research and development (R&D) branch of the global market leader of subsea production systems in the subsea oil and gas industry. The R&D department works with new technology to increase safety, efficiency, reliability and increased oil recovery, in addition to taking system developments into new markets or environments.

The focus of this study is the implementation of the intervention, maintenance and repair (IMR) functions of a subsea production system in an Arctic environment, by the means of a semi-autonomous Remotely Operated Vehicle (sa-ROV). IMR is performed to increase well life and production rates during the fields operational life. IMR operations are typically relatively light repair- and intervention work that can be carried out without retrieving the subsea equipment from the sea bottom.

**The Challenge.** IMR operations is critical to successful operation of an efficient, reliable and safe hydrocarbon production field. Traditionally, IMR is performed by specialized IMR-vessels with ROVs on board, which travel in-between subsea fields at costly day rates to perform tasks. The fact that ice covers the water for up to 8-9 months per year in the Arctic (Norwegian Polar Institute, 2016) prohibits the access to the sites for the traditional IMR-vessels. Even in the season where operations are usually possible, the IMR-vessel would run a risk of getting caught by screw-ice. The harsh climate makes the traditional ROV an intolerable solution to the IMR needs in an Arctic subsea field, thus an Arctic semi-autonomous ROV (sa-ROV) is in need for new systems development. The comparisons between sa-ROV and ROV are shown in Table 1.

Table 1. Comparison of sa-ROV and ROV

| sa-ROV Features | Sa-ROV Pros & Cons | ROV Features | ROV Pros & Cons |
|---|---|---|---|
| No IMR-Vessel | Year-Around Operation | IMR Vessel | IMR Vessel |
| Battery Powered | Limited Power | Tether Powered | Tether Powered |
| From-Shore Operated | Increased HMS, Low Cost | On-Site Operated | On-Site Operated |
| New Application of Existing Technology | No Track-Record, Few Contingency Options | Well Proven Method | Well Proven Method |
| Can Operate in Arctic Environment | Suitable for Arctic Subsea Fields | Cannot Operate in Arctic Environment | Cannot Operate in Arctic Environment |

The systems development should be based on the following design constraints given by the customer:

- The solution shall be a based on a traditional ROV.
- The Arctic sa-ROV shall permanently reside with the Subsea Production Equipment (SPS).
- The Arctic sa-ROV shall be autonomous in some given tasks, whilst remotely operated in others.
- The Arctic sa-ROV shall be battery powered.
- Electricity shall be provided from the Subsea Production System.
- The battery shall be harnessed to the Arctic ROV.
- The Arctic sa-ROV shall reside in the Subsea Warehouse.

Current practices for systems development in company X is largely based on experienced personnel and their knowledge and experience, combined with previous projects' know-hows. In order to resolve the complex systems development in an efficient and systematic manner, the Systems Engineering Process (INCOSE Handbook, 2014; Kasser and Zhao, 2014) is the common method to be applied. However, in dealing with this sa-ROV system for an extreme and unfamiliar situation, there is still a lack of a systemic method. Therefore, this study aims to "*Create a systemic method for* *determining battery capacity requirements for a permanently residing sa-ROV in an Arctic environment."*

## Current State

According to the Encyclopedia for American Industries, the objective of industrial R&D is to obtain new knowledge applicable to the company's business needs, that eventually will result in new or improved products, processes, systems, or services that can increase the company's sales and profits (Das 2015). However, current industrial operations often prohibit effective R&D.

1) **Experience-based R&D.** The R&D are often conduced by the most-experienced subject matter experts and seasoned personnel with many years of experience in the company and the industry. Since information and knowledge obtained during R&D projects are what the company will continue working on for future growth, the information is often highly classified so that only a small group of key personnel have access. The disadvantage of this grouping of R&D people is that they tend to be set in their past ways and thus reluctant to look into new fresh thinking and ideas, especially ideas that didn't seem to work in the past cases. This traditional experience-based R&D development potentially prohibits the novel solutions, especially when the design context is largely different from previous projects such as the Arctic scene.

