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Mapping of practitioner needs for Innovation and Knowledge Exchange in the ANA region

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EXECUTIVE SUMMARY

The primary purpose of this deliverable report is to provide a categorised mapping of practitioner needs for innovation and knowledge exchange in the Arctic and North Atlantic (ANA) region, within the search and rescue (SAR) safety and security context of the ARCSAR project. This is achieved through two separate tasks, task 2.1 (Define Target Areas for Improvement) and task 2.2 (Map Innovation and Knowledge Needs) of the project. These tasks were undertaken in the first eight months of the ARCSAR project, September 2018 – April 2019. The resulting classification is intended to be fundamental for shaping the needs and gaps to be concentrated on in the remainder of the ARSCAR project, as well as providing a reference classification for other current and future ANA research projects. Further work in the period March-November 2020 has resulted in the addition of sections 2.3,2.4,5 and 6, which derive a subset of priority tasks and the nature of the collaborations needed within and beyond the ARCSAR project to ensure progression in meeting them.

The first task (T2.1) involved the collection and collation of relevant practitioner information through a set of diverse activities, overviewed in Figure 1. Section 2.1 details the qualitative methodology and rationale for these data collection activities. Sections 3.1-3.4 gives more detailed explanations of each source of information. Section 3.1 provides a comprehensive review of past project recommendations and an overview of relevant scientific literature. Section 3.2 gives the details of the three organised practitioner workshops, in Bodø, Norway, Portsmouth, UK and Rome, Italy. The workshops were attended by between 20-50 delegates each. Different approaches were used in each workshop appropriate to the subject matter, including group discussions, panel discussions and root cause analysis of ANA incidents. The summaries of the information gained from the workshops, identifying gaps and needs, can be found in Section 7.3 of this report. Section 3.3 provides an explanation of the set of six qualitative questionnaires used to gather further need and gap information, along with their design rationale and means of distribution. The six thematic topics of the questionnaires and working groups are described in Section 2.1 and are inspired by the topics of the Polar Code. Twenty-nine responses were received for the six questionnaires, with the full comments given in Section 7.4 of this report. Section 3.4 gives the rationale for, and membership of, the six associated working groups who gave feedback and helped shape the format of the questionnaires. These working groups will have an enduring role within the ARCSAR project beyond the completion of Tasks 2.1 and 2.2.

The second task (T2.2) contained the analysis and classification of the data from the sources of information listed in the first task. The methodology for the combination of the data sources into a coherent classification is given in Section 2.2. The classification of ANA SAR safety and security needs and gaps is given as a series of Six Tables (Tables 14-19). These can considered as the principal output of this deliverable. The classification is a three level hierarchy. The first level is based on the six thematic areas inspired by the Polar Code, listed in Section 2.1. The second level is a broad category of need whilst the third level is specific sub-needs. In total, **twenty categories** of broad need are found, which are divided into **seventy five sub-categories.** Each sub-category is referenced by the sources of information from whence it arose and classified as needing further innovation, knowledge, research and/or collaboration. A cross reference for inter-thematic needs and gaps is also given. Furthermore,

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the summaries of sources of information in Sections 3.1, 7.1, 7.3 and 7.4 of this report are also cross-referenced with the needs or sub-needs that they contributed to.

As expected from a region with complex and emerging SAR safety and security needs such as the Arctic and North Atlantic, the listed needs are diverse, yet they paint an overall picture of required developments to ensure the improved and enhanced safety and security of the region. The listed needs ranged from strategic, tactical to operational and concerned both continuous day-to-day needs and dealing with sudden large-scale emergencies. This could be a compromised large cruise ship, a significant oil spill or an Arctic radiological disaster. The identified needs and gaps span through the technological, scientific, physiological, cultural, communicational, regulatory and educational and concern all inhabitants and stakeholders in the ANA space as well as the need to ensure the safety and preservation of the wider ANA eco-sphere. There are, however, two provisos to note when utilising the classification to drive future Arctic safety and security enhancements. Firstly, the information presented is deliberately collected from a practitioner perspective. Whilst care has been taken to collect information from as wide a range of practitioner participants as possible, the nature of the ARCSAR project may mean a slight bias to the SAR practitioner viewpoint. The recommendations are current as of the data collection dates (September 2018 – April 2019). However, it is intended that the classification given in the Section 4 forms the basis of a dynamic database of gaps and needs that will be updated at regular intervals throughout the ARCSAR project. The second proviso is that the classification pertains to the focus topic of ANA SAR safety and security, and hence should not be taken as a comprehensive list of all ANA scientific gaps and needs, which would be significantly more extensive.

Given the significant number of ANA needs and gaps identified in this report, two further analyses have been conducted as an addendum of Task 2.2. These are the prioritisation of sub needs (detailed in Sections 2.3 and 5) and methodology for collaboration during and beyond the scope and timeframe of the ARCSAR project (detailed in Sections 2.4 and 6). The prioritisation task yielded **a set of 17 priority sub-needs** that will give a focus to the ARCSAR project. The Possible, Implement, Challenge, Keep Back (PICK) and goal programming methodology utilised in Section 2.4 ensures that these are balanced both with respect to their topics of application (according a classification taken from the Polar Code) and with respect to their timeframe for achievement. The resulting list in Section 5 should therefore prove highly useful in shaping and setting national and uber-national ANA SAR research agendas from a medium to long term perspective. In the shorter term it will also guide the ARCSAR project's work. The collaboration methodology is also designed to yield results both within and beyond the ARCSAR project. The resulting Table 25 of **suggested means of collaboration and ARCSAR partners assigned to sub-needs** in Section 6 also has implications other different timeframes. In the shorter term it gives a definitive list of which ARCSAR partners will collaborate with respect to the sub-need under the auspices of Tasks 2.6 and 2.7 which monitor and report the uptake of new technologies and research to meet the sub-needs. In the medium and longer term Table 25 also gives the nature of the collaboration that needs to take place in order to resolve the sub-needs. It is important to note, particularly for the more challenging sub-needs, that the scope of the ARCSAR project is to map and encourage uptake of new technologies to meet the sub-needs rather than conduct fundamental research into them.

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1 Introduction

This report contains a description of the organisational and scientific activities necessary for the completion of Tasks 2.1 and 2.2 of the Work Package 2 of the ARCSAR project. The relevant deliverable description is:

D2.1 Mapping of practitioner needs for innovation and knowledge exchange in the ANA region (ARCSAR, 2017)

The mapping mentioned in the deliverable description can be found in Section 4 of this report. The cross-referencing of evidence sources for this classification can be found in Sections 3.1 and in section 7 - Annexes. An extract of the Task 2.1 description is given below, which concentrates on the necessary organisational and scientific activities needed to gather the relevant information for the classification.

"Task 2.1. Define target areas for improvement. Gather first-hand information on target areas for improvements in current security and emergency capabilities across the Atlantic and North Atlantic (ANA) region, through workshops, surveys and reports. Practitioner views and knowledge will be prioritized. Two participatory workshops co-designed by practitioners will take place early in the project (Month 1 and Month 6) to obtain direct information from practitioners on common capabilities and gaps with regards to the emergency preparedness system, aligned with routine as well as crisis situations. Examine relevant investigation reports of previous incidents or situations, and conduct targeted surveys of practitioner groups within and outside the project. Create working groups under key focus areas emerging from the workshops and surveys, to direct the reporting of common capabilities and innovation needs. Workshop 1 will take place in Bodø in Norway to coincide with the kick-off meeting at the beginning of the project (M1) and Workshop 2 will take place in later in Year 1 (M6) to coincide with Project Meeting 2…" (ARCSAR, 2017)

A full description of the mentioned evidence sources: literature and past project reviews, workshops, questionnaires and expert groups can be found in Sections 3.1, 3.2, 3.3 and 3.4 respectively. Furthermore the methodology of data collection from these sources is outlined in Section 2.1 and the workshop and questionnaire information can be found in Sections 7.3 and 7.4 respectively, cross referenced by the classification indices from Section 4.

The mapping, analysis and classification of the collected data forms Task T2.2 of the ARCSAR project, whose description is given below:

Task 2.2. Map innovation knowledge and research needs. Using the information generated in Task 2.1, map the needs and target areas for improvement in security and emergency capabilities across the Arctic and North Atlantic (ANA) region. Root cause analysis will be integrated into this task in order to give a full analysis of the innovation and needs. This mapping will be the first step in developing the innovation exchange arena, available electronically on the ARCSAR network platform. Characterise the types of practitioner needs under different thematic or operational areas, and establish if the need relates to a need for innovation, research, knowledge or collaboration. (ARCSAR, 2017)

The methodology for the analysis of the collected data is given is Sections 2.2-2.4 of this report. The usage of root-cause analysis can be found in the details of the second workshop in Section 3.2. The complete classification of the gaps, as well as their needs for innovation, research, knowledge and/or collaboration can be found in Section 4. This classification utilises a three-level hierarchy of thematic area, need and sub-need.

It is important to note the context and boundaries of the classification in this deliverable. The classification developed in Section 4 specifically relates to identified **practitioner** needs for innovation and knowledge exchange within the context of ANA safety and security provision. By this context, this report does not focus on general Arctic needs and provision, as important as they may be. Neither does it focus on academic viewpoints, although an overview of relevant recommendations from relevant scientific literature is presented in Section 3.1.5.

2 Methodology

2.1 Methodology for Data Collection

In order to fulfil Task 2.1 (Define target areas for improvement) and Task 2.2 (Map innovation knowledge and research needs), multiple sources of information have been researched and analysed in the period September 2018 – April 2019. These have been brought together as a coherent whole in the period February-April 2019 in order to produce this Deliverable 2.1 mapping report. The specific objectives that this mapping will facilitate in the remainder of the ARCSAR project include (i) the monitoring of research and innovation with a view to recommending uptake (ii) the expressing of common requirements in order to fill in capability gaps and (iii) the indication of priorities with respect to standardization.

In order to collect and analyse the required data, a number of sources of information and active means of data collection were utilised. The principal sources of information, as per the Task 2.1 description cited in Section 1, are:

- A set of three **workshops**, co-designed by academics and practitioners.
- An overview of the relevant publically available scientific **literature**
- A comprehensive review of past and current **relevant projects**
- A set of six **questionnaires**, categorised by six thematic topic areas (described below)
- A set of six **working groups**, categorised by six thematic topic areas (described below)

A detailed description of each of these data sources is given in Section 3. The inter-relation between these data sources and the central mapping task of Task 2.2 is visually demonstrated by Figure 1.

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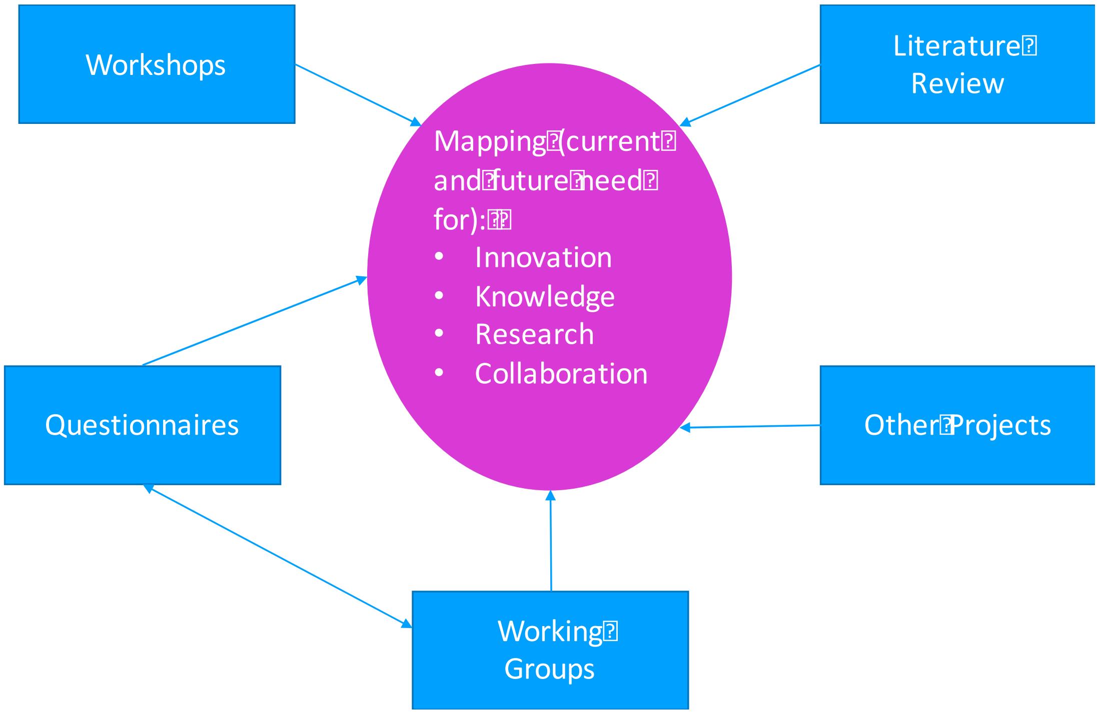

Figure 1: Sources of Information for Mapping

In order to produce a systematic classification and to channel the relevant expertise effectively, the broad topic of ANA security and emergency preparedness from a practitioner perspective is divided into six thematic topics. The reference source for these topics is the Polar Code (IMO, 2017), with the 17 Chapters of the code being grouped into six key areas of relevance and meaning to the ARCSAR project. These thematic topics are:

- **Vessel structural and equipment issues**
- **Lifesaving appliance and sea and cold survival issues**
- **Communication Issues**
- **Pollution and incident control issues**
- **Navigational and voyage planning issues**
- **Personnel, training and education issues**

These thematic topics will form the first level by which the classification of needs and gaps will take place. They also allow for the formation of the six working groups detailed in Section 3.4 and for the design of the six questionnaires detailed in Section 3.3. The working groups have permanence beyond Tasks 2.1 and 2.2, as they will be utilized throughout the ARCSAR project (ARCSAR, 2017).

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2.2 Methodology for Data Analysis

The data collection methodology detailed in Section 2.1 and analysis resulted in 20 statements of need and gaps, divided into 75 distinct statements of sub-need or gap. Most of these statements are qualitative in nature and range from high level strategic gaps to specific operational needs. Considering research methodology paradigms, the information to be classified is thus primarily **qualitative** rather than quantitative. Considering the analytics paradigm[1] (Delen and Demirkan, 2013), the goal of this deliverable (D2.1) is to describe and classify present gaps and future needs of SAR topic of ANA security and emergency preparedness from a practitioner perspective. Therefore the needed analytics are primarily **descriptive** and secondarily predictive. The prescriptive decision elements are largely contained in later ARCSAR tasks (ARCSAR, 2017). Considering the available analysis actions with the collated information, the primary purpose is therefore to **identify** and **classify** needs and gaps rather than to compare, rank, weight, prioritise, select or examine trade-offs between their achievements (Jones and Tamiz, 2010). The latter actions are intended as a future consequence of the classification presented in this deliverable.

A three level classification approach is undertaken, the results of which are given in Section 4. The first level of classification is by the thematic topics derived by the Polar Code given in Section 2.1. The second level of classification is by broad areas of need identified from the sources of information given in Figure 1. For example:

P2 – Enhanced and Standardised International Arctic Pollution Regulations

The third level of classification is that of specific sub-needs or gaps within the main category of need. For example:

P2A – Standardised regulations for prevention of oil spill

Where a need or sub-need is identified, which belongs to more than one thematic topic, a main topic is assigned and the secondary topic noted in the classification figures in Section 4.

The classification was achieved by simultaneous consideration of the sources of evidence in Figure 1, with a leading initial source of the workshops due to their combination and synthesis of collective experience. This allowed for an iterative process of consideration until all sources of information were included and a stable clustering around the classification categories given in Section 4 was achieved. A further classification of each of the 75 sub-needs into the categories of requiring innovation, knowledge, research or collaboration was then undertaken. This was based on the associated statements from the sources of information that led to the initial classification. Relevant statements in Sections 3.1, 7.3 and 7.4 of this deliverable are therefore labelled with the associated needs or sub-need(s) which they give rise to. All classifications given in Section 4 are of a binary type, that is a tick (or workshop number) if the source/type is relevant and an absence of a tick if it is not. This is in line

[1] The analytics paradigm divides data analytical techniques into three categories (i) descriptive analytics that analyse the data in order to describe the past or current state of affairs; (ii) predictive analytics that analyse the data in order to provide insight into likely future trends and scenarios and (iii) prescriptive analytics that analyse the data in order to provide decision maker(s) with the strengths and weaknesses of courses of action, and optionally a recommended course of action.

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with the previously described philosophy of identification and classification rather than numerical weighting or prioritisation.

2.3 Methodology for Prioritization

The data collection and analysis stage results in a substantive list of sub-needs, however there remains a need for further analysis. In order to set the focus of the remainder of the ARCSAR project and identify short and long term needs for ANA research and innovation, a classification and prioritization procedure is necessary. The process outlined in Section 2.1 is guided by experts and stake-holders which gives confidence that all 75 sub-needs identified in Section 4 are significant and relevant issues, however bringing structure to this list would benefit decision-making stakeholders in the task of selecting which sub-needs to engage as a matter of priority.

A further questionnaire has therefore been designed and was actively distributed amongst the working groups and wider practitioner networks of ARCSAR. The purpose of this questionnaire pertaining to this deliverable was to gain information on:

1. A quantification of the level of importance of the sub-need (on a 1-10 scale)
2. A quantification of the challenge of resolving the sub-need (on a 1-10 scale)
3. A qualitative list of products, services, systems, approaches and/or emerging research that could potentially be used to meet the sub-need.

As quantitative information was being sought, it was important to gain at least three independent practitioner scorings of the level of importance and challenge associated with each sub-need. The following responses by topic were received.

- **Vessel structural and equipment issues: 5** responses
- **Lifesaving appliance and sea and cold survival issues:** 4 responses
- **Communication Issues:** 3 responses
- **Pollution and incident control issues:** 6 responses
- **Navigational and voyage planning issues:** 5 responses
- **Personnel, training and education issues:** 5 responses

The ARCSAR project is focussed on SAR in the Arctic and North Atlantic, hence safety, risk, reliability and maintenance are crucial general disciplines that underpin the scope of the project. Our methodology for prioritisation of needs is based on operational research methods for decision analysis guided by the mentioned disciplines.

Safety and security domains are similar in that they deal with prevention and management of hazardous incidents or threats; the main difference relates to intent. It can be observed that the evolution of subsequent generations of research and development in safety and security disciplines can be summarised comprising four generations in terms of their increasing value. The First Generation is characterised as being '*descriptive*' in nature and aims to answer the question of '*What*

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happened?'. The Second Generation is characterised as '*diagnostic*' and aims to answer the question of '*Why did it happen?*'. The Third Generation is characterised as '*prognostic*' and aims to answer the question of '*When will it happen?*'. Finally, the Fourth Generation is characterised as '*prescriptive*' and aims to answer the question of '*What must be done?*' (Mobley, 2004). Hence the highest value in this classification is the prescriptive nature of models in order to strategically, and dynamically, inform the decision maker on what policies, strategies, or actions should be carried out.

The basic idea of decision grids is that they aim to provide a visual representation based on two or more criteria, and hence the term 'multiple criteria', and they therefore directly address the prescriptive requirement in strategic decision-making. Examples of such grids in are the Decision Making Grid (DMG) (Labib, 2004), Jack-Knife Diagram (JKD) (Knights, 2001), and PICK (Badiru, and Thomas, 2013).

In the prioritisation methodology described in this section we construct a revised structure of the two-by-two PICK diagram, and employ a variation of the JKD to determine the position of the thresholds between categories in the grid. The quantification of sub-needs by importance and level of difficulty (challenge) is hence used to produce a categorisation. An adapted version of the PICK chart process (George, 2003) is used for this purpose. The classic PICK (Possible, Implement, Challenge, Kill) chart is a bi-objective categorisation process (Badiru and Thomas, 2013).
The geometric mean is used in order to adapt the process to the multi-expert situation of the questionnaire responses. That is, assuming that a given sub-need s is quantified by $e_s = 1, \dots, E_s$ experts where $s = 1, . . ,75$. The importance and difficulty scores can thus be defined as:

i_{e_s} : level of importance assigned to sub-need s by e_s'th expert, $s = 1, . . ,75;\ e_s = 1, \dots, E_s$

d_{e_s} : level of difficulty assigned to sub-need s by e_s'th expert, $s = 1, . . ,75;\ e_s = 1, \dots, E_s$

The overall level of importance for sub-need S, denoted I_s is calculated as the geometric mean of the experts' assigned importance values:

$$I_s = \left(\prod_{e_s=1}^{E_s} i_{e_s} \right)^{\frac{1}{E_s}} , \qquad s = 1, . . ,75$$

Similarly, the overall level of difficulty for sub-need S, denoted D_s is calculated as the geometric mean of the experts' assigned difficulty values:

$$D_s = \left(\prod_{e_s=1}^{E_s} d_{e_s} \right)^{\frac{1}{E_s}} , \qquad s = 1, . . ,75$$

The set of 75 (D_s, I_s) co-ordinates are then plotted on a 2-dimensional graph, given by Figure 2, which forms the basis of the PICK chart.

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In order to classify the sub-needs into the four groups of the PICK process, horizontal (D^*)and vertical (I^*) lines represented the classification boundaries for difficulty and importance respectively are calculated and plotted on the graph. As the values are comprised of expert opinions, the method is refined to use the geometric rather than arithmetic mean of all expert responses across all sub-needs (E). This gives the threshold value calculations:

$$I^* = \left(\prod_{s=1}^{75} \prod_{e_s=1}^{E_s} i_{e_s} \right)^{\frac{1}{E}}$$

$$D^* = \left(\prod_{s=1}^{75} \prod_{e_s=1}^{E_s} d_{e_s} \right)^{\frac{1}{E}}$$

Where,

$$E = \sum_{s=1}^{75} E_s$$

The plotting of the horizontal line at level of difficulty D^* and vertical line at importance level I^* on Figure 2 allows for the sub-needs to be divided into four categories:

Possible (low difficulty, low importance). These sub-needs are possible to meet in the sense that they are judged to have a relatively low level of challenge in meeting them. However, they are not classed as a high priority due to their relatively low level of importance.

Implement (low difficulty, high importance). These sub-needs are prioritised for immediate action as they are judged both as important and relatively easy to resolve.

Challenge (high difficulty, high importance). These sub-needs are prioritised for further research and innovation effort as they are judged to be both important and difficult to resolve.

Keep Back (high difficulty, low importance). The sub-needs are not prioritised as they are judged to be both difficult to resolve and of low importance. Note that the terminology has been changed from "kill" as these sub-needs were still identified as valid by this process and hence should not necessarily be discarded, but rather kept in reserve whilst other sub-needs are resolved.

The results from this process can be shown in the Figure 7 and the tables of section 5.

The categorisation process can be extended to developing a prioritization methodology using the values obtained for the PICK chart. A weighted goal programming model (Jones and Tamiz, 2010) is built to solve a multi-objective knapsack problem that selects a set of priority sub-needs up to a maximal level of total difficulty whilst attempting to achieve the following goals as closely as possible:

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Goal 1: Achieve the maximal level of importance within the total allowable difficulty limit (classic knapsack objective). The limit *D* is determined to be the value 15x*D**, with the number 15 coming from the Pareto principle (80% of the effects come from 20% of the causes) and 15 being 20% of the 75 sub-needs.

Goal 2: Achieve a balance between the less challenging (possible, implement) and more challenging (challenge) topics chosen. This is needed in order to mix short and long term choices, otherwise the knapsack will fill with less challenging projects. Note that the "keep back" topics are not eligible to be chosen.

Goal 3: Achieve a balance between choosing sub-needs from the six topics. This is needed to ensure a balanced portfolio of chosen topics, the topic areas are all assumed of equal importance to future Arctic safety and by balancing these selections it can counter any potential expert evaluation bias (ie. Weighting everything in a topic maximum importance).

Model Description

Indices

Topics(t): $1, \dots, 6$

Sub-needs for topic t: $1, \dots, N_t$

Data

D : Maximum total difficulty level of chosen projects (size of knapsack)

i_{ts} : Importance level of sub-need s from topic t

d_{ts} : Difficulty level of sub-need s from topic t

$$\alpha_{ts} = \begin{cases} 1 & if\ sub-need\ s\ from\ topic\ t\ in\ implement\ category \\ 0 & otherwise \end{cases} \quad t = 1, \dots, 6; s = 1, \dots, N_t$$

$$\beta_{ts} = \begin{cases} 1 & if\ sub-need\ s\ from\ topic\ t\ in\ possible\ category \\ 0 & otherwise \end{cases} \quad t = 1, \dots, 6; s = 1, \dots, N_t$$

$$\gamma_{ts} = \begin{cases} 1 & if\ sub-need\ s\ from\ topic\ t\ in\ implement\ category \\ 0 & otherwise \end{cases} \quad t = 1, \dots, 6; s = 1, \dots, N_t$$

I^*= Target level of total importance (found through single objective backpack optimization)

To find I^* solve

$$Max\ I = \sum_{t=1}^{6} i_{ts} x_{ts}$$

Subject to,

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$$\sum_{t=1}^{6}\sum_{s=1}^{N_t} d_{ts}x_{ts} \leq D$$

B^*=Highest level of imbalance between challenge and possible/implementation sub-needs (found through optimizing number of possible/implementation projects that can fit in backpack)

1) To find B^* solve:

$$Max\ B = \sum_{t=1}^{6}\sum_{s=1}^{N_t}(\alpha_{ts} + \beta_{ts} - \gamma_{ts})\, x_{ts}$$

Subject to,

$$\sum_{t=1}^{6}\sum_{s=1}^{N_t} d_{ts}x_{ts} \leq D$$

C^*=Highest level of imbalance over the set of topics (found by maximizing numerator of third term of achievement function subject to backpack constraints and conditions $n_{ij} \times p_{ij} = 0 \quad i = 1, \dots, 6, j = 1, \dots, 6, j > i$)

1) To find C^* solve:

$$Max\ C = \sum_{i=1}^{6}\sum_{j=1, j>i}^{6}\left(n_{ij} + p_{ij}\right)$$

Subject to,

$$\sum_{t=1}^{6}\sum_{s=1}^{N_t} d_{ts}x_{ts} \leq D$$

$$n_{ij} \times p_{ij} \quad n_{ij}, p_{ij} \geq 0 \;\; i, j = 1, \dots, 6, j > i$$

w_1 = Weight associated with the minimization of unwanted deviations from the first (importance level) goal, set at w_1 =0.5 when producing the results given in Section 5.

w_2 = Weight associated with the minimization of unwanted deviations from the second (balance between categories) goal, set at w_2 =0.25 when producing the results given in Section 5.

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w_3 = Weight associated with the minimization of unwanted deviations from the third (balance between topics) goal, set at w_3=0.25 when producing the results given in Section 5.

Decision and Deviational Variables

$$x_{ts} = \begin{cases} 1 & if\ sub-need\ s\ from\ topic\ t\ chosen\ in\ priority\ set \\ 0 & otherwise \end{cases} \quad t = 1,\dots,6; s = 1,\dots,N_t$$

n_1 : Negative deviation from the first goal target

p_1 : Positive deviation from the first goal target

n_2 : Negative deviation from the second goal target

p_2 : Positive deviation from the second goal target

n_{ij} : Negative deviation from goal target concerning the difference between topics i and j $(i > j)$

p_{ij} : Positive deviation from goal target concerning the difference between topics i and j $(i > j)$

Weighted Goal Programme

$$Min\ a = \frac{w_1 n_1}{I^*} + \frac{w_2(n_2 + p_2)}{B^*} + \frac{w_3 \sum_{i=1}^{6} \sum_{j=1,j>i}^{6} (n_{ij} + p_{ij})}{C^*}$$

Subject to,

$$\sum_{t=1}^{6} i_{ts} x_{ts} + n_1 - p_1 = I^*$$

$$\sum_{t=1}^{6} \sum_{s=1}^{N_t} (\alpha_{ts} + \beta_{ts} - \gamma_{ts})\, x_{ts} + n_2 - p_2 = 0$$

$$\sum_{s=1}^{N_i} x_{is} - \sum_{s=1}^{N_j} x_{js} + n_{ij} - p_{ij} = 0 \quad i,j = 1,\dots,6, j > i$$

$$\sum_{t=1}^{6} \sum_{s=1}^{N_t} d_{ts} x_{ts} \leq D$$

$$x_{ts}\ binary\ t = 1,\dots,6; s = 1,\dots,N_t;\ n_1, p_1, n_2, p_2 \geq 0; \quad n_{ij}, p_{ij} \geq 0\ \ i,j = 1,\dots,6, j > i$$

The above methodology was then applied, giving an equal weight between the maximization of importance (goal 1) and the maintenance of balance (goals 2 and 3). The results obtained can be seen in section 5.

2.4 Methodology for Collaboration

The prioritization process gives a list of Arctic security and safety priority sub-needs for the ARCSAR network to focus on within and beyond the project. This is in order to (i) collaborate to ensure uptake of innovative technologies to meet the sub-needs and (ii) to inform future research and innovation agendas of required new knowledge, products and services in order to meet the more challenging sub-needs. Therefore, there is now the need to establish optimal collaboration groups (leaders and partners) from the ARCSAR members (and appropriate non-consortium entities) to implement a plan to advance the above agenda for each of the selected sub-needs. Given that the prioritization methodology is designed to result in 10-20 sub-needs, selected with a balance from the six working groups, and the ARCSAR network consists of a variety of participants (in total 21 from academia, practitioners, industry, and organizations), there is the need to establish a framework for assigning partners to collaboration groups and to decide what form of collaboration needs to take place for each priority sub-need.

From the literature on collaborative working, (Gredig et al., 2020), in the context of research-practice collaboration in social work, offer a relevant tool for distinguishing between types of collaborative projects. They provide a matrix for comparing projects in a systematic approach by which projects can be classified into one of five types according to their attributes:

(i) Production of scientific knowledge (SK)
(ii) Development of new methods (DM)
(iii) Development of organizations/practitioners (DP)
(iv) Development and implementation of services (IS)
(v) Evaluation of new service/policy (EP)

These group types relate to the context of ARCSAR sub-needs as follows.

(i) Sub-needs that require new technology and greater understanding of the underlying science knowledge are classified as Production of scientific knowledge (SK)
(ii) Sub-needs where technology exists but is not in sufficient use or maturity are classified as development of methods (DM)
(iii) Sub-needs that require enhancing of training, skills and communication are classified as Development of organizations/practitioners (DP)
(iv) Sub-needs looking to improve the system for sharing information and data are classified as implementation of services (IS)
(v) Sub-needs relating to issues of standardizing protocol and concerns with the Polar code are classified as Evaluation of new service/policy (EP)

This wide range of potential collaboration types is appropriate given the variety of Arctic security and safety sub-needs provided by the classification process detailed in Section 2.2. Other characteristics and properties provided by (Gredig at al., 2020) that help classify and define the prioritized sub-need challenges and to identify collaboration partners for these projects are the actors involved and the relationships between them, the project output and the target audience.

The process to assign the priority sub-needs list to groups based on the objective of the ARCSAR project was undertaken by three decision makers with knowledge of the sub-need selection and prioritization process, all being co-authors of this report. The decision makers (DMs) independently assigned Low-Medium-High relevance levels to each group type for every sub-need. Using these three levels provides a means for successfully evaluating the degrees of mapping a preference ordering. The combined results found more agreements than disagreements, especially with the categories of science (SK) and policy (EP). The DMs then discussed these results to reach a unanimous choice for each sub-need and group preference level. This involved clarifying an issue of whether sub-needs belonged in the groups with objectives belonging in the categories of developing methods or new services, a problem caused by interpretation of group objective meaning, and also to minimize decision maker bias (providing too many high or low evaluations). The results of this process can be seen in Table 23 in Section 6.

