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Maritime Search and Rescue Air Operations in a Radiological/nuclear Environment: Coordination, Complexity and Risk

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Abstract

The presence of radiological and nuclear (RN) material in the Arctic poses a risk for serious incidents and accidents in the region. To mitigate the catastrophic potential of such RN-emergency in the Arctic, a lot of organisations and resources will have to effectively coordinate their collected search and rescue (SAR) effort.

To enhance the emergency preparedness, and mitigate the consequences of such accidents, a handbook (RNSARBOOK) has been developed by RN and SAR experts from the Nordic countries to propose harmonised guidelines and recommend procedures for RNSAR. The research associated with this master's thesis has supplemented the handbook development, with the following research question underlining the study: "*What is the Norwegian capability to coordinate maritime search and rescue air operations in a complex, radiological/nuclear emergency?*"

Aircraft is a highly relevant asset in this context, and the thesis aims to fill some of the existing research gap on the phenomenon, focusing on coordination of multiple aircraft in a demanding RN-environment in the Arctic. The study also aims to provide a practical contribution through the mapping of aircraft capable of RNSAR for the RNSARBOOK-project, and to conclude with recommendations for improving coordination during RNSAR air operations.

The theoretical framework underlining the study comprises traditional and contemporary research of three concepts: coordination, complexity and risk perception. Coordination of RNSAR air operations is the central focus, and I have studied the relationship with the other variables and their effect on coordination at the operational and unit level. This was found to add another perspective on the existing theories.

The thesis has followed a case study approach, using the techniques of within-case and cross-case analysis to strengthen existing theory on the phenomenon. The data was selected and collected from relevant documents, semi-structured interviews of five informants, and field notes from observations of three RNSAR workshops and a tabletop exercise (TTX) at Nord University. During the data collection and analysis several findings, concepts and possible relationships between the variables emerged, which were further refined to develop a hypothesis and a theoretical model. This was compared with existing theory and resulted in the following highlights.

Coordination of air operations during RNSAR is complex, as multiple, specialised organisations establishes interdependencies in a temporary RNSAR-system in response to the emergency. Furthermore, complexity is found in a dynamic operational environment involving RN materials and the tasks associated with the RNSAR-operation.

Coordination mechanisms exists to reduce this complexity, and the formal function of the aircraft coordinator (ACO) is central in coordinating multiple aircraft during RNSAR-operations. However, lack of RN-specific procedures and knowledge results in an emerging coordination at the scene of emergency which appears to be a function of trust and communication, more than formalised procedures.

Radiation was found to shape the individuals risk perception, mainly as a function of prior experience (or lack thereof). Without experience and knowledge of radiation, intuitive emotions could negatively influence the individual aircrew assessing the risk.

Knowledge was introduced as an important variable for the overall effectiveness of the RNSAR-operation. Basic knowledge and understanding of radioactivity and RNSAR-operations could reduce uncertainty resulting from complexity and the individuals' risk perception.

The study has shown that Norway has capable aircraft and organisations for performing RNSAR-operations, but knowledge, procedures and equipment are needed to effectively coordinate multiple aircraft in response to an RN-emergency. Looking at the Norwegian RNSAR-capability through the lens of Complex Adaptive Systems provides an explanation for how the RNSAR-system collectively respond to the emergency. The individual aircrew at the unit level adapts through flexibility and improvisation, which makes up for some of the limitations identified in this study.

Foreword

What you're about to read is the culmination of three years as a part-time student at Nord University, combined with a full-time employment as a staff officer in the Royal Norwegian Air Force. During this time, I also became a dad – twice. It has been a challenging and almost delicate act of prioritising and balancing between what matters most at home, work and the enjoyable work of this thesis.

First of all, I want to thank my supervisor, Associate Professor Natalia Andreassen at Nord University, for the opportunity to participate and contribute to the RNSAR-project. Without it, I would've never thought of combining radiation with air operations, and even less so for improving search and rescue in the Arctic. She has always been available, both in the project and throughout the research process, and provided valuable insights and comments to my research.

Furthermore, the Joint Rescue and Coordination Centre North Norway (JRCC NN), and the participants in the RNSARBOOK-project deserve my gratitude. Thank you for welcoming me to the project, listening to my ideas and sharing your professional knowledge for my thesis. The innovative work you do to improve preparedness in the Arctic is nothing less than inspiring. A special thanks to the RNSARBOOK project manager Mikel Dominguez Cainzos at the JRCC NN and senior advisor Øyvind Aas-Hansen at the Norwegian Radiation and Nuclear Safety Authority for their always positive and helpful attitude and assistance in identifying informants, answering my difficult questions, and putting me in touch with the right professionals.

Most important, thanks to my wife for being patient with my late hours at the home office, allowing me to drift off and focus on the thesis. And my two daughters, for always reminding me of what matters most in life.

Finally, it soon became clear to me that radiation isn't that dangerous once I had acquired some basic knowledge of the subject. As with many other hazards, it's a risk that can be managed. Hopefully, this thesis can provide a small contribution to the ever-improving Norwegian SAR-system, this time with the focus on placing RN- in front of SAR.

Christoffer Hveding

Bodø, 20 May 2022

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Abbreviations and acronyms

ACO	Aircraft Coordinator
CAS	Complex Adaptive Systems
DSA	Norwegian Radiation and Nuclear Safety Authority
ICS	Incident Command System
JRCC	Joint Rescue Coordination Centre
OSC	On-Scene Coordinator
RADIAC	Radioactivity, Detection, Indication and Computation
RN	Radiological/nuclear
RPAS	Remotely Piloted Aircraft System
SAR	Search and Rescue
SME	Subject Matter Expert
SOP	Standard Operating Procedures
SRU	Search and Rescue Unit
UAV	Unmanned Aerial Vehicle

1. Introduction

Radiation. Just thinking about it may evoke feelings of fear and unpleasant mental images of nuclear bombs and the Chernobyl disaster. These feelings are a result of our risk perception, and may even dominate and produce behaviour that is counterproductive (Loewenstein et al., 2001).

Ship traffic in the Arctic includes nuclear-powered vessels, transport of spent nuclear fuel and radioactive waste, and newly developed floating nuclear power plants (Arctic Council, 2019). The presence of radiological and nuclear material in the Arctic poses a risk for serious incidents and accidents that may affect both humans and environment in the region. The response to such emergencies will be challenging and require close cooperation between several actors.

To enhance the emergency preparedness, and mitigate the consequences of such accidents, national radiation and nuclear (RAD) authorities together with search and rescue (SAR) authorities from Nordic countries have established a RNSARBOOK project. The project aims to develop a handbook for search and rescue in maritime radiological/nuclear (RN) emergencies, and propose harmonised guidelines and recommend procedures for the handling of these.

This research project has supplemented the handbook development, focusing on search and rescue air operations in maritime RN emergencies. Informed decision making requires accurate and timely information on the radiation hazard around the distressed vessel. Aircraft[1] are often first on scene and an effective search and rescue tool in such emergencies (Schmied et al., 2017). Aircraft have the range to operate in the Arctic, and could be equipped with the necessary measuring systems to provide timely information. In addition, aircrew are capable of assessing local meteorological conditions to assist in predicting the movements of the hazard. All in all, a highly relevant SAR asset in an RN-environment.

However, large scale air operations involving several actors can quickly become complex, especially during an RN-emergency, indicating a complex operational environment. Furthermore, an emerging question is how the assumed lack of radiation knowledge could affect the aircrew in their risk perception and the SAR effort that follows. Thus, the purpose of this research project is to map existing capacity to conduct search and rescue air operations

[1] The definition of aircraft includes aeroplanes, helicopters and unmanned aerial vehicles (UAV).

during a maritime RN-emergency in the Arctic, and provide recommendations for further development of such operations.

1.1. Background and context

Maritime search and rescue operations in the Arctic are often complex and challenging, and requires close cooperation among many actors (Arctic Council, 2019). For the aerial search and rescue units, this results in a complex and volatile operational environment, making coordination particularly challenging (Andreassen et al., 2018; Borch & Andreassen, 2015).

Studies have already suggested that the Arctic environment requires a more flexible approach to coordination in search and rescue operations (Andreassen et al., 2018; Andreassen et al., 2020). Aircraft operations aren't an exception to this notion, which is central to this study. For the last decades, several disasters have showed challenges in coordinating multiple aircraft operations, and resulted in the need for more formal coordination mechanisms for SAR (Olsen, 2016). While international joint procedures have been developed for organising aeronautical and maritime SAR through the IAMSAR-manual, specific procedures for RNSAR are lacking (IMO/ICAO, 2016a). As such, roles and coordination mechanisms for SAR are defined, but work remains to operationalise these to an RN-environment.

In the case of emergencies involving RN materials, experience, knowledge and necessary protective equipment and measuring equipment varies among those that would respond to such emergency (Arctic Council, 2019). To correctly perceive risk requires knowledge of the hazard (i.e. RN materials) and could otherwise limit the SAR effectiveness (Comfort, 2007). For the search and rescue units (SRU), such incidents are in the grey zone between standard operations and crisis, again challenging traditional coordination (Wolbers & Boersma, 2018).

From a theoretical point of view, contemporary research call for more studies on inter-organisational coordination during search and rescue efforts – particularly in the Arctic context (Borch & Andreassen, 2015; Comfort, 2007; Dynes, 1994; Kapucu, 2005; Schmied et al., 2017). Furthermore, little research exists on roles and coordination of multiple aircraft conducting SAR in particular (Olsen, 2016). The capability to coordinate actions among specialised organisations are crucial for search and rescue in the region. The Arctic conditions are challenging for SAR operations, thus representing a relevant case study for how to perform effective coordination between organisations in such environment (Andreassen & Borch, 2020; Andreassen et al., 2018). This thesis aims to fill some of the existing gap, focusing on coordination of multiple aircraft in a demanding Arctic environment, adding RN materials as a variable. The study aims to supplement existing research on inter-organisational coordination in different contexts, introducing new variables of complexity and risk perception and their relationship with coordination.

The study also aims to provide a practical contribution through the mapping of aerial assets for the RNSARBOOK-project, and to conclude with suggestions and recommendations for improving coordination of multiple aircraft in an RN-environment. As the RNSAR-procedures are being developed, this thesis aims to contribute with the perspective on air operations, to further improve the RNSAR capability. By including the characteristics and challenges of employing aircraft into RNSAR, allows for the development of specific procedures for air operations in such environment. It is my hope that the work of this thesis will result in a small contribution to a safer and more efficient conduct of air operations in the Arctic.

1.2. Research question

My main focus has been to study the coordination of aircraft during an RN-emergency, in order to understand how the respective organisations operate in the larger RNSAR-system. This study aims to contribute to increased preparedness toward such incidents, and includes an assessment of the current RNSAR-capacity within relevant Norwegian organisations, together with practical recommendations for air operations in such operational environment.

The study addresses the aircraft in the Norwegian SAR-system. In addition to being the phenomenon studied, the practical findings of the study will be relevant for these stakeholders. However, the results of the study would be applicable for any organisation operating aircraft in a dangerous and complex environment.

The context and arguments presented so far, allowed for the development of the following research question which will form the basis for the study:

What is the Norwegian capability to coordinate maritime search and rescue air operations in a complex, radiological/nuclear emergency?

Several terms and concepts are introduced in the research question and will be further operationalised.

The concept of "*capability"* involves both the specific RN-equipment needed and the competence and knowledge of the people working in the organisations which operates aircraft to be used in SAR operations. It is a qualitative assessment with ties to the military vocabulary, and refers to the ability to conduct a given task, in this case coordinate such air operations in an RN-environment (Forsvarets høgskole, 2019).

The capability to "c*oordinate"* the actions of multiple aircraft is the central question of this study, and essential for maintaining flight safety and carrying out an effective SAR mission (IMO/ICAO, 2016a). The need for inter-organisational coordination arises when these actors depend on each other in order to successfully handle the emergency (Kristiansen et al., 2017). The analysis will focus on coordination at the unit level, which takes place at the scene of the emergency, between formal organisations and emerging networks (Boin & Bynander, 2015). However, the scope also includes rules, plans, procedures etc. developed ahead of the emergency. Coordination at the operational level needs to be addressed to enhance the understanding of the phenomenon, but it is not the focal point of the analysis.

"Maritime search and rescue" focus the research question onto the operational environment and the organisations which are studied. Maritime search and rescue exclude the land domain, which is outside the scope of this study. Also, albeit not explicitly stated, the maritime domain and Norwegian area of responsibility, implies an Arctic environment. This is an important nuance, linking existing research on the phenomenon of Arctic SAR with the result of this study.

Aircraft with a relevant role within the SAR effort, are those conducting *"air operations"* during an emergency. This primarily involves helicopters, but also aeroplanes and unmanned aerial vehicles (UAV) have designated roles in such environment. The Norwegian organisations operating these aircraft, represent the selection of the study.

"Complexity" in this context is made up of several factors. First is the Arctic region in itself, characterised: "by vast distances, a harsh climate, limited infrastructure, communication challenges, and sparse population" (Sydnes et al., 2017, p. 110). This adds to the challenge of joint SAR operations in the Arctic (Andreassen et al., 2020). A "*nuclear or radiological emergency"* is a situation where the rescue and emergency workers could be subject to radiation exposures higher than normal (Nordic radiation and nuclear safety authorities, 2014). Radiation adds to the complexity by being another variable to consider in the overall

search and rescue effort. Lastly, multiple "*air operations*" are in itself complex, coordinating the actions of several types of moving aircraft operating in a confined area (Olsen, 2016).

In order to conceptualise the research question and provide a framework for empirical data collection in this study, an analytical model is developed to show how the abovementioned context and variables relates to each other. This is a practical model built to structure the research. Albeit, from a theoretical standing point, it visualises the emerging question of how complexity and risk perception influence the coordination between actors. Coordination is the dependent variable to measure, and complexity and risk perception represent independent variables to manipulate.

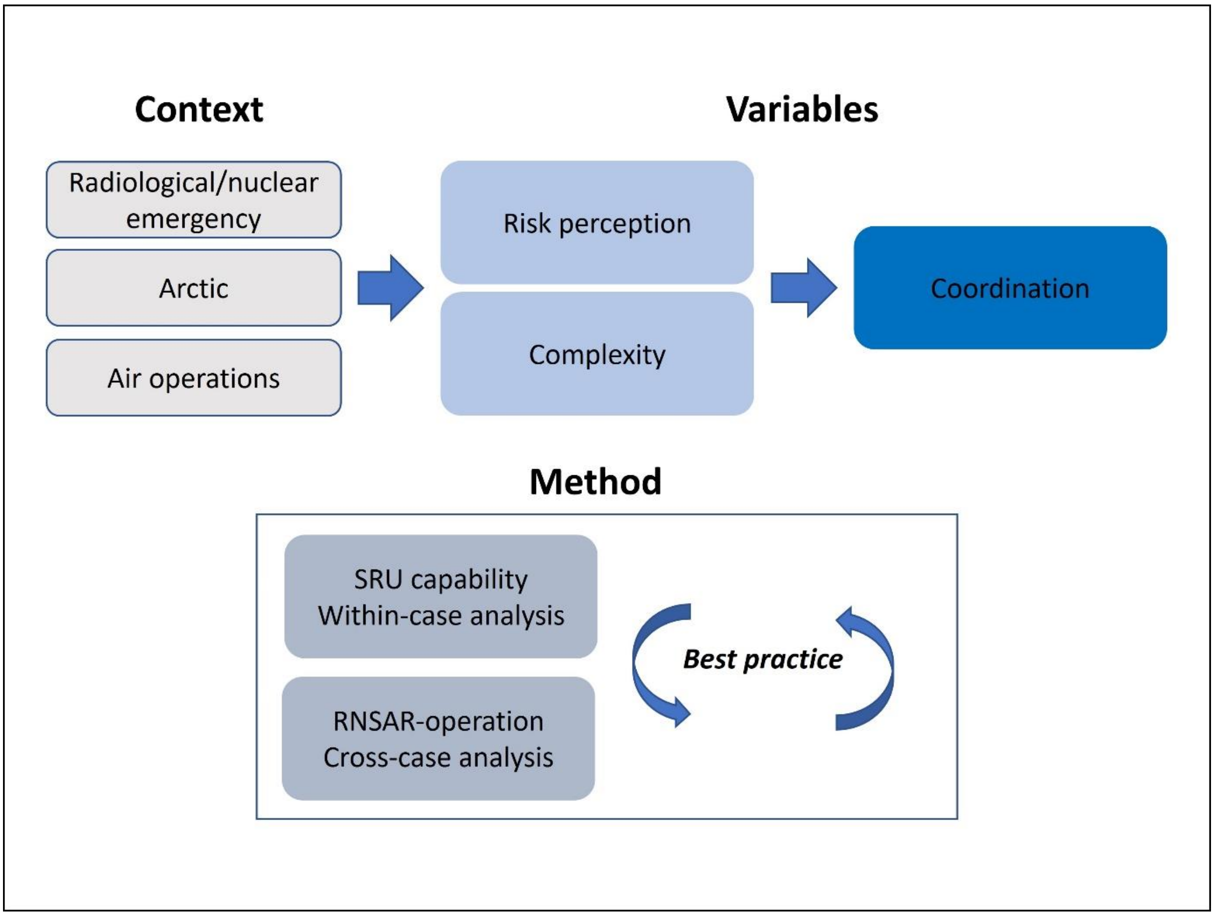

Figure 1: Analytical model

1.3. Exclusions and structuring of the thesis

What is perhaps most significant in this thesis, is the exclusion of other Arctic states conducting SAR air operations in a maritime environment. While Norway could have different governance structure from the other states, the operational context would present similar challenges in operations and coordination for all Arctic states.

The workings of this thesis were part of the RNSARBOOK-project, which included several Nordic partner countries. While the partner countries involved in the RNSARBOOK-project were part of the observations, this thesis only focused on the Norwegian organisations. This enabled an in-depth view of the Norwegian RNSAR system, but limited the scope and the ability to generalise findings. I still believe the findings will be relevant for any organisation responding to, and coordinating maritime SAR efforts in response to RN-emergencies.

Two principal distinctions are made throughout the thesis to structure the analysis and perspectives on the research questions. The first is between operational and unit level. The operational level addresses the overall SAR-system in Norway, with the JRCC being at the centre of analysis. The unit level comprises the individual aircraft responding together with other air and maritime assets to an RNSAR emergency. The second distinction distinguishes between transit to the distressed vessel, and the operations taking place at the scene of emergency. JRCC primarily coordinates and allocates resources including aircraft to the distressed vessel, while local coordination mechanisms are established and found on-scene.

Following the introduction in chapter 1, the further structuring of this thesis is as follows: Chapter 2 provides the theoretical framework for the study, outlining the central variables of coordination, complexity and risk perception. The study will be using a qualitative research design, as described in chapter 3. Topics include case study, data collection, analysis and ethical considerations. The findings resulting from within-case and cross-case analysis of the collected data from interviews, observations and literature study are presented in chapter 4. The findings and their relationships to the theoretical framework are analysed and discussed in chapter 5. Lastly, conclusions and recommendations are presented in chapter 6.

2. Theoretical framework – coordination, complexity and risk perception

The analytical model suggest that the context of this study generate variables of complexity and risk perception, which in turn will affect coordination. The theoretical framework is outlined with this in mind, with coordination of RNSAR air operations as the central, followed by how the different variables affect this coordination. An emergency involving radioactive exposure in the Arctic is assumed to have a catastrophic potential, which is dimensioning for the scale of emergency management required, and therefore the analysis in this thesis.

Such emergency management entails the way of organising processes to mitigate the effect of the crisis (Wolbers & Boersma, 2018). Four conceptual key processes underlines this effort and are summarised as the four C's of crisis management: Cognition, Communication, Coordination and Control (Comfort, 2007). The theoretical perspective provided in this study fits within this framework, mainly when considering coordination. However, elements of all four C's are present when adding the variables of complexity and risk perception. More interesting is the study of these variables and their relations at the unit level, and how they relate and affect coordination of multiple aircraft.