2) **Requirements created from "Wants" not "Needs".** In developing new systems or system applications, the challenges often range from defining requirements to resolving technical realization. The requirement identification acts as the roadmap for the whole development life cycle and is critical for systems development success. However, they are often created based on a few people´s understanding of the problem and its environment, rather than on facts. Moreover, the customer "wishes" tends to be what is captured, rather than the "needs". Without a thorough need analysis in the front-end development, late system design changes may occur, and thus lead to cost overruns (Tranøy and Muller, 2014).

3) **Indiscriminately use of previous projects.** Far from all systems developments are replicable. Poorly documented requirements from past R&D projects can even lead to over- or under-engineering in new systems developments. The result of indiscriminately use of previous projects can cause over-featured products, low reliability, high development cost and unnecessary specifications. Though the Systems Engineering techniques can improve the quality of past knowledge documentation and reduce the risk of misunderstandings (INCOSE Handbook, 2014), they have not been well used in reality.

4) **Lack of holistic system view.** In a complex system development, plenty of external entities affect the system and sub-systems. Without a methodical approach, the operating environment of the systems of systems, can easily be neglected, or introduced late in the design process. This may cause system failure due to poor understanding of operational conditions. Together with the the copy-paste mentality in the industrial practices, this neglect poses huge risk of costly late design changes and limits innovation.

Based on the four main concerns above, it is found an urgent need for a systemic approach to methodize the gathering of factual information from actors in a system or systems of systems development, rather than solely relying on previous experience. It has been found that the context-enabled toolkit can close the gap of context neglect during the systems development. However, studies are yet to explore its application in complex systems (Salber, Dey and Abowd, 1999; Dey, 2001; Dey et al., 2001). The complex systems usually encounter more development difficulties due to its long development life cycle and complex interventions, than the traditional use of context-enabled toolkit in fast-prototyping's, e.g. web-systems (Dey et al., 2001; May et al., 2011). When introducing the context as a design factor early in the complex systems development, it is important for a smart design to ensure that a system and its systems of systems are suitable for the actual tasks while introducing the context as a design factor from the start of the complex system development.

This study focuses on resolving this problem in the fuzzy-front end, to ensure that proper high-level system requirements for the complex system development are the end-result. In this study, we use a real-life case to illustrate the research. The sa-ROV is the system of interest, and the Arctic environment are the system context. The study ranges from capturing needs until creation of system battery requirements.

## The Conceptual Solution

This study applies the Systems Engineering approach as the back-bone thinking. According to INCOSE Handbook (2014), Systems Engineering is an interdisciplinary approach and a mean to enable the realization of successful systems. When the context is unknown to the world, the problem space become fuzzy and the problem itself is often ill-structured, also known as a wicked problem (Kasser and Zhao, 2016). To resolve it, the systems engineering problem-solving process is not necessarily sequential but performed in a parallel and an iterative manner (Kasser, Zhao and Mirchandani, 2014; Kasser and Zhao, 2016). More importantly, multiple systems engineering elements are needed. To ensure an effective and reliable system development, we jointly deploy a method that contains the systems of systems thinking, context-enabled architecting, ConOps and HAZID.

**System of Systems Thinking.** To characterize a system as a systems of systems, there are two principal distinguishing characteristics; operational and managerial independence, that needs to be exhibited. (Maier, 1998). The systems need to be independent and operable, and networked together for a period of time to achieve a certain higher goal. (Jamshidi, 2009). The sa-ROV can be seen as a systems of systems according to these definitions. The systems of systems thinking (INCOSE Handbook, 2014), helps to enable the system-oriented development without losing sight of the big picture. In this study, the ROV and sa-ROV represent complex systems that consist of many individual systems that together realize the overall functionalities (Dahlmann, 2008). These individual systems can be seen as complex systems by themselves, and their complexity increases with the overall system. In particular, by applying the systems of systems thinking, the complexity can be reduced due to the focus on functionalities as a whole, not single components, nor individual parts.

**Context-Enabled Architecting.** Traditional context-enabled applications take the environmental contexts into account by using a software component called a Widget, to provide the application with access to the contextual information of their operating environment. Context-enabled applications have mainly been used to enhance the interactions between the user and software by leveraging available environmental information (Dey, 2001).