From this assignment we then took the other characteristics related to the collaboration group types that had highest preference, to show what was required for each sub-need based on the highest of the low-medium-high evaluations. Each sub-need received at least one high match, demonstrating the appropriateness of this approach. This characteristic to sub-need mapping information can be seen in Table 25.

The actors involved are taken from the social work origins of the original work, however an appropriate association with the work of the ARCSAR partners can also be made. In the above table the taxonomy drawn from (Gredig at al., 2020) includes the following categories of organisation: University of Applied Science (UAS), Annex Institute (AI*),* Independent Research Institute (IRI) are primarily academic actors. The practitioner actor types are Human Service Organisation: Frontline (HF), HSO: Management (HM), Private Association NGO (NGO), and Local Welfare Politics (LWP). Translating this taxonomy into the context of ANA safety and security, in particular the ARCSAR network, yields the following:
UAS: Universities with an applied focus and a wide range of competencies
AI: A research institute within a University with a specific competency related to ANA safety and security
IRI: An independent research institute with a specific competency related to ANA safety and security
HF: Organisations directly involved in frontline SAR or other ANA safety and security activities
HM: Organisations involved in managerial and/or support roles for SAR or other ANA safety and security activities
NGO: Industrial and non-governmental organisations providing products and services in and for the ANA region
LWP: Organisations concerned with the welfare of, and development of policies for, the ANA region.

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Table 25 in Section 6 contains the list of ARCSAR partners and the prioritized sub-needs they have been selected to work on. The column giving the category of the partner organisation shows which of the above actor types these represent.

Knowledge of the sub-need collaboration group type, together with the specifics of the ARCSAR working group related to the sub-need can be used on a case-by-case basis to assign appropriate lead partners and collaborators. This process was undertaken by a group of ARCSAR participants, the project leader, work package leader and participants working on this process. Together they selected the relevant partners to lead and support in the collaborations, based on the expertise of the organisation and the types of actors needed to work on the specific sub-needs. The outcomes of this meeting and the collaboration process can be seen in Table 26 of section 6.

To conclude, a summary of the collaboration methodology process in terms of inputs and outputs is as follows:

Inputs to the process:
1) The prioritized sub-task's data (PICK grid of importance scores versus difficulty scores).
2) The five types of collaboration projects with their scores (L,M,H)) from three decision makers (co-authors of the report).

It then produces collaborative **outputs** in terms of:
1) Mix of actors involved in the collaboration.
2) Nature of collaboration / interaction.
3) Expected type of output(s) from collaboration.
4) Expected audience (stakeholder) that will benefit from such collaboration outcome.

The results of the collaboration methodology can be found in Section 6.

3 Analysis of Evidence Sources

3.1 Past Projects and Scientific Literature

A comprehensive review of existing literature and past and current projects in the area of Arctic and Northern Atlantic security has been undertaken. In line with the aims of the ARCSAR project, the focus is on finding gaps and needs aligned to the various aspects of the thematic areas detailed in Section 2.1. The discovered gaps and needs will be further categorised by whether they are in research, innovation, collaboration, or knowledge in the classification of Section 4. When, a specific need or aim is identified, the relevant gap or need code from Section 4 is given in parenthesis, e.g. (P1B).

The primary source for information is previous project reports, both EU and non-EU, which cover Arctic and Northern Atlantic security concerns and also any related scientific publications. Significant documentation was available and keyword searched for terms including ’gaps’, ’future research’, ’recommendations’, and ’shortcomings’ as well as analysing contents pages for suitable sections

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within the reports. The information gathered from these reports is considered alongside that gathered from the opening ARCSAR project workshops and the practitioner questionnaires, detailed in Sections 3.2 and 3.3 respectively. The quality of the sources used is straightforward to verify in terms of project final reports, and examining the participants and funding source. Arctic and Northern Atlantic security is an already an established field of research, with significant work already done on the topic. However not all reporting includes gaps or needs for future work, just the findings and results of individual projects. This section provides a comprehensive synopsis of relevant projects focussing on recommendations or shortcomings in the current research, while a list of other related projects with no accessible final reports or published results are included in Section 3.1.4 for the sake of completeness.

3.1.1 Linked Projects

As outlined in the ARCSAR proposal documentation there are a number of ongoing or recently finished research and innovation activities that are relevant to the project outcomes. Table 1 presents an overview:

At this stage no final reporting offering needs for future work are available. As with all current and ongoing projects, recommendations for future work or known gaps will be incorporated into the ARCSAR project's continuing innovation monitoring task as they become available.

Table 1: List of relevant projects that will be included when results are available/published

Project short name	Long name	Funded by	Planned end date
MARISA	Maritime Integrated Surveillance Awareness	EU	2019
RANGER	RAdars for loNG distance maritime surveillancE and SaR opeRations	EU	2019
HELIOS	Second Generation Beacon for GALILEO/EGNOS EGNSS Search And Rescue applications	EU	2019
LYNCEUS2MARKET	An innovative people localisation system for safe evacuation of large passenger ships	EU	2018
ACOPE	Arctic Operational Emergency Agency Innovation Platform	Norwegian Ministry of Foreign Affairs	2019

The Marpart international R&D project; The SARiNOR project; and The University of the Arctic Thematic Network on Arctic Safety and Security. Several reports and papers have been published relating to the MARPART (Maritime Preparedness and International Partnership in the High North) Nord University project. *"The main purpose of this project is to assess the risk of the increased maritime activity in the High North and the challenges this increase may represent for the preparedness institutions in this region."*

(Roud et al. 2016) provide the limitations and implications for further research as; *"This study was based on three cases all taking place in favourable weather conditions where the outcomes were on the positive side, saving all lives and salvaging all the vessels. There should be studies of cases and exercises in more extreme conditions and with a scale where improvisation and mobilization of resources from a broad range of institutions and host nation support are included. This may provide a*

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greater focus on tactical and operational level coordination and communication issues, especially related to the on-scene coordinators, incident commanders, and the operational and strategic management on shore. In addition, there is a need to emphasize the resource mobilization, decision making process and logistics challenges of the host nation support cases of the Arctic region." (T1B, T1F, T2, T4)

(Marchenko et al. 2018) state the following; *"The capacity efforts should be directed towards development of the joint emergency response system, improvement and sharing of emergency resources and advancing competences in emergency management in the Arctic seas. This calls for increased frequency and complexity level on joint exercises like the Exercise Barents. There is a need for full-scale exercises in remote areas and preferably in the autumn and wintertime, where the challenges are significantly higher than in the summer. The risk assessments point to the need for emergency response plans, resource allocation and an organization of the preparedness system in an optimal way. This may also include strengthened cooperation across borders. We need to look into the competences of both the vessel crew and the emergency response resources to deal with the Arctic water challenges. This includes research on training and exercise schemes on less likely large-scale incidents demanding efforts from a broad range of emergency response actors, and cross-border support from other nations where institutional dimensions may represent an extra factor.* (T1A, T1B, T1F, T4B)

Publications and presentations entitled 'The roadmap to Norway's Arctic policy' from the Maritime Forum North (2016) provide the main findings for the first phase of the SARiNOR project and outline the future work in the project.

These outline the **major challenges** in the areas of:

- Alerting and notification (Communication limitation far north, practical design of equipment, culture, language and general knowledge about alerting)
- Search (Long distances and difficult polar conditions, long time to implement new technology, long way from end user to decision makers)
- Rescue (climate, equipment are not adapted to the actual operation, effective utilization of available resources)
- Survival in cold climate (time, low temperatures (hypothermia), Lack of equipment)
- Shared situation awareness (Difficult to get access to the right information, different interface no common standard platform for sharing of information, today's technological potential for sharing text, images and live streaming is not fully exploited)
- Training and competence (Different actors, different background and competence, different experience). (C1, L2, T4)

The same source provides the **main findings** across these same topics as:

- Alerting and notification (Develop a common standard for alerting, improve satellite coverage, better sharing of available information)
- Search (Simplify acquisition process - more end user impact, implement state of art equipment, Increase helicopter range by establishing more fuel depots)

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- Rescue (need to develop test and performance standards for polar rescue equipment - lifeboat, rafts, clothing, personal equip., drop-kit, develop more effective equipment for evacuation and rescue of personnel from vessels, sea, lifeboats etc., develop training courses and accomplish practical training to ensure effective utilization of all available resources)
- Survival in cold water (need to adapt existing equipment and procedures to polar environment, general training must include evacuation and survival in cold climate, holistic approach to the total rescue chain)
- shared situation awareness (need for a common standard interface between the C31 systems - command, control, communications and information, Access to Broadband will expand the possibilities to sharing of data, drills are important for establishing and developing a shared situational awareness)
- Training and competence (Need for a common basic training, all phases to be included: preparedness before an incident, ensure a common understanding about a typical SAR operation, follow up and implementation of improvements after an incident). (L2A, L3D. T1A, T1B, T4B, V2A, C1A, C1B, C2A)

The following measures are identified in the SARINOR project: Any factor that can cause delay and thereby increase the rescue time must be identified. All measures identified must be evaluated and prioritised to make the rescue chain more efficient.

Examples of the measures identified are: (C2A, T1B, L2, N3A)

- Improvements to infrastructure
- Communications and broadband coverage
- Advance storage
- Establishment of equipment depots that are suited to operational needs
- Emergency medical preparedness, including the use of telemedical equipment must be improved
- All categories of response personnel must be identified to ensure swift mobilisation, including the use of the Norwegian Armed Forces' special forces units (rostering systems will be evaluated)
- Establishment of a task force specially trained for demanding and "long-term" operations in cold climates
- Evaluation of the setup for airdrops of rescue personnel and equipment in the case of major accidents
- Improvements to R&D to make rescue operations more efficient, by putting new and modern equipment into use, including the use of drones
- Arctic rescue equipment
- Improved search and monitoring, etc.

3.1.2 The Arctic Council Working Groups

Significant work has been undertaken by the Arctic Council, *"the leading intergovernmental forum promoting cooperation, coordination and interaction among the Arctic States, Arctic indigenous*

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communities and other Arctic inhabitants on common Arctic issues, in particular on issues of sustainable development and environmental protection in the Arctic." (Arctic Council, 2019). The council consists of six working groups;

1. Arctic Contaminants Action Program (ACAP)
2. Arctic Monitoring and Assessment Programme (AMAP)
3. Conservation of Arctic Flora and Fauna Working Group (CAFF)
4. Emergency Prevention, Preparedness and Response Working Group (EPPR)
5. Protection of the Arctic Marine Environment Working Group (PAME)
6. Sustainable Development Working Group (SDWG).

Substantial amounts of documentation produced by these working groups is available at https://arctic-council.org/index.php/en/documents.

Some of the most relevant publications and results from the Arctic Council working groups, with regards to ARCSAR objectives, is presented here:

'Synthesis for Arctic Leaders'

The 2017 **'Synthesis for Arctic Leaders'** is a document that integrates the key findings from the Arctic Resilience Assessment. This work (Arctic Council, 2017) follows from previous Arctic Resilience Reports and is guided by the AMAP working Group. It highlights the following relevant needs:

1. Integrate social and ecological monitoring using a systems perspective. Integrated monitoring to strengthen these abilities for decision-making requires data gathering, synthesis, and assessment strategies that integrate human and biophysical dynamics. (P1, P3B)
2. Strengthen knowledge integration. The Arctic Resilience Report points to important knowledge gaps that are partly an outcome of the structures through which knowledge is pursued and organized. (T2)
3. Increase the capacity of Arctic people to engage with, respond to, and shape change. Increasing the capacity of various actors to engage with and shape change also encompasses the previous two categories for action: integrating monitoring using a systems perspective and strengthening knowledge production and integration. It also requires the collaborative development of decision support tools and decision making processes. Shaping change can take many forms, including choosing from among possible adaptive responses to inevitable changes. (T4A, T4B)

Arctic Marine Shipping Assessment report

The Arctic Marine Shipping Assessment report (Arctic Council, 2009) was prepared by the Arctic council after asking the Protection of the Arctic Marine Environment (PAME) working group to conduct a comprehensive Arctic marine shipping assessment. This was outlined under the Arctic Marine Strategic Plan (AMSP) under the guidance of Canada, Finland and the United States as lead countries and in collaboration with the Emergency Prevention, Preparedness and Response (EPPR) working group and the Permanent Participants as relevant. The following relevant need points from this report are listed below by category. For ARCSAR, the main focus is on Arctic Marine Safety. The report is also covering the topics: "Protection of Arctic People and the Environment" and "Building the Arctic Marine

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Infrastructure". These topics are also reviewed and relevant results are highlighted and presented in the annex part 7.1.

Enhancing Arctic Marine Safety

Linking with International Organizations: That the Arctic states decide to, on a case by case basis, identify areas of common interest and develop unified positions and approaches with respect to international organizations such as: the International Maritime Organization (IMO), the International Hydrographic Organization (IHO), the World Meteorological Organization (WMO) and the International Maritime Satellite Organization (IMSO). In order to advance the safety of Arctic marine shipping; and encourage meetings, as appropriate, of member state national maritime safety organizations to coordinate, harmonize and enhance the implementation of the Arctic maritime regulatory framework.

IMO Measures for Arctic Shipping: That the Arctic states, in recognition of the unique environmental and navigational conditions in the Arctic, decide to cooperatively support efforts at the International Maritime Organization to strengthen, harmonize and regularly update international standards for vessels operating in the Arctic. (P2F)

Uniformity of Arctic Shipping Governance: That the Arctic states should explore the possible harmonization of Arctic marine shipping regulatory regimes within their own jurisdiction and uniform Arctic safety and environmental protection regulatory regimes, consistent with UNCLOS, that could provide a basis for protection measures in regions of the central Arctic Ocean beyond coastal state jurisdiction for consideration by the IMO. (P2)

Strengthening Passenger Ship Safety in Arctic Waters: That the Arctic states should support the application of the IMO's Enhanced Contingency Planning Guidance for Passenger Ships Operating in Areas Remote from SAR Facilities, given the extreme challenges associated with rescue operations in the remote and cold Arctic region. Strongly encourage cruise ship operators to develop, implement and share their own best practices for operating in such conditions, including consideration of measures such as timing voyages so that other ships are within rescue distance in case of emergency. (N2A, N2B)

Arctic Search and Rescue (SAR) Instrument: That the Arctic states decide to support developing and implementing a comprehensive, multinational Arctic Search and Rescue (SAR) instrument, including aeronautical and maritime SAR, among the eight Arctic nations and, if appropriate, with other interested parties in recognition of the remoteness and limited resources in the region. (P2)

Arctic Marine Shipping Assessment (AMSA) IIc

Following the recommendations of the above Arctic Council AMSA report led to a project on the Identification of Arctic marine areas of heightened ecological and cultural significance. The document AMSA IIc 2009 (Arctic Council, 2013) provided a section of the necessary next steps, which are reported below:

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The Arctic has extensive, valuable cultural sites and practices along nearly its entire coastline. Readily available information makes the extent of this cultural legacy clear, but details are lacking. This report has presented as examples a subset of the information available about communities and their interactions with the sea, about heritage sites, about archaeological and historical sites, and about traditional use areas. While this information is incomplete from an Arctic perspective, it is nonetheless sufficient to begin work to determine how best to reduce negative impacts from increasing vessel traffic in the region. At the same time, it is important to fill in the gaps in knowledge so that important sites or activities are not neglected through ignorance.

The potential impacts of shipping on areas of heightened cultural significance have not yet been evaluated to determine which are most damaging and most widespread. The specific threats are likely to vary with each area and its characteristics, but an overall evaluation of the relative severity of each type of threat should nonetheless be possible at this stage.

This evaluation would lead to an assessment of protective measures and their application to vessel traffic around the Arctic, again to determine widely shared approaches that can be refined according to the specific conditions at each site or in each region. Such protective measures should of course be evaluated in connection with their relevance for ecological protection, as many approaches may serve both goals. Preparedness for accidents and emergencies should be part of this exercise. The desirability of IMO action, either for PSSAs or as part of the Polar Code, should also be included. (P2D)

3.1.3 Project Report Findings

The 2018 report **"Offshore Service Vessels in Arctic Oil and Gas Field Logistics Operations - Fleet Configuration and the Functional Demands of the Cargo Supply and Emergency Response Vessels"** (Borch 2018) is a result of the project "Operational logistics and business process management in High Arctic oil & gas operations". The project emphasizes operational logistics management for oil and gas fields in the Arctic, and offers many factors as potential challenges in the following areas:

1. Knowledge base – lack of field knowledge
2. Vulnerability of environment
3. Stakeholder complexity
4. Infrastructure limitations
5. Distances from supply base to drilling field
6. Wind, Waves, Visibility
7. Low temperatures (fog, icing, ice).

The conclusions of the report states "When it comes to all-year operations the complexity and turbulence of the Challenging and Extreme Arctic regions make the functionality demands and the following technology need sky rocketing compared with the close to shore operations in milder climate (P1).

There is a need to develop each of the different types of offshore service vessels and especially discuss how much functionality and overlap between the different types there should be. For the equipment producers, there is a special challenge of developing the tools that may function in extreme temperatures with icing conditions (V1).

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The high complexity and volatility in an Arctic environment demand a very broad resource base and the bundling of both high tech physical resources. The operation demands a tailor-made value chain and broad set of organizational adaptations within the organizations involved. Increased complexity due to a broad range of stakeholders, institutional arrangements and other factors call for a broader range of services including ice management, additional or different type of communication capacity and a number of units involved for emergency preparedness reasons.

Dynamism or volatility is related to natural conditions like the icebergs, floes or bergy bits, fog, distances to base for spare parts and repair and political and military sensitivity. This calls for a broader range of physical resources including more and better equipped vessels with a broader range of functions needed if something unpredicted were to have happened (V1A).

More costly vessels with ice class and icebreaker capacity had to be included even in summer operations. Winter operations would demand all vessels and rigs with the highest ice class and a much larger capacity of ice breaking vessels for both ice management and escort of platform service vessels, increasing the costs and the risk related to the operation significantly. Increased risk also calls for a significant upgrading of the maritime preparedness system, including both land bases, emergency rescue helicopters and oil recovery vessels (L3B, P1).

The implications of these findings is that offshore oil and gas operation in the High Arctic environment demands both redundant resources and a broader range of physical resources including a broad range of multi-functional vessels. The distances and resource scarcity of the operational area means that only to a limited extent will it be possible to add resources after the operation has started. The multifunctionality of vessels and multi-competence personnel have to be included and trained in realistic environments (T1A).

This report shows that offshore operation in icy waters is not “business as usual” and implies a broad range of physical resources. Several of the physical resources may be included in the same vessels to keep the costs down. In addition, one may discuss if there should be developed a new class of vessels, especially combined Hub and depot vessels. Finally, there is the challenging task of putting together the completely self-servicing fleet of vessels into an “expedition concept, with the optimal combinations of functionality and the necessary back up. The need for tailor-make, for technology development, and the costs of investment and operation imply that there should be a lot planning and innovation period for the most challenging fields, with significant R&D and discussions around a safe, sustainable, and efficient operation.” (V1)

The Red Cross Arctic Disaster Management Study (Finnish Red Cross, 2018) is a project which “develops capacities for evacuations in major accidents in cold conditions and maps out the existing capabilities and capacities of the Red Cross for Arctic response”. The study received funding from the Finnish Border Guard’s Arctic Maritime Safety Cooperation (SARC) project, and gives 13 recommendations based on the collected data and the conclusions drawn. The recommendations are directed to the Red Cross and the aim is to support the development of Arctic capabilities and capacities in the future.

The report recommends that The Arctic National Red Cross Societies should:

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1. Consider strengthening volunteer management capacities together
2. Explore how the Emergency Response Units (ERU) could be ensured to operate in cold conditions and to be prepared for Arctic accidents.
3. Explore harmonization and pooling of emergency units and assets for major accidents in the Arctic and for cold conditions in general.
4. Together with authorities analyse and strengthen how medical readiness for emergencies in the Arctic could be improved by utilizing Red Cross capacities in the Arctic preparedness planning better
5. Explore developing pre-planning of logistical chains and establishment of logistical hubs together with regional actors, taking into account the challenging geography, remoteness, long distances and the existing infrastructure in the area.
6. Explore the possibility of establishing Arctic Regional Disaster Response Team (RDRT) training and teams
7. Institutionalize the cooperation between the National Red Cross Societies in the Arctic to improve sharing of information and preparedness and to ensure the continuity of the cooperation.
8. Strengthen their cooperation with states and relevant authorities in the Arctic through formalization of cooperation in the form of agreements, MoUs and arrangements.
9. Strengthen and expand on existing partnerships with the NGO sector as well as explore new forms of cooperation with different NGOs.
10. Explore sharing experiences internally and actively regarding cooperation with the private sector.
11. Together with the IFRC strive to formalize the coordination and arrangement of the Observer work in the Arctic Council and ensure fluent information exchange and better awareness of the Arctic Council work among the National Societies
12. Together with the IFRC more actively utilize the Arctic Council and the variety of communication channels that the Arctic Council Secretariat uses in better conveying the message of the Red Cross.
13. Together with the IFRC deepen the cooperation with the Arctic Council Permanent Participants and build on the common questions of community resilience, health and adaptation to learn from the local communities and also share experiences of the Red Cross from long-term programmes, community resilience projects and relevant tools.

More detailed analysis on these 13 recommendations are given in annex section 7.1.4.

A work related to the above project is the **Arctic Search and Rescue Capabilities Survey from the Finnish Border Guard,** subtitled Enhancing International cooperation (Ikonen, 2017). This survey is developed under the Arctic Maritime Safety Cooperation (SARC) project launched by the Finnish Border Guard and the Ministry for Foreign Affairs of Finland. The SARC project aims to develop cross-border collaboration with the maritime safety authorities of the Arctic countries as well as various other stakeholders representing the Arctic industry and research. Based on potential areas of cooperation 15 recommendations were agreed on together with the SAR experts as the main recommended initiatives for coast guard cooperation. These are listed below:

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1. Keeping each other informed on the new developments of relevant infrastructure and equipment.
2. Establishing a working group on technological developments related to the Arctic operating environment. (P1)
3. Liaising with the Arctic Council, Emergency Prevention, Preparedness and Response (EPPR) working group and the Arctic Economic Council on new developments in connectivity and communications.
4. Arranging a seminar on Arctic telecommunication innovations. Investigating opportunities for working together with the Arctic Economic Council regarding potential events.
5. Testing new technology in exercises, such as the AIES system or other situational awareness tools.
6. Developing a shared platform for sharing general SAR related data. Such platform could include features such as information on all Arctic RCCs and organizations responsible for and involved in SAR, resource asset data, weather and ice data, AIS data etc. (P4A)
7. Encouraging more exercises and the systematic sharing of lessons learned. (P4A)
8. Developing a database or a log system for sharing exercise and incident reports, calendar, blogs and other relevant information between coast guards and/or SAR authorities. (P4A)
9. Developing an annual joint course or workshop on Arctic navigation and operations involving junior officers, and senior leaders with first-hand experience.
10. Encouraging cooperation between coast guards, academia and the industry by involving them in exercises for evaluation and the testing of equipment. (T4B)
11. Encouraging information sharing between the industry and coast guards, such as sailing plans, emergency plans, SAR cooperation plans and vessel information. (N2B)
12. Including embassies in exercises or contingency planning, in order to develop common procedures for coordinating foreign patients.
13. Including local medical authorities, voluntary organizations and other local actors as stakeholders and recognizing their key role. (T4A)
14. Reaching out to the AECO and CLIA or other industry groups to establish connection and cooperation. (V3B)
15. Encouraging interest in safety issues, also among the non-Arctic countries.

The survey recommends further research regarding new possibilities for Arctic SAR training and education, as well as information sharing on new technological solutions. Further studies or research could be done on possible evaluation concepts and tools, through which the lessons learned and recommendations for future development could be systematically shared in a standardized form. Further research should also be directed towards the latest technological solutions related to communications, connectivity, navigation, rescue and survival equipment, and other operational SAR-related technologies. (T1B)

The publication **Utilising Local Capacities by the Centre for Military Studies**, from the University of Copenhagen (Østhagen, 2017), is a report that is a part of the Centre for Military Studies' policy research services for the Denmark Ministry of Defence and the political parties to the Defence Agreement. The purpose of the report is to examine and analyse the different ways Arctic countries are utilising local capacities when managing emergency situations in the maritime Arctic. This report has outlined a number of recommendations for further enhancing Arctic emergency response capacities, as listed below:

Information

- Improve the spread of information concerning offshore safety and survival for the local population.
- Mandate training/exercise participation for maritime actors. (T2)
- Mandate so-called 'self-rescue' training and equipment for maritime tourists.
- Organise 'how to' campaigns in local communities together with relevant non-profit organisations. (T4A)
- Make use of the Arctic engagement of non-profit organisations with additional resources, like the WWF and Red Cross, to create projects aimed at local capacity enhancement.

Response

- Increase the number of vertical and horizontal exercises between the various local actors.
- Enhance community role-clarification with clearly defined lines of responsibility in preparation for large-scale incidents. (T4A)
- Explore how local maritime industries can be further included in a system or network for local emergency response. (T4A)

Operations

- Every Arctic community has some form of local engagement in case of an emergency. It is thus up to the local and national governments to provide a framework in which these resources can be further improved and utilised. (T4A)
- Explore the options for a maritime component to the already existing schemes, such as the Canadian Rangers or Longyearbyen Red Cross.
- Consider establishing a dedicated tool or hub for learning and knowledge enhancement concerned with maritime emergency management that can work on both the local and national levels by informing communities and the public debate" (P4)

The UK Government Foresight: Future of the Seas project looks at the important future trends, challenges and opportunities for the UK from the sea. A 2017 report Future of the Sea: Implications from Opening Arctic Sea Routes (Melia, Haines and Hawkins, 2017) "summarises the evidence for the projected loss of Arctic sea ice and opening of shipping routes due to climate change. It explores how these changes will make trans-Arctic shipping routes more navigable and profitable, and explores the resulting challenges and opportunities for the UK." Among the reports findings they state "The UK's leading role in Arctic science has wide reaching positive implications for international collaboration. To enhance predictions of the future Arctic, further developments in climate modelling and science are required. (Melia, Haines and Hawkins, 2017) includes a section entitled 'Arctic Data Requirements for Informed Policy Decisions', a relevant extract of which is given below:

"Recent environmental changes in the Arctic are so pronounced that they have been identified despite incomplete and uncoordinated observing capabilities. The lack of adequate and coordinated pan-

Arctic observations currently limits society's capability to identify, respond to and predict the geographic extent and severity of ongoing changes. A robust Arctic observation network is needed to address these limitations; such a network would be founded on existing platforms and observatories, starting with a set of key variables that are already measured at many locations but are not often collated.

The UK leads the world in hydrography with the maps produced by the UK Hydrographic Office (UKHO) setting the international standard. Much of the Arctic lacks detailed hydrographic data, but upgrading existing charts is a comparatively low priority for the UKHO. The UK would benefit from supporting the improvement of charts for the Arctic not least to retain the UKHO's leadership, but also in fostering international partnerships. The Met Office is a world leader in weather forecasting and both the UKHO and the Met Office are ideally placed to provide world-class charting and forecasting services that could provide significant income streams for the UK. Better Arctic observations are required for safe tactical operations in the Arctic Ocean in addition to both scientific, and commercial strategic progress. The UK Government Response to the UK House of Lords 2015 Select Committee Report highlighted the importance of continued investment into ocean science and climate-modelling centres like the National Oceanography Centre and the Met Office, and science programmes like those coordinated by Natural Environment Research Council (NERC) Arctic Office, to allow better predictions of the future Arctic." (P1E)

The GENICE project (https://www.genice.ca/) addresses Canada's need to develop preparedness and response strategies for fuel spills in Arctic waters. Funded by Genome Canada, the project brings together a broadly interdisciplinary and multi-sectoral team to combine innovative genomics, analytical chemistry, and sea-ice geophysics with economic, policy and end-user expertise to focus on the role of and potential for bioremediation of fuel spills in the Arctic marine environment. The 2016 publication of the report on the first knowledge exchange forum (GENICE, 2016) states the fourth objective of the forum was to isolate relevant policy gaps and problems identified by participants. The following relevant points from (GENICE, 2016) are listed below:

"Participants identified a series of policy gaps and problems related to shipping, spill response, and spill kits. Around shipping these included:

- *Inability to access reports of ship activity at the community level.* People felt reports should be provided. There is particular concern around smaller recreational ships as participants commented that there is no registry for this type of vessel.

  There is no clear understanding of the fuel directives for shipping in Hudson Bay. In Svalbard, for example, only diesel fuel is allowed. There have been foreign ships delivering P50 fuel in the communities. People questioned whether foreign ships are subject to the same regulations as Canadian ships? (P1F)

- *Around spill response:* Participants understand that all are supposed to have spill kits on board but are uncertain if this policy is enforced. Uncertainties exist around:

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- Who is responsible for mitigation and preparedness measures, and who is responsible for dealing with the aftermath of a spill; (P2E)
- When does the Federal Government take over responsibility for responding to and remediating spills; (P2E)
- What resources are available to communities as first responders
- Particularly with respect to oil spill kits community members are uncertain as to their content, when and how to use the kits, and who is responsible for providing training to community members. (P1C)

Understanding spill kit contents and obtaining spill response training were perhaps the most commonly cited gaps in spill preparedness. The access to and use of kits is considered problematic by end-users across the board – from individual community members, to representatives of the Coast Guard, to the private sector. In addition, there is clearly a lack of either actual policy or a gap in understanding of existing policy related to shipping – reporting, tracking, monitoring, and providing information. Community members are looking for ways to easily access this information, and other End-Users are looking for ways to streamline or more effectively coordinate effort across responsibilities and among responsible parties under spill conditions. " (P1C)

The Arctic Coast Guard Forum seminar entitled "Coast Guard Cooperation in a Changing Arctic". Report main involvement from the Munk-Gordon Arctic Security Program (Canada) and the Norwegian Institute for Defence Studies (Østhagen & Gastaldo, 2015).

The following recommendations are stated from the report:

- Arctic states should continue to engage Russia in the planning and operation of the Arctic Coast Guard Forum, despite the current challenges of military-to-military contact in the region. (P2C)
- The Forum should initially avoid becoming an arena of "hard security dialogue" and focus on safety and environmental initiatives.
- The Arctic Coast Guard Forum should focus on building a community that will facilitate sharing of best practices, real-time data and information, and expertise at an operational level. (P4)
- The Arctic Coast Guard Forum should serve as a platform for search and rescue and oil spill exercises at both circumpolar and regional/ bilateral levels. (P4)
- The Arctic Coast Guard Forum must share information with other Arctic relevant bodies while still maintaining its independence and setting its own agenda.
- The Arctic Coast Guard Forum's Terms of Reference should include mechanisms to work with communities, indigenous organizations and the private sector.