The Arctic region is characterised by remoteness, unpredictable climate and communication challenges (Sydnes et al., 2017). A SAR-actor operating in the Arctic operational context face difficulties in predicting nature and the capacities of other resources available, due to cultural and political differences and varying experience (Borch & Andreassen, 2015). This operational context represents a high complexity and volatile operational environment, implying the need for sophisticated coordination mechanisms between organisations. Thus, coordination is central throughout the search and rescue effort. The theoretical framework will attempt to define coordination, and how it is facilitated by coordination mechanisms. To explain how this can be organised, the Incident Command System (ICS) is presented as a system to understand how coordinative actions are taken. ICS' are temporarily organisational forms established to facilitate leadership, coordination and information flow (Rimstad et al., 2014).

Arctic SAR-operations, and especially mass rescue operations are considered complex, where complexity in organisations, environment and task are evident (Schmied et al., 2017; Thompson, 2003). An RN-emergency is assumed to increase complexity, in an already complex operational context. The theoretical framework will continue in looking into complexity as a system, where several factors are present to explain how and when complexity arises. All in all, the many factors present could be described as discontinuity and ambiguity which make it difficult to predict which organisations will, and should, be involved, and what tasks and expertise are needed (Wolbers et al., 2017).

Comfort argues that "cognition is central to performance in emergency management. Cognition is defined as the capacity to recognise the degree of emerging risk to which a community is exposed and to act on that information" (Comfort, 2007, p. 189). Thus, risk perception can be directly related to the RNSAR effectiveness. In the operational context, all the functional systems in air operations produce some sort of risk, that needs to be handled (ICAO, 2018). The potential serious consequences of air accidents in terms of injury, death or property loss have led to a great deal of research centred on risk analysis (Wang et al., 2019). Unintended and uncertain consequences of the Arctic context in general, and the RN-environment in particular, further increases risk.

In this thesis, the latter is in focus, and studies of risk perception indicates that nuclear power scores high as a "dread" risk, due to the perceived lack of control, dread, catastrophic potential and possible fatal consequences (Slovic, 1987). The assumption is that the individual risk perception will in turn affect how the given aircrew operate, or even operate at all. Taken together, risk perception at the unit level emerges as an interesting theoretical perspective to study.

The obvious limitations of the theoretical framework and the study as a whole, are the variables chosen. It is not intuitively understood why these matter over other perspectives within the four C's, and widening the scope of this study would certainly bring a more holistic approach to the research question. However, studying complexity and risk perception at the unit level, and how they relate and affect inter-organisational coordination represent a new and interesting perspective to the research on coordination.

2.1. Coordination and structuring mechanisms

Coordination has been at the centre of organisational theory since the 1960s. A basic definition of the term is provided by Faraj & Xiao which states that: "At its core, coordination is about the integration of organisational work under conditions of task interdependence and uncertainty" (Faraj & Xiao, 2006, p. 1156). Within organisations, coordination takes place through standardisation, plans or mutual adjustment (Thompson, 2003). The more variable and unpredictable situation, the greater the reliance on coordination by mutual adjustment. In this chapter, I will adhere to the contemporary view of coordination as an emergent process, encompassing coordination as contextualised and temporarily unfolding (Wolbers et al., 2017). This view is particularly fitting for organisations operating in fast-paced environments. In order to achieve a shared goal, i.e. the search and rescue of a distressed vessel, interdependent actors coordinate by engaging in mutual adjustments of their actions (Wolbers & Boersma, 2018).

To facilitate coordination, several mechanisms are in place in the organisational structure, consisting of both formal and emergent elements. Traditional coordination mechanisms found in literature, can be summarised into five different types (Okhuysen & Bechky, 2009). **Plans and rules** define responsibilities for tasks, resource allocation and develops agreements among actors. **Objects and representations** encompass technologies for information sharing, structure for activities, aligning work, and creating a common perspective across organisations. **Roles** with their associated tasks and responsibilities represent expectations as to who does what in an organisation. **Routines** coordinate by providing templates for task completion, bringing people together and creating a common perspective across groups. **Proximity** supports coordination by influencing communication and interaction between people, enabling monitoring and familiarity between individuals, and facilitates knowledge sharing and trust development.

Interdependence and uncertainty during coordination efforts represent complexities in the organisational structure and external environment (Borch & Andreassen, 2015). These complexities increase during crisis management, characterised by a volatile and unstable situation in which the development and outcome is difficult to predict. Rapid and unexpected changes in the situation, makes it increasingly difficult to rely on designed coordination mechanisms (Wolbers & Boersma, 2018). In such situation, actions quickly need to be coordinated both horizontally and vertically, internally and between organisations. Hence, coordination mechanisms are established through the process of coordinating, not so much as a result of prior arrangements (Jarzabkowski et al., 2012). In practice, organisational members are often found to coordinate intentions, goals and actions through discourse (Dooley, 2004). Dynamic situations are prone to a changing environment, where predefined interdependencies differ in practice. Classical coordination theories do not fully incorporate such dynamics (Wolbers & Boersma, 2018). Thus, traditional coordination theories have limited applicability in complex and volatile environments, involving multiple organisations (Boin & Bynander, 2015; Wolbers et al., 2017).

Many fast-response organisations have developed structures and risk-mitigation processes to operate under demanding operational environments (Faraj & Xiao, 2006). One way is the conventional command and control approach, following a rigid, centralised system based on clearly defined objectives, procedures and formal structure (Dynes, 1994; Schneider, 1992). However, the uncertainty resulting of such environments requires less formal and more interpersonal mechanisms (Boin & Bynander, 2015). This suggest a system more in line with the “problem-solving model”, which focuses on mechanisms for coordination, common decision-making and improvisation (Dynes, 1994). In reality, a combination of the two is key to success in organising for emergency response. Formal structure, doctrines and standard operating procedures (SOP) should underline the response organisations, while creativity, improvisation and adaptability are central in responding to an emergency (Harrald, 2006).

Thus, organisations face a dilemma, as it is stated by Faraj & Xiao:

> …on the one hand, there is a need for tight structuring, formal coordination, and hierarchical decision making to ensure a clear division of responsibilities, prompt decision processes, and timely action; but, on the other hand, because of the need for rapid action and the uncertain environment, there is a competing need to rely on flexible structures, on-the-spot decision making, and informal coordination modes. Thus, such organizations paradoxically emphasize both formal and improvised coordination mechanisms (Faraj & Xiao, 2006, p. 1157).

With this dilemma in mind, formalised mechanisms to *facilitate* coordination both vertically and horizontally, needs to be of a specific nature in order to be effective and not counter-effective (Boin & Bynander, 2015). Preparing for, and thinking about the challenges of coordination beforehand, and how they can be solved is essential for effective operations during a crisis. Crisis management could bring organisations together with little or no prior shared experience to perform complex and urgent tasks, where reliable performance depends on formalised structures melded together with flexibility-enhancing processes (Klein et al., 2006). Thus, established procedures will only partly cover the situational demands in such environments, and when combined with multiple complex organisations, a need for more sophisticated coordination mechanisms rises (Borch & Andreassen, 2015). One such coordination mechanism is the use of standardised operating procedures within and between organisations. The procedures should be simple, based on known coordination challenges and formalised across organisations (Faraj & Xiao, 2006).

So far, this chapter has emphasized mechanisms for enabling coordination through integration of tasks. However, an alternative approach follows the fragmentation perspective, which argues that incoherence and contradictions are expected and indispensable parts of regular coordination practices (Wolbers et al., 2017). This perspective gives added value, widening the perspective on coordination, with focus on the different organisations involved in an emergency. Wolbers et al. argue that: "discontinuity and ambiguity make it difficult to predict which organisations will engage in which part of the response operation, and what tasks, people and expertise are needed at different times" (Wolbers et al., 2017, p. 1522). They found that the on-scene dynamics of coordination involves **working around procedures** for unexpected events, **delegating tasks** to allow time for individual sensemaking and **demarcating expertise** to the individual/team with the specific expertise for a given situation. Taken together, these adds to the fragmentation of coordination, however, arguably provides a way of achieving flexibility, sensitivity to operations and improvisation that are regarded as key to successful and effective crisis management (Wolbers et al., 2017). Flexibility in the decision-making process is important at all management levels, and includes creative problem-solving, and adapting SOPs to the prevailing environment (Andreassen et al., 2018).

Literature suggest that coordination during the initial response to an incident is the result of functionality and trust (Boin & Bynander, 2015). Functionality encompasses formal structure and control, while trust relates to the already existing or emerging trust between the actors responding to an incident. The latter demonstrates the dynamic, processual and socially nature of coordination mechanisms (Jarzabkowski et al., 2012). During fast-response situations, coordination can be regarded as an emergent process, in which different interdependent action trajectories are synchronised (Wolbers et al., 2017).

Hence, coordination in emergencies should occur in a system, which encompasses formal structure and control, and the social nature of coordination mechanisms. Emergencies involving multiple organisations require temporary organisational forms, reliable in dynamic and volatile environment. Such an organisational structure is the Incident Command System (ICS), which may perform reliable in under extreme conditions (Bigley & Roberts, 2001). In large-scale rescue operations, incident command systems are established to facilitate leadership, coordination and information flow between multiple participating actors (Rimstad et al., 2014).

ICS combines bureaucratic features such as formalised structures, specialisation, and hierarchy with the flexibility of cross-organisational coordination of diverse resources in volatile and time-constrained operations (Bigley & Roberts, 2001). Structuring mechanisms, consisting of four basic processes are identified in enabling a rapid altering of formal organisational structure. **Structure elaborating** emphasises methods for the immediate construction of a temporary system at the scene capable of organising and coordinating several organisations, search and rescue units (SRU) and people. **Role switching** relates to the activation of roles and relationships in accordance with the functional requirements of a situation. Furthermore, if the emergency situations changes, personnel can be moved or assigned into new roles, enabled by well-defined expectations and reporting relationships in any given role within the system. **Authority migrating** occurs when informal decision-making authority are decoupled from the formal hierarchy and migrated to individuals who possess the expertise to solve particular problems. **System resetting** is the complete redirection or reconfiguration of the system, following a recognition of the current approach as non-sufficient. These structuring mechanisms represent procedures for assembling and reassembling diverse organisational elements or modules into a variety of configurations as the situational requirements dictates.

The structuring mechanisms in ICS complement the traditional coordination mechanisms. However, two more conceptual categories are also leading to reliable ICS performance under dynamic emergency situations: organisational support for constrained improvisation and cognition management methods (Bigley & Roberts, 2001). These will not be further elaborated in this thesis, but elements from both categories are found in the following theories of complexity and risk perception. Hence, ICS provides a system for coordination mechanisms, in a complex environment influenced by risk perception.

2.2. Complexity

Complexity is a difficult term that is often used, but not defined. The different coordination mechanisms described in the previous subsection is in many ways a response to variations in complexity (Thompson, 2003). Thus, this marks a suitable transition to the subsection on complexity, employing a broader theoretical lens on the concept. First, complexity in general is explained, through the research of complex system science. Then, complexity is outlined with regards to organisations, environment and task. Organisational complexity in itself is one factor, as well as being dependent on the factors of environment and task complexity. Any change in the latter two, will influence the complexity in the organisation (Thompson, 2003). This aims to show complexity in broad terms, with the potential to influence RNSAR air operations in many ways.

To begin with, one should differ between what is complicated, and what is complex. Weick & Suthcliffe provides an explanation: “A complicated system is one that can be described in terms of its individual constituents, whereas a complex system is one that can be described only in terms of interactions among the constituents” (Weick & Suthcliffe, 2015, p. 67). A more easy to grasp definition is provided by Lingel et al.,: “Something that is complex has many parts that are interdependent and may create emergent behaviours” (Lingel et al., 2021, p. 5). Traditionally, the term complexity has been associated with the inner workings of an organisation (Dooley, 2004). While most sciences focuses on the components within a system, complex systems science focuses on how the components within the system relates to each other (Siegenfeld & Bar-Yam, 2020). Thus, complex system science will be helpful in understanding the complexity of organisations, contextual variables and how they relate to each other.

Within complex system science, complexity is defined and a function of the number of possible behaviours that a system could exhibit (Siegenfeld & Bar-Yam, 2020). Albeit quantitative in nature, this also serves as a qualitative definition by stating that the greater number of possibilities exhibited within a system, the larger the complexity of the system. Some basic definitions are needed before continuing: systems are made up of elements and their relationships in a structure (Lingel et al., 2021). Several elements form nodes in a system that are connected in a network. The individuals or organisations that compose the nodes within the system are called agents.

Many complex systems are organised into multiple levels, and different levels of a system have different characteristics (Lingel et al., 2021). One important facet when studying complexity, is the lense, or scale of which one is studying the phenomenon. This multiscale structure gradually increases complexity when looking at the system in more detail (Siegenfeld & Bar-Yam, 2020). Within this perspective, complexity “refers to the manner in which the system behaves relative to its internal structure; its aggregate behaviour is not predictable from and cannot be reduced or understood from its component parts" (Dooley, 2004, p. 357).

Related to the multiscale structure is the trade-off between adaptability and efficiency (Siegenfeld & Bar-Yam, 2020). High complexity systems involve many possible actions happening in parallel and gives rise to adaptability. Efficiency arises when the many of a system works in concert at the largest possible scale. This leads to an interesting argument, where a very efficient system will, due to its necessarily lower complexity, not be as adaptable to unforeseen variations within itself or its environment. An adaptable system on the other hand, designed to handle all sorts of shocks, will necessarily have to sacrifice some larger-scale behaviours. Due to this trade-off between complexity and scale, any mechanism creating larger scale complexity will in turn reduce individual complexity. In many cases it is often worth trading some individual level freedoms for larger-scale cooperation.

2.2.1. Complexity in and between organisations

In this context, each involved organisation is a system in its own. More importantly, organisations constitute the agents that makes up the RNSAR-system. Thus, complexity is found within, and in the interplay between organisations. An important factor to consider is that organisational size alone, doesn't result in complexity (Thompson, 2003). Complexity means more or deeper interdependencies, and therefore more points of contingency.

During a crisis, organisations normally detached from each other, might find itself dependent on each other resulting in the ad hoc coordination mechanisms described earlier. This way of organising both draws on existing complexity, and creates emergent complexity more adapted to the present situation (Weick & Suthcliffe, 2015). However, the complexity of this could possibly lead to critical functions being abandoned, and the collapse of organisational coordination (Johannessen, 2017).

SAR organisations follow both operational and bureaucratic practice (Johannessen, 2017). Operational practices are the activities designed and assigned to prepare for and respond to crises and emergencies. In the everyday routines of these operational organisations, various kinds of administrative routines are integrated, part of the term bureaucratic practice. Operational practice follows the ideas about clear hierarchies, command structures, and responsibilities, whereby leaders at different hierarchical levels are supposed to perform different tasks. However, modern organising takes place in a net of fragmented, multiple contexts, happening in many places at once (Czarniawska, 2004). Most organisations, search and rescue services in particular, are expected to react to an incident as it unfolds. However, this leaves little time to select a mode of reacting. These organisational practices form in dynamic and uncertain ways (i.e. unpredictable, diffuse consequences and different interpretation of decisions) resulting in strong limitations to leaders and their ability to control complex organisational activities (Johannessen, 2017).

An organisation is a system in itself, but has to react to the environment which also is a system in its own (Siegenfeld & Bar-Yam, 2020). In this perspective, to be effective, the organisation must match, (or exceed) the complexity of the environment. More complex situations require a higher degree of complexity in the response pattern, which becomes visible in the organising (Johannessen, 2017). Such organisations have to master both the operational and bureaucratic practice, prepare for parallel organising and coordination, and act as quickly as time permits. The organisation in this context cannot be properly understood as a controllable, hierarchical organised system, or structure designed by leaders, within which people act. Organisations can rather be understood as self-organising processes created of communication that are coordinated and patterned between people.

Such system can be understood within the Complex Adaptive Systems (CAS) framework. CAS have interdependent components or agents that are animate and adapt, in contrast to complex systems where the parts are inanimate and do not adapt (Lingel et al., 2021). In response to a changing environment and decisions made by other agents, the system as a whole responds collectively to challenges. Thus, connectivity and interactions exists as linear or non-linear flows between agents (Dooley, 2004). This also results in uncertainty as to how the different elements of a CAS will behave (Siegenfeld & Bar-Yam, 2020). Central to CAS is network organising, where systems and networks, referred to as nested nodes, are hierarchically placed within larger systems and networks (Lingel et al., 2021). The principle is that tightly integrated functions should be managed together.

2.2.2. Complexity in the environment

Complexity in the environment can be described as discontinuity and ambiguity which make it difficult to predict which organisations will, and should, be involved, and what tasks and expertise are needed (Wolbers et al., 2017). Complexity in the environment could therefore refer to the external organisations and institutions of an organisation's network, as well as the physical surrounding that affects the organisation through a dynamic and unpredictable environment (Roud & Schmied, 2020). People working in varied, complex environment, needs varied, complex sensors to register the environmental complexities (Weick & Suthcliffe, 2015). Simple expectations produce simple sensations.

Emergency organisations have to operate in the latter environment, characterised by the movement between the known and unknown – between recognisable and unpredictable (Johannessen, 2017). Such complex and dynamic environment is best realised in extreme events, which creates a severe condition of disruption and destruction (Hossain & Uddin, 2012). While the severity of an event can be predictable, the time and place of the event is unpredictable. It is almost impossible to predict where and when a radiological accident will happen in the Arctic, however the severity of the accident is easier to understand.

In this context, one also needs to consider the human operator of an aircraft. A cognitive and psychological perspective exists on the individual level, on what causes complexity in the environment. Human expertise arises from the ability to learn the regularities of an environment, to further assess the predictabilities of that environment from which judgement is made (Kahneman & Klein, 2009). The ability to learn these regularities is challenged when many causalities and interacting agents exist in a complex system, such as CAS (Konrad & Sheard, 2016).

2.2.3. Complexity in tasks

Emergency response organisations generally exercise command skills in demanding, risky and uncertain situations, and decision-making is decentralised to the expertise best suited to respond to the complexities of such situations (Crichton & Flin, 2017; Weick & Suthcliffe, 2015). This could be seen both as a response to, and also generating, task complexity. Generally, one way of seeing task complexity is through the lens of decision-making and possible outcomes (Campbell, 1988). In such case, an increase in number of outcomes increases task complexity. Another perspective addresses the person-task interaction, where the tasks complexity is relative to the task-doers' capabilities of performing the given task. In order to integrate these perspectives, a complex task is defined as: "one which high cognitive demands are placed on the task doer" (Campbell, 1988, p. 43). The characteristics of a task could be complex, but the task-doers experience with the given task would reduce complexity.

Task complexity increases with the number of potential paths towards the desired end states, the number of possible end states, conflicting interdependence along the paths to the desired outcome and uncertainty present among the paths and outcomes (Campbell, 1988). The relationship with coordination is striking, where interdependence between multiple actors can have an exponential effect on task complexity (Hærem et al., 2015). Task complexity is a result of the number of, and relationships among components towards a goal. On the other hand, those organisations that have developed trust among each other prior to an emergency response, experiences fewer challenges in collaborating on complex tasks (Schmied et al., 2017).

Also related to task complexity is technologies and the associated complexity. The complexity of a technology could exceed the comprehension of the individual, mainly due to the lack of experience with the given technology (Thompson, 2003). The ability to perform the tasks are relative to the capability of the individual performing it (Campbell, 1988). On the organisational level, increased complexity of technology or task environment may require more flexibility within the organisation, than the already existing structure (Thompson, 2003).

2.3. Risk perception

The situation assessment and the associated risks are important factors in the decision making process (Crichton & Flin, 2017). Both rely on the decision maker's perception of the situation and risk at hand. Individual differences in background and experience can affect people's interpretations of the same situation (Bigley & Roberts, 2001). Hence, lack of experience of a particular situation can make it difficult for an individual to fully comprehend an RN-emergency situation. Thus, risk perception has the potential to have a major impact on the SAR-effort, influencing the decision-making process from the beginning.