Based on the context and widget theory (Salber, Dey and Abowd, 2001), the context-enabled architecting should be an aid to the development of the sa-ROV in the Arctic environment. To better grasp the effects of the challenges regarding context/operating environment of a physical system, we adapt the widgets to be made up by the sub-systems and functions of the sa-ROV, whilst the environment in which the ROV operates is interpreted as the context. The key challenges are not to develop an entirely new product or function, but combining existing technologies and new needs that have emerged from the environmental challenges. As a result, the industrial dominant design of a ROV is introduced as the benchmark and implemented into the context/operating environment as a design factor in the development process. The new systems requirements should then be created more accurately with good understanding of the impact of the external factors through task handlings.

**ConOps.** The Concept of Operations (ConOps) has been known as “describing the mission of the system, its operational and support environments, and the functions and characteristics of the system within an overall operational environment” (INCOSE Handbook, 2014). The ConOps helps to get an overview of the intended system characteristics and can convey the quantitative and qualitative attributes to the stakeholders. To enable a holistic view of the intended overall operations in the Arctic, the ConOps is adopted (Fairley and Thayer, 1997). The ConOps is used as a tool to develop different scenarios that the sa-ROV will operate in, and thus enables the definition of the system characteristics.

**HAZID.** Hazard identification (HAZID) study is the method of identifying hazards to prevent and reduce any adverse impact that could cause injury or become a liability to personnel, damage to, or loss of property, environment and production (INCOSE Handbook, 2014). Thus, the HAZID is important to utilize in this study, to be able to evaluate and determine effects and impacts of exposure to hazards, and thus to create mitigation strategies for the risks in a system (McCoy et al., 2000). Through a study group, a HAZID can be performed to identify the specific challenges that affect the sa-ROV system in the context of the Arctic environment. Hazards relating to amongst other, sa-ROV specifics, site specifics and weather conditions, needs to be identified and investigated.

The conceptual solution for the working method can be crafted into following tasks.

**Task 1. Context-enabled System Overview:** First, it is necessary to get a holistic view of the problem and then define the challenges. The generic factors of the context/operational environment of the ROV, such as temperature, wind, soil conditions, etc., needs to be gathered at the system level. To further conduct the analysis, the sa-ROV as a system needs to be divided as sub-systems into Widgets, so that the widgets as a unit can interpret and adapt to the inputs from the new context. To conduct a system overview, it has to be determined what is known and what is unknown regarding the Arctic environment, the sa-ROV and the relevant subsea equipment. The best available information and knowledge needs to be obtained accordingly. It is expected that a field-layout of the field where the sa-ROV is to be operated, could be determined based on how the industry believes that a future Arctic field-development would look like. In addition, a thorough understanding of the Arctic sa-ROV operational context should be found based on real meteorological data.

**Task 2. Benchmarking Analysis of Dominant Design in New Contexts:** First, we need to identify the dominant ROV design in the industry and harvest the existing information and knowledge in this regard. Then, using the traditional ROV as a benchmark for operating in the Arctic environment, the goal is to analyze the effects of the context on the existing system and to identify the challenges to be solved for a successful development of a new system (i.e. sa-ROV in the Arctic environment).

**Task 3. Operation Scenario Creation and Hazard Identification:** The challenges must be determined and analyzed before proceeding with requirements and solutions. Based on ConOps, a holistic view of operations in the Arctic needs to be acquired by the existing deployment of Company X. Then the HAZID method can reveal the specific hazards for the intended sa-ROVs' operation in the Arctic. The expected outcomes are working scenarios and hazards related to the sa-ROVs´ operation in the Arctic environment.

**Task 4. The Impact Evaluation:** To facilitate different scenarios, the findings from the HAZID and the specific power consumption of each sub-system of the sa-ROV, needs to be gathered. The impact of the hazards and the functional partitioning of the sa-ROV needs to be investigated. The expected outcomes are the division of the system into context and widgets with coherent power consumption based on the context-enabled architecture.

**Task 5. Sum-up New Systems Requirements:** A numeral model can be created and used for calculating the battery boundary requirements of the sa-ROV in the Arctic environment. It should sum up the power usage of the entire system and its sub-systems. The model needs to take into account the power usage of each individual power consumer and the time that each of these consumers are used in a specific scenario. It is expected that the battery power requirements of the sa-ROV will be the outcome of the mathematical model developed.