ACCESS (Arctic Climate Change, Economy and Society - http://www.access-eu.org/) was a 2011-2015 European Union Project with the main objective to assess climatic change impacts on marine transportation (including tourism), fisheries, marine mammals and the extraction of oil and gas in the Arctic Ocean. (Crépin *et al.,* 2017) is an overview paper containing the results from this project. The conclusions and discussions of this article are given below:

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Regulations relating to Arctic offshore oil and gas activities must be strengthened and harmonized while taking into account differences in local conditions in terms of type of resource, infrastructure in place, and local and indigenous communities. The new Polar Code for shipping, the SAR agreement and the Fairbanks Agreement on enhancement of scientific cooperation are good examples but the details for their implementation still need to be specified. Similar regulations of oil spill response, Arctic tourist activities, and associated infrastructure, require prompt action. (P2A)

New key developments in physical infrastructure will certainly concern communication (broadband) in Polar Regions. No existing technology is available at the moment at the needed scale (pan-Arctic) but technical solutions exist, although expensive. Many challenges pertain for marine transportation like the lack of charts, training of polar operators and ice navigators, the development of an Arctic marine traffic awareness system, and the implementation of recent international agreements like the IMO Polar Code, the Arctic SAR and the Arctic Oil Pollution Preparedness and Response. (C2A, C2B, N2A)

Sound facts are a good basis for all governance decisions. Hence infrastructure for supporting scientific observations is a top priority. There is an urgent need to increase and improve observations in the Arctic atmosphere, ocean and sea-ice at a pan-Arctic scale and also at the regional scale. This is important not only to better understand processes but also a prerequisite to be able to parameterize and simulate them. Better observations are also necessary to improve weather forecasts, urgently needed for all kinds of activities in the Arctic, in particular for human and environmental safety reasons. The technology has improved to such extent that it is now conceivable to set up a proper Arctic observing network (SAON). This would involve observations from space (satellites) including some ground truth for validation and in situ components mainly composed of fixed (Eulerian) and mobile (Lagrangian) platforms for the ocean, the atmosphere and the cryosphere. ACCESS encourages coordination in the surveillance of marine ecosystems that are subject to climate variability and climate change beyond the Arctic proper, to include for example the Iceland fisheries.

There is a pressing need to address the lack of socioeconomic data for the Arctic. Such data should be collected in ways and at spatiotemporal intervals such that it can be used jointly with biogeophysical data in a meaningful way. This would allow a better understanding of social–ecological and cross-sectoral interactions and improve forecasting capacity in all domains where human–nature interactions matter. Ideally a socio-economic data observing system should be part of the initiatives already discussed for biogeophysical data just mentioned (e.g., SAON). Other data needs concern quantification and understanding of the provision of ecosystem services and data with high enough resolution and number of observations to help anticipate and analyse potential abrupt changes and tipping points in all domains. (C1C)

Decision making based on state of the art scientific knowledge and advice requires more quantified and specific approaches to assess impacts. Governance tools better adapted to fulfil multiple goals could be developed building on tools like integrated ecosystem-based management, marine spatial planning, constructive and carefully chosen indicators, and resilience assessments

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Any management action should also account for people's potential reactions to such action because anticipation of some changes may trigger stronger reactions than the actual changes. People also often have general difficulties in interpreting risk and probabilities.

In that context it may matter for example how potential future changes (e.g., in resource stock abundance, market conditions, policies and management strategies) are communicated. Visualization tools and coordination devices may help people take better informed decisions.

The policy-making process in the Arctic needs to actively incorporate traditional knowledge. National and industry interests should not systematically be allowed to override those of the environment or indigenous and local populations. We are convinced of the benefits of retaining a dialogue between non-Arctic States and the Arctic Council, in agreement with international law requirements for High Seas fisheries and Seabed areas beyond national jurisdiction (UNCLOS Art. 123). An active dialogue between all international stakeholders involved in Arctic governance issues is essential for successful and sustainable development and the wellbeing of the people. Standardization/harmonization of regulations would be ideal for all activities and in particular for transboundary live and mineral resources. For this to succeed there needs to be a commitment beyond the national level." (T4A)

(Wilkinson et al., 2907) focus on oil spill response in the Arctic and conclude "there are deficiencies in our understanding that need to be addressed so that these gaps can be bridged and solutions found. In order to comprehend fully our level of understanding and readiness to deal with an Arctic oil spill, field exercises that encompass a broad spectrum of sea ice, ocean and meteorological conditions will be necessary. Whilst a handful of controlled oil spills experiments have occurred in sea ice the past, new developments and techniques suggest that further controlled field trials are needed to evaluate and improve oil spill response capabilities and technologies. These exercises, whilst very challenging, should be encased within the realities of the climate-driven changes within the region." (P1F, T1F)

3.1.4 Other Projects Identified

The following projects are identified as either (i) ongoing with no written report at the time of writing or (ii) not having an accessible written report. It is therefore recommended that these projects form part of the ongoing monitoring tasks of work package 2 for the duration of the ARCSAR project.

- IMRF MRO - International Maritime Rescue Federation Mass Rescue Operations Project
- HuSArctic - Human Security as a promotional tool for societal security in the Arctic: Addressing Multiple Vulnerability to its Population with Specific Reference to the Barents Region. Arctic Centre, University of Lapland (2015-2019)
- SARC - Phases II & III Finnish Border Guard (2016-2019)
- CCAPPTIA - Climate Change and Adaptation Planning for Ports, Transportation Infrastructures, and the Arctic (GENICE Workshop, 2018)
- ARENA - Arctic Remote Energy Networks Academy, Arctic Council's Sustainable Development Working Group
- MOSAiC - Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC), International Arctic Science Committee (IASC)
- SMACS - Small Craft Emergency Response and Survival Training for Arctic Conditions, Northern Periphery Programme (EU, 2007-2013)

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- ResQU2 platform project consortium - (ChemSAR -Operational plans and procedures for maritime search and rescue in HNS incidents, DiveSMART Baltic - Diving with state maritime resources in the Baltic, HAZARD - Mitigating the effects of emergencies in the Baltic Sea Region Ports, and MIRG-Ex - Maritime incident response groups)

3.1.5 Scientific Publications

Work relevant to outlining the needs and shortcomings of Arctic Safety and Security is also available in the wider scientific literature. Further publications have been written in support of the **MARPART project** with findings relevant to the work of the ARCSAR project. The (Marchenko et al., 2016) conclude "When it comes to fire and terror there are severe challenges in all regions for life, especially for remote areas with severe weather conditions, even though the probability of such events are regarded as theoretically low. There is a need for more efforts as to capacities, technology development, improvement of routines and competence to reduce the probability of accidents. Also, governments should continue to discuss constant monitoring and regulation of traffic in high risk areas. Within the new Polar code (adopted by IMO's Maritime Safety Committee (MSC), in November 2014) there should be special efforts from the governments in the North to implement special rules and regulations to avoid accidents, and to increase competence. Finally, there is a need for developing better search and rescue technology, oil spill response capacities in cold water areas, and not at least communication and transport infrastructure within the region for fast emergency response." (V1A, T1B, P2A)

While the **HuSArctic** project is yet to conclude and publish the final report, several publications are available. The project uses "Human Security as a promotional tool for societal security in the Arctic: Addressing Multiple Vulnerability to its Population with Specific Reference to the Barents Region" (Hossain et al. 2017). This work states that "promoting and sustaining societal identity is necessary to support overall human security in the Arctic."

An earlier work by (Hossain, 2016) discusses the "transformation of the Arctic by climate change and its impacts has resulted in new challenges and opportunities… explore how indigenous peoples in general and the Sámi in particular understand security which promotes their societal security"

(Sydnes *et al,*. 2017) present a publication on Arctic search and rescue international cooperation and conclude "the Arctic SAR regime is still under implementation. A constituting agreement has been negotiated and entered into force. However, a series of steps need to be taken to ensure that the regime leads to behavioural changes among the parties. This includes institutionalized cooperation through the regular meetings of parties, and the development of principles, rules and procedures for operational cooperation." (T3, T4)

(Ray *et al.,* 2019) focusses on performance after cold exposure and how this impacts safety and performance. This review "found that there is a limited amount of research on how to optimize training for cold environments… also found that the current body of research is primarily based on findings from tasks that are biased towards motor or cognitive demands, but not both, and that most tasks studied are low in complexity." They conclude that "Based on this review there are two key issues that need to be addressed. The first issue is that there is a gap in our knowledge regarding how cold exposure affect more complex tasks, which have both cognitive and motor elements, that are

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performed in dynamic and unpredictable environments. This lack of research could lead to an underestimation of the effects of cold exposure because it remains unclear how the effects of cold exposure interacts with increased cognitive and sensorimotor demands of performing complex manual skills in open environments. Therefore to improve the safety of those who work in cold environments, research is required that specifically investigates how body transport, body stability, task complexity and the cognitive and motor demands of a task all influence the effects of cold exposure on manual performance. The second issue is that there is a paucity of research that addresses how to organize training to best promote the learning, retention and transfer of trained skills to cold environments. Without research that investigates how to maximize both learning and performance, individuals may face situations where they are unable to retain trained skills once they are in their work environment or they may not be able to transfer their trained skills to dynamic and changing conditions of cold environments. Therefore, to better gauge how training will transfer to performance in cold environments it is imperative to design studies that manipulate the variables that are known impact the retention, transfer and performance of motor skills (contextual interference, variable practice, practice specificity effects, thermal conditions)." (L1C, L1D)

(Pietikäinen, 2018) details research arising from the of the Cold Rush research project, which is examining dynamics of language and identity in expanding Arctic economies. The discussion section of this paper states "Emerging new conditions call for new strategies, acting within and against economic power, dominant forms of identity politics, and hegemonic discourses about multilingualism and identity. They reflect a complex sense of the fixity and fluidity of ethno-linguistic categories, where language becomes not only an identity marker but also capital for economic development. These transformations impact not only on the ways in which people make a living but also on how their identities and languages are valued or disregarded, and their ability to cope with and reshape these changes." (T4A, N2D)

(Romero Manrique *et al.*, 2018) discusses how climate change will lead to the displacement of native communities in the Arctic region. The paper discusses the challenges faced and offers the following recommendations; Foster collaborative engagement of traditional knowledge and science, recognise the value of traditional knowledge and change the approach towards a framework of co-creation of knowledge, avoid imprecise policies and vague recommendations, and avoid over-protectionism and paternalism. In their final remarks it is stated "we suggest that scientists, technical experts, and policymakers establish and use closer cooperation channels with local native communities. These channels could be developed through, e.g. collaborative networks, observer networks, citizen science initiatives, and projects based on traditional knowledge, since these kinds of actions would allow on the one hand, a direct connection and collaboration between Arctic peoples and scientific organisations and actors; and on the other hand, it would allow the elaboration of more concrete strategies and policies." (T4A)

3.1.6 Needs and Gaps Identified During ARCSAR Bid Preparation

Additionally, a set of existing broad need categories has been developed in the preparation phase for the ARCSAR project (Arcsar, 2017):

- Ways to achieve broadband communication in the polar areas (C2A)

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- Technology to meet the IMO Polar Code requirements under Arctic and North Atlantic conditions
- Cold climate Maritime Mass Rescue Operations (MRO) technology, and situational awareness challenges focusing on operations in sea ice (L2)
- Technology for cold climate tests of rescue equipment and techniques in a simulator or laboratory (L1D, L2)
- Technology for cold climate Marine Oil Spill Response (P1)
- Radiological and nuclear incident responses, and environmental threat responses in ANA region (P3C, P4C)
- Technology for rescue when there is risk of radiological exposure (P3C, P4C)
- Technology to cope with hazardous goods during an emergency in the Arctic and North Atlantic (P1, P2)
- Technology for improved education in maritime emergency management in the Arctic and North Atlantic region (T2)
- Technology for seamless sharing of situational awareness between emergency management agencies and other emergency actors, cross sector and cross border. (C1D)
- Risk assessment and decision-making - need for advanced root cause analysis techniques, risk-assessment concepts, analysis of scenarios of vulnerability, and selection of appropriate response policies and decision- making as applied to retrospective and prospective scenarios in the Arctic and North Atlantic region and using real life case studies and investigation reports. (N1B, N2C, T1F)
- Satellite-based data needs and intelligence (C1B)

3.2 Workshops

The first specific activity has been the organisation of three **practitioner workshops**. Each workshop was attended by between 20-50 delegates, and was co-designed by University of Portsmouth academics and relevant practitioners from the ARCSAR consortium. The first of these took place in Bodø, Norway in September 2018 and concentrated on meeting the requirements of the Polar Code. The discussion part of workshop took the form of division of delegates into self-selecting groups, with ensuing discussions on the gaps and needs and potential resolution actions arising from the polar code. These were then synthesised by the group and recorded by flip-chart. The six groups represented the six thematic topics derived from the polar code listed in Section 2.1. These were divided chronologically into two groups of three so each delegate could attend at least two topics. Additionally, delegates were free to move between discussion groups if they wished to input to further topics. The summary of the identified needs and gaps from the six groups is given in Section 7.3.1, classified by the identified thematic needs and gaps found in Section 4.

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Figure 2: Group session at second workshop in Portsmouth, UK

The second workshop took place in Portsmouth, UK in November 2018 and concentrated on the capabilities, gaps and priorities with respect to disaster management (maritime, shipping, oil spillage and radiological incident), as well as methodologies for their mitigation and preparedness. This workshop had some tutorial aspects in order to train delegates in the necessary root cause analysis techniques to identify and analyse needs, gaps and threats. Several well-known maritime, pollution incident and radiological catastrophe scenarios (Labib, 2014) were used to illustrate the techniques. Delegates then worked in self-selecting groups, each developing maritime, pollution and radiological disaster scenarios and using the taught techniques to identify root cause capability and procedural gaps and needs for enhancement. The conclusions of each group for each scenario were recorded and presented on flipcharts. The summary of the gaps and needs identified is given in Section 7.3.2, classified by the identified thematic needs and gaps found in Section 4.

The third workshop took place in Rome in February 2019 and concentrated on ANA satellite communication technology, technology for cold climate rescue and involvement of indigenous peoples. This workshop was structured differently from the first two workshops due to the subject matter under consideration. Each topic had a session in which several expert speakers gave presentations. This was followed by a panel based discussion with questions from the audience of delegates. The minutes of each session were recorded and used to identify relevant needs and gaps. The summary of the gaps and needs identified is given in Section 7.3.3, classified by the identified thematic needs and gaps found in Section 4.

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3.3 An overview of Current ANA SAR

3.3.1 The Current State of Accidents and Incidents in the Arctic

There are few publicly data available to evaluate Arctic Accidents and Incidents. However, there is genuine cause for concern that an accident will occur, and that it may be catastrophic (Clarke and Harris, 2003). The Accident Incident Databases which were compiled for the Arctic Marine Shipping Assessment (AMSA) and the Future of Shipping in the Arctic, are chosen for analysis (the publicly available data on marine accidents in the Arctic). The reports contain a summary of the incidents and accidents that occurred in the Arctic region from 1995 to 2004, and from 1955 to 2019. These datasets are compiled from multiple sources (Ikonen, 2017 and Cottle and Kern, 2019). In its final report, the AMSA included the following summary statistics from the database: vessel type, primary reason, month, and year. Accidents and incidents (henceforth "accidents") are classified into six categories. The dataset also includes the type of vessel, date of the incident, location, number of fatalities, whether fuel was spilled, the amount of fuel spilled (in tonnes), whether the ship was an actual or constructive total loss, and whether ice damage occurred. (Huntington, 2015).

Table 2: Accidents by Vessel Type in the Arctic and ANA region

Vessel Type	Arctic			ANA
	1995-2004 (Arctic Council, 2009)		1955-2019 (Cottle, 2019)	1955-2019 (Cottle, 2019)
	Frequency	Percent	Percent	Percent
Bulk Carrier	37	12.7%	5%	5%
Container Ship	8	2.7%	N.A.	N.A.
Fishing Vessel	108	37.0%	47%	45%
General Cargo Ship	72	24.7%	17%	17%
Government Vessel	10	3.4%	N.A.	N.A.
Oil/Gas Service & Supply	1	0.3%	N.A.	N.A.
Passenger Ship	27	9.2%	7%	12%
Tanker Ship	12	4.1%	11%	14%
Tug/Barge	15	5.1%	6%	2%
Unknown	2	0.7%	7%	5%
Total	292	100%	100%	100%

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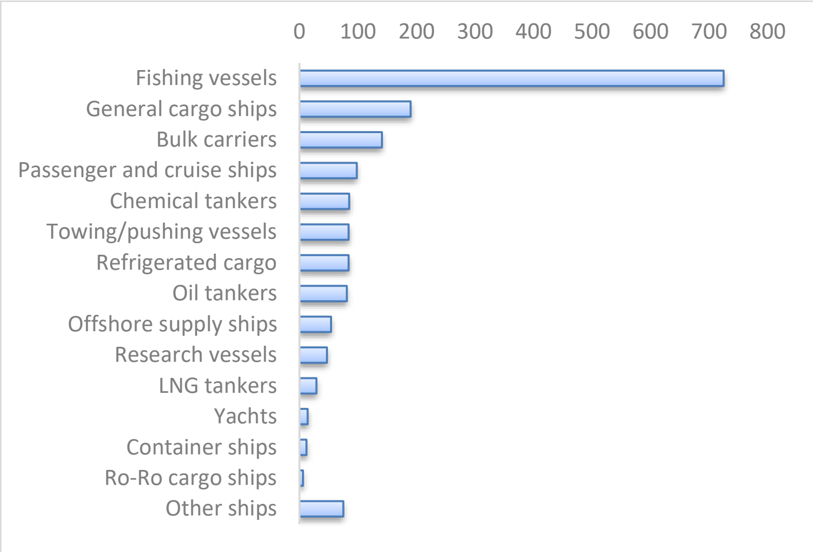

Figure 3: Number of unique vessels entering the Arctic Ocean between 2013 and 2019, by vessel type (PAME, 2021)

In the past sixty-four years, fishing vessels, general cargo vessels, and tanker ships have dominated accidents in the Arctic and North Atlantic. However, trends have shifted slightly since 1995-2004, when bulk carriers were involved in the third most Arctic Sea accidents (Arctic Council, 2009). The data reveal a significant relationship between the incidents and the entries given in Figure 3 and Table 2. Considering data from (Cottle,2019) and (Arctic Council,2009) in the Arctic Sea, bulk carriers have been involved in the seventh most accidents over the past 64 years, fewer than passenger ships. However, data from 1995 to 2004 indicate a rising trend in bulk carrier accidents.

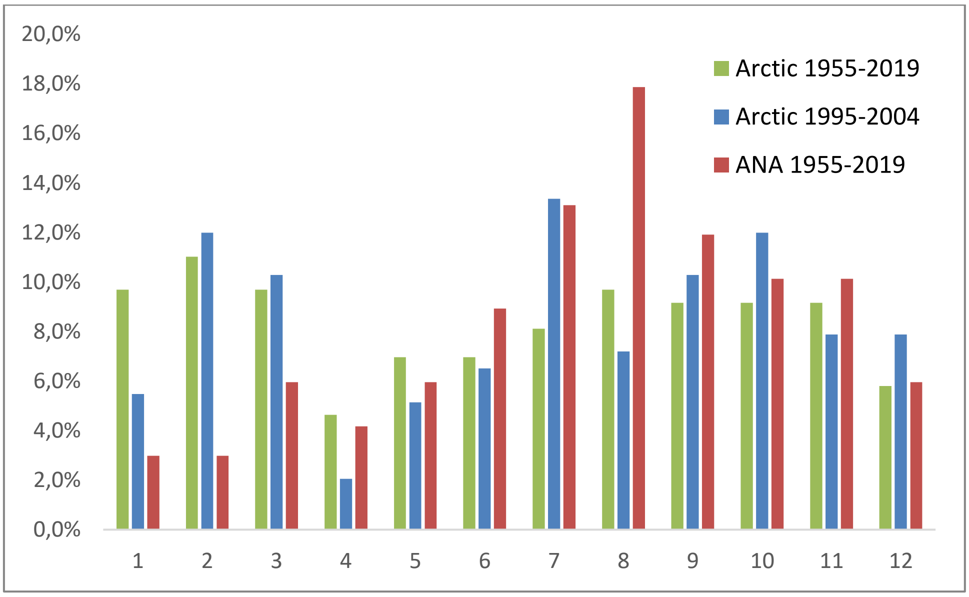

Figure 4: The most dangerous months in Arctic and ANA region (Arctic Council, 2009), (Cottle, 2019)

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Table 3: A Comparison of Arctic Marine Accidents by Month 1995-2004 (Arctic Council, 2009)

Month	Frequency	Percent
January	16	5.5%
February	35	12.0%
March	30	10.3%
April	6	2.1%
May	15	5.1%
June	19	6.5%
July	39	13.4%
August	21	7.2%
September	30	10.3%
October	35	12.0%
November	23	7.9%
December	23	7.9%
Total	292	100%

Figure 4 and Table 3 depict the occurrences of vessel accidents by month. These show that the accidents reach their peak in the Arctic in July and the North Atlantic in August. This can be explained by the fact that there is a greater volume of shipping in the Arctic region between July and September. Even though crossing the Arctic circle for various vessel types has recently become more feasible, the current trend is largely seasonal and not year-round. The data also gives a good indication as to in which months to concentrate SAR resources.

Table 4: Accidents in Arctic by Locations 1995-2004 (Arctic Council, 2009)

	Frequency	Percent	Cumulative
Arctic Archipelago	21	7.19	7.19
Arctic Ocean	1	0.34	7.53
Baffin Bay/Davis Strait	16	5.48	13.01
Barents Sea	37	12.67	25.68
Beaufort Sea	1	0.34	26.02
Bering Sea	97	33.22	59.24
Chukchi Sea	3	1.03	60.27
East Greenland Shelf/Sea	2	0.68	60.95
Faroe Plateau	8	2.74	63.69
Gulf Of Alaska	3	1.03	64.72
Hudsonbay	19	6.51	71.23
Iceland Shelf/Sea	19	6.51	77.74

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	Frequency	Percent	Cumulative
N/A	8	2.74	80.48
Newfoundland-Labrador Shelf	5	1.71	82.19
Norwegian Sea	49	16.78	98.97
West Greenland Shelf	3	1.03	100
Total	292	100	

Table 4 reveals that more than half of all Arctic sea accidents occurred in the Bering, Norwegian, and Barents seas, with half of them occurring in Norwegian territory. This gives an indication of the weighting of Norwegian data in subsequent analyses.

From 1995-2004 (See Table 5), technological factors such as machine failure and vessel damage have been the leading cause of accidents, accounting for more than 40% in the Arctic Sea. However, from the1990s onwards, this factor increases to 60% as the principal cause of accidents.

Table 5: A comparison of Arctic and ANA region Marine Accidents by Reason

Reason	Arctic			ANA
	1995-2004 (Arctic Council, 2009)		2008-2017 (Cottle, 2019)	2008-2017 (Cottle, 2019)
	Frequency	Percent	Percent	Percent
Collision	22	7.5%	9%	6&
Damage to Vessel	54	18.5%	25%	29%
Fire/Explosion	25	8.6%	11%	7%
Grounded	68	23.3%	9%	15%
Machinery Damage/Failure	71	24.3%	35%	37%
Miscellaneous/ Missing	10	3.4%	0.2%	0.6%
Sunk/Submerged	42	14.4%	11%	6%
Total	292	100%	100%	100%

Considering the environmental consequences, the possibility of a large oil spill in the Arctic is equally as catastrophic as a mass rescue operation (MRO). An oil spill would be disastrous for the region's wildlife, destroying habitats, killing animals, and disrupting migration patterns, as well as for the indigenous communities that depend on these animals. Cleanup of oil spills is also extremely expensive. Cohen (2010) asserts that the cost of cleaning up the Exxon Valdez spill in Alaska in 1989 — approximately 10.8 million gallons — exceeded $630 per gallon. He estimates the total cost to be $6.8 billion in 2010 dollars, excluding "the cost of the oil, litigation costs to Exxon, punitive damages, etc" (Cohen, 2010, p.4). Furthermore, it is still debatable whether it is even possible to clean up an oil spill in an environment that is completely or partially covered by ice (Petterson, 2010 & Reiss, 2012). Even if feasible, the tyranny of distance applies to oil spill response operations. The relocation of assets and personnel across vast

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distances would take time. All the recorded incidents illustrate the difficulties associated with Arctic distance, extreme weather, and lack of infrastructure. Considering the Exxon Valdez incident, from December 2004 to June 2006, it took 18 months to clean up the more than 300,000 gallons of fuel and other waste (NOAA, 2006). The incident cost a minimum of $100 million (Huntington, 2015). Figures 3 and 4 depict the types of vessels entering the Arctic Ocean which provides an indication of risk of environmental incident in the Arctic and North Atlantic Oceans.

Table 6: A Comparison of the Number of Accidents Involving Fuel Spills 1995-2004 (Arctic Council, 2009)

	Frequency	Percent
No Spill	268	92%
Fuel Spill	24	8%
Total	292	100%

Table 7: A comparison of accidents involving fatalities 1995-2004 (Arctic Council, 2009)

	Frequency	Percent
No Fatalities	278	95%
Fatalities	14	5%
Total	292	100%

Table 8: A comparison of accidents by loss 1995-2004 (Arctic Council, 2009)

	Frequency	Percent
Actual Total Loss	61	21%
Constructive Total Loss	2	1%
Not A Loss	229	78%
Total	292	100%

From 1995 to 2004, 10% of accidents had a chance of a fuel spill, 5% of victims resulted in death, and the total loss was 20%. This number will increase if the trend shown in Table 9 continues.

Table 9: A Comparison of Arctic Marine Accidents by Year 1995-2004 (Arctic Council, 2009)

Year	Frequency	Percent
1995	35	12.0%
1996	52	17.8%
1997	23	7.9%
1998	19	6.5%
1999	21	7.2%
2000	19	6.5%
2001	31	10.6%
2002	30	10.3%
2003	28	9.6%
2004	34	11.6%
Total	292	100%

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3.3.2 The Current State of ANA SAR System

In general, all ANA SAR nations share comparable SAR principle of SAR operations and inter-organisational coordination. The operator, coordinator, and volunteer direct and manage the operational processes, while the SAR regulator monitors and controls them (see Figure 5.). However, the processes are the responsibility of a variety of authorities, agencies, and levels of national and international institutions. Several nations, such as Norway, the United Kingdom, Ireland, Canada, Finland, and Iceland, have included land-based SAR in their national SAR programmes. Regarding these incidents, the entire nation depends upon the police authorities (see Table 10). Some of the organisations responsible for search and rescue, such as the Icelandic Coast Guard, are civilian organisations, whereas in other countries, such as Denmark, the Danish Defence Ministry is the primary SAR operator. In other nations, such as Canada, semi-military organisations are responsible for SAR. The responsible authorities also collaborate with other government entities, such as environmental agencies and health care authorities, involved in cross-sector search and rescue incidents. Non-governmental organisations and private businesses also contribute to search and rescue operations. Depending on each nation's emergency preparedness system, the use of resources varies from country to country. This organisational diversity further complicates the challenge of provided effective co-ordinated SAR services, including sharing of protocols, across the Arctic and North Atlantic region.

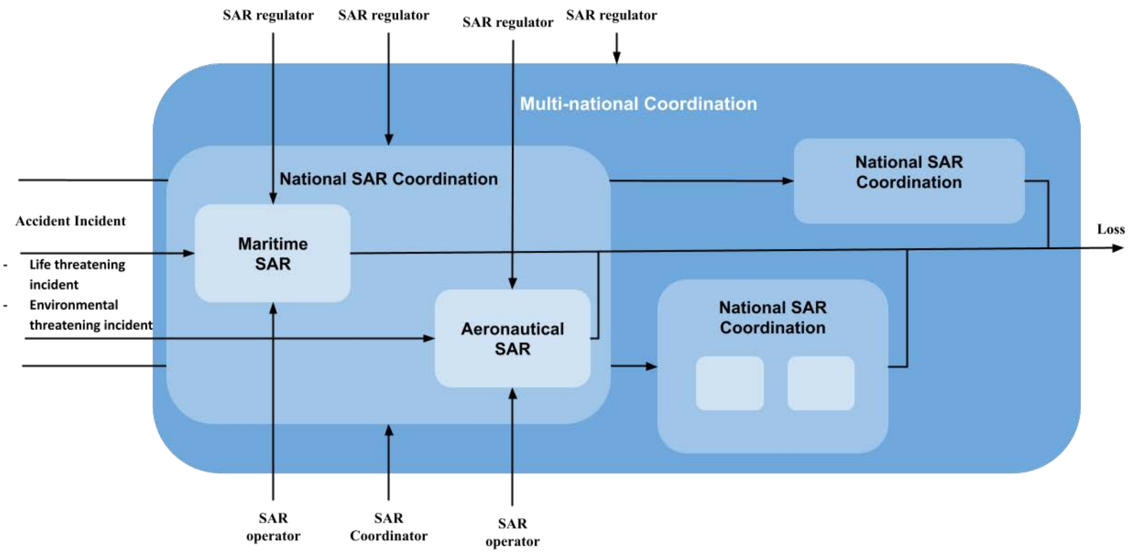

Figure 5: SAR System in Arctic Region

To coordinate effectively the SAR processes in Arctic, all Arctic and North Atlantic nations, have their own national (Joint) Rescue Coordination Centers ((J)RCC). The national Rescue Coordination Centers (RCC) are responsible for coordinating and leading search and rescue operations, as well as monitoring the accident scene and assigning the necessary resources. In order for such coordination to be effective, the RCCs must maintain a high level of situational awareness, including knowledge of the available resources, and a continuous flow of information from the scene of the incident and the vessel in distress,

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while maintaining overall control of the situation. Situational awareness includes basic information, positional and readiness data on SRUs, register data, Maritime SAR Plans, and maritime and air situational images. In addition to current contact information for other maritime SAR authorities, volunteer associations, and other organisations, basic situational awareness also includes this information (Ikonen,2017). Additionally, cooperation between authorities and agencies must be seamless. Decision making and an effective response rely heavily on the timely and accurate exchange of accurate information as well as proper logistics. In addition, multi-sectoral and mass rescue incidents frequently necessitate knowledge and coordination of the resources and support of other nations. Due to an abundance of communication channels and a lack of infrastructure, the operational environment of the Arctic presents obstacles for these crucial aspects of effective SAR operations and coordination.

To govern the SAR processes, each nation in the region assigns a national-level authority. Finland and Russia have transport authorities, Iceland and Norway have justice authorities, the United States and Denmark have defence and security authorities, Sweden has maritime authorities and Ireland has National Police or “The Garda”. However, Canada and UK have a different approach. Canada involves the military, fisheries, and maritime, whereas the United Kingdom has established a governance committee that includes all stakeholders, such as the Chair and Secretariat, National & Local Police, Association of Ambulance, Cabinet Office, Firefighter organisations, Local Governments, Environment authorities, Health authorities, Justice authorities, Home Office, Maritime and Coastguard, Defense authorities, and Lifeboat Institutions.

Considering the international context, the International Convention on Maritime Search and Rescue (Hamburg Convention) is the principal international agreement on maritime SAR services under the International Maritime Organization (IMO) and is applicable to all Arctic nations. The International Convention for the Safety of Life at Sea (SOLAS) mandates that maritime SAR services be provided. The International Aeronautical and Maritime Search and Rescue Manual (IAMSAR), published by the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO), contains guidelines for maritime and aeronautical SAR, including mission coordination, operations of search and rescue units (SRUs), and the provision of SAR-related training. The manual is not legally binding, but it provides the accepted framework for the provision of maritime and aeronautical SAR services. (International Maritime Organization 2017; Finnish Border Guard, Maritime SAR Manual, 2010)

The IMO’s recently adopted International Code for Ships Operating in Polar Waters (Polar Code) is "intended to cover the full range of shipping-related issues pertinent to navigation in waters surrounding the two poles – ship design, construction, and equipment; operational and training concerns; search and rescue; and, equally important, the protection of the unique environment and eco-systems of the polar regions" (IMO, 2017). In addition to these international rules for SAR and Arctic shipping, the Arctic countries

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have adopted regional agreements. Under the auspices of the Arctic Council, the eight Arctic nations signed a legally binding international agreement on aeronautical and maritime SAR in the Arctic in 2011.