Several fields of research has contributed to our understanding of risk perception, including geography, sociology, political science, anthropology and psychology (Slovic, 1987). The psychological research will be the focus of this thesis, originating from empirical studies of probability assessment, utility assessment and decision-making processes. This seems to be most fitting when analysing risk perception at the unit level, where the broad conception of risk is qualitative and complex.

Early studies found two higher order characteristics or factors related to the perception of risk: unknown risk and dread (Fischhoff et al., 1978). Dread encompasses perceived lack of control, feelings of dread, and perceived catastrophic potential, while the risk of the unknown relates to the extent of which the hazard is judged to be unobservable, unknown, new, or producing delayed harmful impacts (Peters & Slovic, 1996). Newer studies have used assessment of probability and judgment of the severity of the consequences as indicators for risk perception (Sjöberg et al., 2004). Acknowledging the multidimensional factors related to risk perception, this thesis will settle for a cognitive appraisal of risk, as it is qualitatively perceived and described by the individual.

Risk perception is selective and varies with the object of attention (Wildavsky & Dake, 1990). Thus, the context from which the hazard arises, affects the individual judgement of the risk (Pidgeon, 1998). People react to risk at two levels: they evaluate it cognitively, and react to it emotionally (Loewenstein et al., 2001). These two reactions are interrelated, but do make up to distinctive ways in which risk is perceived and acted upon; risk as *analysis* and risk as *feelings* (Slovic & Peters, 2006). Risk as feelings refer to the instinctive and intuitive reactions to danger, including emotions of fear and worry. Risk as analysis is the logic, reasoning and scientific deliberation underlaying risk assessment and decision making. The latter is part of the consequentialist perspective, where people make decisions based on assessment of the consequences of possible choices (Loewenstein et al., 2001).

However, intuitive feelings are the predominant method by which risk is evaluated, and the *affect heuristic* explain a more subtle reliance on feelings as information to guide judgement and decision making (Slovic & Peters, 2006). People perceive risk, not only by what they think about it, but also how they feel about it. This means that the emotional effects experienced are subtle and not always known to us (Sjöberg, 1998). Affect influences estimates of risk directly, not as a result of prior analytical evaluation (Butler & Mathews, 1987; Slovic & Peters, 2006). This works both ways: automatic positive and negative feelings towards a hazard will assess the perceived risk as either low or high, regardless of the actual (real) risk (Slovic, 2010). This again influences risk perception, as higher perceived benefit (positive feeling) is associated with lower perceived risk, and vice versa. Risk as feeling tends to disproportionally weight frightening consequences in certain situations, a tendency that is strengthened under time pressure without available time for analytical evaluation (Slovic & Peters, 2006).

Risky situations often result in direct emotional influences, including feelings of worry, fear, dread or anxiety (Loewenstein et al., 2001). These feelings emerge as a reaction to an individual's cognitive assessment of risk. Worry is worth highlighting, given the assumption of aircrew being professional emergency workers. Worry may result from threatening information in ambiguous events, elevating the risk perception for that situation (Butler & Mathews, 1987). In this case, worry is a result of the context, not a personality trait. Worry is preoccupation with thoughts about uncertain and unpleasant events (Sjöberg, 1998).

Hence, due to the affect heuristic, emotions often conflict with cognitive evaluations of a situation, and could cause the individual to deviate from what would the best course of action (Loewenstein et al., 2001). When such situations arise the emotions (i.e., fear) could dominate and produce behaviour that is counterproductive. Fear reacts to the probabilities and outcomes in very different manner than cognitive and rational decision making. Fear typically peaks just before a threat is experienced and is highly dependent on mental imagery. Such emotions stands in contrast to risk denial, where people claim to be less subjected to risk than others, or doesn't acknowledge the risk at all (Sjöberg, 2000).

Both experts and the public are subject to biases when perceiving risk as feelings, due to the strategies, or heuristics, that people employ to make sense out of an uncertain world (Slovic, 1987). Such biases includes **representativeness** when judging probabilities, **availability** of scenarios when assessing how a situation might develop and **anchoring** in a relevant number when attempting to predict a number (Tversky & Kahneman, 1974). These heuristics are usually effective, but may lead to systematic errors in an uncertain environment. Uncertainty in the environment can arise as a result of the inherent unpredictability of random events (Tannenbaum et al., 2017). Another dimension is the uncertainty arising from the lack of knowledge or skill about a particular situation. Related to aviation risk analysis, Wang et.al., have described it as two types of uncertainties: "aleatory uncertainty (caused by inherent randomness of the system) and epistemic uncertainty (originating from the lack of knowledge about the system)" (Wang et al., 2019, p. 86664). Thus, employing the terminology originating in Hacking's (1975) philosophical distinction between aleatory and epistemic probabilities.

Experts' perceptions of risk tend to see risk as consistent with the risk assessment of probability and expected mortality, in line with the risk as analysis approach (Slovic, 2010). Different definitions of the concept implies that variation in knowledge of the risk at hand leads to different risk perceptions. Lower educational level is associated with higher judgements of nearly all risks (Sjöberg, 1998). Some experience with a given type of risk, appears to give a more realistic risk perception (Sjöberg, 2000). Familiarity with a hazard, knowledge, controllability and voluntariness are factors that decrease the perceived level of risk (Fischhoff et al., 1978).

2.3.1. Risk perception of radiation and nuclear materials

Much of the previous research referenced above are related to the perceived risk of radiation and nuclear accidents. This section will end with a closing remark, describing some of the findings as it is particularly relevant for the thesis.

Radiation and nuclear energy are associated with powerful negative imagery (Slovic, 2012). Associations comes to mind of the atomic bombs of World War Two and the accidents at Three Mile Island, Chernobyl and Fukushima. The perception of radiation risk differs between experts and the general population, as it is generally found in the research above (Perko, 2014). This indicates that an increase in knowledge of radiation science, shortens the gap between experts and laypersons (Slovic, 2012). This also had a slight effect on the emotional affect to radiation risk management strategies. In addition, professional experience (voluntariness and knowledge), and the feeling of being protected from radiation with protective measures (personal control) are found to lead to lower perception of radiological risks (Perko, 2014).

2.4. Summary and analytical implications

The theoretical framework revolves around the concepts of coordination, complexity and risk perception. Large amount of literature and research have studied these concepts, and I have attempted to identify and describe both traditional and contemporary research in order to understand these concepts related to the research question.

Each of these theoretical concepts are interesting in its own, when studying the effect of the Arctic context *and* an RN-environment. With the added complexity of multiple aircraft operations, this thesis aims to add another perspective on the theories. What is even more intriguing is how these three concepts relate and affect each other, in the present context. Already in the theoretical framework, these concepts are cross-referenced and theoretical relationships are indicated. The empirical data provided could strengthen or weaken existing theories, or even suggest new theoretical paths to follow. Thus, the theoretical model will be revised after the analysis, hopefully bringing new insights to the research question.

3. Methodology

Studies in social science involves the collection, analysis and assessment of data (Johannessen et al., 2020). As a researcher, I have my own perception of the phenomenon studied. Thus, an open and thorough review of the method used in during the research process is necessary to achieve transparency and understand the choices and decisions made in order to increase the reliability of the study. This chapter will review the research design with the case study approach, how data was selected and collected through document study, interviews and observations, and the method for analysis. In addition, a discussion and reflections regarding validity and reliability, the scientific method used, and ethical questions will be provided. Some of the text in this chapter originates from the finishing exam of a methods course in preparation for the work on this thesis (Hveding, 2021).

3.1. Research design

With reference to the operationalising of the research question, maritime SAR air operations in the Arctic represent the phenomenon studied. Working on this master's thesis, I have gone into depth on the phenomenon, with the purpose of assessing the current capability to conduct RNSAR air operations. Furthermore, the study has aimed to identify and provide recommendations for improving coordination of multiple aircraft in an RN-environment. These recommendations are normative and adds data to a field in need of further studies. This suggests an exploratory research design, where the study could result in data which serves as a basis for new hypothesises and theory (Jacobsen, 2015).

I have chosen a qualitative approach for this study. Qualitative research methods are well suited to collect detailed and complementary information on a phenomenon, especially if previous research is scarce, which is the case in this study (Johannessen et al., 2020). In the research question, I am assessing *capability* which is a term difficult to measure through quantitative research methods. In addition, the theoretical framework for this study is subject to interpretation, which again favours the qualitative approach.

To my knowledge, there are little to no previous research on SAR air operations in an RN-environment, which leads to the lack of specific theory as a basis for the study. In other words, existing research does not address the current research question (Eisenhardt & Graebner, 2007). Thus, the study will rely on an empirical approach, where the data drives the research process. Such a theory-generating approach allows for an abductive research process, alternating between theory and empirical data until theoretical saturation is reached (Johannessen et al., 2020). A master's thesis is limited in time and resources, and I wasn't able fully reach theoretical saturation in this study. However, my participation in the RNSARBOOK-project facilitated the alternation between data collection and theory building. My findings were discussed with professionals on the field, verifying the connections between theory and data, and strengthening the validity of the conclusions, regardless of me not achieving theoretical saturation.

3.2. Case study

Case study research allows for methodological flexibility in the conduct of surveys, and will be the holistic method for this study (Johannessen et al., 2020). Case studies are rich, empirical descriptions of a phenomenon, and therefore well suited for the development of hypothesises, defining concepts and generating theory (Eisenhardt & Graebner, 2007). For this study, the phenomenon in question is maritime SAR air operations in the Arctic, and the cases are represented by the respective organisations operating the relevant aerial assets. Thus, the method will include multiple cases of Norwegian organisations, in the context of RNSAR and the RNSARBOOK-project. This enables a contextualised theory generating approach, through the abductive research process.

With this in mind, I have chosen a multi-case theory-building approach, sometimes referred to as "The Eisenhardt Method". This approach synthesises previous research on qualitative methods, case study research and Grounded Theory building into a process for generating theory through cross-case analysis (Eisenhardt, 1989). For this study, theory is considered a set of constructs linked together in relationships that are supported by theoretical arguments (Eisenhardt, 2021). Hence, the generated theory seeks to explain the phenomenon of SAR air operations in an RN-environment, by studying the relationships between a set of theoretical concepts. Although the purpose is to generate new theory, the importance of existing theory within the phenomenon is not to be neglected (Eisenhardt, 1989). Cross-case studies merely offers a new perspective to study a phenomenon.

It is rare to find a method that is a perfect fit for a study, which is also true in this context. However, the Eisenhardt Method is in my opinion a good framework for how to conduct a study in answer to the research question. This also includes some modifications on my part, which will be explicitly stated in the following description of the eight steps which make up the entire methodological process.

Step 1 is the project start up, which in my case was part of a method course preparing for the master thesis. An initial research question was defined to explicitly state a clear focus for the study. This is to avoid information overload for the researcher, and enables an early prioritisation of data collection (Eisenhardt, 1989). There should be little theory and/or empirical evidence underlying the research question, in order to provide opportunities for theory building (Eisenhardt, 2021). As previously argued, little research addresses how an RN-environment influences SAR air operations, and studying how the different terms and concepts relates to each other, which makes up the research question is quite unique for this study. The three theoretical perspectives of coordination, complexity and risk perception was described early in the process, as a starting point for understanding the phenomenon. Although the abductive approach allows (and encourages) the changing of different theoretical perspectives throughout the process, only minor changes were made as they were assessed as adequate in understanding the phenomenon. However, knowledge as a variable was later added to further explain the relationships between the theoretical concepts.

Step 2 revolves around selecting cases. For this study, the cases were selected on the basis of who would provide the most information. The selection strategy in this study is based on identifying key individuals according to specified selection criteria, which is further described in the following subchapter. The selection is not randomly chosen, due to the purpose of discovering similarities and relations between cases, from which constructs and hypothesis may be developed. With the phenomenon of SAR air operations in the Arctic, every organisation involved in this will represent a potential case. This study has selected five cases or organisations, which is on the lower scale of the recommended number in order to generalise the results (Eisenhardt, 1989). These organisations make up almost all of the relevant actors in Norway, and also a considerable amount of the organisations operating aerial assets in the Arctic on an international scale. As such, the number of cases was assessed as appropriate.

Step 3 is called crafting instruments and protocols (Eisenhardt, 1989). Instruments refer to which data collection techniques will be used, and protocols refer to the data collection methods. In theory-building, several data collection methods are commonly used. This results in triangulation of data, which underlies and strengthen the development of constructs and hypothesis. For this study, the data collection technique is qualitative, while the data collection was performed through a combination of document study, participant observations and interviews.

Step 4 involves entering the field. In theory-building case studies, data collection and data analysis overlaps (Eisenhardt, 1989). It is often appropriate to begin the data collection early in the project, thus enabling the adjustment of theory and perspectives for what is interesting in the empirical analysis (Tjora, 2021). To achieve this, field notes are an essential tool and may function as a log for the researcher throughout the study (Johannessen et al., 2020). I have used field notes for my own reflections and comments during, and after the interview. In addition, field notes were frequently used for my observations and in dialogue with practitioners and experts within the field of study. The flexibility of theory-building case studies is evident in this step, giving the researcher the freedom of making adjustments (i.e. follow up on emerging moments or add questions to the interview guide) along the process (Eisenhardt, 1989).

Step 5 is the analysis of data, and the core of building theories from case studies. Data analysis is divided into two phases: within-case and cross-case analysis (Eisenhardt, 1989). Within-case relates to the specific case, and is primarily conducted on transcribed data from the interviews. It also encompasses the analysis and findings of the document study and field notes. The within-case analysis resulted in an overall assessment of the capability to conduct SAR air operations in an RN-environment, which is an important finding for both the RNSARBOOK-project and this thesis. In this study, the within-case analysis primarily performed data reduction from the interviews, but some patterns already emerged at this stage. In contrast to the method outlined by Eisenhardt, I have chosen to prioritise considerably less efforts on the analysis of each case, but rather focus on the abductive process to identify a common approach to coordination of air operations in a RN-environment. At this stage, the goal was to get to know the specific organisation and its relation to the research question, to further accelerate the cross-case analysis in the next.

Cross-case analysis compares the findings from the respective cases, in search of patterns. The technique used was to choose characteristics and categories from the data collected from the interviews, and look for similarities and differences (Eisenhardt, 1989). The goal was to avoid bias and first impression to affect the results, through a structured approach in the analysis. The cross-case analysis has attempted to define concepts and variables within the phenomenon studied (Eisenhardt, 2021). Defining concepts is the creative process of "what is this a case of?", and was abductive with relevant existing theory in mind (Tjora, 2021).

Step 6 is the shaping of hypotheses, based on the tentative themes, concepts and possible relationships between variables which emerged during the analysis (Eisenhardt, 1989). This takes place as an iterative process, comparing theory and data until the researcher has developed theoretical hypotheses which closely fits the data. When more cases have coincident data, a hypothesis is supported and strengthened (Johannessen et al., 2020). On the other hand, lack of coincident data might lead to the hypothesis being modified or scrapped all together. The purpose of this step is to define testable and generalisable hypotheses outside of the participants in the study from which the data was collected (Eisenhardt, 1989). At this point the theoretical model was revisited and modified accordingly, based on the findings. Terms and constructs were defined before the analysis, and further assessed and modified throughout this process. These assessments have been explicitly stated for the reader as they were identified in the analysis.

Step 7 compares data and findings from the analysis with existing theory (Eisenhardt, 1989). Developed concepts, constructs and hypotheses are compared with the existing theoretical framework underlining the study. Both conflicting and supported findings in the literature are compared to increase the understanding of the phenomenon. Conflicting findings may lead to creativity and new perspectives, while supporting findings increases the internal validity and generalisability. The coupling to theory is particularly important in this study, due to the small number of cases available for theory building. This process will be further elaborated in the sub section on data analysis, categories and elements.

In step eight, the conclusions are drawn up, and represent the end of the project. Two essential questions arises in this step: when do one have enough empirical data, and when can the researcher finish the iterative process between theory and data (Eisenhardt, 1989). Ideally the data collection is stopped when theoretical saturation is reached. However, in practice this is limited by available time and resources for the project. For this study, the number of cases was already decided, and the data collection stopped before reaching theoretical saturation. The iterative process on the other hand, should be finished when there is minimal new information supporting the theory generating process. The end product of this study was a theoretical framework underlining recommendations for improving coordination of multiple aircraft in an RN-environment. Even though this resulted in what is likely considered a relatively small theoretical contribution, the practical value for conducting RNSAR-operations is more important.

Summarised, the process in this research design has been iterative and flexible. I have for the most part followed the steps in order, but when needed I had to jump between steps to optimise the result. This became best visible through continuous adjustment of theory and analysis, generating new questions and theoretical paths to follow for the next interview. It was an exciting process, which was hard to predict the outcome of.

3.3. Literature review

The literature review was mainly conducted using Nord University's access at oria.no. Additional literature was found using Googlescholar and other open access sources available. The literature review for the theoretical framework was conducted by searching on the following topics, adding subtopics when applicable.

Coordination	- Review - In organisations - Incident Command - Structuring mechanisms - Mechanisms - Crisis management
Risk perception	- Review - Social science - Nuclear - Radiation
Complexity	- Review - Science - System - Organisations - Environment - Task

Table 1: Literature review

Moreover, I aimed to start with review articles to get an overview of the subject, and then follow up on the references listed in those articles. The international articles found, was peerreviewed and originated from recognised journals, while the books were written by leading authors on the field in question.

3.4. Data selection and collection

The selection strategy in qualitative research should consist of a systematic assessment and identification of which informants that possess relevant information about the phenomenon in question (Johannessen et al., 2020). For this study, the target group was informants belonging to Norwegian organisations that operates aircraft, relevant in a search and rescue mission in the Arctic. This being an RN-environment, I had to widen the target group to also include those aircraft not normally thought of in SAR, as new procedures could potentially involve those assets in ways not seen before. At first, I thought of including all of the partner countries involved in the RNSARBOOK-project, but later decided to limit the target group to Norwegian organisations only. This is where the richest empirical data was found on my part, and made it more applicable to discuss the theoretical perspectives and their relation to the Norwegian SAR-system in contrast to several systems from different countries. This allowed me to collect information on the individual level to generalise for the SAR-system in Norway. That being said, the implications of this study would be relevant for all involved countries in the Arctic.

From each of the respective organisations identified, one key informant with expertise and experience in the field was recruited to participate in an interview, based on the following selection criteria: (1) Thorough knowledge about the procedures and operations related to the aircraft, (2) operational experience with / or knowledge about SAR operations in the Arctic and (3) knowledge of his own organisation.

The RNSARBOOK project manager with the Joint Rescue and Coordination Centre North Norway (JRCC-NN) proved helpful in identifying and recruiting informants from the target group. Their professional network allowed me to identify the key informants who were most likely to provide valuable information. As such, being part of the RNSARBOOK project partly functioned as a door opener for informants I may have had issues in reaching on my own. During the selection process, I still needed to verify that the identified informants were selected according to the defined selection criteria of this study. The informants, their organisation and aircraft are listed in the table below.

ID	Organisation	Aircraft
Informant A	Coast Guard, Royal Norwegian Navy	RPAS
Informant B	330 Squadron, Royal Norwegian Air Force	Sea King / SAR Queen
Informant C	333 Squadron, Royal Norwegian Air Force	P-3C /-N Orion
Informant D	Geological Survey of Norway	Leased helicopter
Informant E	Norwegian Coastal Administration	Beechcraft B350ER

Table 2: List of informants

A golden rule during a study is to limit the number of informants to the point where no new information is provided and data saturation is reached (Johannessen et al., 2020). Five informants in total were selected for this study, and even though they provided good data, it would be an overstatement to conclude that data saturation was reached. More important, this points towards a weakness in the data selection and possibly the study as a whole, as other countries operating relevant aircraft in the Arctic, including Russia and USA, were excluded. Including these would most certainly provide valuable data. The reason for excluding these was foremost due to limitations in time and resources, but the selected informants still turned highly relevant to the research question as they represented nearly all of the relevant organisations in Norway. As such, the findings and conclusions made in this study would be somewhat generalisable to the excluded countries, given the Norwegian experience in operating in the Arctic.