## Research Methodology

To conduct the tasks in this sa-ROV case, we mainly adopt the expert interviews for data collection and results validation. The task-related practices were discussed with subject matter experts throughout the process in an effort to increase validity. The information gathered is mostly from Company X and a whole-owned sister company which specializes in ROVs and robotics. In addition, the authentic second-hand data from Norwegian Meteorological Institute is collected for Arctic–related information.

In Task 1, expert interviews were performed to obtain data regarding specific information and personal experiences to get a system overview. Three ROV experts from different domains, two experts in the Arctic environment and three subsea equipment experts, were interviewed. To ensure the sufficiency of data, the initial eight interviews got expanded into two extra interviews with ROV experts and one extra interview with the Arctic expert.

To solve Task 2, five rounds of expert interviews were conducted to obtain the complete data as needed. Expert interviews have been applied critically since they may result in subject matter experts' personal opinion, which can be biased, rather than objective facts. To ensure objective results, several experts have been consulted in matters where a subjective opinion may be given.

Task 3, utilizes the gathered knowledge about the Arctic climate and specific functions and sub-systems of the sa-ROV. Two rounds of interviews with the ROV experts, and two interviews with the Arctic experts provided the necessary information about the specific ROV performance data. The interviews showed concrete knowledge about hazards and challenges regarding the sa-ROV operation in an Arctic environment. This information was utilized in the ConOps and the HAZID.

In Task 4, the battery requirements and the power consumption of each function, or widget was determined. In addition, a final review of the numeral method (in Task 5) with experts from each of the actual domains was performed. Finally, there was one interview round with the ROV experts, the Arctic experts and the subsea equipment experts. These expert interviews served the purpose of validation and verification of the applied methods and results.

## Application of the Conceptual Solution

The data collected from the expert interviews are used as a starting point for the new systems development. The systems of systems thinking is applied for a holistic view of the problem space, and helping define the problem statement based on the customer needs. Once the problem was clearly defined, information gathering related to the existing ROV, such as its performance and power consumption, was conducted.

**Context Setting.** Experts were consulted to help determine how an operational deployment in the Arctic may look like if realized. It's decided to use a typical field layout, with slight modifications for Arctic applications. The field is determined to be located in the northernmost license area on the Norwegian Continental Shelf defined by the Norwegian Petroleum Directorate as "Moffenflaket Ny", as shown in Figure 1.

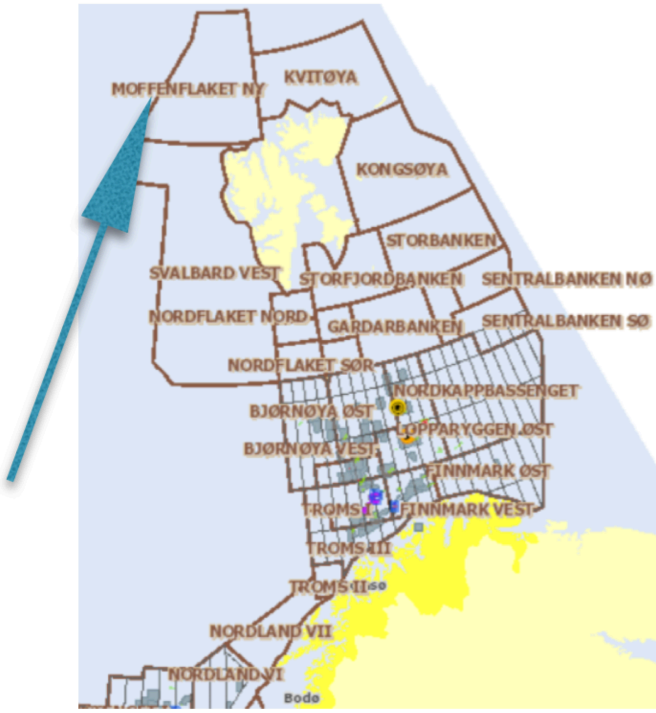


Figure 1. Moffenflaket Ny

The subject experts assumed that large distances will be a reality for the future Arctic field, due to the lack of infrastructure present in these areas (Figure 2).