Several Arctic nations have bilateral SAR cooperation agreements. Under the SAR agreement of the Arctic Council, it is in the Arctic Coast Guard Forum's best interest to promote and facilitate information sharing and coordinate activities with the Arctic Council and its Emergency Prevention, Preparedness, and Response (EPPR) working group. Due to the division of roles among numerous national authorities and institutions, international cooperation on Arctic search and rescue issues must accommodate sectors and authorities at various levels. Table 10 therefore lists, based on stakeholder questionnaire responses, the authorities responsible for search and rescue in the Arctic, as well as the relevant Rescue Coordination Centres for their Arctic search and rescue regions and other organisations engaged in search and rescue activities.

Table 10: ANA SAR Organisations and Coordination

SAR Participant	Responsible Authority	Governing Authority	Coordination Centre	Other authorities and organizations involved
Coast Guard	Canada, Iceland, United States of America, Ireland		Ireland, United Kingdom	Norway, Sweden, Russia
Air Forces	Canada			United States of America, Ireland, United Kingdom, Norway
Navy				Canada, Ireland, Norway
Armed Forces		Canada		Finland, Norway, Russia, United States of America, Ireland
Rescue Coordination Centre (RCC)			Russia, United States of America	
Maritime RCC (MRCC)	Finland, Faroe Islands		Finland	Russia
Aeronautical RCC (ARCC)	Finland		Finland	
Joint RCC (JRCC)	Norway, Greenland		Canada, Iceland, Greenland, Norway, Sweden	
Rescue Sub-Centre (RSC)			Russia (Norway *)	
Defence Authorities	Denmark	Denmark		United States of America, United Kingdom
Transport Authorities	Russia, United Kingdom	Finland, Russia		Canada, Iceland
Fisheries Authorities		Canada		
Justice Authorities		Iceland, Norway		
Maritime Authorities	Sweden	Canada, Sweden	United Kingdom	Denmark
Aviation Authorities			Ireland	
Security Authorities		United States of America		
Police	Ireland *	Ireland *	Ireland, United Kingdom, Norway *	Canada, Finland, Iceland, Denmark
Red Cross				Finland, Norway
Health Care Organisation				Faroe Islands, Greenland, Sweden, Ireland, Norway
Vessel Traffic Service				Russia, Norway
Air Traffic Service				Finland, Russia, Norway
Air Ambulance				Norway
Emergency authorities				Finland, Norway, Faroe Islands, Greenland
Environment authorities				Finland, Iceland
Meteorogical Institute				Finland, Norway
Lifeboat Association				Finland, United Kingdom, Norway, Sweden
Civil SAR Association				Canada, Iceland, Norway, United States of America, United Kingdom
Firefighter				Sweden, Ireland, United Kingdom, Norway
Shipping companies				Russia
SAR Joint Govern Committee		United Kingdom		

* = applicable for land SAR

Canada
Denmark
Faroe Islands
Finland
Greenland
Iceland
Ireland
Norway
Russia
Sweden
United States of America
United Kingdom

Communication with other countries' units and other stakeholders, including the vessel crew, land-based authorities, and vessels of opportunity involved in the incident, poses a

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challenge to situational awareness and, ultimately, RCC coordination with regard to multinational rescue operations in the Arctic. Information management poses the greatest obstacle to achieving situational awareness in multinational SAR operations in the Arctic, according to the responses to the questionnaire. The general flow of information, the increasing number and severity of incidents, distances and the locations of resource assets, trust and cooperation, and communication between authorities and other stakeholders are among the most significant obstacles regarding situational awareness in multinational SAR operations in the Arctic.

Information and reports from vessels sailing in Arctic waters are crucial for achieving and maintaining situational awareness, as they enable close monitoring of potential emergencies. All Arctic nations have their own Vessel Traffic Service (VTS) as well as national or international reporting systems for vessels entering national waters, as noted by SAR experts during the ARCSAR workshops. For instance, Greenland utilises its GREENPOS system, Canada utilises NORDREG, and in Russia, reporting is conducted via FSUE "Rosmorport" branches, etc. Despite this, it would be advantageous if Automatic Information System (AIS) data were shared or at least a shared perspective was obtained with all Arctic nations. Authorities, forums, and the academic community have requested common information-sharing platforms for Arctic authorities that contain information on SAR resources. In this regard, the Arctic currently lacks adequate satellite broadband for receiving vessel information in a timely manner. Unannounced vessels and fishing vessels that do not wish to reveal their location, as well as smaller vessels, such as pleasure craft, that do not require reporting or AIS systems onboard, are another concern for emergency authorities and VTS.

The utilisation of foreign units in situations necessitating international cooperation is dependent on the accident's location. For geographically close countries such as Sweden, Finland, Norway, and Western Russia, the use of foreign units could potentially be quite efficient. Although there are relatively more SAR assets in the Arctic than in the ANA region (see Figure 6.), some Arctic nations are separated by great distances. Even if bilateral cooperation were otherwise fluid, distance and response times would limit the use of the assets of the closest neighbours. In both the responses and the workshop discussion, different communication systems and communication barriers were identified as additional obstacles to the use of foreign units. Here is the SAR assets of Arctic operation and ANA region that has been recorded (1955-2019)(Cottle,2019):

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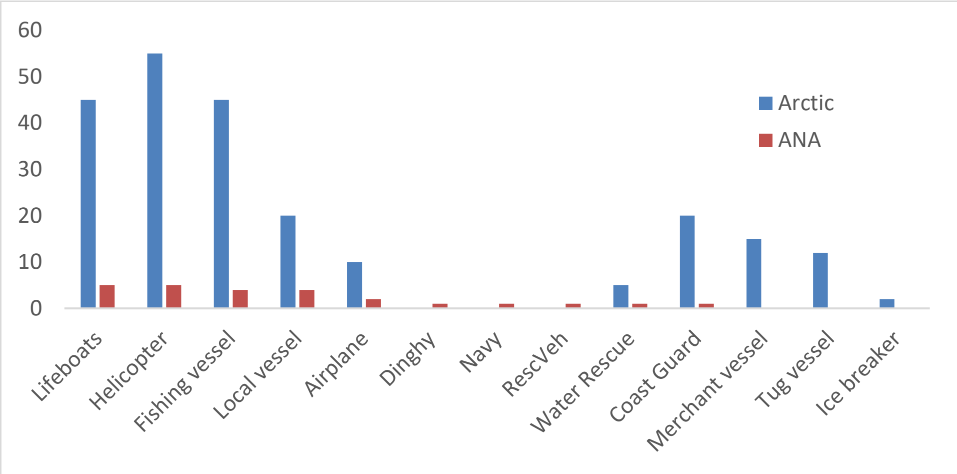

Figure 6: Asset in SAR Operations in the Arctic and ANA region

Regarding the efficient coordination of resources, it is also essential to distinguish the nature and severity of incidents. Large cruise ships sailing in the Arctic, in which case the scale of the incident would be large and require extensive national and international efforts, are the authorities' and public's greatest concern. However, the vast majority of maritime emergencies in the Arctic are of a smaller scale and require local resources for an effective response. The majority of local incidents are managed by local first responders and volunteer resources.

Several Arctic nations utilise private helicopter companies as additional SAR assets. The majority of offshore extractive industry companies have emergency plans and assets, and salvage companies are sometimes employed for SAR operations. However, in Iceland, Norway, and the Baltic Sea, where industrial activity is high, RCCs are more likely to request assistance from vessels of opportunity near incident sites (Ikonen, 2017). In order for RCCs to maintain a high level of situational awareness and coordination in regard to available resources, the transparent and comprehensive sharing of information on resources and vessels sailing in the Arctic, as well as fluent communication with various authorities and foreign units, would be essential.

3.3.3 Search and Rescue Training in the Arctic

The overall search and rescue chain frequently consists of personnel of varying ranks and institutions that vary from country to country. When discussing competence building, a wide range of actors, including distress vessel crews, on-scene coordination and rescue personnel, and shore coordination with operational, tactical, and strategical management, should be considered. SAR personnel in Arctic nations have access to their respective educational and training institutions' professional education and training programmes. However, there is no comprehensive education programme that focuses on search and rescue in the Arctic. Each nation and organisation design its own SAR courses and training programmes. The SARiNOR project, which addressed SAR training and educational needs in the High North, notes that international and national standards provide a foundation for the development of SAR-related competencies, especially in the education of vessel crew and officers. From the perspective of Arctic SAR, the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) is crucial. The International Code for Ships Operating in Polar Waters (Polar Code) is introducing new standards for icy waters at this time. The following SAR theoretical and training courses were mentioned as current options for other Arctic nations:

- Cold weather sea survival training
- Inland survival training
- Ice rescue training
- Maritime Search Planning course
- Search Mission Coordinator course
- On-Scene Coordinator course
- Aircraft Coordinator course
- Arctic policy course

All Arctic nations were interested in developing Arctic-specific courses and training programmes jointly. In the context of the Arctic, the following courses were mentioned to be arranged together:

- Ship and ice operations
- Ice navigation
- On-Scene Coordinator course
- Aircraft Coordinator course
- Search and Rescue Mission Coordinator course
- Introduction to other countries' SAR equipment and resources
- Testing of different survival gear
- Ice rescue courses

Some of the countries expressed a desire to participate I in Arctic maritime SAR courses offered by other Arctic nations in order to determine whether to adopt similar Arctic-specific training. During the expert workshop at the Arctic Coast Guard Forum in Boston, the issues of cost and removing SAR personnel from their regular duties were also brought up when discussing course arrangements and participation. One expert suggested that a one-week annual course combining multiple topics could be organised with other Arctic nations. Some exercises were described in Table 11:

Table 11: Example of ANA SAR Joint exercises (Ikonen, 2017)

Name	Participant countries
The ARCTIC GUARDIAN Table-Top Exercise (TTX)	USA, Canada, Iceland, Kingdom of Denmark, Norway, Sweden, Finland, and Russian Federation.
Live exercise and TTX Exercise Barents, annual	Norway and Russian Federation
Live exercise SARex Spitzbergen 2016	Norway and academics from Canada

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Name	Participant countries
Live exercise and TTX Bold Mercy, every second year	Iceland, Kingdom of Denmark and the UK
Tabletop exercise Joint Arctic SAR TTX, Association of Arctic Expedition Cruise Operators (AECO), annual	Arctic countries and AECO members
Live exercise SAREX, annual	Kingdom of Denmark, USA, Canada, Iceland, Norway and observers from Russian Federation
Tabletop exercise CPX 2014	Kingdom of Denmark and Iceland
Live exercise ARCTIC RESPONSE 2015	Kingdom of Denmark and Iceland
Live exercise LIVEX 2016	Kingdom of Denmark and Iceland
Live exercise Chinook 2016	USA, Canada and observers from Finland, Norway and Russian Federation
Tabletop exercise Arctic Zephyr TTX	All Arctic countries
Tabletop exercise ACGF TTX	All Arctic countries
Live exercise Crystal Serenity 2016	Canada and USA
Tabletop exercise Northwest Passage 2016	Canada and USA
Live exercise Barents Rescue 2015	Finland, Norway, Russian Federation and Sweden
Annual SAR exercises	Russian Federation, Finland, Sweden, Estonia

However, in this international Arctic SAR exercises, the utilisation of foreign units are also recognised as challenging factors, as the distances make sending assets to an exercise costly and time-consuming, and require detaching an asset from what may already be a limited national response capacity. Depending on the region of the Arctic where the exercise is conducted, only a few nations can participate at once.

For individual competences, the key personnel of vessels operating in Polar waters where ice is present must demonstrate proficiency in a variety of tasks, such as contributing to the safe operation and manoeuvring of vessels operating in Polar waters, monitoring and ensuring compliance with legislative requirements, applying safe working practises and responding to emergencies, ensuring compliance with pollution prevention requirements, planning and conducting a voyage in Polar waters, and managing the safe operation and manoeuvring of the vessel. Each nation's maritime training institutions are responsible for providing training that adheres to STCW and the Polar Code.

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Chapter 12 of the Polar Code specifies training requirements for ships operating in Polar waters to ensure that the masters, chief mates, and officers in charge of navigational watch have the necessary experience and have been appropriately educated and trained in accordance with the STCW Convention. However, additional modules in the Polar context regarding the entire SAR chain from contingency planning to evacuation, and survival and the rescue phase should be added to the current course requirements. For IMO courses, they suggest the following additional Polar code training modules:

"1. All safety crew on board distress vessels

All members of the safety crew need to have the IMO Safety Course at operational level. Also it needs to be discussed, that all other crew members should also have at least a basic-safety education. For passenger ships an additional Crowd and Crises Management course is required. For both these courses, there is a need for additional modules:

- Polar code operational level safety course module on escape/evacuation, use of collective rescue equipment, lifeboat/raft management and rescue processes in icy waters
- Polar code crowd and crisis additional module on taking care of a broad range of passengers (young, old, weak and sick passengers) within life rafts/life boats in icy water

2. Officers on board vessels in distress

According to the STCW-convention and the Polar Code the deck officers on board need the following training:

- IMO Safety course at management level
- IMO Polar code navigator course
- IMO Polar code master course

This training should not be exclusive for deck officers. The engine officers play a vital role in the operation of ships, not the least in polar waters. Therefore, there should be a basic and advanced course for chief engineers and 1st engineers on board vessels in polar waters. In addition, for passenger ships with many passengers on board, there are special considerations to be taken as to evacuation in polar regions. Therefore, an additional course in polar water mass rescue operations should be available for officers. We are therefore in need of the following additional courses:

- Basic and advanced Polar Code course for chief engineers and 1st engineers
    - o should include polar water risk assessment of technical systems and taking care of collective rescue equipment such as life boats, MOB boats in cold climate
- Polar code Mass rescue operation safety course
    - o should include alternative escape routes, large crowd management, improvisation management in different emergency situations
- IMO Safety course at management level additional modules:
    - o evacuation, survival at sea and rescue operations in polar waters

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o Polar region contingency planning for SAR operations in polar waters

3. Masters and navigators onboard rescue vessels

With limited professional capacity in polar waters, even smaller vessels may have to serve as on-scene-coordinators (OSC) on behalf of the SAR mission coordinator. The OSC-role is given only a superficial place in the traditional GMDSS-training. Additional polar water modules should therefore be included in the GMDSS-course. Limited basic training is also the case for the IMO medical course. There is a need for special training in medical issues related to cold climate conditions, especially as the crew and passengers may be stuck in icy waters for several days. Therefore, the following modules should be added to the IMO courses for deck officers:

• GMDSS course additional modules

o Polar Code additional module on OSC (On scene coordinator) / ACOair coordinator roles

• IMO Polar Code additional medical course

o Frost wounds, hypothermia, triage and emergency logistics" (Borch, 2016)

Greater interaction between ANA nations such as the United Kingdom and Ireland is required to enhance the quality of knowledge transfer and innovation in the Arctic region.

3.4 Questionnaires on Gaps and Issues

The third specific activity is the design and distribution of a set of **questionnaires** in order to gain detailed and current information about capability or procedural gaps and the need for research, innovation, knowledge or collaboration in order to fill the gaps. Six questionnaires were designed, each of which reflect a thematic topic given in Section 2.1. An open, qualitative design was used to avoid directing the respondents and to attempt to elicit as wide as possible a range of gaps and needs. The questionnaires were sent to the working group members (identified in Figure 7) prior to distribution for comment and refinement in order to ensure a correct practitioner focus.

The questionnaires were first distributed in paper format in the Rome workshop in February 2019. They were then subsequently distributed electronically to all ARCSAR consortium members in March 2019, who in turn distributed them amongst their practitioner contact networks. A total of 29 completed questionnaires were returned. These were then analyzed and triangulated against the other sources of information as described in Section 2. The complete responses to the questionnaires, categorized by the classification scheme of Section 4, are given in Sections 7.4.1-7.4.6. Each respondent's comments are represented in an individual question by a specific colour, although there is no colour correlation across questionnaires.

3.5 Working Groups

The fourth specific activity is the formation of six **working groups**. In the context of this deliverable they are utilised to inform the questionnaire design in Section 3.3, however they will also have an enduring role throughout the ARCSAR project. The six working groups are based on the classification

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derived from the Polar Code in Section 2.1. The members are largely, although not exclusively, drawn from the ARCSAR consortium partners and workshop attendees. The identification of experts for the different working groups took place by the University of Portsmouth in collaboration with the ARCSAR lead partner (JRCC NN). The membership of the working groups, along with organisational and country affiliations are given in Table 27 in annexes section 9.2.

4 Classifications

This Section presents the classification of the needs and gaps by evidence source(s) and by need for further innovation, knowledge, research and innovation. As described in Section 2, a three level classification is used. The first level is according to the thematic topics detailed in Section 2.1. The following coding is used:

V: Vessel structural and equipment issues

L: Lifesaving appliance and sea and cold survival issues

C: Communication Issues

P: Pollution and incident control issues

N: Navigational and voyage planning issues

T: Personnel, training and education issues

As some needs will be cross-thematic, a major theme is chosen for each need and the final column of Tables 12-17 denotes the secondary theme(s).

The second level of classification is given as a numerical index, to indicate a broad identified need within a theme, and is given in the first column of Tables 12-17. The third level, given as an alphabetical index, is a specific identified sub-need within a broad area of need, and is given in the second column of Tables 12-17.

Columns 3-5 in Figures 4-9 give the evidence sources for each sub-need. Columns 3 and 5 are binary tick indicators for whether the sub-need is found in a previous project report or scientific literature or raised by a questionnaire respondent respectively. Column 4 gives the numbers of the workshops (if any) at which the sub-need was identified.

Columns 6-9 in Tables 12-17 give the classification of need for future innovation, knowledge, research and collaboration respectively. A binary tick indicator is used to assess each sub-need for each of the four categories.

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Table 12: Vessel structural and equipment classification

Need	Sub-Category	Evidence Source			Classification of Gap or Need				Secondary Classification
		Lit./Proj	WS	Quest/WG	Innov.	Know	Res	Collab	
V1 – Enhancements in vessel design	V1A – Pro-active vessel design and construction to minimise likelihood and impact of emergency incidents	√	2	√	√	√			Pollution and incident control
V2 – Enhanced vessel equipment	V2A – Ensuring accessibility of lifeboats/rafts at all times	√	2		√	√			Lifesaving appliance and sea and cold survival
	V2B – Standardisation of requirements (including maintenance schedules) for life saving equipment		1			√		√	Lifesaving appliance and sea and cold survival
	V2C – Enhanced vessel based mass or individual marine rescue equipment			√	√		√		Lifesaving appliance and sea and cold survival
V3 – Collaboration between vessel and SAR stakeholders	V3A – Formation of a “buddy” rescue system for vessels		1			√		√	Navigation and voyage planning
	V3B – Learning and transference from other sectors (e.g offshore energy)	√	1			√		√	
	V3C – Clarification on points of regulation for vessels		1			√		√	
	V3D – Enhanced collaboration between vessel owners and SAR and industrial stakeholders		1					√	

Table 13: Life saving applicance and sea and cold surival classification

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Need	Sub-Category	Evidence Source			Classification of Gap or Need				Secondary Classification
		Lit/Proj	WS	Quest/WG	Innov.	Know	Res	Collab	
L1 – Understanding and mapping of Survival in ANA region	L1A – Research into mapping of actual realistic survival times by category (age, vulnerability, location, conditions)		1	√		√	√		
	L1B – More nuanced survival planning with respect to type of vessel and incident		1			√	√	√	
	L1C – Research into human behaviour and decision making when cold	√	3	√		√	√		
	L1D – Research into gap between lab/mannequin tests and ANA realities	√	3			√	√		
L2 – Technologies to enhance Survival	L2A – Enhanced lifeboat / raft technology and design	√	1,2,3	√	√		√		
	L2B – Technologies to combat heat loss		3		√		√		
	L2C - Technologies to provide water and combat dehydration		3		√		√		
	L2D – Enhanced flotation suits suitable for ANA conditions			√	√		√		
L3 – Collaboration between and regulations for ANA lifesaving stakeholders	L3A – Enhanced liaison between industrial developers and SAR practitioners		1	√		√		√	
	L3B – Increased numbers of sharing of helicopters to provide adequate coverage	√		√		√		√	

	L3C – Collaboration on how to meet "5 day" requirement of polar code		3	√		√		√	
	L3D – Common training of all crews/workers in ANA in lifesaving/survival issues	√	3	√				√	

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Table 14: Communication issues classification

Need	Sub-Category	Evidence Source			Classification of Gap or Need				Secondary Classification
		Lit/Proj	Workshp	Quest/WG	Innov	Know	Res	Collab	
C1 –Enhanced Satellite Coverage and Capability in ANA region	C1A - Ensuring sufficient satellite coverage of ANA region	√	3	√	√			√	
	C1B – Communication Technology to ensure satellite data is accessible within required timescale	√	3	√	√	√	√		
	C1C – AI and data analytics for processing of satellite data	√	3		√	√	√		
	C1D – Collaboration between satellite stakeholders to ensure maximal coverage and emergency preparedness and protection against cyber-threats		2,3	√	√			√	
	C1E – Systems and Training to allow effective satellite data usage by SAR and indigenous communities		1,3	√		√		√	Personnel, education and training
C2 – Enhanced Quality and Coverage of Broadband in ANA region	C2A – Broadband coverage of the ANA region	√	1,3	√	√			√	
	C2B – Technology to allow Improved broadband speed In the ANA region	√	1	√	√		√		

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C3 – Improvements in local / on-vessel communications technology	C3A – Need for enhanced batteries with longer life for usage in ANA region		1		√		√		
	C3B – Technology to allow enhanced communications through water in ANA conditions		1		√		√		
	C3C – Multi-national isotope detection system and response protocols		2		√		√	√	Pollution and Incident Control
	C3D – Enhanced radio communications coverage			√	√		√	√	

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Table 15: Pollution and incident control classification

Need	Sub-Category	Evidence Source			Classification of Gap or Need				Secondary Classification
		Lit/Proj	Workshp	Quest/WG	Innov	Know	Res	Collab	
P1 – Technology for dealing with oil spills and pollution	P1A – Autonomous technology capable of operation in dangerous and harsh conditions.		1		√				
	P1B –Technology for detecting oil under ice		1	√	√				
	P1C – Development of user-friendly “Arctic tool box” for oil spill management	√	1	√	√				
	P1D – Satellite data analysis tools for oil spill management		1	√	√		√		Communication
	P1E – Need for enhanced pollution monitoring sensors	√	1		√		√		
	P1F – Enhanced technology for oil recovery under ANA conditions	√	2		√		√		
P2 – Enhanced and Standardised International Arctic Pollution Regulations	P2A – Standardised regulations for prevention of oil spill	√	1	√				√	
	P2B – Enhanced international agreements treatments and commitments relating to nuclear facilities and vessels in the ANA region		2					√	
	P2C – Demilitarisation strategies in the Arctic region	√	2	√				√	
	P2D – Regulations on heavy oils in the Arctic region		2	√				√	

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	P2E – Further development of international decontamination strategies and technologies	√	2	√	√			√	
	P2F – Ensuring all vessels covered by Polar Code or similar regulations	√		√					Navigation and voyage planning
P3 – Research to understand Arctic pollution and how to respond to it	P3A - Skills assessment of new competences needed to deal with Arctic pollution incidents	√	1	√		√	√		Training
	P3B – Classification of Arctic pollutants and their consequences	√	1	√		√	√		
	P3C – Research into the effects of a nuclear incident in the Arctic		2			√	√		
P4 – Pollution Incident Data Sharing	P4A –Pollution risk and incident data sharing and analysis	√	2	√			√	√	
	P4B – Further definition of acceptable response times	√	2	√			√	√	
	P4C – Need for prevention measures and protocol for dealing with fire on a nuclear vessel		2			√	√	√	

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Table 16: Navigation and voyage planning classification

Need	Sub-Category	Evidence Source			Classification of Gap or Need				Secondary Classification
		Lit/Proj	Workshp	Quest/WG	Innov	Know	Res	Collab	
N1 – Enhanced ice mapping and navigation systems	N1A – Automated system to avoid and investigate alarms		1		√		√		
	N1B – AI and data analytic tools and apps for advanced ice and route condition forecasting	√	1,3	√	√	√	√		
	N1C – Technology to ensure systems are not weather affected		1		√		√		
	N1D – Emergency port identification system and associated logistics planning		1		√	√		√	Pollution and Incident Control
N2 – Enhanced collaboration between ANA stakeholders in Navigation field	N2A – Creation of Navigational ship areas of corridors	√	1	√		√		√	
	N2B – Creation of (electronic) platform for sharing past and current ship and route information	√	1,2		√	√		√	N1
	N2C – Resilience plans for navigation in case of Arctic incident		2		√	√		√	Pollution and Incident Control
	N2D – maps that incorporate indigenous community names	√	3			√		√	

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	N2E – Dissemination of available technology to all ANA stakeholders			√		√		√	Personnel, training and education
	N2F – Liaison between product developers and ANA end-users to ensure correctly developed and used technologies			√		√		√	Personnel, training and education
N3 – Enhanced navigation technology	N3A – Assistive drone technology	√	1		√		√		
	N3B – enhanced ANA vessel traffic management systems	√		√	√		√		

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Table 17: Personnel, training and education classification

Need	Sub-Category	Evidence Source			Classification of Gap or Need				Secondary Classification
		Lit/Proj	Workshp	Quest/WG	Innov	Know	Res	Collab	
T1 – Development and Delivery of Training Material	T1A – Advanced, age appropriate training for crews of vessels (including small vessels)	√	1,2	√		√			
	T1B – Development of advanced, ANA training materials for SAR teams	√	1	√	√	√			
	T1C – Training and technology to fill the language gap		1		√	√			T2
	T1D – Specific training to deal with nuclear incidents		2			√		√	Pollution and Incident Control
	T1E – Enhanced development of Arctic simulators			√	√	√	√		
	T1F – Further live exercises to train for different types of incidents	√		√		√		√	Pollution and Incident Control
T2 – Technology to enhance training and awareness	T2A –Age appropriate multi-media technology for emergency situations		1		√	√			
	T2B – Collection of information from crew and passengers involved in ship abandonments		1			√			
T3 – Regulations to enhance safety	T3A – Formal certified courses for Arctic crew vessels		1					√	
	T3B – Regulations to ensure compulsory medical care		1					√	

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	insurance for all ANA passengers								
	T3C – Standardised protocol for incident investigation and implementation of lessons learned		2	√		√		√	Pollution and Incident Control
T4 – Enhanced ANA stakeholder communication	T4A – Enhanced involvement of indigenous partners in SAR activities	√	3	√		√		√	
	T4B – Enhanced sharing of results of ongoing SAR projects within ANA SAR community	√	3	√		√		√	
	T4C – Enhanced liaison with hospitals for emergency incident planning	√		√		√		√	Pollution and Incident Control

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5 Prioritization Results

The prioritisation methodology described in Section 2.3 is applied to the 75 sub-needs given in Section 4, utilising the importance and difficultly information collected from the working groups and practitioner networks as detailed in that Section. Figure 7 shows the categorisation of the sub-needs into the four PICK classes.

Figure 7 and Tables 18-21 show the results of the categorisation process for the sub-needs.

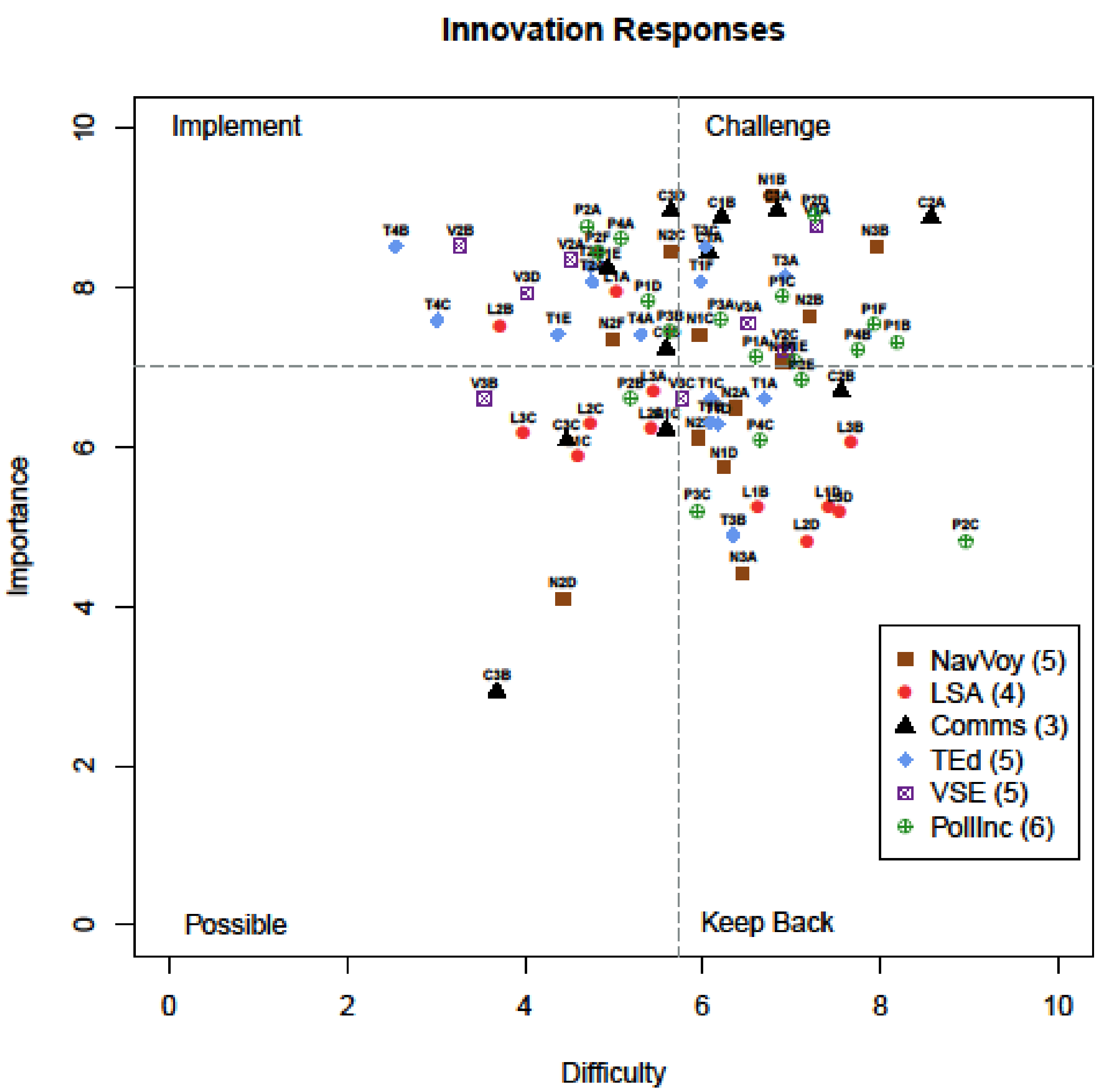

Figure 7: Categorisation of sub-needs

The numbers in parenthesis in Figure 7 after the topic abbreviated names represent the number of survey responses received. It should be noted that not all respondents provided values to all possible

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sub-needs for each topic, often due to not feeling they had sufficient knowledge or expertise. The process desired a minimum 3 responses to calculate a reasonable mean value and this was achieved by 74 of the 75 sub-needs. The only missing value was for the difficulty component of sub-need C3C (Multi-national isotope detection system and response protocols), which only received 2 responses. This sub-need was categorised as possible and was not selected using the prioritization process. Full details to the responses are given in Appendix 9.5. Tables 18-21 give the sub-needs in the four respective PICK categories, along with their geometrically aggregated levels of importance and difficulty.