Worth mentioning is how specific selection criteria can result in a homogenous selection. However, this shouldn't be regarded as a weakness in this study, as its primary focus in this context is to identify and describe similarities for improving coordination of aircraft in an RN-environment. Hence, a homogenous selection is seen as a strength in this context, as it sharpens the empirical data collection within the phenomenon and increases generalisability for the theories being developed (Eisenhardt, 2021).

3.5. Document study

As previously described, a document study was conducted to map existing agreements, rules and procedures and their relevance in an RN-environment. The process of the document study followed the description in step five in the case study section. Initially, this served as a basis for the within-case analysis. Later in the process, findings and their theoretical relationships were further discussed together with the other findings in the main analysis. It was not meant to be a complete document study, as the best empirical data was collected from the interviews. However, it served as a supplement to the understanding of the phenomenon through the triangulation of data. In addition, lack of data directly related to the RN-environment was partly expected due to main purpose of providing such data through this study. The documents were chosen based on their relevance for the study, and mainly comprised of international and multilateral agreements and conventions. The document study was flexible, and some relevant documents emerged and was later added as a result of the interviews.

In general, the researchers' interpretation is the main weakness of document studies (Jacobsen, 2015). In principle, document studies are based on secondary sources, where the data material has been subject to assessment and data reduction by the original data collector. Important factors for this study, may already be left out from the original data material. This represent weaknesses one needs to be aware of in the process. In consequence of this, the findings of the document study were continuously validated with subject matter experts (SME) in the RNSARBOOK-project and through the interviews. Thus, much of the document study had to be completed prior to the interviews. Due to the nature of the data material being agreements and conventions, I remain confident that this weakness had limited impact in answering the research question.

3.6. Semi-structured interviews

Qualitative interviews are particularly suitable for achieving rich and detailed descriptions of the phenomenon studied, which harmonises with the purpose of this study (Johannessen et al., 2020). The conducted interviews provided the richest empirical data, as the focus laid with the informants' experience, viewpoints and reflections concerning SAR with aircraft in an RN-environment. To encourage this, the interview guide consisted of open questions which encouraged dialogue around the phenomenon. At the same time, some structure was needed to ensure that all the identified and related factors to the research question were covered. Hence, the interviews were semi-structured, following an interview guide with central subthemes and key questions. I assumed that the informants would be motivated and willing to share information and the key questions was asked early in the interviews. The assumption proved right, and all of the interviews provided fruitful dialogue.

The flexibility of the abductive process allowed for further development of the interview guide as new nuances and moments arrived, which previously weren't thought of. One example was when it became necessary to differentiate between unmanned and manned aircraft. The interview guide was adjusted with this in mind, downplaying the risk perception related questions when addressing UAVs. Furthermore, one interview was conducted with each informant, with the option for a follow up through e-mail correspondence if further questions and moments arose in the aftermath.

The interviews were recorded digitally, and then transcribed. This was a time demanding process, and one reason to limit the number of informants. The transcribed interviews represent the primary data collected, but my own reflections and notes during the process were also used. Initially, I wanted to perform the interviews face-to-face, but due to the Covid-19 pandemic the interviews were conducted through video using Microsoft Teams. This wasn't necessary negative, as the information provided through online interviews are similar and just as good as traditional face-to-face interviews (Johannessen et al., 2020).

A number of factors affects the relation between the researcher and informant (Johannessen et al., 2020). I would like to address some of these, and how this was handled. The initial part of the interview consisted of me legitimising the project to secure the information value of the interview. I stressed the voluntarism of the informant and confirmed his informed consent to participate in the study. I assumed that the informants had knowledge of the RNSARBOOK-project, but it was still important to describe how the master's thesis was related and how the information provided by the informants could be used. The video interviews enabled the informants to choose their own, undisturbed location, which allowed for a relaxed atmosphere. This also applies for the way I am perceived by the informant, through my body language. I have limited experience in conducting interviews, but I felt confident in that role and had a natural interest in what the informant shared. Thus, my impression is that the interviews were conducted in an appropriate way to provide the most useful information.

3.7. Participant observations

Observation is a method for collecting and analysing information through direct or indirect involvement in a situation and observing people in it (Johannessen et al., 2020). It allows for the direct interaction with the phenomenon studied. This method enabled observations of, and discussions with SME in the field of RN and SAR, respectively, for a deeper insight into the phenomenon studied. As a participant observer, I was partaking in the situations I was observing, e.g., three RNSARBOOK workshops and a Nord University tabletop exercise (TTX). Although this is considered a small number of settings, even observations of a limited scope can provide insight and supplement the data of other methods, e.g. interviews (Tjora, 2021).

The degree of how much the researcher is involved in the observations varies. Both the researcher and the ones being observed could be influenced by the observation, a well-known effect in this method (Tjora, 2021). One challenge throughout the process is maintaining analytical distance (Johannessen et al., 2020). In my case, I had little involvement in the interaction between the participants, both in the workshops and the TTX. I was aware of the observation effect and didn't feel this influenced the data collected. My participation in the setting was as an outside observer, an open role which was clear from the beginning (Johannessen et al., 2020). Of note, as a participant, I was able to contribute with my experience and existing knowledge of air operations in the different settings. In the handbook development, I started to feel part of the team developing the handbook. In some way, I felt that added legitimacy for being involved and increased the participants' trust in me, making it easier to gain access to information. On the other hand, this could influence my perspective, and limit my ability to collect relevant data, or even misinterpret the situation. This was a fact I needed to be aware of throughout the process.

The observations were conducted in two main settings; digital workshops on Teams to develop the RNSARBOOK for the Nordic countries, and a TTX at Nord University. The table below provides an overview:

Participants (the ones being observed)	Setting	Date
Approximately 20 participants with RN and SAR expertise from the Nordic countries	Digital RNSARBOOK workshop 1	19 Apr 2021
Approximately 40 MASIK students at Nord University	Nuclear Exercise – 2021 (TTX)	30 Sep 2021
Approximately 10 participants with RN and SAR expertise from the Nordic countries	Digital RNSARBOOK workshop 2	6 Dec 2021
Approximately 10 participants with RN and SAR expertise from the Nordic countries	Digital RNSARBOOK workshop 3	14 Jan 2022

Table 3: Overview of observations

The workshops included SMEs in the field of RN and SAR, respectively. This provided different experience and knowledge of the two areas in question. The participants came from different organisations and countries: the Norwegian Radiation and Nuclear Safety Authority, the Joint Rescue Coordination Centre North Norway, the Icelandic Radiation Safety Authority, the Icelandic Coast Guard, the Joint Rescue Coordination Center Denmark, the Danish Emergency Management Agency, the Finnish Border Guard, and Nord University. This provided both depth and width in the data provided by the observations.

The nuclear TTX at Nord University, aimed to give the participants an understanding of the organisation of the Norwegian nuclear preparedness system. The roles, responsibilities, and coordination of different organisations involved in a nuclear accident were discussed. This exercise was conducted at Nord University, and I had the role as a facilitator and observer. The exercise provided an insight in the attitudes, experience and opinions of the students, when discussing the preparedness system for such an emergency.

My involvement in the field was temporary, limited in time and space to the four abovementioned situations. However, in some way I really never left the field, as I had frequent contact with SMEs and the project coordinator throughout the process. It is often challenging to gain access to the field in observational studies, which luckily was not the case for this study (Johannessen et al., 2020).

After each situation I wrote field notes of relevant observations and my initial interpretations and reflections of them. Thus, the field notes were a combination of theoretical and personal notes, combining initial analysis, interpretations and ideas with the researchers' reflections (Johannessen et al., 2020). I had a pragmatic approach, noting what was salient based on my subjective interpretation of the situation, and knowledge of the theoretical framework (Tjora, 2021). My reflections, questions and ideas were also noted as comments, separating it from the observations. The observations were unstructured, meaning I hadn't any predefined information I was looking for, but rather entered the field with an open view to gain insight into the phenomenon. On a positive note, by participating in the RNSARBOOK development and maintaining a holistic overview of theory and the direction of the study, I was able to collect complex information and follow the abductive process. In some way, data was processed immediately after observation by discussing findings with SMEs, a valuable feature of participant observation (Johannessen et al., 2020).

3.8. Data analysis, categories and elements

The following subsection expands on the process of analysis found in the steps five through seven of the methodological process. This involves both analysis and assessment, two terms that need elaboration (Johannessen et al., 2020). Analysis is the process of dividing something into elements, while assessment is the process of discussing findings and their relevance to theory. The research question of this study shows that the phenomenon of maritime RNSAR air operations in the Arctic consists of several elements. This was consistent with categories and elements found in the within-case analysis.

At this point I found it necessary to structure the analysis along two main distinctions: the organisational level and the place of operations. The organisational distinction between the operational and unit level, allowed for an analysis with different perspectives on the RNSAR-system and the individual aircrew responding to the RN-emergency, respectively. The perspectives are strongly connected, but the distinctions allow for the systemising of findings and recommendations. The second distinction is between aircraft transiting to, and the situation at the scene of emergency, and allowed for the analysis of the different coordination mechanisms that emerged at the different phases of RNSAR.

Working with text, resulting from the document study and transcriptions, was the primary analytical process. This involved interpretative reading of the material, where both what was actually said and the meaning of that were relevant in the study. This allowed for field notes and my reflections throughout the study, which in some cases was followed up and validated with the informant or SMEs in the RNSARBOOK-project. Data reduction and systemising of the material initiated the analysis, and were important to avoid losing important information and a prerequisite for the analysis to follow (Johannessen et al., 2020).

I began with organising the information into four themes, three of those directly related to the theoretical framework, and one related to the capability assessment. Field notes and observations were also organised and added to the analysis. Through the within-case analysis, the sorted information was assessed and grouped into categories and codes with the purpose of remaining close to the empirical data. This part of the process was inductive, and an important step in remaining true to the empirical data for generating theories (Tjora, 2021). Out of these categories I was able to develop concepts and the related variables for the cross-case analysis (Eisenhardt, 2021). The purpose of this conceptualising is to develop concepts that fits with both theory and empirical data, which was summarised into findings in the cross-case analysis. A summary of the categories and number of empirical codes (elements) are found in the following table:

Theme	Categories	Code (with examples)
Capability		Total number: 41 *"RN-specific procedures are lacking"*
Coordination	Operations Plans and procedures The importance of trust Communication	Total number: 37 *"IAMSAR-procedures works for coordination in an RN-environment"*
Complexity	Organisation Oversight and situational awareness Operational environment	Total number: 31 *"Radiation affects coordination because of the resulting uncertainty"*
Risk perception	Understanding risk Standardising Knowledge of radiation	Total number: 31 *"Knowledge reduces fear of radioactivity"*

Table 4: Coding of empirical data

This system of indexing the data through defined tags allowed me to systemize and find the relevant data, and then search and identify common themes in the cross-case analysis. Both the document study and within-case analysis resulted in several findings relevant to the research question. Cross-case analysis strengthened these findings across cases and allowed for the development of the main hypothesis. *Assessment* was the process of discussing these findings and developed hypothesis with existing theory to understand and explain these. It was this process that led to the recommendations that concludes the thesis.

3.9. Validity, reliability and generalising

Determining validity, reliability and how the findings are generalisable are central in assessing the methods of this study and its conclusions. In the following subsection I will reflect upon these terms related to my work and findings in this thesis.

In general, *internal validity* is about the extent to which there is a connection between the empirical data collected and the phenomenon being studied (Johannessen et al., 2020). Are the data credible (valid) representations of the phenomenon of maritime RNSAR air operations? In qualitative research this relates to the method and findings in the study, and how they represent the real world. For this thesis it is essential to assess to which degree the case design is a suitable method to provide valid answers to the research question, as it has been discussed earlier in this chapter. For instance, a systematic approach in the cross-case analysis will increase the likeliness of valid data (Eisenhardt, 1989).

Internal validity is not an absolute requirement, but one should strive to achieve this in order to show valid results and conclusions (Johannessen et al., 2020). For this study, several methodical choices were made to increase internal validity. Method triangulation is one, and several data collection methods were used in this study: document study, interviews and observation. Furthermore, the informants were offered to look through the transcribed interviews to avoid ambiguities, and I had the opportunity to contact them afterwards for follow-up questions. Of note, when data coincided from several informants, the validity of those data were strengthened. Another moment is the abductive process in itself, which gave the opportunity to increase the credibility of data through discussion of my interpretations with SMEs in the RNSARBOOK-project.

Reliability relates to the data collected, analysed and applied in the study (Johannessen et al., 2020). As opposed to quantitative research, this study is conducted within a specific context and the data collected are subject to my subjective interpretations. Thus, a duplication of this study is impossible. However, the steps taken to increase reliability are a thorough description of the context of the case design and an open and detailed description of the methods used for this study. Remaining true to the empirical data in the coding process of the analysis, is an important step in avoiding researcher bias and “gut feeling” influencing which codes are brought forward (Tjora, 2021). Arguably, the share amount of empirical data contribute in reducing researcher bias (Eisenhardt, 2021). The abductive process as it is described in the case design is another way of increasing reliability through discussing and assuring quality of the data with SMEs.

External validity or generalisability relates to the results of the research, and if they are applicable for similar phenomenon (Johannessen et al., 2020). Descriptions, terms, concepts, interpretations and explanations found in this study should be useful in other areas than the already established focus. This might be even more important in a theory-building approach, in this case, findings and conclusions relevant beyond the phenomenon of RNSAR. Five cases is on the lower scale of the recommended number in order to generalise the results (Eisenhardt, 1989). These organisations make up almost all of the relevant actors in Norway, and also a considerable amount of the organisations operating aircraft in the Arctic on an international scale. This likely results in a higher degree of generalising in Norway, albeit to a lesser degree to all of the Arctic actors.

The fact that the chosen cases are not random, as they are based on the organisations encompassed by the phenomenon studied, is arguably one way of increasing external validity. This sharpens the empirical focus, thus limiting alternate explanations and increasing generalisability (Eisenhardt, 2021). To further strengthen the generalisability, ample descriptions of the phenomenon are provided, with the goal of allowing other to assess whether the results provided are transferable to other contexts.

3.10. Ethical considerations

Put simply, in social research, people are the ones being studied. Thus, the researcher needs to consider ethical questions and issues (Johannessen et al., 2020). My research has been conducted in line with the guidelines provided by The National Committee for Research Ethics in the Social Sciences and the Humanities (NESH) and Nord University (NESH, 2016; Nord universitet, 2018). After I reviewed those guidelines, I found that this study mainly needs to account for access to, and the use of personal data provided through the interviews. The information collected through participant observations was only registered as field notes, and it wouldn't be possible to identify the individuals observed. For the interviews, I have a duty of information to the informants that I was collecting information about, according to Norwegian law. All informants received an information letter to participate prior to the interviews and provided a voluntary, explicit and informed consent to participate. The study is assessed to not treat sensitive information, which may go against the researcher's duty to accept the informants' privacy and avoid damage.

The informants of this study will be able to be identified, and the research process needs to follow the Norwegian law and the General Data Protection Regulation and Personal Data Act (Personopplysningsloven, 2018). The personal data processed is limited to the full name, job position and organisation of the individual. Special categories of personal data needing additional approvals are not processed in this study. In addition, audio recordings of the interviews are considered registering and storage of personal data. Thus, I have stressed the importance of processing and securing the information according to current guidelines and collected consent from the informants prior to the interview. The consent should be informed and was recorded on the audio recordings. To ensure the ethical aspect was taken care of, the research project was reported and approved by the Norwegian centre for research data (NSD), before the informants were recruited.

3.11. Chapter summary

To summarise, this chapter on methodology began with a description of the research design for the study. The thesis follows a case study approach, using the Eisenhardt method for generating theory through the techniques of within-case and cross-case analysis. The data was selected and collected from relevant documents, semi-structured interviews of five informants, and field notes from observations of three RNSAR workshops and one TTX at Nord University. Furthermore, the chapter elaborated on how data was structured and analysed, and provided a discussion and reflections on validity, reliability and the ethics concerning this study.

4. Findings

The following chapter is made up of three sections. First, the findings from the document study are presented, along with an overview of relevant documents and agreements. Particular attention is paid to the IAMSAR-manual, as this is the most relevant, internationally agreed upon, coordinating mechanism available at this time. The second section provides an overview and assessment of the capability of the Norwegian organisations to operate aircraft in an RN-environment, resulting from the within-case analysis. The third and final section presents the findings of the cross-case analysis, presenting concepts and the emerging relationships of variables. The findings are supplemented by my own reflections and observations throughout the data gathering process. The theoretical model was revisited and modified accordingly at the end of this chapter.

4.1. Document study: Air coordination in international conventions and agreements

The International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) are responsible for the international conventions and standards for aeronautical SAR services. Rules and regulations for aeronautical SAR services are found in The International Convention on Maritime Search and Rescue – Hamburg Convention (International Maritime Organization, 1979) and the Convention on International Civil Aviation – Chicago Convention (International Civil Aviation Organization, 1944). In 1946, an Annex 12 of the latter convention was added, recommending standards and practices for search and rescue (International Civil Aviation Organization, 2004). The need to coordinate the SAR organisations are emphasised in all of the above conventions. For instance, the Hamburg convention explicitly states: “The activities of units engaged in search and rescue operations, whether they be rescue units or other assisting units, shall be co-ordinated to ensure the most effective results” (International Maritime Organization, 1979, p. 131). Maritime-air coordination and common procedures are also standards the parties should ensure as far as practical possible.

Similar recommendations are found in Annex 12. Additionally, it recommends the establishment of Joint Rescue Coordination Centres to coordinate aeronautical and maritime search and rescue operations (International Civil Aviation Organization, 2004). It also recommends common SAR plans and procedures to facilitate coordination across organisations and countries.

Other UN conventions regulating safety and law at sea, is the International Convention for the Safety of Life at Sea (SOLAS) and the United Nations Convention on the Law of the Sea (UNCLOS). However, they are not directly related to the aeronautical SAR services and consequently not further discussed.

One multilateral agreement relevant to the Arctic is worth mentioning. The multilateral Arctic SAR agreement was signed by the member states of the Arctic Council, and includes the entire Arctic region. The objective of the agreement is to: "strengthen aeronautical and maritime search and rescue cooperation and coordination in the Arctic" (Multilateral agreement, 2011). The SAR response is improved by serving as a framework for information sharing, while also identifying and improving mechanisms for cooperation, coordination and support in SAR and emergency response.

FINDING 1: While the abovementioned conventions and agreements emphasise the need to coordinate aircraft, none of these specify how this should be done. This could be due to the nature of such documents, representing overall agreements among nations, delegating responsibility to develop specific procedures to the nations involved.

4.2. IAMSAR manual

To assist nations in meeting their own SAR needs, and the obligations they accepted under many of the abovementioned conventions, the IAMSAR manual provides guidelines for organising aeronautical and maritime SAR services (IMO/ICAO, 2016b). Volume II and III assist in planning and coordination SAR operations, with the first being more comprehensive and the latter to be carried aboard SRUs. Both volumes have a dedicated chapter on multiple aircraft SAR operations. According to the IAMSAR manual, the SAR system has three levels of coordination: the SAR coordinator (SC), the SAR mission coordinator (SMC), and the on-scene coordinator (OSC). It became clear during the within-case analysis that the procedures of coordination outlined in the IAMSAR manual, was generally considered "good enough" by the informants. This finding is in line with Olsen, which states that the IAMSAR manual is the: "key procedure document specifically on how to organise and provide for search and rescue services" (2016, p. 42). Furthermore, this was also said to be applicable in an RN-environment, given an aircraft coordinator (ACO) in place. Thus, the following document study went further into depth of the IAMSAR-procedures with a unit level perspective and attempted to identify factors related to air operations in an RN-environment.