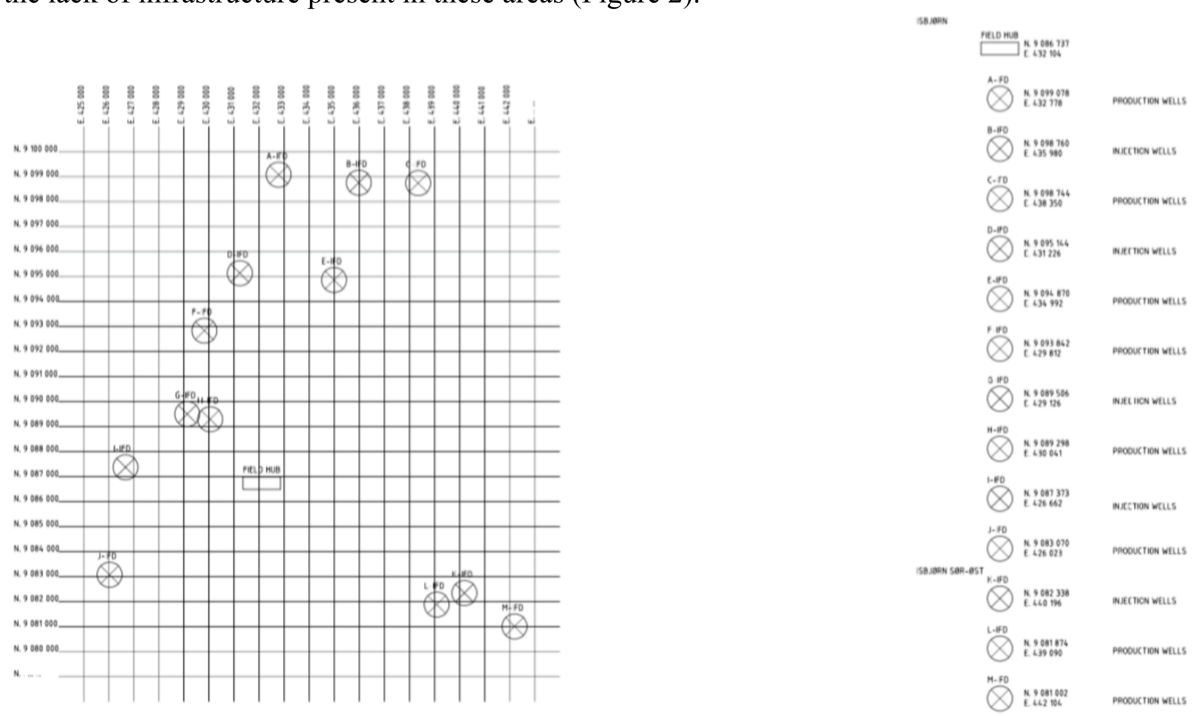

Figure 2. Field Layout

**Decomposition.** Based on data from the interviews, the environmental impact on the system development is identified as the most prominent issue. The context-enabled architecting can be reinterpreted and divide the overall system into two layers; 1) context, where the Arctic environment and subsea production equipment are the context; 2) system of interest, where the sa-ROV is the system of interest. Arguably, the battery system in the sa-ROV is the system of interest in this study. However, since the battery requirements are determined by the power usage of the sa-ROV under specific work-loads, it has been determined to keep the sa-ROV as the system of interest instead. In the new system development of the sa-ROV, the issue then is to implement existing technologies into an existing product and cope with new environments, where the environment itself becomes the critical design factor. Context-enabled applications in software engineering takes the environmental context into account to create a richer interaction (Salber, Dey and Abowd, 2001).