Table 18: Sub-needs in the Implement (High Importance, Low Difficulty) category

Implement	High Importance – Low Difficulty		
Sub-Need	Brief Description	Importance	Difficulty
C3D	Enhanced radio communications coverage	**8.962809**	**5.646216**
P2A	Standardised regulations for prevention of oil spill	**8.768655**	**4.704316**
P4A	Pollution risk and incident data sharing and analysis	**8.617739**	**5.084606**
V2B	Standardisation of requirements (including maintenance schedules) for life saving equipment	**8.523982**	**3.277165**
T4B	Enhanced sharing of results of ongoing SAR projects within ANA SAR community	**8.516391**	**2.550849**
N2C	Resilience plans for navigation in case of Arctic incident	**8.454672**	**5.650469**
P2F	Ensuring all vessels covered by Polar Code or similar regulations	**8.434327**	**4.820285**
V2A	Ensuring accessibility of lifeboats/rafts at all times	**8.346243**	**4.521602**
T2B	Collection of information from crew and passengers involved in ship abandonments	**8.257836**	**4.742881**
C1E	Systems and Training to allow effective satellite data usage by SAR and indigenous communities	**8.242571**	**4.932424**
T2A	Age appropriate multi-media technology for emergency situations	**8.073444**	**4.762481**
L1A	Research into mapping of actual realistic survival times by category (age, vulnerability, location, conditions)	**7.952707**	**5.029734**
V3D	Enhanced collaboration between vessel owners and SAR and industrial stakeholders	**7.930037**	**4.020109**
P1D	Satellite data analysis tools for oil spill management	**7.829735**	**5.386847**
T4C	Enhanced liaison with hospitals for emergency incident planning	**7.59067**	**3.017088**
L2B	Technologies to combat heat loss	**7.521206**	**3.722419**
P3B	Classification of Arctic pollutants and their consequences	**7.444839**	**5.634626**
T1E	Enhanced development of Arctic simulators	**7.413949**	**4.373448**
T4A	Enhanced involvement of indigenous partners in SAR activities	**7.413949**	**5.304566**

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Implement	High Importance – Low Difficulty		
Sub-Need	Brief Description	Importance	Difficulty
N2F	Liaison between product developers and ANA end-users to ensure correctly developed and used technologies	**7.353665**	**4.982924**
C1D	Collaboration between satellite stakeholders to ensure maximal coverage and emergency preparedness and protection against cyber-threats	**7.230427**	**5.593445**

Table 19: Sub-needs in the Challenge (High Importance, High Difficulty) category

Challenge	High Importance – High Difficulty		
Sub-Need	Brief Description	Importance	Difficulty
N1B	AI and data analytic tools and apps for advanced ice and route condition forecasting	**9.146101**	**6.780873**
C3A	Need for enhanced batteries with longer life for usage in ANA region	**8.962809**	**6.839904**
P2D	Regulations on heavy oils in the Arctic region	**8.909127**	**7.259356**
C1B	Communication Technology to ensure satellite data is accessible within required timescale	**8.87904**	**6.214465**
C2A	Broadband coverage of the ANA region	**8.87904**	**8.572619**
V1A	Pro-active vessel design and construction to minimise likelihood and impact of emergency incidents	**8.768655**	**7.282257**
N3B	Enhanced ANA vessel traffic management systems	**8.516391**	**7.962143**
T3C	Standardised protocol for incident investigation and implementation of lessons learned	**8.516391**	**6.034176**
C1A	Ensuring sufficient satellite coverage of ANA region	**8.434327**	**6.073178**
T3A	Formal certified courses for Arctic crew vessels	**8.144672**	**6.931448**
T1F	Further live exercises to train for different types of incidents	**8.073444**	**5.985111**
P1C	Development of user-friendly “Arctic tool box” for oil spill management	**7.893664**	**6.895751**
N2B	Creation of (electronic) platform for sharing past and current ship and route information	**7.633558**	**7.206747**
P3A	Skills assessment of new competences needed to deal with Arctic pollution incidents	**7.59067**	**6.207382**
V3A	Formation of a “buddy” rescue system for vessels	**7.544601**	**6.513556**
P1F	Enhanced technology for oil recovery under ANA conditions	**7.543891**	**7.930037**
N1C	Technology to ensure systems are not weather affected	**7.413949**	**5.96629**
P1B	Technology for detecting oil under ice	**7.318103**	**8.19069**
P4B	Further definition of acceptable response times	**7.208434**	**7.745967**
V2C	Enhanced vessel based mass or individual marine rescue equipment	**7.200411**	**6.928203**
P1A	Autonomous technology capable of operation in dangerous and harsh conditions	**7.132978**	**6.603854**
P1E	Need for enhanced pollution monitoring sensors	**7.07521**	**7.038964**
N1A	Automated system to avoid and investigate alarms	**7.068052**	**6.903498**

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Table 20: Sub-needs in the Possible (Low Importance, Low Difficulty) category

Possible	Low Importance – Low Difficulty		
Sub-Need	Brief Description	Importance	Difficulty
L3A	Enhanced liaison between industrial developers and SAR practitioners	**6.700738**	**5.449632**
V3B	Learning and transference from other sectors (e.g offshore energy)	**6.608062**	**3.545174**
P2B	Enhanced international agreements treatments and commitments relating to nuclear facilities and vessels in the ANA region	**6.603854**	**5.192494**
L2C	Technologies to provide water and combat dehydration	**6.292693**	**4.738137**
L2A	Enhanced lifeboat / raft technology and design	**6.235739**	**5.421612**
C1C	Ensuring sufficient satellite coverage of ANA region	**6.214465**	**5.593445**
L3C	Collaboration on how to meet “5 day” requirement of polar code	**6.160141**	**3.984283**
C3C	Multi-national isotope detection system and response protocols	**6.073178**	**4.472136**
L1C	Research into human behaviour and decision making when cold	**5.885662**	**4.600653**
N2D	Maps that incorporate indigenous community names	**4.095345**	**4.426728**
C3B	Technology to allow enhanced communications through water in ANA conditions	**2.924018**	**3.684031**

Table 21: Sub-needs in the Keep Back (Low Importance, High Difficulty) category

Keep Back	Low Importance – High Difficulty		
Sub-Need	Brief Description	Importance	Difficulty
P2E	Further development of international decontamination strategies and technologies	**6.839904**	**7.113787**
C2B	Technology to allow Improved broadband speed In the ANA region	**6.69433**	**7.559526**
T1A	Advanced, age appropriate training for crews of vessels (including small vessels)	**6.608062**	**6.69391**
T1C	Training and technology to fill the language gap	**6.608062**	**6.093346**
V3C	Clarification on points of regulation for vessels	**6.603854**	**5.768998**
N2A	Creation of Navigational ship areas of corridors	**6.490684**	**6.371444**
T1B	Development of advanced, ANA training materials for SAR teams	**6.309573**	**6.093346**
T1D	Specific training to deal with nuclear incidents	**6.284131**	**6.172507**
N2E	Dissemination of available technology to all ANA stakeholders	**6.116909**	**5.957892**
P4C	Need for prevention measures and protocol for dealing with fire on a nuclear vessel	**6.073178**	**6.6494**

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Keep Back	Low Importance – High Difficulty		
Sub-Need	Brief Description	Importance	Difficulty
L3B	Increased numbers of sharing of helicopters to provide adequate coverage	**6.0548**	**7.667317**
N1D	Emergency port identification system and associated logistics planning	**5.743492**	**6.238589**
L1D	Research into gap between lab/mannequin tests and ANA realities	**5.243611**	**7.415586**
L1B	More nuanced survival planning with respect to type of vessel and incident	**5.233176**	**6.619502**
P3C	Research into the effects of a nuclear incident in the Arctic	**5.192494**	**5.943922**
L3D	Common training of all crews/workers in ANA in lifesaving/survival issues	**5.18004**	**7.544601**
T3B	Regulations to ensure compulsory medical care	**4.891382**	**6.344228**
L2D	Enhanced flotation suits suitable for ANA conditions	**4.820571**	**7.172119**
P2C	Demilitarisation strategies in the Arctic region	**4.820285**	**8.962809**
N3A	Assistive drone technology	**4.416333**	**6.454218**

The geometric mean of all the difficulty opinions, needed to determine the knapsack size is calculated to be 5.73, while the average value importance was 7.03. Given that the process for obtaining these values involved the same experts as who provided the sub-needs list it is unsurprising that the average importance is above the average of a 1-10 scale.

The data given in Tables 18-20 is then used to calculate the priority list. With a weighting scheme of (0.5,0.25.0.25) providing a balance between the goals of maximizing the importance level and the evenness between the selection from classification categories and ARCSAR topics. The sub-needs priority list selected can be seen in Table 22, in which the sub-needs are sorted in the same order presented in the tables of the classification in section 4.

Table 22: Sub-Needs in the Prioritized selection (using balance of goals)

Prioritization	Selection with balance of goals			
Sub-Need	Brief Description	Category	Importance	Difficulty
V2A	Ensuring accessibility of lifeboats/rafts at all times	**Implement**	**8.346**	**4.522**
V2B	Standardisation of requirements (including maintenance schedules) for life saving equipment	**Implement**	**8.524**	**3.277**
V3D	Enhanced collaboration between vessel owners and SAR and industrial stakeholders	**Implement**	**7.930**	**4.020**
L2B	Technologies to combat heat loss	**Implement**	**7.521**	**3.722**
L3C	Collaboration on how to meet "5 day" requirement of polar code	**Possible**	**6.160**	**3.984**
C1A	Ensuring sufficient satellite coverage of ANA region	**Challenge**	**8.434**	**6.073**

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Prioritization	Selection with balance of goals			
Sub-Need	Brief Description	Category	Importance	Difficulty
C1B	Communication Technology to ensure satellite data is accessible within required timescale	**Challenge**	**8.879**	**6.214**
C3A	Need for enhanced batteries with longer life for usage in ANA region	**Challenge**	**8.963**	**6.840**
P2A	Standardised regulations for prevention of oil spill	**Implement**	**8.769**	**4.704**
P2F	Ensuring all vessels covered by Polar Code or similar regulations	**Implement**	**8.434**	**4.820**
P3A	Skills assessment of new competences needed to deal with Arctic pollution incidents	**Challenge**	**7.591**	**6.207**
N1B	AI and data analytic tools and apps for advanced ice and route condition forecasting	**Challenge**	**9.146**	**6.781**
N1C	Technology to ensure systems are not weather affected	**Challenge**	**7.414**	**5.966**
N2B	Creation of (electronic) platform for sharing past and current ship and route information	**Challenge**	**7.634**	**7.207**
T3C	Standardised protocol for incident investigation and implementation of lessons learned	**Challenge**	**8.516**	**6.034**
T4B	Enhanced sharing of results of ongoing SAR projects within ANA SAR community	**Implement**	**8.516**	**2.551**
T4C	Enhanced liaison with hospitals for emergency incident planning	**Implement**	**7.591**	**3.017**
Knapsack Size = 15*5.732 = 85.987 Maximum Importance (no balance goals) = 154.561		**Total**	**85.941**	**138.37**

The model has selected 17 sub-needs, two more than the target level of 15 as some chosen subneeds have lower than average difficulty, thus allowing for the selection of more sub-needs in the priority list. Table 22 also shows there is good balance in the topics (all topics have 3 selected, except Category L: LSA which has only 2) and also strong balance in the categorization, with 8 each for the Challenge and Implement categories and a single selected Possible category sub-need. These minor imbalances are related as it is the selection of the second LSA Possible sub-need, while filling to near capacity the difficulty-related knapsack, needed for the topic goal. The LSA category has only two sub-needs in the Implement and Challenge categories, with five in each of the Possible and Keep Back categories (see Figure 7.)

In terms of the importance related goal this selection is within 10.5% of the maximum possible available given the knapsack size, without compromising on selecting evenly from topics and categories. These results show useful grouping within the 20 need categories, with V2, C1, P2, N1, and T4 all having two sub-needs chosen. This suggests the possibility to work on prioritized issues that are related simultaneously.

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The priority list given in Table 22 is a key finding of this deliverable as it gives a balanced set of sub-needs which then can form the focus of future tasks and deliverables of the ARCSAR project. Furthermore, as it contains equal proportions of implement and challenge category sub-needs, these can also be used to inform shorter-term (implement category) and longer term (challenge categories) national and trans-national ANA research agendas and priorities. A further exploration of each of the sub-needs on the priority list, together with the collaboration required within and beyond the ARCSAR project in order to achieve them is given in Section 6.

Table 23: Sub-Needs definitions

Sub-Need	Sub-Need Title	Category	Description of Sub-Need
V2A	Ensuring accessibility of lifeboats/rafts at all times	**Implement**	Although the cruise ship will often be the safest place to stay during a serious incident, it is sometimes necessary to evacuate the ship. Proper rescue equipment on board a cruise ship can be crucial in reducing the risk of loss of life. This may be a problem in some situations i.e. if the vessel grounds and starts listing, so that lifeboats are not possible to lower/be used for evacuation. There is a need to look at optimal strategies in this type of situation.
V2B	Standardisation of requirements (including maintenance schedules) for life saving equipment	**Implement**	There are some existing standards for life saving equipment abroad vessels, defined by the IMO Maritime Safety Committee. These would benefit from further analysis and of there functionality in Arctic waters and potentially the development of enhanced or modified standards. Optimisation modelling can suggest necessary and optimal maintenance schedules for life saving equipment on polar vessels.
V3D	Enhanced collaboration between vessel owners and SAR and industrial stakeholders	**Implement**	It can be challenging to establish a joint understanding of a situation during major actions, especially if the SAR agencies and the home offices/vessel owners have not been liaising before. The SAR agencies may also not be aware what kind of capacities the vessels have on board and what kind of help could they possibly offer during an incident. There is a need to increase cooperation between the vessel owners, home officer and SAR agencies including visits briefing, and smaller joint exercises, in order to better understand each other's operations and capacities better. Additionally, In the Arctic organisations such as AECO who is a consortium that represents cruise ships operators and owners as well as organise events for table top exercises of simulation (TTXs) help to enhance collaboration and communication among stakeholders. There is a need to sustain and further develop such exercises, and develop other means to enhance collaboration.

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L2B	Technologies to combat heat loss	**Implement**	A plethora of innovative personal protective clothing and equipment is available for use in cold environments. However, whether this clothing and equipment can combat heat loss, and meet the minimum 5-day requirement in ANA regions, in both young and older individuals is unknown. Today's requirements for standard rescue equipment are not sufficiently adapted to the conditions that may arise during voyages. In addition, most deaths in older individuals are caused by thrombotic events post cold exposure, possibly linked to skin cooling and dehydration, rather than cold *per se* and this should also to be considered within this need.
L3C	Collaboration on how to meet "5 day" requirement of polar code	**Possible**	The International Maritime Organization (IMO) based regulation, the International Code for Ships Operating in Polar Waters, also known as the Polar Code, was implemented in January 2017. The code enforces various requirements in respect of search and rescue equipment including 'those evacuating from a vessel in distress in polar waters should be able to survive a minimum of five days in the rescue equipment, be it in a lifeboat, a life raft or in equipment arranged on the ice'. In cooperation with several universities and institutions, the Norwegian Coast Guard conducted a search and rescue exercise in 2016 in Svalbard, in order to evaluate this requirement and the usability of the standard survival equipment. The exercise report (Solberg et al. 2016) concluded that, if the expected five-day rescue period utilizing the standard SOLAR approved equipment required by the Polar Code is to be fulfilled, the related technology must be developed in order for the equipment to be realistically functional. As the Polar Code is open to interpretation by each vessel operator performing their own assessments, the assessment on is suitable and required may differ across the industries. (Solberg et al. 2016; Ikonen, 2017) There is a need for collaboration between Arctic SAR stakeholders to collaborate and develop protocols to ensure this requirement is fulfilled in all circumstances and territories, and map what the barriers are for why it could not be fulfilled (Kruke and Auestad, 2021).
C1A	Ensuring sufficient satellite coverage of ANA region	**Challenge**	The Arctic satellite connections, broadband, radio coverage and other means of communication are limited due to remoteness and the lack of relevant infrastructure, however satellite coverage around the Arctic areas is increasing rapidly, as more satellites are sent to cover the whole Arctic during the next few

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			years. There is a need to map which satellite services are currently available to Arctic operations and what is still needed, especially from the viewpoint of a smaller operator that is still lacking needed coverage for High North operations.
C1B	Communication Technology to ensure satellite data is accessible within required timescale	**Challenge**	Due to the satellite passings and lack of 24/4 coverage of satellite in the Arctic, there are latencies in receiving satellite data for i.e. navigation, situational awareness, up-to-date ice charts, and ice drift and wind data. Some private operators may be able to provide real-time satellite data however the cost may be a barrier.
C3A	Need for enhanced batteries with longer life for usage in ANA region	**Challenge**	Due to the conditions in the Arctic, which may especially during winter time be very harsh, freezing temperatures affect battery life in various applications i.e. radio communications equipment, phones, drones and other equipment that may be necessary in an emergency situation or for navigation.
P2A	Standardised regulations for prevention of oil spill	**Implement**	More experience is needed to fully understand the limitations in current MER procedures and what plans exist for future standardised procedures in the High Arctic. The Arctic Council also already has the MOSPA agreement, with preventative measures. As part of MOSPA, Arctic States have agreed to (i) maintain a national system to promptly and effectively respond to oil pollution incidents, including a minimum level of available oil spill response equipment, training procedures, and communication capabilities; (ii) share information about national authorities to facilitate effective communication across borders in case of an emergency and (iii) assess oil pollution incidents in the Arctic and immediately inform all Parties to the agreement whose interests could be affected.
P2F	Ensuring all vessels covered by Polar Code or similar regulations	**Implement**	The IMO polar code has clear guidelines on the requirements for vessels operating in polar waters in order to ensure their safety. This need concerns regulatory and collaborative advances that are needed to close any loopholes allowing vessels not covered by the polar code to operate unsafely in polar waters.
P3A	Skills assessment of new competences needed to deal with Arctic pollution incidents	**Challenge**	New types of fuel for shipping are constantly being developed and this poses challenges to

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			the oil spill authorities, as they need to be aware of the behaviour and consistence of these new fuels. Some also behave very differently in cold conditions. There is a need to know what kind of skills, competence and knowledge the responders and operational coordinators need in order to respond to the challenges of oil spills in the ANA region. Additionally, R&D on the field is needed to keep up the pace with these changes to respond to MER (Marine Environmental Response) incidents efficiently. In addition, knowledge on the topic combined with contextual knowledge is necessary to conduct operations without exposing SRUs (SAR responding units) to unnecessary hazards and guarantee the continuity of the SAR system.
N1B	AI and data analytic tools and apps for advanced ice and route condition forecasting	**Challenge**	A principal challenge for vessels in the Arctic is the existence of, and hence navigation through, different forms of ice. Advances in artificial intelligence and data analytics have allowed for the better prediction of meteorological conditions, and of ice flows and formations. However, this information needs to be brought to a sufficient technology readiness level and availability whereby it can be effectively used to inform vessel future Arctic routes with greater accuracy and hence safety as well as to swiftly direct SAR responding units towards operation areas and avoiding unwanted situations while operations are ongoing.
N1C	Technology to ensure systems are not weather affected	**Challenge**	Due to the cold conditions, especially in the Arctic region, icing often occurs on board vessels and communications infrastructure on land. This may affect the navigational systems. There is a need to ensure that i.e. ice accumulation prevention on antennas are in place.

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N2B	Creation of (electronic) platform for sharing past and current ship and route information	**Challenge**	With the current and projected increase of vessel traffic in the polar region due to climatic change, there is a need for an enhanced system of recording and sharing ship and route movements through and between Arctic territories. Advances in artificial intelligence also allow for the measurement of risk and the detection of anomalies indicating potentially dangerous and/or unsafe vessel behaviours to be built into a future electronic platform.
T3C	Standardised protocol for incident investigation and implementation of lessons learned	**Challenge**	Most ANA emergency preparedness and response organizations have their own systems and procedures for logging after action reports from incidents and exercises and identifying follow-up actions however as of yet, there are no ANA-wide standards available for emergency response agencies on exercise/incident reports, as well as SOPs for implementing lessons learned from major cases in the region. There is a demand for a systemised effort for pulling out key lessons learned from a common system. A significant problem in terms of lessons learned as outcome of an incident investigation is that at an individual level, the motive of learning is sometime not clear, especially when the main aim of being involved in such investigation is to avoid blame. There are also external influences such as budgetary and time constraints that may hinder implementations of lessons learned.
T4B	Enhanced sharing of results of ongoing SAR projects within ANA SAR community	**Implement**	There are a variety of SAR related projects in the ANA region and each producing reports or results. There is a need to establish a systematic approach as to how will the results from SAR projects reach the wider ANA SAR community, and how will the SAR organizations actually learn from the results. This involves existing fora and should use terminology common to the SAR community. This will offer opportunities to share best practices, develop advanced technologies for SAR and situation awareness, and enhance existing skills capabilities through organisation of TTX and LivEX simulation exercises.
T4C	Enhanced liaison with hospitals for emergency incident planning	**Implement**	In case of an Arctic mass-casualty incident, there needs to be a pre-planned clear line of communication and logistics planning between healthcare providers, the local communities and the SAR responders. This plan should consider the need to remoteness and limited capacity of healthcare facilities in some Arctic territories, and hence the potential need to utilise facilities across multiple territories.

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6 Collaboration on Priority Tasks

With the knowledge of the selected sub-needs we can now use the collaboration methodology from section 2.4 to assign ARCSAR partners to the prioritized tasks. The following table shows the results of allocation collaboration group types to the chosen sub-needs (details on these sub-needs can be found in Table 23).

Table 24: Collaborative group types of sub-needs

	General Objective of Collaboration Project				
Sub-Need Code	Scientific knowledge (SK)	Develop Methods (DM)	Develop Practitioners (DP)	Implement Service (IS)	Evaluate Policy (EP)
V2A	L	H	L	M	L
V2B	L	H	M	M	H
V3D	L	M	H	H	M
L2B	H	H	L	L	L
L3C	L	M	M	L	H
C1A	H	H	L	M	M
C1B	H	H	L	M	L
C3A	H	M	L	L	L
P2A	L	M	M	M	H
P2F	L	M	L	M	H
P3A	L	M	H	M	M
N1B	H	H	L	L	L
N1C	H	H	L	L	L
N2B	M	H	L	H	L
T3C	L	M	H	M	H
T4B	L	M	H	M	H
T4C	L	M	H	M	M

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From these assignments the relevant collaboration group specifics (actors, actor proximity, outputs) was taken from the proposed methodology and ARCSAR partners were assigned to satisfy these requirements. The allocation by ARCSAR partner for priority sub-need collaboration can be seen in Table 25. The lead partner for the majority of sub-needs come from the category of academia, and this is due to these members of the ARCSAR network being more strongly suited to this task, in line with the ethos of the ARCSAR project of academic partners liaising with a range of practitioner and industrial partners in to promote collaboration.

Table 25: ARCSAR partner sub-need collaboration assigments

Network Category	ARCSAR Partner	Collab. Lead	Collab. Partner
Academia (Actor types - UAS, AI, IRI, HM, HF, LWP)	Memorial University Newfoundland – Canada (MU)	V2B	L2B, C3A, N1C
	Admiral Makarov State University of Maritime and Inland Shipping – Russia (AMU)	P2F, N1C	C1A
	Cork Institute of Technology – Ireland (CIT)	C3A, T4B	N2B
	Lapland University of Applied Sciences (LUAS)	T4C	C3A, T4B
	University of Portsmouth – UK (UoP)	L2B, N1B	L3C, C3A, T3C
	Nord University – Norway (Nord)	V2A, P3A	T3C
	Laurea University of Applied Sciences (Laurea)	N2B	C1A, C1B, N1B, T3C
Industry (Actor types - IRI, HF)	Polar Quest – Sweden (PQ)		V3D
	e-GEOS – Italy (e-GEOS)	C1A	C1B
Practitioners (Actor types – AI, IRI, HF, HM, NGO, LWP)	The Norwegian Meteorological Institute (NMI)	C1B	N1B
	Norwegian Coastal Administration (NCA)	P2A	P3A
	Marine Rescue and Coordination Center Bremen (MRCC-B)		L2B, N1C
	Norwegian Coast Guard (NCG)		P3A
	Rescue Coordination Center New Zealand (MNZ)		V2B, P2F

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	United States Coast Guard Academy – USA (USCG)	L3C	V2B, N2B, T3C
	Maritime and Coastal Agency – UK (MCA)		P2A, T4B
	Marine Rescue and Coordination Center Torshavn (MRCC-T)		P2A, T4B
	Joint Rescue and Coordination Center – Iceland (JRCC-I)		V2A, V3D, P3A, T4C
	Joint Rescue and Coordination Centre – North Norway (JRCC-NN)	T3C	V3D, T4C
Organizations (Actor types – NGO, LWP)	Arctic Expeditionary Cruise Operators (AECO)	V3D	P2F
	Maritime Forum North (MFN)		V2A, V2B, L3C

Key for Actor Types:
UAS: Universities with an applied focus and a wide range of competencies
AI: A research institute within a University with a specific competency related to ANA safety and security
IRI: An independent research institute with a specific competency related to ANA safety and security
HF: Organisations directly involved in frontline SAR or other ANA safety and security activities
HM: Organisations involved in managerial and/or support roles for SAR or other ANA safety and security activities
NGO: Industrial and non-governmental organisations providing products and services in and for the ANA region
LWP: Organisations concerned with the welfare of, and development of policies for, the ANA region.

The combined table of collaboration group characteristics and the assigned partners can be seen in Table 26. The partner organisation short name codes used in Table 26 can be found in Table 25. The work undertaken here has established a subset of the most significant identified Arctic security and safety concerns and set up collaboration groups, among the ARCSAR network partners, to begin investigating them. The work to be done by these collaboration groups will become an integral part of tasks throughout the remainder of the ARCSAR project, especially tasks T2.6 and T2.7 which involve monitoring and reporting on the uptake of innovations and knowledge. Future ARCSAR meetings and workshops will track the progress of, and find the barriers to, this innovation and these collaboration groups will lead this process.

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Table 26: Collaboration characteristics and partner assignments

Sub-Need	Collaboration Objective Group Type	Actors Involved (Researcher/ Practitioners)	Actors' Interaction Role/Proximity	Primary Output	Secondary Output	Audience for Output	Selected Lead	Selected Partners
V2A	**DM**	UAS,IA,HF,HM	Complementary /Distant	Increase Prestige & Gain Knowledge	Uptake Science Community	Science/ Professional Community	Nord	MFN, JRCC-I
V2B	**DM/EP**	UAS,IA,HF,HM, IRI,LWP	Complementary /Distant & Interconvertible /Close	Increase Prestige & Gain Knowledge, New Networks	Uptake Science Community & Professional Community	Science/ Professional Community, User/ Community groups	MU	USCG, MFN, MNZ
V3D	**DP/IS**	AI,HM,NGO, IRI,LWP	Complementary /Distant & Interconvertible /Close	Gain Knowledge & New Procedures/Service, Change in Practice/Service	Uptake Science Community & Professional Community	Professional Community, Administration, User/ Community groups	AECO	JRCC-NN, JRCC-I, PQ
L2B	**SK/DM**	UAS,IA,HF,HM	Complementary /Distant	Publication, Increase Prestige & Gain Knowledge	Uptake Science Community	Science/ Professional Community	UoP	MU, MRCC-B
L3C	**EP**	IRI,LWP	Interconvertible /Close	New Networks	Uptake Professional Community	User/ Community Groups	USCG	UoP, MFN

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C1A	**SK/DM**	UAS,IA,HF,HM	Complementary /Distant	Publication, Increase Prestige & Gain Knowledge	Uptake Science Community	Science/ Professional Community	E-Geos	Laurea, AMU
C1B	**SK/DM**	UAS,IA,HF,HM	Complementary /Distant	Publication, Increase Prestige & Gain Knowledge	Uptake Science Community	Science/ Professional Community	NMI	E-Geos, Laurea
C3A	**SK**	UAS,HF	Complementary /Distant	Publication, Increase Prestige	Uptake Science Community	Science Community	CIT	UoP, MU, LUAS
P2A	**EP**	IRI,LWP	Interconvertible /Close	New Networks	Uptake Professional Community	User/ Community Groups	NCA	MCA, MRCC-T
P2F	**EP**	IRI,LWP	Interconvertible /close	New Networks	Uptake Professional Community	User/ Community Groups	AMU	AECO, MNZ
P3A	**DP**	AI,HM,NGO	Complementary /Distant & Interconvertible /Close	Gain Knowledge & New Procedures/ Service	Uptake Science Community & Professional Community	Professional Community, Administration	Nord	NCG, JRCC-I, NCA
N1B	**SK/DM**	UAS,IA,HF,HM	Complementary /Distant	Publication, Increase Prestige & Gain Knowledge	Uptake Science Community	Science/ Professional Community	UoP	Laurea, NMI

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N1C	**SK/DM**	UAS,IA,HF,HM	Complementary /Distant	Publication, Increase Prestige & Gain Knowledge	Uptake Science Community	Science/ Professional Community	AMU	MU, MRCC-B
N2B	**DM/IS**	UAS,IA,HF,HM, IRI,NGO,LWP	Complementary /Distant & Interconvertible /Close	Increase Prestige & Gain Knowledge, Change in Practice/ Service	Uptake Science Community & Professional Community	Science/ Professional Community, Administration, User/ Community Groups	Laurea	USCG, CIT
T3C	**DP/EP**	AI,HM,NGO, IRI,LWP	Complementary /Distant & Interconvertible /Close	Gain Knowledge & New Procedures/ Service, New Networks	Uptake Science Community & Professional Community	Professional Community, Administration, User/ Community Groups	JRCC-NN	Laurea, Nord, UoP, USCG
T4B	**DP/EP**	AI,HM,NGO, IRS,LWP	Complementary /Distant & Interconvertible /Close	Gain Knowledge & New Procedures/ Service, New Networks	Uptake Science Community & Professional Community	Professional Community, Administration, User/ Community Groups	CIT	LUAS, MRCC-T, MCA
T4C	**DP**	AI,HM,NGO	Complementary /Distant & Interconvertible /Close	Gain Knowledge & New Procedures/ Service	Uptake Science Community & Professional Community	Professional Community, Administration	LUAS	JRCC-I, JRCC-NN

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7 Conclusions

A total of twenty broad ANA SAR safety and security needs and gaps across the six thematic areas have been identified during the classification exercise presented in Section 4. These give rise to seventy-five individual specific sub-needs or gaps. There is a good degree of triangulation between sources, with most (60%) of the sub-needs associated with more than one information source. Due to the inter-disciplinary nature of the ANA SAR subject, the majority (81%) of the sub-needs present in multiple innovation, research, knowledge and collaboration categories. A minority of the sub-needs (17%) present a secondary thematic classification.

With respect to the listed needs and sub-needs, there is a large range of identified items, indicating the diverse and complex nature of supporting SAR activities in the ANA region. There are, however, certain commonalities identified across the six thematic areas. In the main, each area presented a range of technological requirements, required regulatory improvements and enhanced communication between ANA stakeholders, along with other needs specific to that thematic area. There was also a balance between strategic and operational concerns and between day-to-day requirements and large-scale disruptive disaster planning (difficulties of a large cruise ship, oil spillage and radiological incident were three scenarios explored via root cause analysis). Further research was shown to be required in many themes, particularly on sea and cold survival in life boats and rafts and usage of satellite data. Concern for supporting and involving the full range of ANA stakeholders, including indigenous communities, and the enhancement of ANA SAR activities in the context of respecting the delicate eco-sphere of the ANA region also came through clearly from the evidence sources.