When multiple aircraft are involved in a SAR operation, the OSC should designate an ACO to coordinate aircraft operations (IMO/ICAO, 2016a). Of the Norwegian assets, the P-3 Orion is probably the best suitable platform, followed by the Coast Guard vessels. The ACO is primarily concerned with flight safety, maintaining safe separation of the aircraft operating in the area. The main coordination mechanism is through radio communications at dedicated frequencies or channels. This is visualised in the following figure found in an earlier version of the International Manual for Aircraft Coordinator (2010), which aims to standardise the basic principles used for a SAR mission involving an ACO:

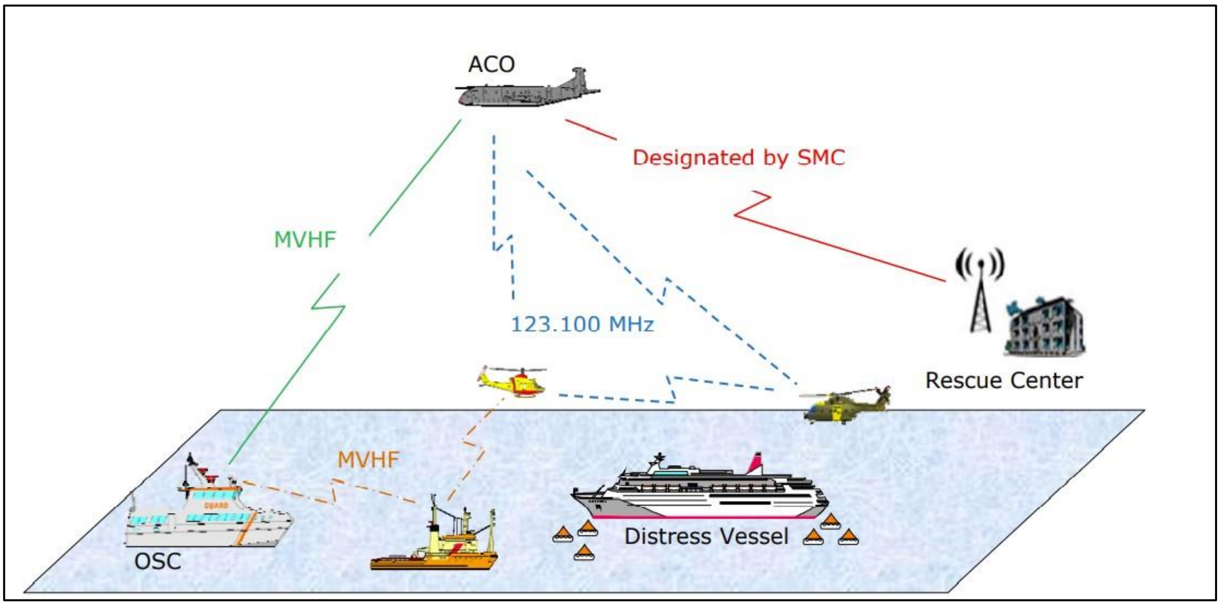

Figure 2: Airborne ACO (Baltic ACO Manual, 2010, p. 9)

There are two principal phases, or mission types, that aircraft can perform in an RN-environment (IMO/ICAO, 2016a). The *search*, in this case mapping of radioactivity, referred to as RN-detection, and *rescue mission* – focusing on the evacuation from the distressed vessel.

When conducting RN-detection missions, low and slow is the preferable method. A normal type of search pattern, should be appropriate, meaning that the coordination of search missions as described in the IAMSAR manual should be sufficient (Informant B).

There are several methods of coordinating the aircraft in this phase, ranging from visual separation between aircraft to zones of coordination, or no-fly zones separating search areas from another (IMO/ICAO, 2016a). The ACO designates entry, and departure points, search areas and methods, in coordination with the OSC.

During evacuation missions involving multiple aircraft, a combination of horizontal and vertical separation of aircraft is ideal (IMO/ICAO, 2016b). Horizontal separation can be achieved by establishing specific routes to, from and within the area of SAR action. Related to the RN-environment, a particular focus should be on the wind direction, and aircraft routes should be off-set to avoid radioactive particles in the air. Vertical spacing separates aircraft at different altitudes and is the primary separation of UAVs. Vertical spacing is dependent on weather.

FINDING 2: The IAMSAR manual is a welcome exception to the previous documents, specifying procedures and command structures for coordination. However, the specific nature of an RN-environment is not described and requires the development of own procedures. For the involved aircraft, it would be up to the ACO to decide on search methods, which implies a need for basic RN-knowledge.

4.3. Within-case: Organisational capability to conduct RNSAR

This section provides an assessment of the Norwegian capability to conduct maritime SAR air operations in an RN-environment, also referred to as RNSAR operations. The assessment is based on the interviews of members from a total of five organisations in Norway, chosen by their relevance to operate aircraft in an RN-environment. The table summarises the organisations and associated aircraft, including roles and capacity:

Organisation	Aircraft type	Relevant roles	Preparedness[2]	Note
330 Sqn / RNoAF	Sea King	SAR RN-detection	15 min 30 min to install RADIAC	RADIAC[3] at Bodø
330 Sqn / RNoAF	AW-101 SAR Queen	SAR	15 min	RADIAC not operational
333 Sqn / RNoAF	P-3C Orion	ACO RN-detection Visual search	Tasked	RADIAC installed during preflight
Norwegian Coast Guard	RPAS/Drone Teledyne FLIR Skyranger R70	RN-detection Visual search	Tasked 1 (5) CG vessels	15nm range from vessel (less to enable time in the operating area)
Norwegian Coastal Administration	Beechcraft B350ER (LN-KYV)	RN-detection Visual search	2 hrs (4 hrs at weekends) 2 hrs to install RADIAC	RADIAC at Gardermoen Needs operator from DSA[4]
Geological Survey of Norway	Leased helicopter Eurocopter AS 350B	RN-detection	Tasked	Limited to land operations No personal protection equipment

Table 5: Overview aircraft and capabilities

At first glance, the capability to respond to RNSAR-emergencies looks quite good, with both SAR-capability and RN-detection equipment available. However, certain limitations were observed.

In general, there is a lack of experience of operating in, and conducting SAR in an RN-environment, mostly due to the rarity of such events. Up until now, there is rare to find examples of exercises and training on operating and coordinating efforts in a RN-environment. An RNSAR-operation is possible today, but would require external assistance with the risk assessment, as most informants felt they lacked the expertise and knowledge of performing it. Also, 330 sqn noted the difference between radiological and nuclear environment (Informant B). The first would be possible to operate in as of now, but the latter difficult because of the airborne nuclear particles.

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[2] Preparedness time is what JRCC could expect for SAR-missions
[3] Radioactivity, Detection, Indication and Computation. Equipment enabling detection, identifying, and measuring the nuclear radiation at a given place (Informant B)
[4] Norwegian Radiation and Nuclear Safety Authority

RN-detection and procedures exists (RADIAC), but there are low organisational experience and knowledge of the system. For instance, the Coastal Administration aircraft would need personnel from DSA to operate the system (Informant E). One also needs to consider where the systems are located and the time needed to install it. Specific procedures are being developed at 330 Sqn, and should be tested on and evaluated on a large-scale exercise in 2022 (Informant B). Furthermore, there are no decontamination procedures available, with the exception of the Coast Guard. As one informant put it, when asked about procedures for decontamination: “it would probably have a slightly improvised feel to it” (Informant C).

Only the military services have protective equipment in form of personal dosimeters. Proper face masks are spare, again with the exception of the Coast Guard. However, all seems to be aware of and considers the given dose limits of radioactivity for the population in their risk assessments.

4.3.1. *Radiation effects on aircraft avionics*

Another important factor to consider, is the effects of radiation on the electronic systems of the aircraft, the avionics. It is outside the scope of this thesis to conduct a thorough research of this, however, already existing literature provides some insight.

Most research found related to this phenomenon revolves around cosmic radiation, and its effect on aircraft and spacecraft (Dyer & Truscott, 1999; Meier et al., 2020; Normand, 1996). They refer to a phenomenon named single event effects (SEE) where high-energy particles collides with the structure of an electronic silicon device, such as the avionics in an aircraft, and causing errors, hardware failure and electric breakdown in the components (Dyer & Truscott, 1999). Experience from the space industry provides evidence for radiation causing errors, computer crashes and hardware failure.

When considering SEE, this suggest that radiation from a source in a SAR-operation, given enough intensity, will have an effect on aircraft avionics. However, there is a high degree of uncertainty linked to these effects, and it is not possible to conclude in this thesis. Still, it should be incorporated in the risk assessments of the aircrew prior to a mission in such scenario. This should prepare the aircrew for possible errors and even partly systems failure, while decision makers should prepare for technical issues that could result in the aircraft relocating or aborting the mission.

4.3.2. *Assessment*

In general, aircraft are quick to respond, and with the assessed capabilities of the Norwegian air assets, several resources are in place to conduct both RN-detection and SAR. Primarily military resources, especially the Coast Guard seems most capable of operating in an RN-environment. However, limitations in knowledge, procedures and protective equipment are found, which may result in uncertainty to the effectiveness of the RNSAR-operation. This is further increased at the unit level, considering the uncertainty of how the technical systems of the aircraft will function. At the operational level, the effectiveness of RNSAR probably lies within the ability to prioritise between RN-detection and SAR, coordinate the effort and decide on the most efficient use of the available resources.

FINDING 3: Norway has the aircraft capable of performing RNSAR-operations. However, several factors, including lack of radiation knowledge, procedures, protective equipment and radiation effects on aircraft, adds uncertainty to the effect of such operations.

FINDING 4: The use of UAVs is a promising technology especially for RN-detection. It enables operations in an RN-environment, without the risk to the personnel in a manned aircraft.

4.4. Cross-case: Coordination – a necessity for safety and RNSAR effectiveness

When addressing coordination of aircraft during RNSAR-operations, four categories emerged during the cross-case analysis: (1) operations, (2) plans and procedures, (3) the importance of trust and (4) communication. These will be elaborated in the following.

4.4.1. Operations

A large part of the discussion about coordination relates to air operations, which is where most informants had their operational experience from. One way of looking at coordination during RNSAR, is to differ between phases in the operation (Informant A). While the JRCC coordinates the transit to and from the distressed vessel, the OSC or preferable the ACO, coordinates the involved aircraft at the scene of emergency. The scope of the RNSAR-operation is another way of categorising coordination, where smaller incidents can be coordinated directly with other units through radio communications, while large scale operations follow the guidelines in the IAMSAR-manual (Informant B). The first type of incident might not need an ACO at all, as the few SRUs involved can coordinate directly and safe with each other. Thus, defined roles and operational phases results in clear lines of coordination in larger emergencies. However, the more actors involved, the more challenging coordination is. This became clear during the TTX which provided an overview of all the involved actors in the Norwegian system responding to an RN-emergency (Observations, 30 September 2021).

As previously discussed, existing coordination procedures seems sufficient, given an ACO in place (Informant B). Although the ACO cannot be responsible for aircraft separation, suitable aircraft like the P-3 Orion have equipment that allows it to keep an overview of all the traffic operating in the area, coordinating for safety, and maintaining communications with other actors (Informant C). Thus, highlighting the relevance of the ACO as a coordination function which works best in a maritime environment, away from the shore, where ATC and JRCC have limitations in the ability to coordinate the operation on-scene.

Near the distressed vessel there is a potential for several aircraft operating simultaneously in the same airspace. Common factors are high speeds and low altitude, which increases risk and the need for coordination as a risk mitigation measure. The ACO maintains an overview of the air traffic in the area to mitigate the risk and coordinates the movements of the different involved aircraft (Informant C). During evacuation, the aircraft would have to be separated from each other with designated entry/exit points and transit routes inside the hot zone. During search and RN-detection, a simple way of coordinating is to allocate search boxes for each aircraft, which is found to work well (Informant E). As such, different ways of separating air traffic are used depending on the airspace and overall situation and can be seen as coordination mechanisms. However, many of these entails the aircraft *not* operating in the same airspace – hence potentially reducing effectiveness in an operation combining both search (RN-detection) and evacuation (SAR) at the same time.

4.4.2. Plans and procedures

Plans and procedures are developed and exists, both for the use of specific RN-detection equipment, and SAR in general. Albeit the experience with using and employing these procedures, especially for RN-detection live, is almost non-existing (Informant D). This leads to uncertainty into how it will work. However, for coordination, existing coordination procedures for aircraft seems suitable (Informant A). The IAMSAR-manual should also work well in an RN-environment, as long as the different areas are defined and restricts aircraft operations if radiation levels are assessed to be above dangerous limits (Informant C). It is the RN-specific procedures for operating in such environment that is lacking. The Coast Guard seems most satisfied with the existing procedures, as they have developed SOPs and checklists which are used all the time (Informant A). The procedures also allow for flexibility, which is important in a dynamic environment.

The use of drones is a promising new technology, a capacity which at the time of writing is limited to the Coast Guard vessels. However, because it is a new technology, there is a lack of procedures considering coordination of drones with other aircraft. At the time of writing, these are in process of being developed at the operational level (Informant A). For now, drones will be allocated to a designated airspace, deconflicted vertically and horizontally to stay clear of other traffic. In some cases, the drone might even be grounded while another aircraft operates in the area. This is a safety issue, but with the procedures in place, a more effective SAR-operation could be expected, allowing more assets operating simultaneously. As one informant put it when discussing the importance of the ACO-role to incorporate coordination of drones in its procedures: "We need to get the formalities in place, so that it never slips" (Informant B).

For the operational level, the RNSARBOOK is developed to be helpful for the SAR-planner in an RN-environment and will hopefully fill some of the identified gaps in the RN-specific procedures (Observations, 14 January 2022).

4.4.3. The importance of trust

Network and trust are important for coordination, but in order to build and maintain this, common arenas need to be available (Informant B). Regular exercises are one way of achieving this, allowing for knowledge exchange, perhaps particularly important when considering RN (Informant D). Exercises allows aircrew to talk and operate together before an emergency, increasing coordination by building trust among each other (Informant C). The in-brief before an exercise is also one way of increasing coordination, by deconflicting airspace and discussing safety prior to live operations (Informant E). For an RN-emergency, there is probably not enough time available to perform such in-brief, but the examples show that trust can be built prior to an emergency. Hence, one could conclude that any limitations in the plans and procedures for coordination, can in some way be mitigated by trust between the aircrew and operators of the involved aircraft. On the other hand, flipping this argument around indicates that the lack of trust might limit coordination among aircraft, which could be even more important considering the potential for several international actors involved in an RN-emergency.

4.4.4. Communications

Of importance, verbal communications through radio (maritime or air frequency) are the primary way of coordinating between aircraft and other SRUs at the scene of emergency (Informant A). Communicating at the same “language” can be challenging, especially in air traffic communications comprising highly standardised phrases which might be difficult to understand for the layman. For instance, the drone operators prefer to talk more plainly on the radio, which can lead to misunderstandings and limit coordination with aircraft operating there. The same applies for the OSC as it often is a maritime vessel. Thus, the ACO-function is even more important, which understands the language, and communicates easily with other aircraft (Informant C). Furthermore, the language gap is likely to be even more evident if RN-specialists are involved, as they might have no experience with aircraft operations. The importance of developing common language between the RN-specialist and the Rescue Coordinator at the JRCC was highlighted in the first workshop, bridging the gap between the RN and SAR profession (Observations, 19 April 2021).

FINDING 5: Procedures and coordination mechanisms exists to coordinate operations involving multiple aircraft, which also applies in an RN-environment. However, some coordination mechanisms might reduce effectiveness of the operation. Building and maintaining trust between actors involved in RNSAR fills some of the gap of limited procedures and experience in coordination.

4.5. Cross-case: Complexity – the many complicating factors of RNSAR-operations

The data collected related to complexity were grouped into three categories: (1) organisations, (2) oversight and situational awareness, and (3) the operational environment. This section will elaborate on complexity of RNSAR-operations.

4.5.1. Organisation

At the operational level and above, the nuclear preparedness system in Norway is described as a large organisation with different state agencies, directorates and private actors (Informant D). In addition, due to the catastrophic potential of nuclear materials spreading through the atmosphere, mechanisms for large international cooperation exists at different levels. The task of managing and coordinating the RNSAR-operations could easily be considered complex, according to the informants. Furthermore, the shear amount of relevant actors in a nuclear emergency can be challenging to keep track of for the individual aircrew, hence increasing complexity when uncertainty arise within the individual aircrew as to which asset would be involved in the operation.

On the other hand, the organisations operating the relevant aircraft are small, specialised parts of larger organisation, enabling them to fully focus on their dedicated tasks (Informant B). The RPAS for instance, is easily incorporated into the larger organisation, i.e., the Coast Guard (Informant A). This allows them to build and maintain high competence in solving the dedicated tasks, although RNSAR might be a small part of the total number of missions they are set to perform.

As previously discussed, an RN-emergency has the potential to involve a several aircraft operating in, or near the same airspace. Even though coordination mechanisms are in place to cope with it, complexity in performing the task for the individual aircraft will potentially increase with the number of involved aircraft to coordinate the effort with. New technology such as drones can increase the complexity even more, being another actor to consider (Informant B). As such, the number of involved aircraft, their operating speed and mutual interdependence in an RNSAR-system, are factors making air operations complex at the unit level.

4.5.2. Oversight and situational awareness

"It is completely unfamiliar to us, and I think that definitely increases complexity" (Informant C). I found this statement to summarise what was the general notion among the informants. The lack of knowledge and limited experience with SAR in an RN-environment increases complexity. Some experience with radioactivity could be found on the individual level, but wasn't institutionalised as organisational knowledge, even less so when addressing RNSAR. Furthermore, the same informant follows up with saying that: "it wouldn't need that much experience for it to be perceived as manageable" (Informant C). Thus, some knowledge could potentially lead to an increase in the overall effectiveness of RNSAR (Observations, 6 December 2021).

Another perspective is the unit and operational level situational awareness during the RNSAR operation. An RN-emergency would be more complex due to the need for additional information from the scene of emergency. Compared to other SAR-operations, the rescue coordinator needs to prioritise intelligence and gaining situational awareness, thus deviating from the normal SOP of immediately sending all available SAR-resources to the distressed vessel (Observations, 30 September 2021). Priority will likely be given to resources with RN-detection equipment in the initial phase. In the Coast Guard RPAS, technology exists to exchange knowledge via a live reach back from the RPAS to the Norwegian Radiation and Nuclear Safety Authority, enabling them to assess and analyse data real time (Informant A). This would possibly also be the case with the new SAR Queen helicopter (Informant B). Thus, technology could reduce complexity by sharing relevant information to all the relevant actors.

Training on complex scenarios involving several organisations, could decrease complexity by adding knowledge and experience to the involved organisations. The Coast Guard conducts training and participates on large-scale exercises frequently, which according to the informant decreased the complexity of such scenarios (Informant A). Barents Rescue is one such exercise, where among others, the ACO-role is exercised (Informant C). For some, participating in the planning phase of such exercises could be even more rewarding and result in more knowledge than the actual live exercise (Informant B). Hence, mechanisms already exist to reduce some of the complexity at the individual level.

4.5.3. Operational environment

The operational environment encompasses maritime SAR operations involving several aircraft and RN-material representing a potential threat to the individual. Several factors emerged through the interviews which added to the complexity of the operational environment. Also in this context, did individual knowledge seem to decrease the complexity of the environment.

Operating at the open sea in long distance to shore, was said to make it more complex than operating at land (Informant A). Including the fact that the nearest capable unit could be far away, this is a common characteristic of the operational environment (Informant C). Taken together with what is already described of the Arctic environment, this provides an initial framing of the operational environment as complex.

Radioactivity could increase complexity, just by being another factor the SRU's need to consider when conducting SAR. One example of where RNSAR differs from other SAR-operations is the evacuation of people. In an RN-emergency these could be contaminated, making it more complex to evacuate them by helicopter (Observations, 19 April 2021). Safety of the SRU's becomes more important, and operating the associated equipment further adds to the complexity (Informant E).