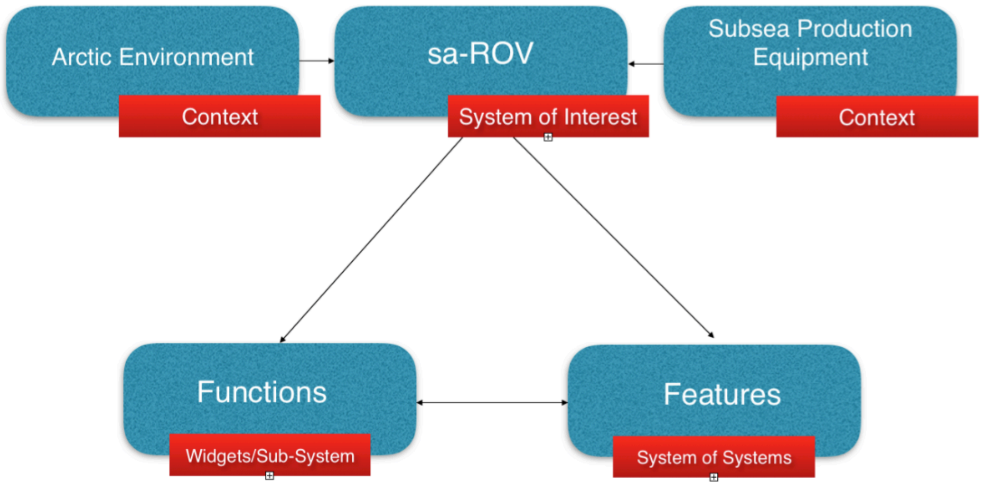

Figure 3. Context and System of Interest

As shown in Figure 3, the system of interest is divided into two sub-categories: functions and features. The functions can can be defined as widgets or sub-systems representing the functionality of the sa-ROV. The features are the combined systems of systems that come together to enable the functions (Jamshidi, 2009). In context-enabled applications, *a context-widget is a software component that provides applications with access to context information from their operating environment* (Salber, Dey and Abowd, 2001). In our sa-ROV case, the widgets become a set of physical sub-systems that operate specific functions of the system in the given context.

Different features or systems of systems enable various functions to operate in these contexts. An example from the sa-ROV case is that the context represented by sea currents will affect the sa-ROV when it is required that the sa-ROV must be stationary to perform a work-task. Introducing the StationKeep Widget, where sensors and propellers work together to counter the effects of the currents, the impact of the current has been defused. Another example is in the case of transportation, where an operator can determine whether or not speed should be chosen over operational time, based on different criterias such as criticality.

**Identified Challenges.** Based on the field placement and layout agreed upon, the working scenarios of the sa-ROV can be defined. Through the initial round of expert interviews, the following ConOps was found to contain a large amount of work tasks for the sa-ROV. A need to generalize the different scenarios emerged. Based on the following-up interviews and collective data from the manufacturers of the traditional ROVs, three different levels of work tasks for the sa-ROV in terms of representative scenarios are defined below:

- Level 1 = Inspection - Completely Autonomous
  - Manually activated
    - Example of work: Inspection of pipes and equipment

- Level 2 = Light Intervention - Partially Autonomous
  - Manually activated, autonomous transport phase, manual control over sa-ROV during work-task

        - Example of work: Stabbing of connectors, operating ROV valve panel

- Level 3 = Intervention - Partially Autonomous
    - Manually activated, autonomous transport phase, manual control over sa-ROV during work-task
        - Example of work: Changing parts, such as SCMs, ALDs, e.g.

Based on the defined operational scenarios, both external and internal hazards that the sa-ROV could encounter during operation are investigated. Since the sa-ROV does not have any physical connection to the location of operation, it is determined to have redundancy on both mechanical and software components to avoid drift-off. Besides drift-off, the most severe hazard is identified as the currents. Due to the large distances within the field, even a small amount of head-current can be enough to drain the power source sufficiently to prevent the safe return of the sa-ROV back to its base.

Due to the potential hazard and impact of the sea currents, the related datasets from satellite surveillance of the sea-climate in the Arctic are collected from the Norwegian Meteorological Institute. The datasets show an overview of the currents in the given areas, in terms of the direction and speed, shown as below. Additionally, even though the currents are found to be fairly strong all year around, the winter-months (November-March) is the period with the strongest currents.

- Average Current - Average: 0,353kts
- Northern Current - Min: 0 — Max: 0,476kts
- Southern Current - Min: 0 — Max: 0,733kts
- Eastern Current - Min: 0,241 — Max: 0,733 kts
- Western Current - Min: 0 — Max: 0,733 kts
- North-East Current - Min: 0 — Max: 0,874 kts
- North-West Current - Min: 0 — Max: 0,874 kts
- South-East Current - Min: 0 — Max: 0,874 kts
- South-West Current - Min: 0 — Max: 0,772 kts

**Generated Scenarios.** After having determined the velocity of the currents, the operational scenarios for the sa-ROV can be specified. Three scenarios were created in collaboration with the ROV experts to match the Levels of work (Level1, 2 and 3) determined above. The yellow line represents the approximate traveling path of the sa-ROV during the scenarios.