The classifications given in Section 4 should be viewed in the context of the practitioners that provided the majority of the sources of information. Care was taken to include a range of stakeholders, however a slight bias towards the SAR community may remain due to the nature of the ARCSAR consortium.

The classifications given in Section 4 are current as of the data collection dates (September 2018 – April 2019). However, it is intended that this classification forms the basis of a dynamic database of gaps and needs that will be updated at regular intervals throughout the ARCSAR project. Also, whilst it is hoped that the results are also widely used to assist Arctic research and innovation projects beyond ARCSAR, the classification pertains to the focus topic of ANA SAR safety and security, and hence should not be taken as a comprehensive list of all ANA scientific needs, which would be significantly more extensive.

The prioritisation exercise of Section 5 has yielded a categorisation of the identified sub-needs by level of challenge and difficulty. Furthermore, a goal programming methodology has been utilised to propose a priority list of 17 sub-needs, given by Table 22. The priority list maintains a high level of importance whilst ensuring a balance between more and less challenging sub-needs and between the six Polar Code derived categories. This list is a key finding that will be of use in guiding the remainder of the ARCSAR project and has potential to inform future research agendas.

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The collaboration methodology detailed in Section 6 has yielded a subset of ARCSAR partners for each priority sub-need, including a lead. These groups are shown by partner in Table 25 and by sub-need in Table 26. This is to ensure collaboration, direction and progress in the remainder of the ARCSAR project and is particularly important to tasks T2.6 and T2.7, which concern the monitoring and reporting on the uptake of innovations and technologies to meet the identified sub-needs. However, the derived collaborations are also of wider interest as they define the mix of types of organisations that need to collaborate in order to optimally resolve the sub-need, together with a suggested nature of collaborative working. This should provide valuable information to all national and trans-national Arctic stakeholders working to improve Arctic safety and security.

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9 ANNEXES

9.1 Details from literature review

9.1.1 Arctic council - 'Synthesis for Arctic Leaders'

Example - Extend community-based monitoring (CBM) of Social-Ecological systems. (T4A, T4B)

Recommended next steps: engage with CBM projects to identify and develop observations to provide knowledge on social-ecological interactions and social consequences of ecosystems change.

Local leaders: engage in workshops for developing and testing criteria for social-ecological observations.

National and regional leaders: provide support for workshops, including funding and technical support

Arctic Council: facilitate use of systems perspective in CBM by promoting collaboration between relevant working groups, encouraging Arctic states to identify relevant goals in the Arctic Resilience Action Framework (ARAF). Implications of knowledge integration for management and decision making. **Recommended next steps**: Initiate local projects and overarching research projects organized to incorporate knowledge from different knowledge systems and academic disciplines. Prioritize projects that actively engage with communities. Local: integrate knowledge through application of diverse, relevant knowledge to practical local goals such as natural resource management or adaptation planning. (T4A, T4B)

Regional and National: prioritize funding and technical support for problem based, interdisciplinary projects that use specific social-ecological challenges to focus knowledge integration, and that meaningfully engage with communities. Arctic Council: prioritize projects that require active collaboration between two or more Working Groups.

Example - Engagement with Change

Recommended next steps: support projects and activities that engage community members in problem solving activities using local knowledge, Indigenous Knowledge, and interdisciplinary science as tools for grappling with those problems. (T4A, T4B)

Local: identify and pursue opportunities to engage community members in constructive problem solving activities, particularly where support is needed in grappling with contentious issues.

Regional and National: prioritize scientific and other community-based projects that facilitate active engagement of community members preparing for and responding to current and future challenges.

Arctic Council: support sharing of good practices and experience of community engagement between Arctic nations; engage expertise across Working Groups. (T4A, T4B)

The Arctic Council survey on water and sanitation services was an endorsed project of the Arctic Council's Sustainable Development Work Group (SDWG), which surveyed professionals and government authorities and Arctic and subArctic residents to describe the current state of water and sanitation services. This work too place in 2016 with the results published in Bressler & Hennessy, 2018. This publication provided the selected "Next Steps" from Participants of the Water Innovations for Healthy Arctic Homes (WIHAH) Conference, September 2016 that relate to the Arctic Council WASH (Water, Sanitation & Hygiene) project:

Develop a database of water and sanitation infrastructure, source water or treatment systems at risk from environmental or climate change. (P4A)

Quantify the economic consequences of inadequate access to in-home water and wastewater services, including direct health care costs (morbidity and mortality, health care expenses) and indirect costs, such as lower educational attainment due to illness, decreased subsistence and employment activities. Such analyses should include methods that account for the unique cultural context of the Arctic, including individual and cultural values.

Conduct an assessment of how much water is needed per-person per-day to provide the best benefit for health in Arctic communities. In doing this, consider newer technologies not available in prior World Health Organization (WHO) water quantity standards. These could include low-flow faucets, separating or dry toilets, and water reuse methods that could conserve water and reduce cost for a similar gain in health. Also, consider the water related needs that can be centralised (e.g. laundry) versus those that must be available in the house (e.g. handwashing).

Through the Arctic Council Sustainable Development Working Group and its Arctic Human Health Expert Group (AHHEG), Arctic states should cooperate to share data about water and sanitation access in their Arctic communities, as well as progress towards the Sustainable Development Goal 6 (Ensure access to water and sanitation for all). (P4A)

Through AHHEG, and through non-Council bodies such as the International Circumpolar Surveillance network, Arctic states should cooperate to track water-related infectious diseases (both water-borne and waterwashed) in the Arctic region over time, and to study how changes in water and sanitation access affect these rates.

The Arctic Council should continue to create forums for Arctic communities to share innovations in water and sanitation technology, cost management methods, and climate change adaptation strategies.

Arctic states should cooperate with one another to assess the quantity of water needed for good health in the Arctic, and to consider adopting standards for providing adequate water quantity and engineering methods for achieving these standards."

9.1.2 Arctic council - Arctic Marine Shipping Assessment report

Protecting Arctic People and the Environment

Survey of Arctic Indigenous Marine Use: That the Arctic states should consider conducting surveys on Arctic marine use by indigenous communities where gaps are identified to collect information for establishing up to-date baseline data to assess the impacts from Arctic shipping activities. (T4)

Engagement with Arctic Communities: That the Arctic states decide to determine if effective communication mechanisms exist, to ensure engagement of their Arctic coastal communities. Where there are none, to develop their own mechanisms to engage and coordinate with the shipping industry, relevant economic activities and Arctic communities (in particular during the planning phase of a new marine activity) to increase benefits and help reduce the impacts from shipping. (N2)

Areas of Heightened Ecological and Cultural Significance: That the Arctic states should identify areas of heightened ecological and cultural significance in light of changing climate conditions and increasing multiple marine use and, where appropriate, should encourage implementation of measures to protect these areas from the impacts of Arctic marine shipping, in coordination with all stakeholders and consistent with international law.

Specially Designated Arctic Marine Areas: That the Arctic states should, taking into account the special characteristics of the Arctic marine environment, explore the need for internationally designated areas for the purpose of environmental protection in regions of the Arctic Ocean. This could be done through the use of appropriate tools, such as “Special Areas” or Particularly Sensitive Sea Areas (PSSA) designation through the IMO and consistent with the existing international legal framework in the Arctic.

Protection from Invasive Species: That the Arctic states should consider ratification of the IMO International Convention for the Control and Management of Ships Ballast Water and Sediments, as soon as practical. Arctic states should also assess the risk of introducing invasive species through ballast water and other means so that adequate prevention measures can be implemented in waters under their jurisdiction. (P3)

Oil Spill Prevention: That the Arctic states decide to enhance the mutual cooperation in the field of oil spill prevention and, in collaboration with industry, support research and technology transfer to prevent release of oil into Arctic waters, since prevention of oil spills is the highest priority in the Arctic for environmental protection. (P1, P2A)

Addressing Impacts on Marine Mammals: That the Arctic states decide to engage with relevant international organizations to further assess the effects on marine mammals due to ship noise, disturbance and strikes in Arctic waters; and consider, where needed, to work with the IMO in developing and implementing mitigation strategies. (P3A)

Reducing Air Emissions: That the Arctic states decide to support the development of improved practices and innovative technologies for ships in port and at sea to help reduce current and future emissions of greenhouse gases (GHGs), Nitrogen Oxides (NOx), Sulfur Oxides (SOx) and Particulate Matter (PM), taking into account the relevant IMO regulations. (P3A)

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Building the Arctic Marine Infrastructure

Addressing the Infrastructure Deficit: That the Arctic states should recognize that improvements in Arctic marine infrastructure are needed to enhance safety and environmental protection in support of sustainable development. Examples of infrastructure where critical improvements are needed include: ice navigation training; navigational charts; communications systems; port services, including reception facilities for ship generated waste; accurate and timely ice information (ice centers); places of refuge; and icebreakers to assist in response. (N1A, C1)

Arctic Marine Traffic System: That the Arctic states should support continued development of a comprehensive Arctic marine traffic awareness system to improve monitoring and tracking of marine activity, to enhance data sharing in near real-time, and to augment vessel management service in order to reduce the risk of incidents, facilitate response and provide awareness of potential user conflict. The Arctic states should encourage shipping companies to cooperate in the improvement and development of national monitoring systems. (N1B, N2B, N3B)

Circumpolar Environmental Response Capacity: That the Arctic states decide to continue to develop circumpolar environmental pollution response capabilities that are critical to protecting the unique Arctic ecosystem. This can be accomplished, for example, through circumpolar cooperation and agreement(s), as well as regional bilateral capacity agreements. (P2, P2A)

Investing in Hydrographic, Meteorological and Oceanographic Data: That the Arctic states should significantly improve, where appropriate, the level of and access to data and information in support of safe navigation and voyage planning in Arctic waters. This would entail increased efforts for: hydrographic surveys to bring Arctic navigation charts up to a level acceptable to support current and future safe navigation; and systems to support real time acquisition, analysis and transfer of meteorological, oceanographic, sea ice and iceberg information." (N1, N3)

Better documentation of areas of heightened cultural significance is also needed throughout the Arctic. Traditional use areas have been recorded in some areas, but in others they are missing or decades out of date. Assessing the ways in which use areas are changing due to climate change as well as technological advances is also necessary, to avoid limiting protection to areas that are not sufficient for current or future needs.

Archaeological and historical sites are known in many places, but often only superficially, and other regions simply have not been surveyed to determine what is there. Priorities should of course be in areas where vessel and other activity is already occurring or expected soon. The designation of more heritage sites will increase the visibility of this cultural legacy, but such action can only be expected for the best known or more important sites. Many other sites will require other forms of protection, not least the greater awareness of Arctic visitors that much of the coastline reflects a long history of human habitation.

Finally, compiling information is the starting point for a more thorough analysis of the cultural values located along Arctic coastlines and farther out to sea. The analysis of the significance of these areas and their relationship with environmentally and economically important areas is also essential to

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determine where conflicts are most likely to occur and to point the way to potential resolutions of such conflicts. The Arctic has much potential for resource development and for shipping, but there is also a wealth of cultural legacy and current practice equally deserving of attention, recognition, and protection." (T4A)

9.1.3 Arctic council – AMAP working group

The AMAP working group along with the United Nations Environment Programme and the Russian Association of the Indigenous Peoples of the North, Siberia and Far East (RAIPON) in 2004 published the final report (AMAP, 2004) on the Persistent Toxic Substances, Food Security and Indigenous Peoples of the Russian North project. This project outlined several relevant recommendations which are listed below:

"The existing system in Russia for statistical reporting of environmental releases do not cover most persistent toxic substances, and in particular, those covered by the Stockholm Convention on Persistent Organic Pollutants. In this respect, it is recommended that new forms of state statistical reports on industrial atmospheric emissions, waste water discharges and solid wastes, be developed and approved, which should be adequate for the requirements of the Stockholm Convention on Persistent Organic Pollutants and other international treaties and agreements aimed at the limitation of environmental and human health effects of persistent toxic substances. In this, it is recommended that experience gained in the development and use of registers for emissions of contaminants and transport be used. (P3A, P3B)

From experience gained during project implementation, existing data and information on PTS pollution sources available to federal and local environmental and human health authorities does not adequately reflect the actual situation in the Russian Arctic regions. Studies and surveys within the project framework have documented the environmental impact of unknown local PTS sources. In particular, there is evidence of relatively fresh environmental releases of contaminants such as DDT and PCB. Taking into account the objectives aimed at implementation of the Environmental Doctrine of the Russian Federation and the Fundamentals of the State Policy in Chemical Safety, it is recommended that a source inventory system be developed and implemented in the Arctic administrative territories inhabited by the indigenous peoples, that covers both former and current releases of PTS from all economic activities. (P3A, P3B)

PCBs can be considered as one of the most serious environmental and human health risk factors for the areas covered by the project, which cannot be adequately explained by long-range transport and existing information on local sources. According to the Russian PCB inventory, 53,000 out of 180,000 tonnes of PCB produced in the former USSR, were used for the production of paints, varnish, lubricants and other products, i.e., they have been used in open systems. Although this type of PCB use could not be taken into account by the inventory, it is likely that some of the PCB related problems mentioned above also resulted from contamination from such sources. Within the framework of the Russian National Action Plan on implementation of the Stockholm Convention, it is recommended that a special section on the rehabilitation of PCB-contaminated sites, including land and housing be developed and implemented. With respect to this issue, special attention should be paid to land and

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settlements inhabited by Arctic indigenous peoples, taking into account their lifestyle and social vulnerability. (P3A, P3B)

A significant proportion of total global PTS in the Arctic environment, is determined by their long-range transport. For example, the pesticide, Mirex has not been produced and used in either the USSR or Russia. However, levels of Mirex in the blood of the indigenous population residing in the Russian Arctic, particularly in coastal Chukotka, are found at clearly detectable levels, albeit lower than in some other parts of the Arctic, such as Arctic Canada. At the same time, the validity of long-range atmospheric transport and deposition estimates is limited by the scarcity of data on remote sources, and a lack of comprehensive source inventories. It is recommended that the Government of the Russian Federation, in cooperation with the other member countries of the Arctic Council, take active measures in the international arena to ensure the reduction, and in the future, the full elimination of environmental and human health threats from global PTS. In particular, it is recommended that the Russian Federation ratifies the Stockholm Convention on Persistent Organic Pollutants, and joins the Aarhus Persistent Organic Pollutants and Heavy Metals Protocols of the UN-ECE Convention on Long-range Transboundary Air Pollution.

Environmental aspects of human health, particularly those associated with PTS exposure of indigenous peoples, are closely linked to the economic and social status of indigenous families. In this respect, a significant reduction in the effects of PTS on human health cannot be successfully achieved without improvement in the economic and social conditions of the Russian Arctic indigenous peoples. It is recommended that, the National Plan of Economic and Social Development of the Northern Territories of the Russian Federation, which, it is envisaged, is to be developed or reconsidered following the Meetings of the State Council Board of the Russian Federation and of the President of the Russian Federation with the representatives of the northern territories of the Russian Federation in Salekhard, 28-29 April, 2004; should fully address improvements to the social and economic conditions of the Russian Arctic indigenous peoples. This action should be undertaken with the full involvement of the indigenous peoples.

In general, PTS levels in the natural environment and biota of the Russian Arctic are at moderate levels compared to other Arctic regions. This presents a means to significantly reduce PTS intake by indigenous peoples without intervening in their basic traditional lifestyle and cultural identity, through the implementation of protection and remedial actions, including improvement of sanitary conditions in the indigenous settlements and by implementation of household and dietary recommendations developed as a result of the findings of this report. As a follow-up to this project, it is recommended that the Russian federal executive human health and environmental authorities, in close collaboration with the Russian Association of Indigenous Peoples of the North, Siberia and Far East and regional and local administrations, develop a set of practical activities aimed at achieving, in full acknowledgement and respect of the traditional lifestyle and cultural identity of the Russian Arctic indigenous peoples, a significant reduction in their PTS intake. These measures, which should be an integral part of the National Plan of Social and Economic Development of the Russian Northern Territories, should include actions required at the federal, regional and local levels, taking into account the circumstances of each area. More specific regionally-based recommendations, addressed to the indigenous peoples should be presented in special publications in Russian.

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The levels of human exposure to PTS in the Russian Arctic, specifically to HCB and HCH, and, in some cases, also to DDT and PCB, is one of the highest reported for all of the Arctic regions. In some cases, exposure has been shown to exceed levels assessed for residents of territories, which are internationally recognised as disaster areas, such as the Aral Sea region, due to long-term use of persistent pesticides. In the areas of the Russian Arctic studied, practically every indigenous family consumes a significant amount of traditional food. Families with low incomes rely to a greater extent on the local, fat-rich traditional diet. As a consequence, low-income indigenous families are at greater risk of exposure to POPs. It is recommended that the human health authorities and administrations of the territories of the Russian Arctic inhabited by indigenous peoples, in close collaboration with the regional branches of RAIPON and in full acknowledgement of the importance of the traditional diet for nutrition and preservation of the national and cultural identity of the indigenous peoples, as part of their lifestyle, develop appropriate targeted measures to reduce PTS intake with traditional food, based on specific recommendations, the improvement of social and economic conditions and the raising of awareness about existing problems.

The highest PTS exposures and associated health risks are documented for the coastal areas of Chukotka, where the traditional diet of the indigenous population is largely based on marine mammals and fish. This corresponds to previous information obtained concerning the Greenlandic and coastal Canadian indigenous populations. It is recommended that, in the development of practical follow-up measures, special attention should be paid to the situation in the Chukchi AO, taking into account both, the social and economic status of the indigenous peoples in this region of Russia, and the health risks associated with PTS intake. On the basis of data obtained within the framework of the project, the coastal areas of the Chukchi AO are of main concern with respect to human health risks.

Indoor and occupational sources of PTS, including contamination of dwellings, are likely to be a significant contributor to blood contamination among indigenous peoples of the Russian Arctic. It was found that all of the houses of indigenous people studied during the targeted surveys, were contaminated by POPs, mostly by PCB and DDT. Levels of indoor PCB contamination correlate to levels of PCB measured in the blood of indigenous families living in these houses. It is recommended that remedial action to remove PTS contamination from the houses of indigenous families, should be an important and urgent action, aimed at e improving the social and economic status of indigenous communities.

It was found that the labelling of chemicals produced and retailed for household protection against insects and rodents, often does not correspond to their actual chemical composition, and that these chemicals sometimes contain toxic substances in high concentrations, particularly DDT and PCB. It is recommended that proposals for amendments to the Federal Law “On safe handling of pesticides and agrochemicals” be developed, to ensure implementation of strict and efficient control measures over the production and trade of pesticides and other chemicals for private use, particularly those used for protection against insects and rodents, which would ensure a complete ban on the use of PTS in these chemicals. (P3)

In a number of cases, home-made local food contains higher levels of PTS contamination than raw products obtained from the natural environment. It has been shown that additional contamination of food by PTS can take place when food is stored, processed, and/or cooked in a contaminated

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household environment. It is recommended that the local human health authorities, in close collaboration with regional branches of RAIPON, work out an efficient action plan to improve sanitary conditions in indigenous houses. These measures should be integrated with communication with indigenous families and efforts to raise awareness about the health risks associated with contamination of home-processed food.

POP concentrations measured in blood serum are highly dependent on age. This phenomenon may reflect past exposure to POPs. The number of breast fed children has also been found to be a significant determinant of POPs serum concentrations in women. Serum concentrations of lipophilic contaminants are reduced by an increase in parity. Statistically significant associations have been found between blood concentrations of total PCBs (Arochlor 1260), lead and a number of non-specific reproductive and developmental health effects such as the prevalence of low birth weight, premature births, stillbirths and major structural malformations. Serum concentrations of total PCBs in maternal blood also appear to be associated with impacts on newborn sex ratios. In contrast with both national and global statistics, female babies of indigenous mothers with elevated POP blood concentrations, have a higher risk of low birth weight and other adverse outcomes of pregnancy when compared to male babies. It is recommended that the Russian human health authorities implement internationally recognized levels of concern for PTS blood concentrations. It is further recommended that dietary safety advice based on the benefits of traditional food are made an important component of prenatal care and of family planning strategies for the indigenous communities at risk.

A close correlation between PTS levels in blood and breast milk has been documented for indigenous women of the Chukchi AO. It is recommended that the international and Russian national health and environmental protection authorities develop recommendations for the assessment of human PTS intake, based on levels of these contaminants in blood and breast milk, taking into account the advantages and drawbacks of using these indicators for different groups within the population." (P3)

The report on Arctic Ocean Acidification (AMAP, 2018) provides the knowledge gaps via the key extracts listed below:

"Understanding of the processes driving ocean acidification continues to improve, although there remain important gaps in knowledge regarding chemical, biological, and socioeconomic responses. With respect to projected changes in ocean chemistry, much of this current understanding is based on global climate models rather than high-resolution regional models. Due to the high spatial heterogeneity of acidification across the Arctic and its surrounding seas, high resolution models will be of critical importance to improving understanding of region-specific processes and trends. Limited in situ observations of Arctic Ocean chemistry, particularly during winter months when the region is difficult to access, restrict our understanding of the system, especially in offshore regions.

Similarly, it is important to understand how individual biological species will respond and how species composition will change under multi-stressor conditions. This is particularly the case with organisms in the Arctic, which are less well studied than those elsewhere. Research should focus on biological responses of individual organisms, such as changes to metabolic performance, survival rates, growth rates, sex transition mechanisms, and reproduction, as well as on ecological and community-level changes, including predator conditions, food availability, and habitat. Of key

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importance is an understanding of the longer-term, multi-generational effects of modified environmental conditions on key species.

The cumulative new understanding of chemical and biological responses contributes considerably to our understanding of how economies and local societies are likely to be impacted by anticipated environmental changes and changes to the distribution, health and availability of important species.

Meanwhile, traditional and local knowledge has only been included in consideration of the effects of acidification to a very limited extent. Better use could be made of this knowledge, and indigenous people might be better engaged in regional, national and international processes, including coastal monitoring and research programs, in response to the effects of acidification and other anthropogenic climate change stressors on food security and well-being in the region."

(AMAP, 2018) concludes with the recommendations "There are specific actions that could be taken to improve the scientific understanding of processes related to ocean acidification. Enhancing research and monitoring of Arctic Ocean acidification must continue to be a high priority within the Arctic Council to promote cooperation between Arctic countries. There is need for a unified monitoring program to harmonize and support adaptation actions in the Arctic and also to provide Arctic communities with the tools and training to conduct local, unified research and monitoring. Future decisions regarding use of living marine resources should take the many uncertainties still surrounding ocean acidification into account.

There is a need for more *in situ* research and observation to better understand the changing chemistry of Arctic waters, and Arctic-specific responses of biota. Based on the gaps identified here, future research should take a multi-stressor approach, given the inter-relationships, interactions and feedbacks between acidification and other stressors. Ecosystem changes should be monitored in such a way that allows identification and differentiation of the impact of each stressor on the ecosystem, as well as the potential synergistic effects of multiple stressors combined. This should also be extended to research conducted in the North Atlantic, given the biological, commercial and subsistence importance of fisheries in these waters and the impact of outflows from the Arctic basin. Laboratory research into physiological responses and genetic adaptation will be key to improving prediction of longer-term responses of biota to environmental change. Due to the scarcity of data and observations in the Arctic, a strong data sharing policy should be put in place and linked to global, open-source data depositories that can be accessed by modelers and the general public.

A lack of certainty about the interplay between biological changes and social and economic impacts of ocean acidification should not preclude action. Adaptation actions should be directed towards providing communities with flexibility, adaptability and economic and ecological resilience in the face of change and uncertainty: monitoring and investment decisions should aim to both reduce uncertainty and the costs of either underestimating or overestimating future impacts.

It is essential that action on adaptation is undertaken concurrently with mitigation. Ocean acidification mitigation is urgently required in order to avoid the most severe consequences that are projected in this report. Mitigation actions include both reducing anthropogenic carbon emissions and increasing carbon sink capacity."

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9.1.4 Red Cross Arctic Disaster Management Study

The recommendation are given below:

The study recommends that the Arctic National Red Cross Societies consider strengthening volunteer management capacities together by sharing best practices and lessons learned, also taking into account the utilization and involvement of spontaneous volunteers. (T4B)

The study recommends that the Arctic National Red Cross Societies explore how the Emergency Response Units (ERU) could be ensured to operate in cold conditions and to be prepared for Arctic accidents. The cold resistance and durability of the general ERU equipment and the equipment of the personnel should be evaluated and verified through equipment testing. Equipment testing could benefit from cooperation with relevant actors dealing with cold conditions, for example icebreaker companies or other companies and authorities operating in the Arctic area. (V2)

The study recommends that in addition to ERU winterization, the Arctic National Red Cross Societies explore harmonization and pooling of emergency units and assets for major accidents in the Arctic and for cold conditions in general. For example, the Icelandic and Finnish Red Cross have developed very similar types of mobile emergency relief units for major accidents. It would be beneficial to explore possibilities of harmonizing and pooling these types of emergency units for major emergencies to be able to better assess existing capacities and enhance joint deployment in the region. Sharing of good practices and lessons learned is key. (P4, P4A)

The study recommends that the Arctic National Red Cross Societies should together with authorities analyse and strengthen how medical readiness for emergencies in the Arctic could be improved by utilizing Red Cross capacities in the Arctic preparedness planning better. The Red Cross has strong knowledge and capacity related to field medical services. A total of three Arctic National Red Cross Societies maintain medical ERU units. In addition, the Finnish Red Cross maintains a specific Emergency Evacuation Hospital (EEH) for rapid deployment. Additionally, many other Arctic National Societies collaborate closely with those National Societies. For example, the Icelandic Red Cross regularly deploys health delegates to those medical ERUs. (T4C)

The study recommends that in order to ensure readiness for major emergencies, the Arctic National Red Cross Societies should explore developing pre-planning of logistical chains and establishment of logistical hubs together with regional actors, taking into account the challenging geography, remoteness, long distances and the existing infrastructure in the area. This would allow better preparedness planning and thus more comprehensive readiness for response.

The study recommends that in order to build stronger regional disaster response systems in the Arctic, the Arctic National Red Cross Societies should explore the possibility of establishing Arctic Regional Disaster Response Team (RDRT) training and teams. Teams trained in the specific context of the Arctic could strengthen the Arctic National Societies day-to-day preparedness and capacity building by supporting, for example, in the arrangement of exercises and trainings. The RDRT members would be deployed at short notice to support and bring assistance to National Societies in the region. The RDRT mechanism would also link Arctic National Societies into the IFRC mechanism for global tools.

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The study recommends institutionalizing the cooperation between the National Red Cross Societies in the Arctic to improve sharing of information and preparedness and to ensure the continuity of the cooperation. The form of the cooperation should be explored, discussed and decided among the National Arctic Red Cross Societies with the support of the IFRC. Examples of well-functioning forms of cooperation could be looked for in existing arrangements including Disaster Management Technical Working Groups between National Red Cross Societies in other areas or other organizations, such as the Arctic Coast Guard Forum, which is independent and informal but at the same time operationally-driven with established practices like a rotating chairmanship. (T4B)

The study recommends that the Arctic National Red Cross Societies strengthen their cooperation with states and relevant authorities in the Arctic through formalization of cooperation in the form of agreements, MoUs and arrangements. Definitions of roles and responsibilities should be streamlined, encourage action and ensure well-functioning cooperation in case of emergencies. (T3)

The study recommends that the Arctic National Red Cross Societies strengthen and expand on existing partnerships with the NGO sector as well as explore new forms of cooperation with different NGOs. The Red Cross would benefit from a better understanding of the NGO sector in the Arctic. For example, the Red Cross could learn from environmental organizations with extensive experience in the Arctic context and particularly from advocacy work related to the Arctic. (T4B)

The study recommends that the Arctic National Red Cross Societies explore sharing experiences internally and actively regarding cooperation with the private sector. Cooperation could improve common preparedness but it may also improve resources through fundraising. The tourism sector is a good example of possibilities for new forms of cooperation. It should be explored how the Arctic innovations among the National Red Cross Societies, like the Arctic First Aid material, could be utilized to promote safe and sustainable tourism in the Arctic, for example by distributing this material to tourist offices. Additionally, collaboration at the local level could be beneficial and the Red Cross could, for example, look to tourist offices and snow mobile safari enterprises for large amounts of snow suits or warm clothes in case of emergencies. (T4B)

The Study recommends that the Arctic National Red Cross Societies together with the IFRC strive to formalize the coordination and arrangement of the Observer work in the Arctic Council and ensure fluent information exchange and better awareness of the Arctic Council work among the National Societies. The Arctic National Societies together with the IFRC should agree upon a well-functioning way of working in the Arctic Council and clarify the role of the National Society in the chairmanship country regarding the preparations of the chairmanship and the involvement in the Arctic Council work. (T4A)

The Study recommends that the Arctic Red Cross National Societies together with the IFRC more actively utilize the Arctic Council and the variety of communication channels that the Arctic Council Secretariat uses in better conveying the message of the Red Cross. The Red Cross communications and for example, the use of Red Cross Field Communication Units, could be explored in the Arctic context, both for the benefit of the Red Cross and the Arctic Council. Improved information flow to the Arctic Council and vice versa is important in the future.

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The Study recommends that the Arctic National Red Cross Societies together with the IFRC deepen the cooperation with the Arctic Council Permanent Participants and build on the common questions of community resilience, health and adaptation to learn from the local communities and also share experiences of the Red Cross from long-term programmes, community resilience projects and relevant tools."

This study provides a basis and opportunities for future research to further elaborate on the themes from the Red Cross point of view. Common and cross-cutting interests, projects and partnerships should be further explored with Arctic research institutes and science networks like the University of the Arctic (uArctic). Further studies should be conducted regarding the cold conditions, cold protection and equipment testing. Bringing together relevant actors already engaged in formalized equipment testing and with existing know-how of the conditions with the Red Cross that has extensive knowledge and experience in disaster management and preparedness could be a fruitful ground to explore new innovations, technological solutions and equipment development for the Arctic. A closer examination of the legal agreements and the role of the Red Cross within these agreements could help clarify the different roles and interdependencies in case of emergencies and disasters. Agreements that specifically concern the Arctic, namely the Arctic SAR agreement and the SAR boundaries should be examined more closely from the Red Cross point of view. Further research should also be directed towards the financial frames and resources that are at play in the Arctic. Better understanding of current cost estimates and funding mechanisms as well as key funders in the Arctic are important for building disaster preparedness and disaster risk reduction mechanisms for the area.