It would be easy for the aircraft to avoid dangerous levels of radiation, if a restriction area or hot zone is defined, which in itself shouldn't add to complexity (Informant C). However, radioactive materials could spread in the atmosphere, making it difficult to clearly define a restriction area as this would be dynamic and prone to change with weather conditions being the obvious factor (Observations, 19 April 2021). One informant downplayed it somewhat, with radioactivity not necessary adding to complexity other than the precursory measures taken before flying near the distressed vessel (Informant A). Furthermore, having access to RN detection and measuring equipment aboard the aircraft would reduce the feeling of complexity among the aircrew (Informant C).

Summarised, this paints a picture of the operational environment as dynamic and changing. "Predictably dynamic" (Informant B), as one informant put it, where the aircrew should be prepared to be surprised. The uncertainty added of an RN-environment, amount of involved national and international actors, and even it in principle being both a SAR-operation and a RN-emergency simultaneously, makes it a complex scenario (Observations, 30 September 2021). When addressing radioactivity in particular, the results were somewhat inconclusive among the informants, with a tendency for the ones with more knowledge and experience seeing radioactivity as less complex. Albeit, in this case it could be more correct to address it as experienced or *perceived complexity* – whether RNSAR is complex or not would be independent of what the individual feels about it. At least in relation to knowledge. Of course, there are many factors that adds complexity, but whether the individual perceives it as complex or not seem to depend on the knowledge of it.

"The way I see it, it [radioactivity] shouldn't be complex, because it is very simple really. But, based on the lack of procedures, safety equipment and knowledge, it will probably result in it being much more complex” (Informant B). This quotation brings together many of the previous points, and leads into the finding:

FINDING 6: RNSAR-operations are complex, due to the many, specialised organisations involved and several complicating factors in the operational environment. Knowledge could significantly reduce the perceived complexity at the unit level in the operational context.

4.6. Cross-case: Risk perception – understanding risk requires knowledge

The empirical data collected on risk perception was sorted into three categories: (1) understanding risk, (2) standardising and (3) knowledge of RNSAR-operations.

4.6.1. Understanding risk

The informants had several perspectives and inputs on how they and their colleagues understand the risk associated with RNSAR air operations. They all agreed upon the need for a risk assessment on all levels. At the operational level, the JRCC rescue coordinators assesses the risk potential of the emergency to frame the planned RNSAR-operation (Observations, 6 December 2021). At the unit level, the importance of a sound risk assessment before operating in such environment was stressed, which should ensure that the entire aircrew and all involved understands the associated risk (Informant E).

A sound risk assessment in an RN-scenario requires information (e.g., measurements of radiation) and the ability to interpret them. For many of the organisations such expertise wasn’t found within the organisation. During operations, some of the organisations depended on external expertise being present on the aircraft to operate the measuring equipment and assess whether to continue or turn around when encountering radiation: “Our active role is simply to get the best possible understanding of the risk involved, but the expertise is not here with us” (Informant E).

For many, radiation is perceived as invisible and dangerous, which could lead to fear (Observations, 30 September 2021). For others, particularly those with some experience and knowledge of radiation, radiation was described as manageable if the doses were monitored and kept low enough (Informant D). They also relied on the equipment to notify them if they encountered dangerous levels of radiation (Informant C). However, most of the aircrew had no experience with radiation, which represented an unknown variable in the planning of air operations and resulted in a healthy scepticism (- more than feelings of fear): “It is not something you just roll into without thinking about it first” (Informant C).

Then it is the question of obtaining the necessary data for the risk assessment. When attempting to calculate the radiation dose and intensity, it is particularly challenging on a dynamic and moving distressed vehicle (Observations, 19 April 2021). Thus, getting accurate and timely data from the distressed vessel is needed to help in these calculations and for planning the following operation. Aircraft can be quickly on scene and is a key resource in providing these data (Observations, 4 January 2022). In the early phase of an operation, this could lead to the aircraft being tasked with getting these data through the measurement equipment (e.g., the RADIAC) (Informant E). This again would contribute to reducing uncertainty following the amount of radiation in the situation (Informant C).

However, this results in a sort of paradox: How do you ensure enough information to provide a knowledge-based risk assessment for the aircrew that would conduct the RN-detection? Without these data, one could end up being unnecessary cautious limiting the effectiveness of the RNSAR-operation (Informant C).

Again, preparing with a risk assessment and risk mitigating measures (e.g., reviewing RNSAR procedures) seems to be the common theme. In all cases the importance of performing the risk assessment based on scientific-based reasoning versus feelings is important (Informant B). This is especially true when radiation seems to tend to influence people on the feelings side of it if no prior experience with it exists. In addition, some basic knowledge of radiation could have a large effect in improving the risk assessment (Informant A).

4.6.2. Standardising

Many of the organisations followed standardised processes for risk assessments. The Coast Guard for instance, followed pre-defined risk assessments for the types of missions they were approved for, which were performed before each flight (Informant A). In the Air Force, every mission needs to be authorised, which in practice is a risk assessment process (Informant C). This Operational Risk Management (ORM) process in the Air Force is standardised, but can be performed based on experience for time-constraining missions (Informant B). However, in an RN-context, this process could be more effective with more knowledge, equipment and procedures in place, according to another informant. All in all, the standardising of risk assessment and related procedures makes the risk manageable in an RN-environment (Informant C).

National and international regulations exist to define radiation limits for rescue personnel, which also applies for the aircrew (Observations, 19 April 2021). These are converted to easy-to-understand tables, which all the informants seemed to be aware of. For some organisations, these are formalised into contracts stating that the aircrew are not to be subjected to a higher radiation dose than the rest of the population (Informant E). But most of all, given proper measuring equipment, they provide limits for how and where the aircraft and aircrew can operate, hence making decision-making easier on the aircrew (Informant B).

4.6.3. Knowledge of radiation

"The largest factor, I believe, is lack of knowledge to safely perform the task" (Informant B). Lack of knowledge creates uncertainty or even fear of radiation, potentially leading the aircrew to be more restrictive, which again could reduce effectiveness of the RNSAR operation (Informant B). This suggest that risk is perceived as more dangerous than it really is, due to uncertainty and fear resulting from the lack of radiation knowledge. On the other hand, lack of knowledge can also have the opposite effect on risk perception, where rescue workers enter an area that's potentially more dangerous than they perceive (Informant A). In both cases, knowledge is needed to correctly perceive and assess the risk involved. It wouldn't necessarily need much effort, some basic knowledge of radiation together with proper safety equipment could have a large effect (Informant B). For instance, the entire aircrew needs to be aware of how much radiation each individual is allowed to be exposed too, how much is voluntarily, and basic mitigating measures one could take. Taken together, knowledge or the lack thereof, became a recurring theme throughout the analysis and should be included as a variable in this context.

FINDING 7: Acquiring a basic knowledge of radiation and following standardised processes for knowledge-based risk assessments is likely to reduce the individuals' negative feelings towards radioactivity, adjusting the risk perception more in line with reality.

4.7. A summary of findings and relationships of variables

"Without a sound risk assessment for what we're getting into, both the pilot in command and the aircrew will question what they're getting in to" (Informant E).

The following section will summarise the findings and discuss the relationships that emerged among the three variables of coordination, complexity and risk perception. This enabled the development of a hypothesis and a revised theoretical model to form the basis for the theoretical analysis in chapter 5.

The importance of coordinating air operations during SAR is internationally agreed upon, with IAMSAR being the key procedure document specifying the ACO-role for such coordination. However, no procedures were found to address the specific nature of the RN-environment. While the SRU aircraft in Norway were assessed to be capable of conducting RNSAR, several factors added uncertainty to the effectiveness of such operations. The use of drones was found to be an important risk mitigation feature in this context, however the technology and procedures are new and limited. Existing coordination mechanisms to coordinate air operations were mostly found to be sufficient, also in an RN-environment. Where gaps in experience and procedures existed, building and maintaining trust between actors were said to fill some of these gaps.

Complexity as a variable became more influential than first indicated in the study. RNSAR-operations were found to be complex, due to the many, specialised organisations involved and several complicating factors in the operational environment. The Norwegian RNSAR-system in response to such complex emergency, is in itself complex due to many, specialised actors involved. Coordination mechanisms exists in the RNSAR-system to reduce the complex relationship between the involved aircraft responding to an RN-emergency, but the more actors involved, the more challenging coordination is. Thus, the relationship between coordination and complexity can be described as bi-directional: complexity results in the need for coordination, but the growing demand of coordination again increases complexity.

Following the discussion above, one cannot understand an entire RNSAR-operation only by looking at how the SRU operates. However, at the unit level, risk perception and complexity were found to affect the operation through the resulting uncertainty of the aircrew. As previously discussed, one contributing factor was the uncertainty regarding the aircraft itself, and how it might perform in such an environment. Furthermore, lack of radiation knowledge among the aircrew could lead to uncertainty in the risk assessment, hence affecting coordination in that way (Informant E). Risk assessment is challenging, when lack of knowledge results in the need for external assistance to provide the information needed for an acceptable risk level for the aircrew. SRUs are likely to be restrictive until an acceptable risk level is achieved (Informant C). Thus, radioactivity could affect coordination, simply because of the uncertainty which follows (Informant B).

Knowledge is the recurring theme throughout the analysis. Knowledge of other actors, RNSAR-operations, operational environment and radiation etc. Lack of knowledge can reduce RNSAR-effectiveness. On the other hand, given enough knowledge, operations in an RN-environment aren't that different from other SAR-operations. Knowledge reduces uncertainty and complexity, and enables a risk assessment of reasoning, not feelings. Specific RNSAR-procedures and experience (e.g., exercises) would help in providing this knowledge.

When incorporating knowledge as a new variable into the model, together with the emerged relationships between the variables in the analysis, the following hypothesis is developed:

Hypothesis: Basic knowledge and understanding of radioactivity and RNSAR-operations, reduces complexity and allows the individual aircrew to correctly perceive and assess risk, hence not limiting coordination of maritime SAR air operations in an RN-environment.

The following revised theoretical model builds on the initial analytical model. It is based on the hypothesis and visualises the variables and their relationships emerging from an RN-emergency. The model distinguishes between the unit level and operational level, as the respective variables were found to have different effects on these levels. Following the radiation hazard from the emergency, risk perception represents potential unknowns for the aircrew at the unit level, affecting their understanding of the risk. At the operational level, complexity is found in the SAR-system, operational environment and the RNSAR-operation. This results in uncertainty at the unit level, while increasing the demand for coordination mechanisms at the operational level. Knowledge as a variable can reduce potential negative effects of risk perception and complexity among the aircrew, hence reducing uncertainty in the risk assessment. These variables on both levels affects coordination, which is essential in providing an effective RNSAR-operation.

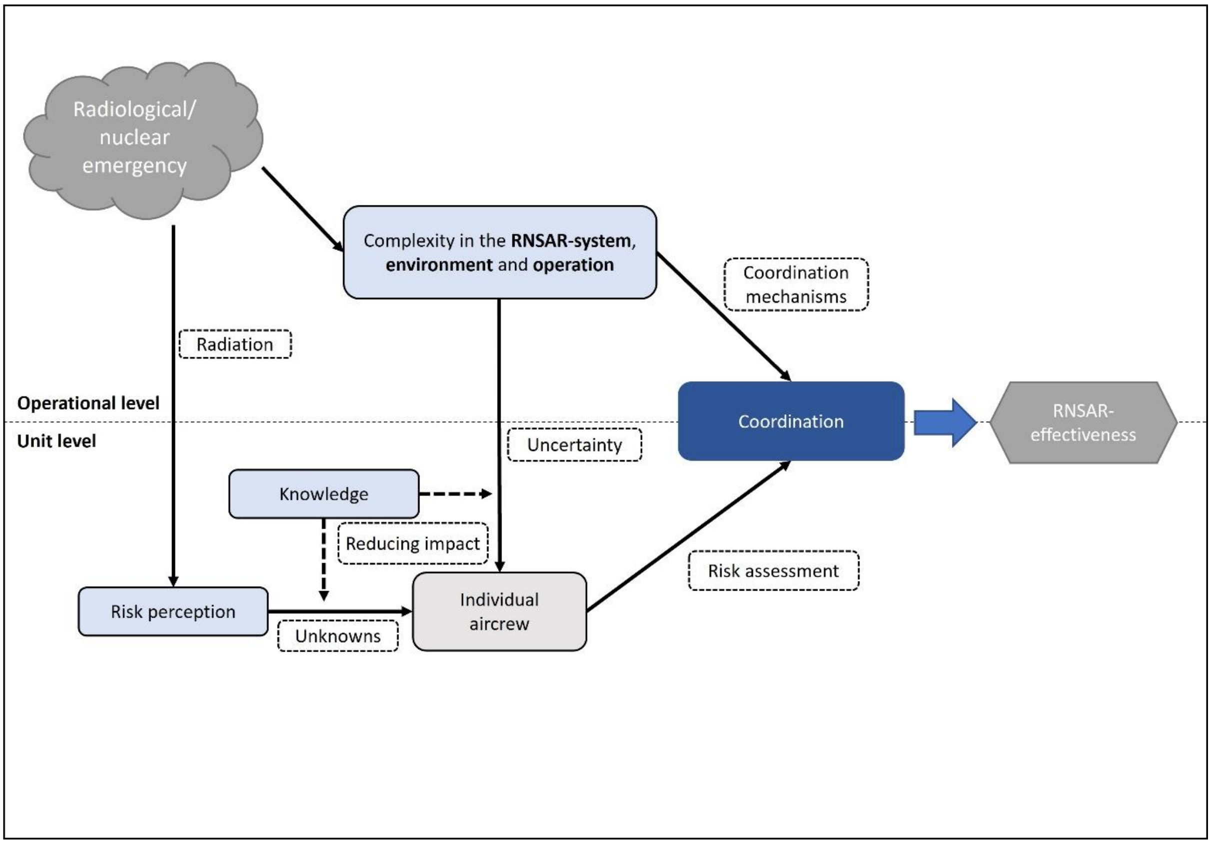

Figure 3: Revised theoretical model

5. Analysis

For this chapter, the findings, relationships of variables and the developed hypothesis are compared with the theoretical framework underlining the study. The chapter follows the logical sequence established in the previous chapters and concludes with a final theoretical model where the theoretical perspectives are integrated to further understand the identified relationships.

5.1. Coordination

The need to coordinate aircraft during SAR is emphasised in UN conventions and multilateral agreements to ensure effectiveness, strengthening the thesis that coordination is central in conducting SAR in the Arctic (Borch & Andreassen, 2015). At the operational level in Norway, the JRCC is established to facilitate the coordination among those involved in such operation. The responsibility to develop specific procedures, i.e., coordinating RNSAR-operations, also lays with the respective country. As such, the development of the RNSARBOOK is partly a result of these conventions and agreements. Even though RN-specific procedures are lacking, the UN conventions and multilateral agreements provides overall direction and focus for the emergency management to mitigate the effect of crisis, leaving it to the respective countries at the operational level to develop procedures and organise the SAR processes (Wolbers & Boersma, 2018).

The IAMSAR manual specifies procedures and command structures for coordinating SAR, with a specific chapter on coordinating multiple aircraft through the ACO function (IMO/ICAO, 2016b). Thus, it provides written procedures for both coordination and control as described in the four C's (Comfort, 2007). The manual applies for both the operational and unit level, but to incorporate all C's in the analysis, the latter continue to be the focus. At the unit level, the coordination mechanisms for aircraft described in the IAMSAR manual were perceived as sufficient in an RN-environment.

So far, the coordination mechanisms defines responsibilities for tasks, resource allocation and agreements among the involved SAR-actors, and what is traditionally described as plans and rules within an organisation (Okhuysen & Bechky, 2009). Albeit, this is at an overall level, not necessarily encompassing the rapid and unexpected changes in the situation which might be experienced by the individual aircrew responding to an RN-emergency (Wolbers &

Boersma, 2018). Thus, according to literature, these mechanisms might not be sufficient for RNSAR-operations (Boin & Bynander, 2015).

Furthermore, the specific nature of an RN-environment, and how this could affect coordination is not described in procedures at the unit level. The importance of this becomes clear when considering the ACO role in deciding search methods for effective RNSAR-operations. In many ways, the ACO is designated to function in a fast-paced environment coordinating the effort of several aircraft. Describing coordination as an emergent process, temporarily unfolding in the airspace surrounding the distressed vessel seems as a fitting description of this context (Wolbers et al., 2017). Even though procedures exist, the ACO still must decide on search methods based on whatever available aircraft at the time, and designate methods for coordination based on several factors (e.g., weather, radiation hazard, risk assessment). Lack of RN-knowledge and a dynamic situation could increase the reliance on coordination by mutual adjustment of the involved aircraft (Thompson, 2003).

Several types of aircraft and organisations in Norway were found to have the capability to conduct both RN-detection and SAR, albeit uncertainty arose to question the effectiveness of such operations. To conduct RNSAR-operations, the organisations and technical equipment were found to be highly specialised. Furthermore, the involved aircraft responding to an RN-emergency would have to perform highly interdependent tasks to ensure an effective RNSAR-operations. These interdependencies are probably reinforced with the introduction of new technology such as the Coast Guard RPAS. The interdependence and uncertainty which arises in RNSAR, represent complexities in the organisational structure and external environment which will be further elaborated in the section of complexity (Borch & Andreassen, 2015). More important, this partly explains how the predefined interdependencies described as traditional plans and rules might differ in practice, depending on which organisations' aircraft respond to the RN-emergency (Wolbers & Boersma, 2018).

So far, the analysis is in line with the different phases of RNSAR. The JRCC coordinates the overall SAR-response, collecting information and getting suitable resources to the distressed vessel on the operational level, while the ACO (if available) coordinates the aircraft operating at the scene of emergency at the unit level. In the initial phase, at least before more information is available, the outcome would be difficult to predict. While some coordination mechanisms exists, the early phase resembles more what Jarzabkowski et al. (2012) describes as establishing coordination mechanisms through the process of coordinating, not so much a result of prior arrangements. Moreover, a distinction can be made between the unit and operational level of coordination. The JRCC primarily coordinates vertically and within (internally) the SAR system, while the aircrew coordinates horizontally and between the involved organisations at the scene of emergency.

The military resources were found to be most capable to conduct RNSAR-operations, as they were part of a military organisation with developed structures and risk-mitigating processes (Faraj & Xiao, 2006). As such, they follow the conventional command and control approach found in the military. However, based on the interviews, the rigid, centralised system as it is described in the theoretical framework was less evident, and a problem-solving approach seemed more present, at least for solving the tasks associated with the operations (Dynes, 1994; Schneider, 1992). This could be related to the lack of specific procedures for operating in an RN-environment (with the exception of the Coast Guard), requiring less formal and interpersonal mechanisms for coordination, decision-making and improvisation (Boin & Bynander, 2015; Dynes, 1994). This approach to emergency response is supported by the literature, where the success lies in combining the formal structure, doctrines and SOPs found in the military organisations, with improvisation and adaptability when solving tasks at the scene of emergency (Harrald, 2006). Hence, the dilemma described by Faraj & Xiao (2006), seemed to be less present for the military organisations in this study, as they emphasise both formal and improvised coordination mechanisms.

Of note, the last section dealt with intra-organisational coordination, but the discussion is also applicable between organisations. Formalised mechanisms to facilitate inter-organisational coordination both vertically and horizontally through existing plans and procedures were found to be sufficient in an RNSAR-operation. Furthermore, the development of the RNSARBOOK is an important step into preparing for and thinking about the challenges of coordination and how they should be solved for effective RNSAR-operations (Boin & Bynander, 2015). Both the RNSARBOOK and the ACO-procedures in the IAMSAR-manual are examples of SOPs between organisations, in some ways based on known coordination challenges of RNSAR and multiple aircraft operations, respectively (Faraj & Xiao, 2006).