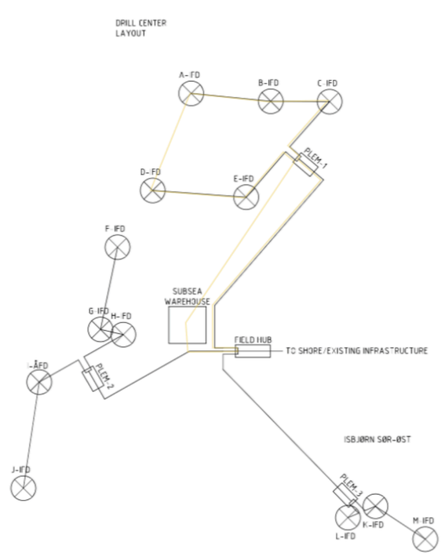


Figure 4. Scenario 1

Scenario 1-L1: The sa-ROV is to perform inspection of the SPS, without any physical interaction. The functions, or widgets, of the ROV in use will be Video Capture and Transportation. A total of approximately 10 hours and 40 minutes of operation, and 40km travel distance is expected for this task, where as 30km, or 8 hours, is with the use of cameras and lights. (Figure 4).

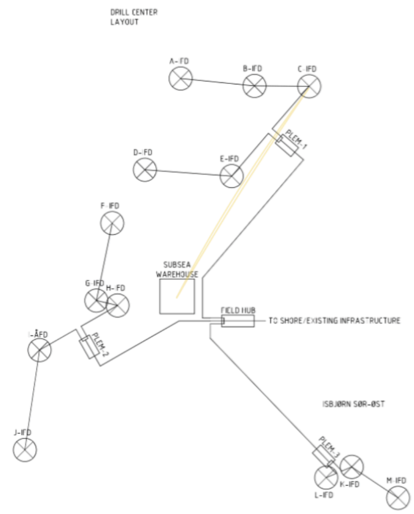


Figure 5. Scenario 2

Scenario 2-L2: Light intervention, such as stabbing of electronic, optical or hydraulic connectors. Its estimated a total of 12 hours of operation, where as 4 hours are intervention work, and 8 hours are travel time (30km). In addition to Cameras and Lights, the sa-ROV will use its manipulators, the StationKeep and Remote Operation in the 4 hours of operation. (Figure 5).

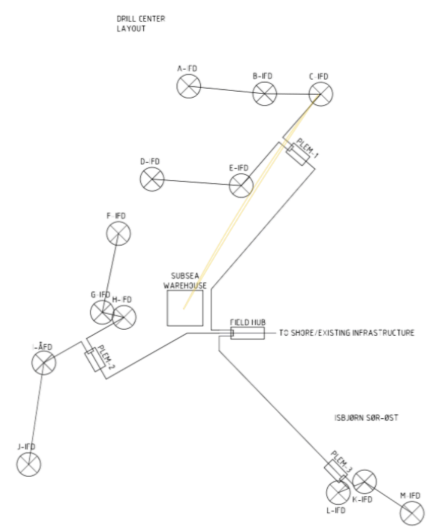


Figure 6. Scenario 3

Scenario 3-L3: Intervention to the SPS equipment, such as changing an ALD. The sa-ROV will use the same amount of time, distributed equally as in Level 2, but will in addition use its Auxiliary Power Source. (Figure 6).

General Assumptions:

- The currents are assumed to be 0.534kts average, against the ROV at all times.
- The sa-ROV shall have a speed of 2,02kts regardless of current-strength
- Operating System/Logic/Software and other “life support” features are equal in all scenarios.

- All scenarios use 3 Lights and 2 Cameras.

**Numeral Modeling.** A mathematical formula can simply sum up all power consuming of the system of systems in the traditional ROV. The created model below takes into account all widgets of the sa-ROV and the time each widget to be used. The result shows the total power consumed under the given assumptions in the different working levels.