9.2 Working groups

Table 27: Membership of the working groups, along with organisational and country affiliations

Working Group title	Members	Organisation	Country
Vessel structural and equipment issues	Henrik Törnberg Nina Jokinen John Evensen Soley Kaldal Thor Torkildsen Edvard Bjarnason	Polar Quest Laurea University NCA Icelandic Coast Guard JRCC NN MRCC Torshavn	Sweden Finland Norway Iceland Norway Faroe Islands
Lifesaving appliance and sea and cold survival issues	Dirk Stommel Sam Williams Robert Brown Tor Husjord Joe Costello Mike Tipton Johan Muller	MRCC Bremen UK Coastguard Memorial University Maritime Forum North University of Portsmouth University of Portsmouth MRCC Torshavn	Germany United Kingdom Canada Norway United Kingdom United Kingdom Faroe Islands
Communication Issues	Rob Lynch Eila Linna	Cork Institute of Technology	Ireland Finland

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	Leif Owe Birkeland Micheil Nevolin Djamila Ouelhadj Donatella Giampaolo Nick Hughes Maria Angelucci	University of Lapland Norwegian Coastguard Admiral Makarov State University University of Portsmouth e-Geos Norway Ice Service E-Geos	Norway Russia United Kingdom Italy Norway Italy
Pollution and incident control issues	Päivi Mattila Mike Hill Jonny Brodersen Ben Strong Birger Ingebrigtsen Ashraf Labib Snorre Hagen Lonnie Wilms Anthony Field	Laurea University Maritime NZ Nordland County Goverment US Coast Guard Norwegian Coastguard University of Portsmouth SAR helicopter unit Svalbard Greenland Oil Spill Response WWF	Finland New Zealand Norway United States Norway United Kingdom Norway Greenland United Kingdom
Navigational and voyage planning	Artmir Galicia Paul Milliken Penelope Wagner Frigg Jørgensen Kevin Willis Paul Browne Hans Mortensholm Sergey Aysinov	Laurea University United States Coastguard Norwegian Ice Service AECO University of Portsmouth UK Coastguard NCA Admiral Makarov State University	Finland United States Norway Norway United Kingdom United Kingdom Norway Russia
Personnel, training and education issues	Eija Raasakka Jørgen Hansen Emmi Ikonen Andrey Kazakov Dylan Jones Wayne Rhodes Bent-Ove Jamtli Odd Jarl Borch	Lapland University of AS Health and Care region North Nord University Nord University University of Portsmouth Maritime NZ JRCC-NN Nord University	Finland Norway Norway Norway United Kingdom New Zealand Norway Norway

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9.3 Summary of Workshops

9.3.1 Summary of Workshop One

Identified Gaps and Needs from Group Discussion Sessions

Note: This is summary of the issues raised and recorded via 24 flipchart pages during group discussion sessions. The groups were divided into six topics loosely arising from the Polar Code and issues categorised into the group in which they were raised. However, some issues span more than one group, as indicated in the list below.

Pollution and Incident Control

The need for development of autonomous equipment technology capable of operation in conditions too dangerous or harsh for humans. (P1A)

The need for pollution risk and incident data sharing and analysis (P4A)

Further definition into current and acceptable response times to pollution incidents (P4B)

Need of technology for detecting oil under ice in event of a spill (P1B)

Satellite data analysis tools for assessment of type of oil and extent of spill (P1D)

Standardised regulations for prevention of oil spill (P2A)

Development of a user-friendly "Arctic Tool Box" for oil spill management. (P1C)

Skills Assessment of new competences needed to deal with Arctic solution, also training to provide these. (P3A)

Classification of Arctic pollutants and their consequences (P3B)

Need for enhanced pollution monitoring sensors. (P1E)

Personnel, Training and Education

Training materials to ensure that crew, passengers and guides all have appropriate levels of information (T1A)

Development of advanced training materials for SAR teams (T1B)

Training in communication in common language across ANA region (English?) to fill language gap (T1C)

Training in very specific knowledge relating to the ANA region is needed. (T1A, T1B)

Training in effective communications with passengers is needed, e-learning material in different languages is required. Bite-Size information sections (T1A, T2A)

Ensuring that crews of smaller vessels are adequately trained (T1A)

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Development of age-appropriate passenger apps for emergency situations. Removal of complacency (T2A)

Formal certified courses for Arctic vessel crews (T3A)

Need to conduct surveys of passengers/crew involved in ship abandonments in order to assess gaps in education (T3B)

Need for enhanced multi-media vessel safety videos and interactive safety instructions to increase passenger engagement (T2A)

Enhanced passenger safety and security awareness by electronic, multi-media means. (T2A)

Regulations to ensure compulsory medical care insurance for ANA passengers. (T3B)

Communication

Enhanced Batteries or removal of battery requirements, assessment of necessity and practicality of PC use. (C3A)

Need for enhanced broadband communication systems (to give more access to imagery and video) (C2A, C2B)

Need to improve GMDSS systems wrt user friendliness, standardisation, adapted design for cold climates, and technical knowledge required of users. (C1E)

Need technology for enhanced communication through water (C3B)

Need standardisation of formats and competence training standards (C1E)

Need more involvement of end users in development process (C1E)

Vessel Structural and Equipment

Effective transition process in order to fulfil new requirements (V3D)

Need enhanced communication between vessel owners and industrial stakeholders (V3D)

Further technological advances in engines, steering and propellers (V1)

Standardisation of requirements (including maintenance schedules) for survival equipment (V2B)

Setting up of a “buddy” rescue system for ships (V3A)

Learning and transference should take place from the offshore energy sector (V3B)

Need clarity on point of regulation, vessel-based or transport through harbour based (V3C)

Navigation and Voyage Planning

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Need for an (electronic) platform for the sharing of information on routes (N2B)

Creation of ship areas or corridors (N2A)

Better data sharing and utilisation of current and historic SAR data (N2B)

Need for dynamic satellite information on ice confidence mapping (Comms)

Need for establish communication standards (Comms)

More automation to avoid/investigate alarms (N1A)

Robust systems that are not weather affected (N1C)

Enhanced sea ice hazard forecasting (N1B)

Emergency port identification software for evacuations. (N1D)

Logistics planning and emergency preparedness resources at selective ports (N1D)

Use of assistive drone technology (N3A)

Lifesaving Appliances and Cold Survival Issues

Review of realism of 5-day survival time, move to goal based system? (L1A)

Innovation in floor insulation, toilet facilities and suits in lifeboats (L2A)

Enhanced mapping of survival times in different regions (L1A)

Planning for commercial aircraft disaster response in ANA region (L1B)

Research required into different vulnerable groups, e.g elderly, children, those with limited mobility (L1A)

Enhanced liaison between industrial developers and SAR practitioners (L3A)

More nuanced requirements mapping with consideration of incident and type of vessel (L1B)

9.3.2 Summary of Workshop Two

Identified Gaps and Needs from Group Discussion Sessions

Note: This is summary of the issues raised and recorded via 27 flipchart pages during group discussion sessions attended by 23 participants. The focus of the workshop was on root analysis techniques for emergency incident and pollution prevention and management. Both actual cases and potential incidents have been investigated. The following case studies were discussed in groups and hence informed the summary points:

Le Boreal Incident (2015, South Atlantic)

Costa Concordia Incident (2012, Italy)

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Vessel Grounding in ANA region (General)

Elgin Oil Platform Incident (2012, Scotland)

MS Estonia Incident (1994, Baltic Sea)

Nuclear Incident in ANA region such as potential hazard from nuclear powered icebreakers, or mobile nuclear power stations (general)

<u>Pollution and Incident Control</u>

The need for effective prevention of and a protocol / means of dealing with a fire on a nuclear vessel (submarine or icebreaker). (P4C)

Research into the effects of a nuclear incident in the Arctic (P3C)

Enhanced international agreements, treaties and commitments relating to nuclear facilities and vessels in the ANA region (P2B)

De-militarisation strategies for the ANA region (P2C)

Further development of international decontamination strategies and technologies (P2E)

Enhanced technologies for oil recovery in ANA conditions (P1F)

Regulations on use of heavy oils in the ANA region (P2D)

<u>Personnel, Training and Education</u>

Need for training drills specific to nuclear incidents (T1D)

Development of nuclear hazard risk scenarios and training (T1D)

Liaison between oil and gas industry and SAR community over incident planning and response (T1A)

Enhanced pilotage training and communication, especially for non-local, small craft (T3C)

Standardised protocol for incident investigation and implementation of “lessons learned” (T3C)

<u>Communication</u>

Deployment of detection (isotope) program/system for early warning and hazard response

Development of specific plans to utilise maximum capacity of satellites in case of large emergency incident in ANA region

Enhanced charting of hazards in key ANA geographical points

<u>Vessel Structural and Equipment</u>

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Pro-active vessel design and construction to minimise likelihood and impact of emergency incidents (V1A)

Ensuring that lifeboats accessible in case of emergencies (V2A)

Navigation and Voyage Planning

Need for resilience planning to deal with disruption to shipping in case of an Arctic incident (N2C)

Enhanced ANA vessel traffic management (N2B)

Lifesaving Appliances and Cold Survival Issues

New, enhanced lifeboat technologies (L2A)

9.3.3 Summary of Workshop Three

Identified Gaps and Needs from Panel Discussion Sessions

Note: This is a summary of the issued raised and needs identified during a three day conference formed of presentations by subject matter experts and subsequent panel discussions with questions and points from the audience. The points below have been synthesised from the notes of the conference. The focus topics of the conference were ANA satellite communications, cold-climate technologies and issues pertaining to indigenous ANA communities.

Personnel, Training and Education

Enhanced Involvement of Inuit and other indigenous partners in SAR activities (T4A)

Need for better sharing of the results of ongoing projects with each other (T4B)

Collection and dissemination of best practice of communication between indigenous and SAR communities (T4A)

Technologies and training to allow local communities access to satellite data services (T4A)

Communication

Earth observation is essential to have control, to monitor and to have a sustainable development of the arctic region (C1A)

It is important to have reliable broadband, ship terminals and airstrips, hospitals in case of emergencies (C2A, C2B)

No broadband available of North 75/78N - Only iridium and narrow band (C2A)

Need to continue work to achieve broadband at higher latitudes (2CA, 2CB)

SAR needs for Narrowband safety messages and Broadband for SAR coordination (C2A, C2B)

Need for smart software solutions - Solving the bandwidth GAP Visual communication when conditions are difficult (C2)

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Need for reducing the response time – the key in SAR operations, by reducing transfer time of images (C1B)

Need for Improved detection probability, by better image precision (C1C)

Need technology for faster delivery of useful information to vessels (C1B)

Need more freedom with antenna systems in roaming – less manufacturer locking (C1D)

Enhanced communications and artificial intelligence technology to download and interpret satellite ice images (C1C)

Improve quality and timeliness of information available in emergencies – lack of 24 hour support (C1B, C1D)

Need for an end user driven process on gaining information during emergencies (C1D)

Further data processing capabilities to process the large and growing amount of information from multiple sources (C1C)

Need for communication systems that allow efficient downloading of accurate ice maps (C1B)

Need for enhanced Comms and broadband, until the new satellites come we have only iridium, it takes 6h to download an ice chart (C1B)

Better communication between indigenous communities and SAR community, particularly with respect to naming. Avoidance of mis-communication. (C1E)

Navigation and Voyage Planning

Enhanced Navigation systems is one key element (N1)

Better and less variable quality of ice maps, which give details of thickness of ice. (N1B)

Need to develop apps that give in-situ observation for sea ice? Development of good practice guidelines in this area. (N1B)

Need for maps that incorporate the indigenous community names as they often incorporate nature of hazards and shapes of geographical features. (N2D)

Lifesaving Appliances and Cold Survival Issues

Enhanced Technology to combat Heat loss (L2B)

Enhanced solutions to provide water and hence combat dehydration (L2C)

Extension of the polar code to cover knowledge (L3C)

Need for enhanced life raft solutions and technology, appropriate to all sizes of vessel (L2A)

Need for more NH90 helicopters (L3B)

Need for further research into decision-making when cold (L1C)

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Systems for monitoring the Health and safety of the professional teams that go into the rescue mission - identify the challenges and the needs (L3D)

Further work on ensuring that lab and mannequin based tests reflect ANA realities as closely as possible (L1D)

Increased research on the variable of human behaviour in ANA studies (L1C)

In large scale exercises missing a gap analysis what happens in the exercises and what would happen in real life. (L1D)

9.4 Issues Questionnaire Responses

9.4.1 Vessel Structural and Equipment Issues

Stakeholder Survey

ARCSAR
Arctic and North Atlantic Security and Emergency Preparedness Network

Vessel Structural and Equipment Topic

(1) Within your area of expertise what are the main common capabilities and innovation needs related to Arctic and North Atlantic Search and Rescue (SAR) Vessels and their Equipment?

Possibility to lift more people with a SAR helicopter at the time

- Ie cages of different sizes pending ship, that are pre-positioned on the outer deck of a ship
- Other helicopter hoist technology allowing to hoist more than two people at the time (V2C)

Sensors for more efficient search in cold, darkness (V2C)

Battery issue (Comms)

LSA for ice (Life Saving)

FFE for cold environment (Life Saving)

Comunication and hardware (Comms)

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(2) What issues with vessel structure and equipment have become most apparent since the adoption of the Polar Code?

LSA and FFE is not appropriate for polar areas (Life Saving)

Communication Equipment – battery – for long time operation in cold temperatures (Comms)

Aerial heating (Comms)

Safety equipment (V2)

(3) Where, in your opinion, are the most significant gaps in available data and knowledge regarding polar SAR vessel structure and equipment issues?

More icebreakers (V3)

LSA and FFE (Life Saving)
Means of escape (V1A)
Means of recovery from ice, water (V2C)

SAR training between country (V3)

(4) What do you feel are the key areas for potential future research concerning polar SAR vessel structure and equipment issues?

Maritime Mass Rescue equipment

LSA and FFE (Life Saving)
Means of escape (V1A)

Means of recovery from ice, water (V2C)

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Radio (Comms)
(5) What do you see as the potential future changes to Arctic use that will impact on requirements of polar SAR vessels and equipment? More traffic, more accidents HFO ban Traffic
(6) Which areas of vessel structure and equipment require greater collaboration? Which topics offer the greatest challenge to this? LSA and FFE (Life Saving) Means of escape (V1A) Means of recovery from ice, water (V2C) Cruise ship
(7) Please add any other comments you feel could be beneficial to the ARCSAR project:
8) What is your field of employment? How many years of experience do you have in this field? Have you worked on any projects related to ARCSAR? If so, please provide details. MET – 20 years PSC – 5 years 20 years SAR

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9.4.2 Lifesaving Appliance and Sea and Cold Survival Issues

Stakeholder Survey

Arctic and North Atlantic Security and Emergency Preparedness Network

Lifesaving appliances and cold survival issues

(1) Within your area of expertise what are (i) the main cold survival issues? And (ii) the most common lifesaving appliances?

Inexperience how to behave in cold climates. Thinking of passengers, this requires high demands to the responsible crewmembers. (L1C)
The certified lifeboats and life rafts are not suitable for longer than 24 H in cold climate. Below 0 Celsius. This is tested in the SARINOR project. (L2A)

SAR operation up to 5 days. Lifeboats for polar areas. (L2A)

Hyperthermia

Helicopters and life raft (L2A, L3B)

To keep dry is lifesaving
To keep warm, not expose bare skin (L2A)

Most common lifesaving appliances
- Flotation suits for Arctic condition (Petroleum industry) – very good
- Flotation suits
- Life vests (L2D)
- Life rafts
- Lifeboats(L2A)

Challenges

The flotation suits are difficult to take on for unexperienced passengers and not very suitable for old people. *It should be possible to produce a watertight suit with individual upper and lower parts.* (L2D)

Flotations suits must keep persons warm and dry and at the same time allow for toilet visits without exposing bare skin more than absolutely necessary (L2D)

Hand held radio devices for Arctic use must be constructed with larger buttons so it is possible to operate the radios using gloves. The same applies to emergency beacons or other alerting systems. Even mobile phones should be possible to operate with gloves on. (Comms)

Life vests are unusable in the Arctic (L2D)

Life rafts and lifeboats must be constructed for Arctic conditions so it's possible to remove humid air and at the same time keep a higher temperature. (L2A_

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It should be more insulation in the seats in the life rafts and lifeboats to keep the survivors warm (L2A)
Workable toilet systems for life rafts and lifeboats Should be constructed (L2A)
Not easy to find a floating person in the darkness, high waves, snow showers. A radar reflector should be part of the hood of the flotation suit (L2D)

Cold and wet environment in a life raft (L2A)
Help from a team buddy!

Meeting the Polar Code requirements for up to 5 day survival in Arctic waters (L3C)
Concerns with cruise liners and individuals on board, specifically the elderly, being able to done survival suits (L1A)
The existing equipment has not been tested researched for Arctic conditions (L2)

(2) What issues with lifesaving appliances and arrangements have become most apparent since the adoption of the Polar Code? And where have the greatest improvements been made?

The demand to be able to stay alive for five days is very challenging in an abandon ship emergency. The way to transfer passengers between Cruise Vessels in large numbers in cold climate. (L3C)

Enclosed lifeboats and insulated immersion suits for all persons on passenger vessels as a minimum but is this good enough. It is a start. (L1D)

Voyage Planning is mandatory and to keep track of Vessels of Opportunity in case you require assistance. (Navigation)

Clothing for crewmembers and passengers. Mandatory minimum requirements for the training and qualifications of masters and deck officers on ships operating in polar waters. (L3D)

Helicopters stationed on oil rigs (L3B)

The lack of technological improvement is the most obvious (L2)

Not in the filed before the Polar code, so I can't tell.

5 day requirement. Not tested/researched in Arctic conditions. May be infact impossible. (L3C)

Dry suits to be carried for all who enter Arctic/Polar waters. Can the elderly put these on? (L1A, L2D)

(3) Where, in your experience, are the most significant gaps in knowledge regarding (i) polar lifesaving appliances and (ii) cold survival issues?

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I think that it is possible to create or buy the equipment necessary to survive for five days in harsh environment, but the economic price will be too high for and it is still a small marked. Lack of experience of the crew members. (L3D) Homepage with all lifesaving equipment in Arctic (Comms) I think that the Polar Code is a weird rule that has not much to do with reality. It has to be able to adapt to the circumstances. (L3C) We also have to deal with the [expletive deleted] SOLAS equipment that are not made for being used (L2) No specific thoughts given to elderly individuals. These are most 'at risk' of cold related injury/survival (L1A)
(4) Are you aware of existing, ongoing or planned research relating to (i) lifesaving appliances and (ii) cold survival? If so, please provide details. I am not aware of any relevant planned research programs. No No No No Yes, but not specific to the Arctic/Polar regions. There is an urgent need for research in this topic. (L1,L2)
(5) How will the way the Arctic is used impact (i) lifesaving appliances and (ii) cold survival in the future? I am afraid that the minimum standards will be the standard unless the demand comes from the paying customers. Perhaps a questionnaire about the different vessels LSA could be an idea, where Companys could list their vessels LSA. Could this be a pilot test for the members of AECO to try out? Perhaps at the Joint Arctic SAR TTX in Reykjavik we can discuss the subject. If the answers are anonymous, they can be listed. But not sure if the Companies will think this is a good idea. Lifesaving appliances should be more reliable. (L2) Lots of trafic will help savings life

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More traffic across the North Pole and along the northern sea routes due to less sea ice will increase the risk for accidents to happen. There will be more use for lifesaving appliances and and cold survival gear (L2) Better communication and more ships will lead to shorter response time if help is needed (Comms) Traffic and cruise liners. Personnel on board is a concern. (L3D)
(6) Which aspects of (i) lifesaving appliances and (ii) cold survival require greater collaboration? Which topics offer the greatest challenge to this? Practical exercises. (L1D) Cruise ships Where the longitudes meet we all have to work together. Biggest challenge is still different languages and cultures. (L3) Link between industry and researchers to work towards meeting the Polar Code survival issues is needed/ Specifically greater funding is required to move this forward. (L3A)
(7) Please add any other comments you feel could be beneficial to the ARCSAR project: Think outside the box and do not build big or expensive systems that will lead to bigger ships with more passengers!
(8) What is your field of employment? How many years of experience do you have in this field? Have you worked on any projects related to ARCSAR? If so, please provide details. SAR Mission Coordinator, 7 years, ARCSAR Partner under practitioner. 20 years SAR experience JRCC, 10 years of experience - project coordinator for ARCSAR and leading the ACOPE project. I have formally worked a lot with land based field safety – mainly in Antarctica and in mountain regions Lecturer and researcher in Human and Applied Physiology. PhD in Cold Physiology

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9.4.3 Communication Issues

Stakeholder Survey

Arctic and North Atlantic Security and Emergency Preparedness Network

Communications Topic

(1) Within your area of expertise what are the main Communications common capabilities and innovation needs related to safety and security in the Arctic and North Atlantic?

Some **Low Data Rate solutions** are currently available:

- L-band constellations (Iridium, 66 LEO satellites)
- VDES services, based on micro/nanosatellites (e.g. AISSat-1/2 and NorSat-1/2 satellites

None of them is suitable to offer high throughput communication services as needed to support currently available applications

Iridium NEXT *is replacing the original Iridium constellation. On January 11th, 2019 the last 10 Iridium NEXT satellites have been placed to low earth orbit (LEO), completing the new constellation.*
Constellation characteristic:

- The system will maintain architecture of **66 LEO** (plus 15 spares: 6 in-orbit, 9 ground)
- near-polar orbit at an altitude of **780 km**
- Global coverage
- **L-band** phased array antenna for generating 48-beams each.
- **Ka-band** links will be also provided for communications with ground-based gateways and for ISLs.
- equipped with Automatic Dependent Surveillance-Broadcast (ADS-B)
- high-quality, truly mobile voice and data coverage over the planet's entire surface (including oceans, airways and polar regions)
  Data throughput of the order of **128 kbit/s to mobile terminals**, up to **1.5 Mbit/s to Iridium Pilot marine terminals**, and high-speed Ka-band service of up to **8 Mbit/s to fixed/transportable terminals**

The Iridium NEXT could then better satisfy the need for mobile terminals connections, to allow the ship-owners sailing the Arctic areas to access/download products relevant to their surroundings and communicated with more stable performances. (C1)

1. Broadband communications for digital exchange of the common operational picture (COP) (C2A,C2B)
2. Broadband communications for improved communications in general (C2A, C2B)
3. Broadband communication for improved weather and sea ice forecasts (C2A, C2B)
4. Better HF radio communication coverage (C3D)
5. More VHF and MF transceivers for improved coverage (C3D)

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At the GMDSS for polar areas we have now only: On-scene VHF communication, NBDP, Inmarsat system (75°N - 75°S), EPIRBs (COSPAS-SARSAT). It was OK for yesterday but not enough for today and tomorrow. (C1A)

MF and Satellite (C1A)

Improved bandwith at higher latitudes (C2A, 2CB)

(2) What issues with polar communications have become most apparent since the adoption of the Polar Code?

For sure, the Polar Code requires for the capability to receive onboard information about ice conditions. This implies the need for a stable and well dimensioned telecommunication channel. (C1)

To adopt equipment (ie hand held radios) to bulky Arctic clothing and survival gear. (C3D)

Modernization of GMDSS. Global coverage system for satellite communication, NBDP technology is rather old and very difficult for operators. Batteries for VHF portable, EPIRB and SART for low temperatures. (C1E, C3D)

Language

Lack of understanding from users on what information they need, specifically requirements broad description. (C2B, C1E)

Standard format to receive information. What is the standard data format for users? (C1D)

(3) Where, in your opinion, are the most significant gaps in available data and knowledge regarding polar communications issues relating to safety and security?

- Internet access everywhere (Un-served / Under-served areas, Mobile users) (C1,C2)
- Data access at any time
- Access at high speed data
- Access at low cost
- Cyber threats (C1D)

Promulgation of Maritime safety information (MSI) for ships at polar waters. International cooperation during search and rescue operation at polar areas. (C1D)

One homepage with all information are missing (C1D)

(4) What do you feel are the key areas for potential future research concerning polar communications?

- Search & Rescue alerts messages transmission anywhere/anytime
- Environmental Monitoring alerts messages transmission anywhere/anytime
- Ice coverage / Iceberg drifting / vessels detection products transmission (C1, C2A)

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Satellite communication, communication during SAR operation at polar areas. (C1D) Internet
(5) What do you see as the potential future changes to Arctic use that will impact on the requirements of polar communications technology? Vessels traffic will increase as a matter of fact in the short/medium-term, with consequences in terms of safety, search and rescue events and environmental protection. This implies the strong need for a more robust communications capability over such remote and wide areas. (C1A, C2A) Less sea ice and more traffic Increasing shipping intensity at polar areas. Arctic cruises. Internet
(6) Which areas of Arctic communications for safety and security require greater collaboration? Which topics offer the greatest challenge to this? SatCom availability anytime and everywhere for SOS calls. (C1D) The greatest challenge is partly technological (some solutions today onboard the vessels could already support for simple messages). Also, sufficient band should be available to exchange more "complex" information products. (C1B) Digital exchange of situational awareness (C1D) Communication during SAR operation. Training exercise with new types of equipment (Iridium, aero VHF, MOB device). (C1D) Internet

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(7) Please add any other comments you feel could be beneficial to the ARCSAR project: R&D institutions should push more, together with political effort, to fund technical solutions and procedures to be established and put in place to increase efficiency. There are many common topics between this WG and WG of Personal, Training and Education.
8) What is your field of employment? How many years of experience do you have in this field? Have you worked on any projects related to ARCSAR? If so, please provide details. Product Management and BD and Sales for Maritime applications (safety, security, environment). 12+ years' experience. Other initiatives related to the Arctic are: • HighNorth18 campaign (https://amboslo.esteri.it/ambasciata_oslo/it/ambasciata/news/dall_ambasciata/2018/08/high-north-18-campaign-mission.html; https://www.e-geos.it/#/news/110) • ARCTIC IAP (https://business.esa.int/projects/arctic-iap) • MARINE EO (https://marine-eo.eu/satocean-services) • Variability of the East Greenland Current in Fram Strait From sub daily COSMO-SkyMed X-SAR Imagery (https://www.researchgate.net/publication/296624551_Variability_of_the_East_Greenland_Current_in_Fram_Strait_From_Subdaily_COSMO-SkyMed_X-SAR_Imagery) • COSMO-SkyMed multi-year data provision to the ESA Data Warehouse over the European Arctic vastly used by several national ice services and meteorological institutes GMDSS instructor since 1995, member of delegation at IMO Sub-Committee of Navigation, Communication and Search and Rescue since 2013. 20 years SAR Researcher, Norwegian Ice service – 10 years experience

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9.4.4 Pollution and Incident Control

Stakeholder Survey

ARCSAR
Arctic and North Atlantic Security and Emergency Preparedness Network

Pollution and Incident Control Topic

(1) Within your area of expertise what are the main common capabilities and innovation needs related to pollution and incident control in the Arctic and North Atlantic?

An Arctic spill knowledge gap exists[2]. Reviews of the available response technology identify major limitations in the options for recovering oil in ice conditions. Even in ideal conditions, without ice, the industry only expects to recover 20% of the oil. There is a major gap in the effectiveness of existing technology[3] including: (P1)

- The inability to detect oil spilled in and under ice in the most common arctic conditions remains a major technical challenge, even with the use of Ground Penetrating Radar; (P1B)
- Oil spill thickness mapping (using multispectral aerial imagery combined with infrared detection) requires additional testing in arctic conditions; (P1D)
- Mechanical response equipment has very low effectiveness in waters with more than 30% ice coverage in the spill area;
- In situ burning is limited to thick, pooled oil (most oils spread out thinly very rapidly on water). Emulsified (containing water) oils are very difficult to burn;
- Dispersants do not remove oil from the sea—rather they spread it through the water column. (P1C, P2E)
  This should be taken into account when considering if these activities are permitted. A precautionary approach should be adopted. (P2A, P2D))

- Arctic spill response gap exists that limits the ability to clean up after an oil spill[4]. Seasonal differences mean that open-water mechanical recovery would not be recommended 73-77% of the year at the Chukchi and Beaufort Sea locations, respectively. It is almost impossible in winter (not favorable 94-98% of the time), and summer response would be marginal or worse (78-80% of the time)[5]. The ITOPF question whether in some cases a clean-up operation would be possible: "The first question to be addressed during contingency planning and following an incident in the Arctic will be: given the location, the time of year, and the environmental conditions, is it possible to respond?"[6] This questions whether certain activities, in certain locations should go ahead. (P4B)

1 [2] Wilkinson, J., Beegle-Krause, C., Evers, KU. et al. Ambio (2017) 46(Suppl 3): 423. Oil spill response capabilities and technologies for ice-covered Arctic marine waters: A review of recent developments and established practices

[3] WWF-Canada (2011) Western Arctic Oil Spill Response Gaps

[4] Bureau of Safety and Environmental Enforcement (2016) OSRR-1022-Estimating an Oil Spill Response Gap for the U.S. Arctic Ocean

[5] Nuka Research and planning group (2016) Estimating an Oil Spill Response Gap for the U.S. Arctic Ocean (Revised)

2 [6] ITOPF (2018) From website: Limitations of Arctic Oil Spill Response (gathered 20/2/2018)

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- There is a lack of Arctic governance for the strategic planning of activities. This not only applies to industrial activities but also to areas vital for wildlife now and in the future. With better governance and strategic planning for activities (and protected areas) the response to pollution and incident control can be tightened up. (P2)

- The case of the Northguider trawler in December 2018 has highlighted the lack of response capabilities, and the international funding of the service. The emergency response boat on Svalbard was mothballed for 3 months because of costs, The helicopter rescue was at the limits of their capabilities, it took 4 days for a Norwegian coastguard vessel to travel from its base to reach the trawler, it took 16 days to remove the 330 tonnes of diesel from the trawler and the salvage operation will probably take place 8 months after it ran aground.[7] (P2, P4B)

Major gaps are related to pollution and accident prevention. This is due to the new challenges that have to be faced with the Northern routes opening and the willingness of many actors to venture the Arctic areas without being well prepared on relevant risks. (P2, P2F)
Oil spill reports based on Earth Observation radar satellites, such as those of the Italian Constellation COSMO-SkyMed or of Sentinel-1 of the European Space Agency, together with the association of emergency services on a 24/7 basis can offer a highly valuable support in case of accident and pollution; they provide information that can be exploited to monitor the event, make a damage assessment and control the evolution of the accident afterword, without associated personnel displacement particularly important in harsh and risky conditions. (P1C,P1D)

As minimum we need tanker reporting procedures and recommended for all passing traffic. The Faroes Islands are very poorly represented in this areas, as there are absolutely no direct reporting for tankers and other vessels passing around and through the Island fjords. (P2)

Oil pollution (P1,P2)

(2) What safety and security concerns relating to prevention, pollution and incident control have become most apparent since the adoption of the Polar Code?

- Non-SOLAS vessels still do not have to abide by the Polar Code. There were 1,733 registered fishing vessels fishing within the CAFF Arctic boundary in 2012. This figure had risen to 3,905 registered fishing vessels in 2016. (P2F)

- There is a lack of comprehensive, well-funded emergency cover as activities increase in the Arctic. Who will ensure cover is provided across the Arctic? At the 2018 Arctic Circle Conference a former Icelandic Prime Minister said: “Some search and rescue will be impossible. It is therefore down to companies to have cover in place in the Arctic.” Shipping experts have highlighted the dangers from Arctic shipping and the lucky escapes due to favourable weather: “In all [incidents] favorable weather conditions, nearby vessels, or accidents close to shore enabled rescues with no or minimal loss of life. “We

[7] Arctic Today (2019) The mission to salvage a stranded Svalbard fishing vessel is on hold until August

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have not experienced severe violent acts in the maritime Arctic"; "… luck has been a significant factor to thus far preventing major loss of life in accidents throughout the Arctic." [8] (P2)

- There is a lack of implementation of the Polar Code by state parties (including the EU), through integration into national legislation. Its integration into national legislation will increase the safety and security of vessels as it raises the bar for safety standards – therefore preventing shipping accidents/incidents from happening. Also it is important for the implementation of flag state inspections particularly by polar states. Under IMO, a state that has enacted multilateral measures into its national legislation would enforce that on visiting ships. (P2, P2F)

- A lack of transparent monitoring into whether port state control has introduced inspections under the Polar Code (the mandatory measures within the polar code on safety and pollution control). This would increase the standards and prevent accidents from happening. (P2, P2F)

According to our knowledge, we suppose that especially for ship constructions, cruise operators and personnel the Polar Code introduces new obligations that reduce the exposure to risks, but also introduce new costs in terms of training, measures to be adopted on board to guarantee the safety of both crew and passengers for at least 5 days. (P2F)

N/A

Large area

(3) Where, in your opinion, are the most significant gaps in available data and knowledge regarding the prevention and management of incidents leading to pollution, safety and/or security concerns?