The need for coordination at the scene of emergency, depends on the scope of the operation. More involved aircraft and SRUs, increases the demand for coordination mechanisms such as an ACO. An RN-emergency, could bring together organisations with limited shared experience to perform complex tasks, and the effectiveness depends on the combination of formalised structures and flexible processes (Klein et al., 2006). As shown in this context, there is a potential for a considerable number of involved actors, making coordination challenging. The lack of knowledge of RNSAR, could make it difficult to predict which organisations would be involved in the operation, supporting the fragmentation perspective (Wolbers et al., 2017). On the other hand, at least in the Norwegian context, there shouldn't be too difficult to predict which organisations that would need to respond to such emergency, given the specific expertise on RN and SAR needed. What is more interesting in the fragmentation perspective is the on-scene dynamics of coordination.

All the organisations operating aircraft were specialised parts of a larger organisation. As such, one could argue that both delegating tasks to the individual aircrew and demarcating expertise to the SAR-professionals were evident in the larger organisations (Wolbers et al., 2017). This is also a suitable description of the RNSAR-system responding to the emergency, were the JRCC coordinates and assembles the relevant RN-expertise at the operational level, while delegating tasks to the unit level. Working around the procedures was less evident, as the RN-specific procedures were lacking except for the Coast Guard. The latter were described as flexible, which were found to be important in this context.

Many of the coordination mechanisms were found to separate aircraft from each other to provide safety of operation. However, this could reduce the potential effectiveness of the RNSAR-operation if the situation demands tasks of both search and evacuation simultaneously. The use of UAVs serves as an illustration for this, as they were not flying if other helicopters operated in the same areas. This shows that even though formalised coordination mechanisms are in place, they can be counter-effective if not specific to the context (Boin & Bynander, 2015). Achieving flexibility, being sensitive to RNSAR-operations and improvising when the procedures lacks or fail to cover the situation at hand seems very much relatable to the findings of the study and key to managing an RNSAR-operation (Weick & Suthcliffe, 2015; Wolbers et al., 2017).

Network and trust between involved actors were found to be important when coordinating the effort, which aligns with the literature, at least in the initial phase of responding to the emergency (Boin & Bynander, 2015). Common areas, such as exercises, can build such trust before an emergency occurs. But trust can also emerge during the response to an RN-emergency, as the aircraft communicates with each other. Verbal communications were found to be the primary way of coordinating aircraft and other SRUs at the scene of emergency, thus demonstrating the dynamic and social nature of coordination mechanisms (Jarzabkowski et al., 2012). Trust can potentially mitigate limitations in plans and procedures for coordination, through communicating intent and synchronising different interdependent task among the involved aircraft (Wolbers et al., 2017). Speaking the same language is a critical factor in doing so, again highlighting the ACO-function as essential in such coordination.

The question remains to whether the temporary RNSAR-system established during an RN-emergency is capable of encompassing both the formal structure and control, with the social nature of coordination mechanisms. It is outside the scope of this analysis to conduct a thorough study of how the RNSAR-system fits within an Incident Command System, but some general observations can be made. The RNSAR-system responding to an RN-emergency will likely be a large-scale operation, involving several actors. A temporary incident command system is established to facilitate leadership, coordination and information flow among the involved actors (Rimstad et al., 2014). JRCC coordinates the effort, combining bureaucratic features with highly specialised organisations responding to the RN-emergency (Bigley & Roberts, 2001).

The four basic processes which enables the formation of an ICS, can also be found in the RNSAR-system (Bigley & Roberts, 2001). The processes of *structure elaborating* and *role switching* are primarily found in the international agreements on how to organise national SAR, and the specific procedures in the IAMSAR-manual. JRCC assesses the situation and constructs the temporary system at the operational level, while the defined roles of the OSC and ACO coordinate and organise the organisations at the scene of emergency. Given the highly specialised aircrew operating the aircraft, assigning new roles would be less applicable in this setting, even though this is part of the latter process. *Authority migrating* would be particularly relevant during RNSAR-operations, as both SAR and RN professionals possess the expertise to solve the tasks. Hence, decision-making is moved down the hierarchy to the SRUs operating at the scene of emergency. Whether the SAR-system is capable of performing the last process, *system resetting*, is difficult to assess based on available data. However, it is reasonable to assume that the JRCC will continue to monitor and assess the situation, tasking new resources to the distressed vessel if the situation dictates. The new SRUs will operate as elements within the already established system.

5.1.1. Partial conclusion on coordination

The analysis has shown that the findings related to coordination are supported by the theoretical framework provided in this study. Formalised coordination mechanisms exist to coordinate multiple aircraft in RNSAR-operations at the operational level, but at the scene of emergency the emerging coordination that occurs can be seen through the fragmentation perspective. The latter could result from lack of knowledge and RN-specific procedures which can be mitigated through trust and communication. Looking at the RNSAR-system through the lens of ICS, shows similarities and should be able to combine formal structure and control, with the social nature of coordination mechanisms.

As such, the existing coordination mechanisms primarily ensures safety of aircraft, more than focusing on the effectiveness the SAR-mission. This could explain why the informants perceived the written procedures for coordination as sufficient, as the aircraft are coordinated for safety to a given airspace, leaving the specific tasks (RN-detection or SAR) to be solved by the individual aircrew. The practice of coordinating intentions, goals and actions through discourse is likely found in this context (Dooley, 2004). Safety will always be a priority, but one recommendation is to allow for flexibility within the ability to effective conduct the search and evacuation missions, which might need some part of (hopefully) knowledge-based improvisation. Furthermore, this will allow for the combination of general SAR SOPs with flexible RN-specific procedures, depending on the involved expertise and network.

5.2. Complexity

As we have seen, the RNSAR-system responding to an emergency, has the potential to involve a considerable number of different actors and specialised organisations. Given the rarity of such emergency, it further amplifies the emergent complexity adapted to the present situation as organisations normally detached from each other form new interdependencies (Weick & Suthcliffe, 2015). Furthermore, international assistance and cooperation will probably be initiated in this context, due to the catastrophic potential of nuclear materials spreading through the atmosphere. Literature suggest that the catastrophic potential could lead to critical functions being abandoned, albeit no finding in this study supported this (Johannessen, 2017). The findings point in quite the contrary direction, since the organisations were assessed as capable to operate in an RN-environment with coordinating mechanisms available, albeit with the previously discussed limitations.

Looking at the organisations responding to an RN-emergency, provide some support to the notion of modern organising taking place at multiple, fragmented contexts at once (Czarniawska, 2004). Each of these organisations represent nodes of elements and relationships connected in a network within the structure of the larger RNSAR-system (Lingel et al., 2021). The organisations represent agents within the system. The number of possible behaviours of the system increases with the number of involved actors, resulting in complexity as the function of these behaviours (Siegenfeld & Bar-Yam, 2020). While no defined number of behaviours exists to what is defined as complex, one could initially conclude in RNSAR-operations as being more complex than other SAR and similar types of operations.

Furthermore, the amount of relevant actors in a nuclear emergency can be challenging to keep track of for the individual aircrew, resulting in uncertainty as to which asset would be involved. Thus, organisational practices formed are uncertain and dynamic, depending on the situation (Johannessen, 2017). The uncertainty of other organisations involved and the consequences the temporary organisational practices, could increase complexity of RNSAR-operations. On the other hand, the aircrews' own organisation would be small and highly specialised parts of a larger organisation. As a result, an RNSAR-operation involving multiple aircraft can be understood as complex, as the specialised organisations attempts to coordinate their actions with each other. Furthermore, when looking at the system of the RNSAR-operation into detail, each of the involved aircraft have their own complexity and a number of behaviours to exhibit. An aircrew of a single helicopter have multiple behaviours within the aircrew, and other factors influencing the individual further adds to this. Thus, showing how the multiscale structure increases complexity when looking at the system in more detail (Siegenfeld & Bar-Yam, 2020).

Thus, each organisation represents a system in its own, part of the larger RNSAR-system, which leads into the perspective on complex organisations matching or exceeding the complexity of the environment (Siegenfeld & Bar-Yam, 2020). The individual organisations are specialised, quick to respond, and likely capable of parallel organising and coordination in the RNSAR-system (Johannessen, 2017). Hence, the individual organisations could be understood as self-organising processes, part of the RNSAR-system. Even though formal mechanisms are in place, the section on coordination showed that the RNSAR-system were less controllable and more a result of emerging coordination. Thus, the RNSAR-system could very well be understood as a Complex Adaptive System, a perspective that will be further discussed in the chapter on the relationships of variables.

An RN-emergency in this context is set to occur in an Arctic environment, possible with large distances to both land and the nearest capable rescue unit. The operational environment during RNSAR-operations is described as dynamic and changing, involving multiple actors, and in principle involving two special types of operations – RN and SAR. Both the physical surroundings and the other involved organisations result in complexity for the individual aircrew (Roud & Schmied, 2020). Thus, discontinuity and ambiguity seems as appropriate descriptions of the environment (Wolbers et al., 2017). Adding the catastrophic potential of radiation support the notion of the extremeness of the event (Hossain & Uddin, 2012). However, while tasks might be unknown, there seems to be consensus on which type of expertise is needed to solve the situation. Radioactivity could add uncertainty to the situation on how it will affect air operations, depending on the knowledge of the aircrew.

The general notion among the informants was that lack of knowledge and limited experience with SAR in an RN-environment increased the complexity of conducting such operations. Looking at the cognitive and psychological perspective, this makes sense as the informants have limited knowledge of the regularities of the environment (i.e. radioactivity) making it difficult to understand, predict and judge the situation (Kahneman & Klein, 2009). In general, decision-making should be de-centralised to the expertise best suited for the complexities of the situations (Weick & Suthcliffe, 2015). In this case, this would be the SAR-professionals at the scene of emergency. But as their knowledge of radiation were found to be limited, their ability to perform the task were also limited. This could be a result of a high cognitive demand on the individual aircrew, hence increasing task complexity (Campbell, 1988). As such, increasing knowledge of radioactivity could have a positive impact on the overall RNSAR effectiveness, as the task-doer's experience with RNSAR reduces complexity.

Another perspective on knowledge is situational awareness of the emergency and ongoing RNSAR-operation. The individual aircrew has to move between the known (SAR) and unknown (RN) – between recognisable and unpredictable (Johannessen, 2017). At the operational level, this was said to increase complexity, due to the need for intelligence and situational awareness before allocating SAR-resources to the distressed vessel. On the other hand, new technology was found to decrease complexity, enabling expertise to assess and analyse data real time and sharing relevant information to all involved actors. Thus, technology could reduce the number of potential paths toward the desired end state by providing data to support decision-making (Campbell, 1988).

During an RNSAR-operation, the complex environment involving many causalities and interacting agents limits the ability to learn (Konrad & Sheard, 2016). Training on complex scenarios beforehand and exercising important coordinating roles such as the ACO-function, could decrease complexity by adding knowledge and experience to the organisations operating the aircraft. When the number of outcomes resulting from decision-making increases, so does task complexity (Campbell, 1988). Many of the informants participated in the planning and execution of large-scale exercises, which were said to reduce complexity at the individual level. One could argue that this reduces the number of possible outcomes, as decision-making becomes more adapt. Another argument is that trust is established prior to the emergency, reducing the challenge on collaborating on complex tasks (Schmied et al., 2017). The question still remains to whether this knowledge is institutionalised to the organisation.

Building on the analysis of coordination, mechanisms exist to cope with multiple aircraft operations in the RNSAR-system. However, complexity of performing the tasks for the individual aircrew will potentially increase with the number of aircraft involved, interdependencies and new technology (i.e., drones), making multiple aircraft operations complex at the unit level. Therefore, the task of managing and coordinating the RNSAR-operations within the RNSAR-system should be considered complex, as interdependence between multiple actors can have an exponential effect on task complexity (Hærem et al., 2015). Radioactivity could increase complexity by adding another factor to the already complex task of multiple aircraft conducting SAR. The aircrew needs to consider radioactivity for safety and how it affects the different tasks that needs to be performed. Even operating the necessary RN-equipment could increase complexity. The latter statement is supported by Weick & Suthcliffe (2015), where a complex environment needs complex sensors to register the environmental complexities (i.e. radiation). As such, the findings support that the ability to perform the tasks are relative to the capability of the individual performing it (Campbell, 1988).

The spread of radioactive materials on the atmosphere is dynamic and prone to change with the weather conditions, possible making it difficult to avoid. The uncertainty of how the technical systems of the aircraft might perform in an RN-environment further adds to the complexity, making it hard to predict (Hossain & Uddin, 2012). However, RN-detection and measurement equipment could reduce the feeling of complexity among the aircrew, helping them to avoid dangerous levels. As such, the task of operating the technology did not seem to exceed the comprehension of the individual (Thompson, 2003). In that case, radioactivity shouldn't add to complexity other than the precautionary measures the aircrew would need to consider.

Much of the findings and analysis points toward complexity, particularly in task and the operational environment. For the individual, this is based on a cognitive assessment and strongly influenced by knowledge. As a result, the concept of perceived complexity was developed to explain complexity at the individual level. No such definition exists in the theoretical framework for this study, but it is implicitly understood as a phenomenon through the analysis. I believe this brings an important nuance to the theoretical understanding of the research question.

5.2.1. Partial conclusion on complexity

Both the findings of this study and the theoretical framework support the notion that complexity is found in organisations, environment and tasks within the RNSAR-system responding to an RN-emergency. Multiple, specialised organisations are involved in the RNSAR-operation, establishing interdependencies in a system which exhibits several behaviours and outcomes. The operational environment is dynamic and changing, and radioactivity is an additional factor for the aircrew to consider at the individual level. Coordinating multiple aircraft operations and combining RN-detection with SAR are particularly challenging tasks. The analysis suggests that the latter two are a function of knowledge. Thus, knowledge could potentially reduce the perceived complexity at the unit level in the operational context.

The analysis of complexity has so far provided theoretical support for the finding that RNSAR-operations are complex. However, the analysis is flawed in mostly looking at the individual complicating factors found in the organisations, operational environment and tasks. As such, the analysis has mostly followed the traditional approach of looking at the inner workings of an organisation (Dooley, 2004). To assess whether and how the RNSAR-system is complex, one needs to move from looking at the individual constituents of the system, to the interactions among them (Weick & Suthcliffe, 2015). A more into depth analysis of these interactions follows in the section on the relationships of variables.

5.3. Risk perception

An RN-emergency represent the context, from which the hazard arises and affect the individual risk perception (Pidgeon, 1998). The informants of this study had different perspectives and understanding of the risk involved, but the need for a risk assessment on all levels before initiating an RNSAR-operation was a common view. All of the informants came from professional organisations, which acknowledges that situation assessment and associated risks are important factors in the decision-making process (Crichton & Flin, 2017). In addition, the different perspectives on understanding risks associated with RNSAR-operations, were probably due to differences in background and experience, affecting their interpretations of the same situation (Bigley & Roberts, 2001). No findings indicated that the informants were subject to risk denial (Sjöberg, 2000). Part of the risk assessment for the aircrew is an understanding of the risk involved, to know which mitigating measures to implement, and to accept the remaining risk.

A sound risk assessment requires information through RN-detection and the ability to interpret the data resulting from it. This is in line with the consequentialist perspective, where the aircrew would make decisions based on the assessment of the consequences of possible choices (Loewenstein et al., 2001). The capability to collect the information needed was available, but the RN-expertise required was not found within the respective organisations. Aircraft were found to be an important asset for obtaining timely and accurate data from the distressed vessel, to assist in the risk assessment. As such, aircraft with measuring equipment tasked early during an emergency could reduce the uncertainty following the amount of radiation. This resulted in the paradox of providing enough data for the risk assessment of the aircrew performing the data gathering. Without it, the aircrew could end up being more cautious and less effective. To mitigate this, professional experience and protective equipment resulting in the feeling of being protected from radiation could lower the perception of (and actual) radiation risk among the aircrew (Perko, 2014).

Radiation is perceived as invisible and dangerous, which fits within Fischhoff et al. (1978) two higher order characteristics of risk perception. Radiation as a hazard is likely judged as an unknown risk being unobservable and producing delayed harmful effects (Peters & Slovic, 1996). As such, the initial risk perception of radiation could be more based on feelings, in contrast to the analytical approach to risk assessment outlined earlier. However, knowledge was found to reduce feelings of fear and making it manageable for the individual, enabling logical reasoning and even scientific deliberation underlying the risk assessment. Personal dosimeters letting the aircrew know when levels of radiation rose to dangerous levels was also a reassuring measure, lowering the degree of worrying (Sjöberg, 1998). No prior experience with radiation resulted in it being introduced as an unknown variable for the aircrew planning the operation, resulting in a "healthy scepticism", again indicating risk as feelings with the emotion of worry (Butler & Mathews, 1987). Thus, radiation can affect the risk perception, moving along the axis between risk as feelings and risk as analysis. More knowledge of radiation tends to move towards the risk as analysis approach, not allowing the instinctive reactions to danger affect the risk perception and decision making of the individual.

The risks involved in an RNSAR-operation would be subject to a cognitive assessment of each individual in the respective aircrew, resulting in some sort of emotions (Loewenstein et al., 2001). Without experience and knowledge of radiation, intuitive feelings could influence the individual aircrew performing the risk assessment, which is the predominant method to evaluate risk (Slovic & Peters, 2006). Thus, it was found to be of importance to base the risk assessment on scientific-based reasoning – not allowing the affect heuristic guide how the individual feels about the situation. This could prove challenging, knowing that emotional effects experienced are subtle and not always known to the individual (Sjöberg, 1998). Even minor basic knowledge of radiation could significantly improve the risk assessment, which is supported by the literature as some experience appears to give a more realistic risk perception (Sjöberg, 2000).

There are different methods of performing a risk assessment, but similar to the section on coordination, standardising the method and related procedures were found to make the risk manageable in an RN-environment. This could also limit the effect of the selective and varying risk among the individuals (Wildavsky & Dake, 1990). The effectiveness of the method would depend on the knowledge and experience with radiation, but standardising is one way of not allowing heuristics lead to systematic errors in an uncertain environment (Tversky & Kahneman, 1974). One particularly effective, albeit simple example of this, is the predefined radiation limits that combined with proper measuring equipment would make decision-making easier during the risk assessment. This provides the individual with less ambiguity of the situation, potentially lowering the degree of worrying and preoccupation of unpleasant thoughts of radiation, and allows the entire aircrew to focus on the task at hand (Butler & Mathews, 1987; Sjöberg, 1998).

Lack of radiation knowledge were found to create uncertainty, or even fear, potentially resulting in the aircrew being more restrictive than they would've been in another situation. Some support is found in the literature, as emotions conflict with cognitive evaluations of the situation, producing counterproductive behaviour (Loewenstein et al., 2001). This would reduce the effectiveness of the whole RNSAR-operation or lead to dangerous situations due to the limited or even wrong risk perception among the individual aircrew. However, familiarity with radiation, knowledge and voluntariness are factors that decrease the perceived level of risk (Fischhoff et al., 1978). That is not to say that all of the focus should be on building radiation expertise among the aircrew, but a slight increase in knowledge of radiation science would shorten the gap between experts and the aircrew (Slovic, 2012). Thus, also in the theoretical discussion on risk perception, knowledge was found to be an important variable to consider in this study.

5.3.1. Partial conclusion on risk perception

Radiation was found to affect risk perception by moving along the axis between risk as feelings and risk as analysis. Without experience and knowledge of radiation, intuitive emotions could influence the individual aircrew assessing the risk. Thus, the literature on risk perception supported the finding that basic knowledge of radiation could adjust the individuals' risk perception more in line with the reality. The risk assessment should be based on scientific-based reasoning – not allowing the affect heuristic guide how the individual feels about the situation. Furthermore, standardising the process limits the individuals' heuristics and emotions to influence the risk assessment. Knowledge once again was found to be an important variable, both theoretical and practical, indeed affecting the effectiveness of RNSAR-operations.