$Tot_{Pow} = (P_{Const} * T_{Const}) + (P_{Trans} * T_{Trans}) + (P_{Stat} * T_{Stat}) + (P_{Manip} * T_{Manip}) + (P_{Aux} * T_{Aux}) + (P_{Light} * T_{Light}) + (P_{Vid} * T_{Vid}) + (P_{Rem} * T_{Rem})$

Const = Constant (Constant system power consumption)
Trans = Transportation (Use of functions for movement)
Stat = StationKeep (Function that counteract the external forces exerted on the system)
Manip = Manipulators (The arms mounted on the front of the ROV)
Aux = Auxiliary (Auxiliary power outlet, for tools mounted to the ROV)
Light = Lights (For better vision)
Vid = Video (Video capture function, and live-feed imaging)
Rem = Remote Control (Operation of the ROV from shore)

**Results.** By following the conceptual solution, it becomes possible to determine how much capacity the battery of the sa-ROV must have to be able to cope with the different work tasks. The numeral modeling can produce results based on the assumptions and scenarios created for this system of interest and its context, and can be further adopted in other similar projects.
For each scenario (Scenario 1-Level 1, S1-L2 and S3-L3), the maximum power usage of the Widgets is used for calculation. The difference between the scenarios are only the time each of the Widgets/Sub-Systems are used, if used.

In a Level 1 scenario, the total power consumption of the sa-ROV will be:
$Tot_{Pow} = (0{,}548 * 10{,}7) + (72 * 10{,}7) + (16 * 0) + (7{,}5 * 0) + (30 * 0) + (0{,}36 * 8) + (0{,}08 * 8) + (0{,}1 * 0)$
**$Tot_{Pow} \approx$ 780kW** **$Instant_{Pow} \approx$ 73kWh**

In a Level 2 scenario, the total power consumption of the sa-ROV will be:
$Tot_{Pow} = (0{,}548 * 12) + (72 * 8) + (16 * 4) + (7{,}5 * 4) + (30 * 0) + (0{,}36 * 4) + (0{,}08 * 4) + (0{,}1 * 4)$
**$Tot_{Pow} \approx$ 675kW** **$Instant_{Pow} \approx$ 97kWh**

In a Level 3 scenario, the total power consumption of the sa-ROV will be:
$Tot_{Pow} = (0{,}548 * 12) + (72 * 8) + (16 * 4) + (7{,}5 * 4) + (30 * 4) + (0{,}36 * 4) + (0{,}08 * 4) + (0{,}1 * 4)$
**$Tot_{Pow} \approx$ 795kW** **$Instant_{Pow} \approx$ 127kWh**

Based on the calculations above, it was found that the most power consuming scenario would require a 795kW battery pack with a delivery of 127kWh. Therefore, this context-enabled conceptual solution enables the realization of a mathematical model that takes into account the different power consuming functions of the ROV, and determines their power draining impact on the system with regard to time used.

## Conclusion

This study intends to create a systemic method for determining the system requirement in an unknown context (i.e. battery requirements of the sa-ROV in an Arctic setting in our case). By creatively utilization of systems of systems thinking, context-enabled architecting, ConOps, HAZID and etc., the context-enabled systems development solution is outlined. This method enables the determination of factors and impact at the system of interest (sa-ROV) on the unknown entities from the context (i.e. the Arctic in this case). It is found that when altering the context toolkit (Dey, Abowd, and Salber, 2001), this method can provide an overview needed for a successful mapping of the unknowns. The context-enabled architecting is found to be useful in the complex systems development to help understand how the contexts and operational environments impact the system. Based on the existing data, the specific operation scenarios and design constraints can be crafted by using ConOps and HAZID. The actual need of power to operate the sa-ROV in the Arctic can be modelled to determine the requirements. Experts have validated and verified that this context-enabled systems development solution is useful as a bridging method to resolve system level problems through good understanding of the context and systems of systems. Despite the fact that the Arctic environments is extreme and its effect on the system is unknown to the world. The reverse design of a holistic understanding of the context to systems of systems operational configurations makes the new systems requirement generation (i.e. sa-ROVs battery power in our case) possible. This context-enabled systems development method on one hand leverages the context toolkit to control unknown entities and extends its application in the complex systems development. On the other hand it paves the way for complex systems to be developed in unknown contexts. At last, this study may serve as a reference of the context-enabled development of complex systems for other applications to be implemented.

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