5.4. Final discussion on the relationships of variables

From a theoretical perspective, complexity was found to be more influential in understanding the phenomenon of RNSAR-operations than initially expected. However, complexity in this context cannot be fully understood without including coordination and the interactions in the RNSAR-system. The interplay between organisations in the RNSAR-system is complex and made up of the interconnectivity of different components. Together with the complicating factors in the operational environment, a need for sophisticated coordination mechanisms was identified to reduce the complexity of RNSAR air operations (Borch & Andreassen, 2015). As such, one cannot understand an entire RNSAR-operation only by looking at how the SRU operates. It seems appropriate to categorise it as a multilevel, complex system, characterised by hierarchical structure where both vertical and horizontal interdependences are established (Lingel et al., 2021).

Consequently, ICS is limited in explaining the complexity of the RNSAR-system, and a more explanatory framework would be to look at the system through the lens of CAS. In general, existing coordination mechanism to coordinate air operations in the RNSAR-system were found to be sufficient. Where gaps in experience and procedures existed, building and maintaining trust between actors were said to fill these gaps. Hence, the actors within the system could be seen as agents that adapt (Lingel et al., 2021). Furthermore, the RNSAR system is organised into a network, and both JRCC and the helicopter flight crews are examples of functional subsystems within the context of a larger complex system. No procedures were found to address the specific nature of the radiological environment. However, the RNSAR-system as a whole seemed capable of responding collectively to the changing environment and decisions made by other agents (Lingel et al., 2021). Furthermore, each aircraft at the scene of emergency fulfils tightly integrated functions of RN-detection and SAR, which in principle should be managed together by the ACO-function.

The RNSAR-system is in itself complex – to handle the complexity in organisations, tasks and environment. Following this analysis, CAS provides some foundation to the claimed bi-directional relationship between coordination and complexity. Complexity in the tasks, environment and multiple organisations within the RNSAR-system results in the need for coordination. However, the growing demand of coordination again increases complexity within the system. To mitigate this, a flexible approach in the decision-making process at the unit level is suggested, together with creative problem-solving and SOPs for an RN-environment are needed (Andreassen et al., 2018).

At the unit level, risk perception and complexity were found to affect the operation through the resulting uncertainty and unknowns for the aircrew (i.e uncertainty about aircraft performance in an RN-environment or lack of radiation knowledge resulting in an uncertainty in the risk assessment). Support for this relationship is found in the literature, as inherent randomness of the RNSAR-system and operational environment could result in aleatory uncertainty, while lack of RN-knowledge could result in epistemic uncertainty (Wang et al., 2019). This further strengthens the notion that radioactivity could affect coordination through the uncertainty that follows.

Furthermore, the analysis has shown that introducing knowledge as a variable in the relationship between coordination, complexity and risk perception strengthens the model and our understanding of the phenomenon. Lack of knowledge can limit decision-making and reduce RNSAR-effectiveness, as the individual aircrew are likely to be restrictive until an acceptable risk level is achieved (Bigley & Roberts, 2001). On the other hand, knowledge can reduce uncertainty and complexity, and enables a risk assessment of reasoning, not feelings (Slovic, 2010). Specific RNSAR-procedures and experience (e.g., exercises) would help in providing this knowledge (Andreassen et al., 2018; Kahneman & Klein, 2009).

To conclude, existing literature supports the findings of the study and the developed hypothesis. Thus, according to the Eisenhardt method, this study strengthens existing theory, more than building new. However, the relationships of the variables, also including knowledge, sheds a new perspective on the theory. Hence, the final model incorporates theoretical perspectives as discussed in the analysis. Also important, the findings, hypothesis and model form a basis from which practical recommendations for the coordination of RNSAR air operations are drawn.

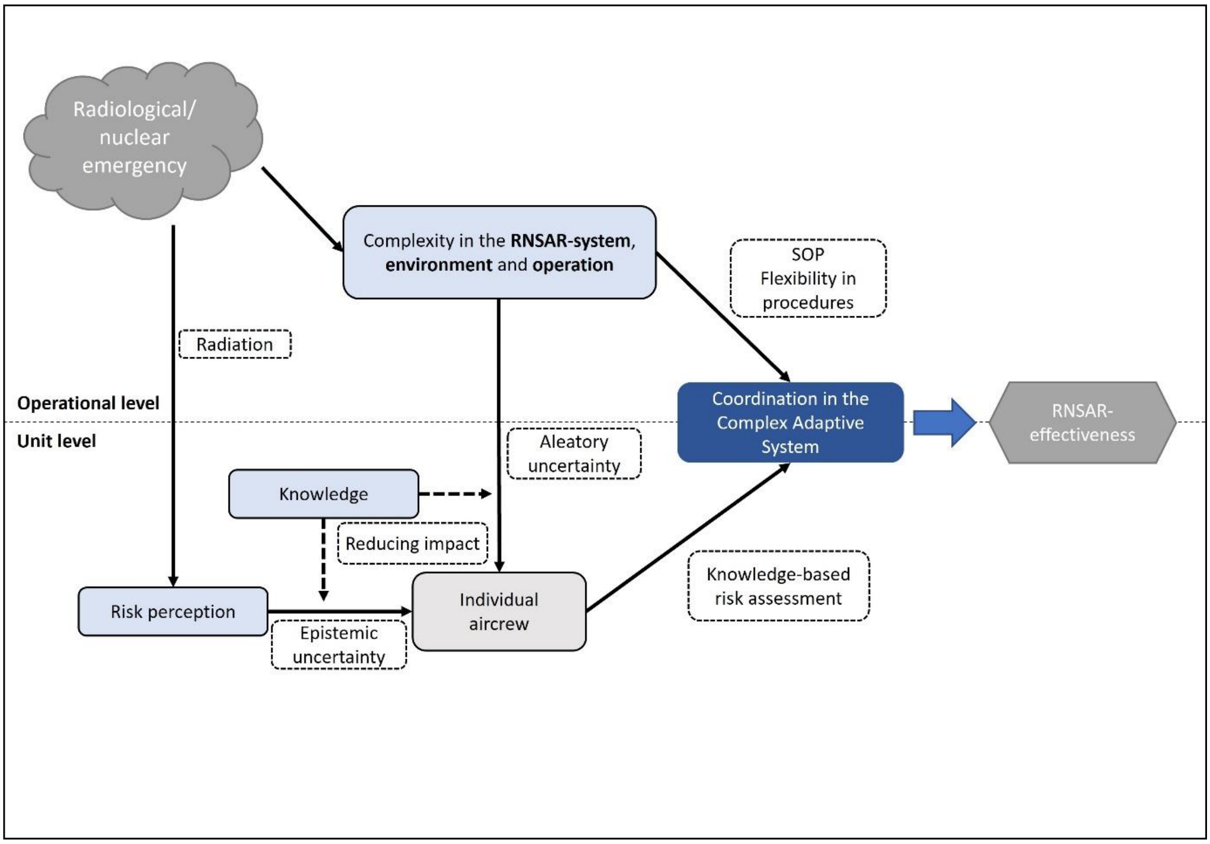

Figure 4: Final theoretical model

6. Conclusions

To mitigate the catastrophic potential of a maritime RN-emergency in the Arctic, a lot of organisations and resources will have to effectively coordinate their collected SAR effort. Aircraft is a highly relevant asset in such environment, and complexity, risk perception and knowledge are important variables to consider for the coordination and effective use of these resources.

The following research question, underlined this study: «What is the Norwegian capability to coordinate maritime search and rescue air operations in a complex, radiological/nuclear emergency?"

Coordination of air operations during RNSAR is complex, due to the number of involved aircraft, operational environment and tasks within the RNSAR-system responding to an RN-emergency. Multiple, specialised organisations are involved in the RNSAR air operation, establishing interdependencies in a system which exhibits several behaviours and outcomes. The operational environment is dynamic and involves radioactivity which adds to the perceived complexity at the unit level. Furthermore, task complexity is found in coordinating multiple aircraft operations and combining specialised tasks of RN-detection and SAR.

Formalised coordination mechanisms through the IAMSAR-manual exists to reduce complexity and coordinate multiple aircraft in RNSAR-operations at the operational level. However, at the scene of an RN-emergency, coordination seems to emerge as a result of trust and communication, more than formalised procedures, probably due to lack of knowledge and RN-specific procedures. Through the ACO-function, aircraft are coordinated for safety to a given airspace, leaving the specific tasks (RN-detection and SAR) to be solved by the individual aircrew.

Radiation was found to shape the individuals risk perception, mainly as a function of prior experience (or lack thereof). Without experience and knowledge of radiation, intuitive emotions could negatively influence the individual aircrew assessing the risk. However basic radiation knowledge and standardising the risk assessment could adjust the individuals' risk perception more in line with reality.

Knowledge emerged as an important variable for the overall effectiveness of the RNSAR air operation. Basic knowledge and understanding of radioactivity and RNSAR could reduce the aleatory uncertainty resulting from complexity in the RNSAR-system, environment and operation. Furthermore, it could also reduce the epistemic uncertainty resulting from the individuals' risk perception of radioactivity. This allows for the individual aircrew to correctly perceive and assess risk, hence not limiting coordination of maritime SAR air operations in an RN-environment. Specific RNSAR-procedures and experience (e.g., exercises) would help in providing this knowledge.

In conclusion, Norway has capable aircraft and organisations for performing RNSAR air operations, but knowledge, procedures and equipment are needed to effectively coordinate multiple aircraft in response to an RN-emergency. Looking at the RNSAR-capability through the lens of Complex Adaptive Systems provides an explanation for how the Norwegian RNSAR-system collectively respond to the emergency. The individual aircrew at the unit level adapts through flexibility and improvisation, which makes up for some of the limitations identified in this study.

6.1. Theoretical implications

Following the Eisenhardt method, this study set forth to generate new theory. However, the findings are more likely to strengthen existing theory than building new. Introducing knowledge, and the influential role of complexity in coordination sheds new perspective on existing theory.

On a related note, the study's main weakness is the limited number of cases, affecting the generalisability of the findings. While the selected cases make up almost all the relevant actors in Norway, and a considerable amount of the international actors in the Arctic, the number is still low for generalising results. However, the selected cases provided rich empirical data for discussing theoretical perspectives on the Norwegian RNSAR-system, which is also highly relevant for other countries in the Arctic with similar capacities.

From a theoretical perspective, this study has shown how effectiveness of coordination can be seen as a function of the variables of complexity at the operational level, and risk perception at the unit level – particularly in a high-risk operation. Furthermore, knowledge could limit the aleatory and epistemic uncertainty resulting from these variables, hence increasing effectiveness.

The RN-emergency further adds to the already existing complexity of the Arctic context, both in the operational environment and tasks in coordinating the highly demanding RNSAR air operation. In response to complexity, the RNSAR-system is in itself complex. With that in mind, the theory of CAS proved to be a useful framework for understanding and further develop the RNSAR-system, which is an important theoretical implication for later studies.

Systematic use of these theoretical findings can potentially increase RNSAR-effectiveness. Furthermore, the findings would be highly relevant in similar types of air operations, for instance military operations or others involving a potential high risk, adding complexity, risk perception and knowledge as factors to consider when coordinating aircraft.

6.2. Recommendations and future research

To be clear, some of the general limitations to RNSAR identified in this study are already being addressed through the RNSARBOOK-project. The handbook aims to fill some of the identified knowledge gap on radiation among relevant actors. That being said, the handbook is being developed at the operational level (JRCC), and it would be up to the unit level to operationalise and refine it for own procedures at their respective organisations.

First and foremost, knowledge is the key to RNSAR-effectiveness. The main recommendation from this study is to build enough basic knowledge of radiation, at all levels, to understand and assess the risk associated with RNSAR-operations. Next is to develop RN-specific procedures that accounts for the complexity in the operational environment, reduce uncertainty and simplifies coordination.

When developing own procedures, while always maintaining aircraft safety, a recommendation would be to allow for flexibility within the ability to effective conduct the RN-detection and SAR missions, which might require some experience-based improvisation. Furthermore, this will allow for the combination of general SAR SOPs with flexible RN-specific procedures, depending on the involved expertise and network.

For coordination, the ACO-function is essential when multiple aircraft are involved in an RNSAR-operation. This function needs to be identified and prioritised early during the operation, especially knowing that this is a limited asset in Norway. Furthermore, there is a potential for developing this function outside the primary task of maintaining aircraft separation. With sufficient knowledge and specific procedures, the ACO could plan, prioritise and coordinate the tasks of SAR and RN-detection among the involved aircraft, thus increasing the effectiveness of RNSAR.

This study has attempted to provide a small contribution to the lack of specific research on multiple aircraft operations in the Arctic – focusing on the challenges surrounding RNSAR-operations. As such, it is merely a steppingstone for future research on the phenomenon, and several concepts and perspectives are worth further studies. RNSARBOOK is a project involving the Nordic countries, but RNSAR as a concept needs to be included at the international level in the future. Future research could build on this study to include aircraft operations and the development of RN-specific procedures for an international concept of RNSAR-operations.

In this context it would be useful to conduct a follow up study on the effects of the RNSARBOOK and connected projects, both for the practical use and employment of the knowledge provided, in addition to coordination of the SAR effort in an RN-environment.

Furthermore, one could build on this study's weakness, and include the other Arctic states in the research. Future case studies in other Arctic countries with different governance structures and cultural backgrounds could provide new information and perspectives on the findings in this study. Social context and culture were not included in the analysis in this study, but these are certainly a variable to consider when international actors respond to an RN-emergency.

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Appendices

Appendix 1: Interview guide (in Norwegian)

Samtykke, legitimitet og intervjuprosess:

- Presentasjon av intervjuholder
- Sammenheng med RNSARBOOK-prosjektet: Innsamlet data vil kun bli benyttet til masteroppgaven og identifiserte funn blir presentert for prosjektet
- Personlige data som vil bli behandlet er navn, stilling og organisasjonstilhørighet. Anonymiseres til stillingstittel og organisasjon i oppgaven.
- Lydopptak for transkribering – slettes i etterkant
- Mulighet til å se over transkripsjon hvis ønskelig (ja/nei)
- Bekreftelse samtykke
- Spørsmål rundt dette før vi begynner?

Problemstilling:

Hvilken evne har luftkapasiteter innen de nordiske landene til å koordinere maritimt søk og redning i et komplekst, radionukleært operasjonsmiljø?

Innledende spørsmål:

- Hva er din stillingstittel og organisasjonstilhørighet?
- Hvilket luftfartøy opererer dere?
- Kan du kort beskrive luftfartøyet og dets kapasiteter, samt deres erfaringer med denne i søk og redning i Arktis?

Nøkkelspørsmål:

Deltema	Nøkkelspørsmål	Oppfølgingsspørsmål	Merknader
Kartlegging	Har dere erfaringer med deres luftfartøy i et radioaktivt miljø?	• Øvelse / Trening / Reelt? • Overførbare erfaringer fra andre hendelser – eksempelvis kjemiske stoffer?	
	Hvilke roller/funksjoner kan deres luftfartøy utføre i et RN-miljø?	• SAR? • Monitorering/detektering av stråling? • ACO/Koordinering av luftressurser?	
	Har dere fått tilstrekkelig opplæring/kunnskap til å operere i et radioaktivt miljø?	• Er dette noe dere trener eller øver på? • Hva savner du eventuelt?	• Trening • Kurs • Erfaring

	Er dere tilstrekkelig utstyrt for å operere i et radioaktivt miljø?	• Hvilket relevant beskyttelsesutstyr har dere for besetningen? • …og luftfartøyet?	• Personlig måleutstyr • Detektering • Beskyttelsesutstyr • Pustemasker
	Påvirkes deres luftfartøy av radioaktiv stråling?	• På hvilken måte?	
	Dersom et større skip med radioaktiv last forulykker i morgen, vil du si dere er forberedt på en slik hendelse?	• Basert på din kunnskap og erfaring, kan du peke på faktorer som gjør at dere er forberedt / ikke forberedt?	
Prosedyrer og koordinering	Generelt, hvilke prosedyrer følger dere ved søk og redning?		
	Hvordan koordinerer dere innsatsen i luften med andre aktører – både egne og internasjonale?	• Er det utarbeidet planer og prosedyrer for koordinering – etterfølges disse? • Hvilke teknologier muliggjør koordinering? • Er roller og ansvar definert? • Hvordan påvirker nettverk og tillit koordinering? • Er det forskjeller på hvordan koordinering utføres, avhengig av hvilke faser en er i under aksjonen?	• Under kontekst av en større maritim hendelse, med flere aktører
	Hva fungerer godt under koordinering med andre aktører i dag? Hva kunne fungert bedre?		
	I tilfelle et maritimt søk og redningsaksjon som involverer radioaktiv stråling – vil det påvirke koordinering av innsatsen?	• Kan du peke på noen faktorer som fremmer / hemmer koordinering i et slikt miljø? • Er det elementer ved et radioaktivt miljø som gjør det annerledes å koordinere søk og redning med andre luftkapasiteter?	
	Er gjeldende prosedyrer tilstrekkelige for koordinering i et slikt miljø?	• Er det egne prosedyrer for operasjoner i et radioaktivt miljø? • Er det fleksibilitet i prosedyrene til å håndtere oppdukkende/ukjente utfordringer? • Er det rom for å omgå gjeldende prosedyrer	

		dersom situasjonen skulle tilsi det?	
Kompleksitet og risikovurdering	Øver dere på større, komplekse hendelser som innebærer koordinering av flere luftfartøy og andre fartøy?	• Hvordan har disse påvirket koordinering av denne typen operasjoner? (Planverk, teknologi, roller, rutiner) • Hvordan har disse påvirket erkjennelsen av risiko i slike situasjoner?	
	Hvordan er din organisasjon bygget opp rundt luftfartøyet dere opererer?	• Stor og kompleks, eller liten og spisset mot oppdraget?	
	Hvordan vil du beskrive det generelle operasjonsmiljøet dere opererer i?	• Uforutsigbart versus forutsigbart? • Kjent versus ukjent?	
	I hvilken grad påvirker radioaktiv stråling kompleksitet i operasjonsmiljøet?	• På hvilken måte? • Hvordan vil det eventuelt være annerledes å operere luftfartøyet i et slikt miljø?	
	Er dere kjent med relevante andre aktørers luftfartøy og deres kapasiteter relatert til radioaktivitet i operasjonsmiljøet?	• Er dette organisasjoner dere opererer sammen med til vanlig?	
	Hvordan utøves risikovurdering før et oppdrag hos dere?	• Hvordan håndteres risiko på ulike nivå i din organisasjon – fra fartøysjef/droneflyger til øvrig ledelse?	
	På hvilken måte vil mistanke eller melding om et radioaktivt operasjonsmiljø påvirke risikovurderingen?	• Vil dere vurdere risikoen som høyere? • Vil risikoen være håndterbar? • Opplever du at dere har tilstrekkelig kunnskap om radioaktivitet til å vurdere risikoen? • Er dette noe som ville bekymret besetningen?	
	Hvilke risikoreduserende tiltak vil dere benytte før et SAR-oppdrag i RN-miljø?		• Referansetabell stråling • Begrensninger i tid i operasjonsmiljøet
	Hvilke tiltak har dere for kontaminert personell og luftfartøy?		• Dekontaminering • Medisinsk oppfølging

God praksis	Etter å ha svart på spørsmål i dette intervjuet, hva er dine refleksjoner rundt søk og redning i et radioaktivt miljø?	• Hva er viktig for din organisasjons luftkapasitet når en skal operere i et slikt miljø?	
	Kan du peke på noen faktorer som både styrker og begrenser koordinering mellom luftkapasiteter i dag – sett opp mot et slikt miljø?		
	Etter ditt syn, hva vil være suksesskriterier for et vellykket søk og redningsaksjon i et maritimt radioaktivt miljø?		

Avrunding:

- Er det spørsmål innen tematikken som du synes mangler eller bør utdypes?
- Kan jeg ta kontakt med deg for oppfølgingsspørsmål, ved behov?

Takk for at du tok deg tid til å stille opp!