- From a shipping perspective there is a lack of an international accident database that catalogues all accidents, vessels involved, locations and the causes from all the Arctic states. PAME has launched one but it doesn't include data from all Arctic states with consistent data quality. (Navigation, P2F)

- Meteorological data and predictability of ice conditions. The loss of ice and changing weather systems are increasing the unpredictability of activities in the Arctic. Increased storms, increased erosion, unpredictable ice conditions are creating new risks and operating environments in the Arctic[9]. Weather forecasting capabilities are poor due to the shortage of meteorological stations. (Navigation)

- Key biodiversity areas for wildlife now and in the future, with the changes in sea ice and wider habitats, need to be mapped and factored into Arctic strategic planning for activities. This should also include the noise landscape as noise is considered a pollutant under UNCLOS[10]. There are species that rely on noise to find food, their families and

[8] High North News (2019) Norwegian Arctic Coastal Waters Among Most Dangerous
[9] Arctic Monitoring and Assessment Programme (2017) Snow, Water, Ice and Permafrost in the Arctic.
[10] UN UNCLOS: Article 145: Protection of the marine environment

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mates. This would allow a strategic separation of activities from these key areas thereby reducing the impacts of any incident on biodiversity. For example PAME in 2009 stated: "Almost the entire area of the Great Siberian Polynya System is covered with oil licenses recently issued and belonging to Rosneft Oil Company. Major threats include the risks of accidental oil spills, and the use of seismic surveys, which may have significant adverse impacts on the cetaceans and other marine life in the shallow waters of polynyas. It is important from migratory birds, ringed seals, polar bears, walrus."[11]. This also includes narwhales. (P2,P3)

In our view, major gaps are relevant to a poor knowledge of the situation awareness in the areas interested by the vessel route, on a large and regional scale perspective, both in terms of observation and monitoring and in terms of forecasting and traffic assessment (both declared and undeclared). (P4A)

VTS reporting not in effect on the Faroe Islands or other places in the polar areas. (P2)

Bad internet (Communication)

(4) What do you feel are the key areas for potential future research leading to a safer and more secure Arctic from pollution prevention and incident control perspectives?

- Protected areas to safeguard key wildlife areas now and in the future, as Arctic conditions change. Locate the key areas and ensure they are included in strategic planning of activities. (P3)

- Working with indigenous communities to ensure their knowledge views are included and important areas are identified. Community based spill response planning should be included in incident planning. Local people who have the knowledge are often the defacto first responders incidents. They need to be trained and well resourceed to play this role. P1C, P3A)

- Alternative non-polluting propulsion technology for shipping in the Arctic. The use and transport of heavy fuel oil should be banned in the Arctic. If the Northguider trawler was carrying heavy fuel oil it is questionable whether it would have been possible to transfer the fuel to the coastguard ship because of its characteristics in sub-zero temperatures. This means the grounded vessel would still pose a pollution risk to the protected area it is grounded within and the wider environment. (P2D)

- Noise pollution and its mitigation. Marine mammals depend on acoustic information to survive. The increase in Arctic economic activities could have a profound impact on these species. Seismic airgun blasts off northern Greenland have been recorded 3,000 kilometres away off Barrow in Alaska. Inuit throughout the Arctic say seismic surveys are driving animals away from their hunting grounds.

[11] Arctic Council and PAME (2009) *Arctic Marine Shipping Assessment 2009 Report.* Arctic Council and Protection of the Marine Environment. Norwegian Chairmanship

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- Technologies exist that reduce noise levels, for example bubble curtains, vibroseis, and quieter ship propellers.
- Operational solutions should be researched, such as slow steaming of ships through sensitive areas for wildlife and strategic spacial planning to help keep noise-producing activities away from important areas for Arctic wildlife.
- Research how noise travels in the Arctic and mitigating measures to reduce the impact of noise on wildlife and therefore indigenous communities. (P2, P3B)

- Research on the impacts of grey water discharges to Arctic waters and their impact on habitats and species should be carried out with the predicted increase in marine traffic. In WWF's views there is a need for grey water discharge regualtions, and potentially a new annex under MARPOL to cover this issue. (P3B)

The adoption of highly integrated and most possibly complete solutions offering the whole set of information layers that can provide data for monitoring and forecasting for sea conditions and prompt response to accidents along with mitigation actions.
This shall include in-situ, satellite and aerial observation means, to be ingested, processed and made available on a single web based user friendly interface. (Communication, Navigation, P1C)

How to implement reporting areas in the polar areas, northeast and northwest passage, and the Faroe Islands. Pollution disaster in the Faroe Islands could have ramifications equivalent to the Exxon Valdez tragedy in Prince Williams Sound. (P2, P3B)

Barents Sea

(5) What do you see as the potential future changes to Arctic usage that will potentially lead to a higher level of incidents causing pollution, safety or security concerns?

- The opening up of the Northern sea route. Increased shipping with increasing numbers of nuclear icebreakers.
- Increased tourism using cruise liners.
- Increased area of the marine Arctic that could be open to fisheries. And the increased trend in fishing boats fishing in the Arctic.
- Mineral exploitation. Hydrocarbon and mineral exploration and exploitation – both for the operations and the associated shipping.
- The degradation of the Arctic land infrastructure through melting permafrost, loss of stable shorefast ice letting go in unpredictable ways and increased erosion and increased number of powerful summer storms[12]. (P2)

Sea ice melting and Northern routes opening together with change of climate are already making the Arctic more accessible and therefore we can observe a traffic increase and consequently an

[12] The conversation (2018) As ice recedes, the Arctic isn't prepared for more shipping traffic

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increase of safety and security concerns. Geo-political interests and tourism are also bringing new non Arctic actors into the region. As a consequence we can observe increasing the risk for accidents and in general pollution due to lack of information and local knowledge, but also of local resources and technologies. We can also observe an increased militarization of the region due to the need to defend regional interests and resources. This may increase risks of pollution of a fragile ecosystem as the Arctic. (P2C)

Increase in traffic moving faster than the innovation and implementation of vessel traffic surveillance. (Navigation)

Tourism-Cruise ships (P2)

(6) Which types of incident require greater collaboration (e.g. oil spill, nuclear contamination, cruise ship incident, fishing boat grounding …)? How, in your opinion, can this be achieved?

- The increased shipping traffic Arctic may lead to accidents with large consequences. A 2018 study called for mitigation efforts from a broad range of resources [13]. Greater international governance in the Arctic. (P2)
- Governance of the Arctic international waters through international agreements, like the Central *Arctic Ocean agreement on fishing signed in October 2018. (P2)*
- The inclusion of non-SOLAS vessels (fishing vessels in particular) in the Polar Code and the implementation of the Polar Code by state parties. (P2F)
- Arctic nations and the EU supporting the ban of heavy fuel oil in Arctic waters (use and carriage of) in IMO. (P2D)
- Funding for training, equipment, rescues and tackling incidents is a critical issue. (P2)

Greater collaboration and technological effort are need for ships collision or intentional derived oil spill, nuclear contamination, air pollution due to vessel traffic increase, thermal shocks and relevant vessel malfunctioning, vessels grounding. State of the art technologies should be adopted but there is a resistant to change that must be overcame also by the Arctic countries. (P2, P3)

Cruise ship incident require a lot room, ships to accommodate passengers, food etc for pax and so on. Oil spill incidents require immediate quarantine of the area. We need to action plans for how to deal with the various scenarios. What crew and ships does it require? How long is the response time gonna be? Can we get ships, equipment, heloes and aircrafts on scene in ample time? (P4B)

Cruise ships

[13] Marchenko, N.A.; Andreassen, N.; Borch, O.J.; Kuznetsova, S.Yu.; Ingimundarson, V.; Jakobsen, U., (2018) Arctic Shipping and Risks: Emergency Categories and Response Capacities

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(7) Please add any other comments you feel could be beneficial to the ARCSAR project:

It should be one of the duty of ARCSAR Working Group to look at and then test state of the art technologies, particularly related to the EO SAR and data analytics services to monitor, observe and measure the changes that are happening in the Arctic to support its sustainable development. The ARCSAR Working group should became an agent of the change by promoting the transnational adoption of the best science based practices already operational in other region of the world for the benefit of the region, of the citizens living there and of our planet. (P1)

8) What is your field of employment? How many years of experience do you have in this field? Have you worked on any projects related to ARCSAR? If so, please provide details.

Over 20 years' experience in sustainable development. I have not worked on any projects related to ARCSAR.

Product Management and Business Development and Sales for Maritime applications (safety, security, environment). 12+ years' experience. Other initiatives related to the Arctic are:

- HighNorth18 Campaign (https://amboslo.esteri.it/ambasciata_oslo/it/ambasciata/news/dall_ambasciata/2018/08/high-north-18-campaign-mission.html; https://www.e-geos.it/#/news/110)
- ESA ARCTIC IAP (https://business.esa.int/projects/arctic-iap)
- MARINE EO (https://marine-eo.eu/satocean-services)
- Variability of the East Greenland Current in Fram Strait From sub daily COSMO-SkyMed X-SARImagery https://www.researchgate.net/publication/296624551_Variability_of_the_East_Greenland_Current_in_Fram_Strait_From_Subdaily_COSMO-SkyMed_X-SAR_Imagery)
- COSMO-SkyMed multi-year data provision to the ESA Data Warehouse over the European Arctic vastly used by several national ice services and meteorological institutes

Watchkeeping officer at Tórshavn Radio and MRCC Tórshavn. 18 months at sea and few weeks on current employment.

20 years in SAR

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9.4.5 Navigation and Voyage Planning

Stakeholder Survey

Arctic and North Atlantic Security and Emergency Preparedness Network

Navigation and Voyage Planning Topic

1. Within your area of expertise what are the main common capabilities and innovation needs related to navigation and voyage planning in the Arctic and North Atlantic?

A tool offering the capability to observe the situation ahead the vessels route operational on a 24/7 basis would allow a better voyage planning preparation and more response capabilities of the Arctic sailing vessels owners in case of accidents. Radar Earth Observation Satellites such as those of the COSMO-SkyMed constellation do offer a contribute in this sense, as they observe very wide areas without personnel or maintenance costs, providing information on sea and ice conditions and maritime traffic. (N1)

Ice charting and ice forecast (N1B)

How to detect ice patches and ice bergs more timely on radar equipment. We need to figure out how to deal with weather forecasts and heavy weather precautions on ships. (N1B)

GPS (Comms)

Use of routine routes to provide more and standardized ice information. (N2A)
Development of training opportunities to link research and operations better. (N2F)
Improved communication needs for better information and data exchange. (Comms)

(2) What issues related to navigation and voyage planning have become most apparent since the adoption of the Polar Code?

For sure, the Polar Code requires for the capability to receive onboard information about ice conditions. This allow a more conscious navigation and offer the possibility to optimize the route ahead and reduce safety and pollution risks.

LSA and FFE is not appropriate for polar areas (LSA)

Communication Equipment – battery – for long time operation (LSA)

Insufficient food/water ration for survival (LSA)

Unfortunately I have no experience and minimal knowledge to the Polar Code, as my line of work the Code has not been relevant.

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No problem

Many ship operators and planners do not clearly know how to get the background requirements for their ships. (Vessel)

Mariners and ship operators lack training and there is a huge need to provide this service for end-users. (T2E)

End-users not knowing what products/info available for sea ice. (T2E)

(3) Where, in your opinion, are the most significant gaps in available data and knowledge regarding navigational and voyage planning issues relating to Arctic safety and security?

The exact and high spatial resolution knowledge of the sea conditions relevant to the planned route of a vessel. As said, a service providing information with one or 2 days advance about the areas to be sailed ahead of the planned route would allow changes and optimization. These services should also be available on a 24/7 basis.

Survival issues in polar waters (LSA)

Possible inaccurate GPS plotting positions due to satellite coverage. No INMARSAT coverage north of 70-76 degrees latitude – hence lack of effective long distance communications since HF comms isn't in use in many parts of the world. We need more effective radio comms in the polar area. (Comms)

Internet (Comms)

Lack of user knowledge on what products are available (T2E)
How to interpret information from a lot of new products developed by research (T2E)
Lack of user training (T2F)
Products/operations not developed with users in mind (T2F)
Information format differences (T2E)
Lack of information available on all tactical and navigation in scales needed at all times. (T1)

(4) What do you feel are the key areas for potential future research concerning polar navigation and voyage planning?

An holistic approach including:

- Use of several kinds of data: Earth Observation satellites, vessels identification data, weather observation and forecast, sea state, water column, etc (Comms)
- Use of robust telecoms system (Comms)
- Provision of value adding services relevant to the area enveloping the vessel route (N3B)
- Availability of a web-based platform reporting all georeferenced features of interest (N1)

Low impact routes, ice forecasting (N1B)

Communications. Accurate position plotting. Timely radar coverage. (Comms)

North Passage (N2A)

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In situ integration with routine products (N2F)
Machine learning for sea ice type, SOD, areas at leads and ridging (N1B)
Improved voyage planning capabilities (N1)
Integration of users during product development (N2F)

(5) What do you see as the potential future changes to the Arctic environment that will impact on polar navigation and voyage planning?

Sea ice melting and Northern routes opening together with other geopolitical events and regional militarization are increasing traffic navigation in the region and consequently the need for routes planning. Increased use of oil and Gas in the Russian Arctic and their transportation, new mines opening, Arctic fish species moving into far north areas may also push for increased operations and therefore the requirements for new port infrastructures to support such development and to assist navigation.

HFO ban

Ice shelves and in constant move, and it will get worse as shelves keep breaking off the North Pole continental area. Makes voyage planning hard. Anti collision rules don't apply to moving land.

Bigger and Stronger Ships

Less stable Ice in the Arctic will allow for increased traffic and need for emergency preparedness
More data available and challenge to select the correct data (N2)
More commercial services for ice information provision (N2)
More regulation

(6) Which areas of Arctic voyage planning and navigation require greater collaboration? Which topics offer the greatest challenge to this?

The holistic approach means that all contributing assets and information need to be correctly interpreted and integrated to be truly useful for route planning purposes. Specific training programs would have to be largely deployed. (N2E,N3B)

Low impact routes, ice forecasting (N1)

SAR

Opportunity for commercial and operation information providers to engage with end-users to clearly identify needs (N2F)
Long-term and sub-seasonal social and temporal resolution scale needs (N1B)

(7) Please add any other comments you feel could be beneficial to the ARCSAR project:

It is recommended to use all available contributing technologies providing usable information within such a complex context, especially SAR EO data and COSMO-SkyMed in particular. Specific training on how EO SAR based services could support navigation should be also considered. (N2E)

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PWOM is a good idea but not always practicable as it should not be approved by any RO as a result I could see quite often it has nothing to do with polar operations at all An outcome from ARCSAR should clearly define roles and responsibilities (N2)
8) What is your field of employment? How many years of experience do you have in this field? Have you worked on any projects related to ARCSAR? If so, please provide details. Product Management and Business Development and Sales for Maritime applications (safety, security, environment). 12+ years' experience. Other initiatives related to the Arctic are: • HighNorth18 campaign (https://amboslo.esteri.it/ambasciata_oslo/it/ambasciata/news/dall_ambasciata/2018/08/high-north-18-campaign-mission.html; https://www.e-geos.it/#/news/110) • ARCTIC IAP (https://business.esa.int/projects/arctic-iap) • MARINE EO (https://marine-eo.eu/satocean-services) • Variability of the East Greenland Current in Fram Strait From sub daily COSMO-SkyMed X-SAR Imagery (https://www.researchgate.net/publication/296624551_Variability_of_the_East_Greenland_Current_in_Fram_Strait_From_Subdaily_COSMO-SkyMed_X-SAR_Imagery) • COSMO-SkyMed multi-year data provision to the ESA Data Warehouse over the European Arctic vastly used by several national ice services and meteorological institutes MET – 20 years PSC – 5 years 20 years SAR Sea Ice Research at Norwegian Ice service – 10 years experience

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9.4.6 Personnel, Training and Education

Stakeholder Survey

ARCSAR
Arctic and North Atlantic Security and Emergency Preparedness Network

Personnel, Training and Educational Issues Topic

1) Within your area of expertise what are the main common capabilities and innovation needs related to training and education in the Arctic and North Atlantic?

Simulators capable of simulating Arctic Conditions (T1E)
Coordinated use of simulators for training and education across public sectors and between Emergency responders and private companies (T1E)
Commonly available tools for information sharing across sectors (T4)

Innovation needs:
E-learning (T1,T2)
Simulation environment learning (T1E)
Courses for voluntary organizations and together with local communities (T2)
MIRG training (T1)

Dedicated training programs on the interpretation of earth observation satellite data and derived information, not only limited to the ice conditions, for the crews of the Arctic sailing vessels and for the local population would improve the consciousness and knowledge of the context and impacts of human activities and natural events. (T1)

SAR training at polar areas. (T1B)

-Preparedness plans in every hospital in the northern region plus in the Regional Health Trust Organisation (Helse Nord RHF). Including exercises, evaluation and implementation of" lessons learned". (T4C)
- In hospital established BEST – practice handling of traumatized patients. Collaboration on different levels with university hospitals. (T4C)
- Training schedules, courses, certifications for personnel. (T4C)
- Specially trained medical staff (doctors and nurses) on rescue helicopters, ambulance helicopters and fixed wings. (T4C)
- Stored equipment for emergency situations in arctic region in designated locations ready for use in relevant situations (med.equipment, medic, food, etc) (P&IC)

Users need to be trained in different ice information features in (…) data and products (T1)
Training for product developers on user needs (T2)
Polar code training provision – funds needed (T1)

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(2) What issues related to personnel management, training and education have become most apparent since the adoption of the Polar Code?

The need for experienced based knowledge transfer (T3C, T4B)

Improved analysis of historical data and data acquired during exercises for transfer to contingency plans, first responders, education institutes and coarse providers (T4B)

Being able to arrange the required courses and finding resources to attend them (T1)

The Polar Code requires for the capability to receive onboard information about ice conditions. So, relevant training programs should be foreseen for the crew. Training information contents should be extended to all of the information about the sea state conditions and the presence of other feature along the vessel route and ahead its position. (T1A)

Polar water training. (T1A, T1B)

Training related to the "circumpolar region" conditions, relevant equipment, communication (T1)

Lack of resources and funds to organize training workshops (T1)

Lack of expertise to run training seminars (T1)

Users not required to have training so there is no opportunity/incentive from management to sponsor training (T1, T3)

(3) Where, in your opinion, are the most significant gaps in available data and knowledge regarding personnel training and education relating to Arctic safety and security?

Proper analysis of experience data and exercises in a way that the data can be used to implement improved technology, methods and procedures
Systematic approach to gather local knowledge and transfer to plans, procedures, methods.
Systematic use of local knowledge in training courses and institutional education

How to implement the lessons learnt and make more concrete actions after exercises and incidents. (T3C)
How to find funding to educate crew members, captains etc. (T1A)
OSC courses for captains (T1A)
Relevant (non-scripted) exercises to enhance the learning of SMCs and other professionals. (T1A)

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Earth Observation derived information and data should be surely included by procedure in the operational management of the Arctic safety and security issues. (Comms)

Survival in the Arctic. (LSA)

Have no studies related to this question.

Users are not aware of certain products
Users may not be familiar with data format
Information providers do not provide adequate information for users to understand information products
Users may not know how to interpret new data if never used before (T1)

(4) What do you feel are the key areas for potential future research concerning personnel management and training for Arctic search and rescue?

Realistic exercises on smaller scale (T1F)
Exercise evaluations and implementing the lessons learnt (T4C)
E-learning and simulations (T1E, T2)

European funding should be dedicated to local populations' technological growth and awareness about observation and monitoring means on large spatial and temporal scales. Also, funding should be dedicated on innovative training methodologies specific for Arctic related matters. (T4A)

Communication during SAR operation at polar areas. Catastrophe live exercise. (T1F)

-Research, development and testing on relevant equipment for handling in cold conditions. Survival suits and boats/floats/zodiacs that is able to meet the demands for many hours/ days in the exposed condition before getting rescued. First-aid equipment is not made for the cold, windy and wet situation. (LSA)

- Education on handling of casualties in arctic, hypothermia etc. (T1B)
- Multidisciplinary exercises and exercises (tabletop and live) to train collaboration between the different countries, systems, rescue authorities/ maritime org./ shipping org./ marines and so on. (T1F)

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-Built mutual understanding of each other's way of acting, capacities and skills. (T4)

Integration of programs with funding opportunities and grants so that stake holders are included in development (T4)
More exercises including users. Management, information providers and others (T1F)

(5) What do you see as the potential future changes to the Arctic environment and indigenous population that will impact on Arctic safety and security?

If Indigenous knowledge and local communities are not take into account in the planning phase and things are done without their consent (T4A)

Sea ice melting and Northern routes opening will increase the traffic and consequently safety and security issues; increasing interest on local natural resources will impact on local environment and so on indigenous population. (T4A)

Increasing number of crewmembers at these regions who have not experience working at polar areas. (T1A)

- Climate changes,
- Avalanches / Landslides
- Ability to build competency in safety and security in the indigenous population. (T4A)

For Arctic environment we expect FYI to not thicken enough during the Winter and not be able to stabilize over the Summer

Thinning of perennial sea ice, opening up more routes in the Arctic for activity

(6) Which areas of Arctic search and rescue training require greater collaboration? Which topics offer the greatest challenge to this? How can indigenous populations be effectively included in this topic?

Voluntary organization and emergency services training together.
Local communities should be included in these discussions. (T4A)
Grassroot level training. A lot of the bigger exercises are mostly showcases but actually training the practitioners and first responders. (T4)

Greater collaboration in our opinion is required for local population training and know how sharing for local technological growth. Major issue is related to the economic and financial coverage, which necessarily should go through public funding as relevant costs cannot be sustained by indigenous population. (T4A)

Catastrophe live exercise. International SAR training exercise. (T4F)

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- Communication, (Comms)
- handle pollution (oil spill) (P&IC)
- "Listen to the locals"….. on the topics they know best….. (T4A)

Information providers and user needs
Information providers need to experience how information is used, capabilities and what is needed during an emergency situation
Lack of communication and funding opportunities to improve collaborations (T4)

(7) Please add any other comments you feel could be beneficial to the ARCSAR project:

There are many common topics between this WG and WG of Communication.

- communication /emergency communication /location. (Comms)
- overview (satelites, drones) (Comm
- Accessibility
- Ability to handle evacuated peoples ("shipwrecked" crowds) needs in marginalized conditions (dark, cold, wet and windy). (LSA)

8) What is your field of employment? How many years of experience do you have in this field? Have you worked on any projects related to ARCSAR? If so, please provide details.

Academia and practitioner organization, mostly project and research related experience

Product Management and Sales for Maritime applications (safety, security, environment). 12+ years' experience. Other initiatives related to the Arctic are:

- HighNorth18 campaign (https://amboslo.esteri.it/ambasciata_oslo/it/ambasciata/news/dall_ambasciata/2018/08/high-north-18-campaign-mission.html; https://www.e-geos.it/#/news/110)
- ARCTIC IAP (https://business.esa.int/projects/arctic-iap)
- MARINE EO (https://marine-eo.eu/satocean-services)
- Variability of the East Greenland Current in Fram Strait From sub daily COSMO-SkyMed X-SAR Imagery
- (https://www.researchgate.net/publication/296624551_Variability_of_the_East_Greenland_Current_in_Fram_Strait_From_Subdaily_COSMO-SkyMed_X-SAR_Imagery)
- COSMO-SkyMed multi-year data provision to the ESA Data Warehouse over the European Arctic vastly used by several national ice services and meteorological institutes
- EO SAR Training programs are already available at e-GEOS since several years. They can be made in Rome or locally. Duration and content is generally agreed prior the start of the course. References and quotations can be made available upon request.

Associate Professor, PhD. Admiral Makarov State University of Maritime and Inland Shipping (24 years).

Researcher at Norwegian Ice service -10 years experience

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9.5 Priority Questionnaire Responses

9.5.1 Vessel Structural and Equipment Priorities

Vessel Structural and Equipment

Prioritisation and Innovation Survey				
Need	**Sub-Category**	**Evaluate the importance/priority of the identified need on a 1-10 scale (10 being highest).**	**Evaluate the challenge in resolving the need based on the time, money and resources involved (on a 1-10 scale with 10 being the most challenging)**	**Provide any sources of innovation that could be used to help solve these challenges.** These could be in the form of available products, services, and technology from recent projects, or emerging research developments. If possible, please give a suitable reference or weblink.
Enhancements in vessel design	Pro-active vessel design and construction to minimise likelihood and impact of emergency incidents	9 10 8 9, USCG needs multi-mission, shallow water capable boats	8 8 5	While designing right first time is more cost-effective than later corrective measures, the concept is too vague – some incidents remain beyond any control measures Internal R&D proposals are pending

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		transportable in the HC130 while trailered 8	8, based on the funding needs, acquisitions, and new material development 8	The Polar Code provides some requirements on vessels, but the structural requirements are not covering all vessels and circumstances. For example, there is no requirement to be ice classed for ships making a single arctic passage, polar certification does not require a physical separate survey and the Polar Code does not apply to fishing vessels and vessels under 500 GT. http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/default.aspx
Enhanced vessel equipment	Ensuring accessibility of lifeboats/rafts at all times	10 10 9 9, cold weather ready with redesigned doors/cabins 5	9 5 3 7, some research assets are being utilized 2	The frequent ship list following a water ingress generally impede the use of half of the rafts (example Costa Concordia) Internal R&D proposals are pending based on platforms with littoral beach access capabilities I am unsure that this is an issue unless referring to non-SOLAS vessels. The International Convention for Safety of Life at Sea (SOLAS) Chapter III sets out requirements for the stowage and access of life rafts (stowage with its painter permanently attached to the ship, stowage with float-free arrangement and automatic inflation, stowed in such so as to permit the manual release, etc.) and lifeboats (size, number and the capacity of the lifeboat, survival equipment

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				carriage, carriage of a rescue craft, gravity davits, launch angels and speeds, hoisting time, etc.) http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx
	Standardisation of requirements (including maintenance schedules) for life saving equipment	10 10 9 10, Standard communications package 5	9 1 3 7, research designs already underway 2	 Already in place Internal R&D proposals are pending As above
	Enhanced vessel based mass or individual marine rescue equipment	8 (10)	8 (1)	 **What**: Temperature Activated Water (TAW) installation **Background**: TAW is a technology that alters the pressure and temperature of any type of water (pure, salt, brackish, etc.) w/o any additives to produce a special vapor-droplet mixture that has been proven to be very effective, amongst its many applications, in fire-extinguishing. The TAW installation can be mounted on marine vessels of varying sizes to provide flexible firefighting capabilities using sea water. The installation's specially designed nozzles eliminate the chance of clogging or freezing, even in Arctic environments.

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		- 7 6, small boats are more for pollution response and remote area access 8	- 6 8 6	Moreover, TAW has been proven to be very effective at breaking up large snow and ice masses that can: 1. Impede vessel navigation; 2. Accumulated on engineering structures and compromise their operations. **Availability**: the TAW installation is currently available with limited production volume. (unclear) Internal R&D proposals are pending As the number of cruise vessels with large numbers of passengers in the arctic increases, this is of increasing importance. There is already a variety of marine evacuation systems commercially available, though the suitability for arctic conditions would have to be established. https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CSNCOE/FPVE%20Knowledge/Issue%206%20FPVE%20Learning%20-%20MES%20(Marine%20Evacuation%20System).pdf?ver=2017-08-08-074810-337
Collaboration between vessel and SAR stakeholders	Formation of a “buddy” rescue system for vessels	9 -	9 -	Annual SAR TTX cooperation of AECO, ICG and JRCC NN (unclear) Real drills with the ship systems (evacuation, firefighting…) are mandated by legislation

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		9 5 8	5 5, USCG is working to improve collaboration 8	 ARCSAR, AMVER, Joint exercises Buddy systems could be an effective way to mitigate risks, but require compatible equipment and procedures and limits the operators flexibility on routes / times. This might be workable for cruise vessels but much more difficult for other commercial vessels (commercial pressures) or the fishing industry. https://munin.uit.no/bitstream/handle/10037/16153/thesis.pdf?sequence=2&isAllowed=y
	Learning and transference from other sectors (e.g offshore energy)	7 8 9 5 5	7 2 4 5, USCG is working to improve collaboration 2	 Certification companies (e.g. BV) and insurers have already this transverse role of transference Ongoing engagements There might be limited learning opportunities, such as mass evacuation from offshore platforms.
	Clarification on points of regulation for vessels	6 - - 6	6 - - 4	 (unclear) When deficiencies are found in regulations, IMO and EU/National Authorities are always reinforcing legislation. Still this is too often the result of a major incident for triggering the revisit of regulations USCG participates in the IMO, Arctic Council, and ACGF on these issues

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		8	8	Not so much clarification but gaps in the current regulations / Polar Code, however closing these will require international agreement within the governing body (IMO) with cost implications for the industries involved (such as the fishing industry). This will be challenging and take time.
	Enhanced collaboration between vessel owners and SAR and industrial stakeholders	7 8 8 7 10	7 2 5 5 3	Annual SAR TTX cooperation of AECO, ICG and JRCC NN Shall include Naval Architects and shipyards USCG is working with communities in Alaska as well as industry to improve spill prevention and response Close continued cooperation with industry bodies such as CLIA as well as the emergency response setups / centres of cruise lines.

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9.5.2 Life Saving Appliances and Cold Survival Priorities

Lifesaving Appliances and Cold Survival

Prioritisation and Innovation Survey

Need	Sub-Category	Evaluate the importance/priority of the identified need on a 1-10 scale (10 being highest).	Evaluate the challenge in resolving the need based on the time, money and resources involved (on a 1-10 scale with 10 being the most challenging)	**Provide any sources of innovation that could be used to help solve these challenges.** These could be in the form of available products, services, and technology from recent projects, or emerging research developments. If possible, please give a suitable reference or weblink.
Understanding and mapping of Survival in ANA region	Research into mapping of actual realistic survival times by category (age, vulnerability, location, conditions)	10 10 8	2 8 8	A specific review of the literature should be the first thing undertaken Golden, F. St.C & Tipton, M. J. (2002) Essentials of Sea Survival. Human Kinetics, Illinois. ISBN 0-7360-0215-4. Power, J., Simones, Re. A., Barwood, M., Tikuisis, P, Tipton, M. (2015) Reduction in predicted survival times in cold water due to wind and waves. Applied Ergonomics. 2015 Jul; 49:18-24. doi: 10.1016/j.apergo.2015.01.001. Epub 2015 Jan 26. Power, J., Tikuisis, P., Re, AS., Barwood, M, & Tipton, M. J. (2016) Correction factors for assessing immersions suits under harsh conditions. Applied Ergonomics 53: 87-94.

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		5	5	
	More nuanced survival planning with respect to type of vessel and incident	5 5 6 5	5 8 6 8	
	Research into human behaviour and decision making when cold	10 3 8 5	2 4 8 7	This research can relatively easily be achieved in a lab environment. Wakabayashi, H., Oksa, J & Tipton, M. J. (2015) Exercise performance in acute and chronic cold exposure. Journal of Physical Fitness, Sports and Medicine 4(2): 177-185.
	Research into gap between lab/mannequin tests and ANA realities	3 7 6 6	9 8 6 7	Too difficult to do? Ethical issues? Tipton, M. J. & Balmi, P. J. (1996) The effect of water leakage on the protection provided by immersion protective clothing worn by man. European Journal of Applied Physiology 72: 394-400. Tipton, M. J. & Balmi, P. J. (1994) Assessment of immersion suit performance: human compared to immersion thermal manikin tests. Proceedings of the 6th International Conference on Environmental Ergonomics, Montebello, Canada. Tipton, M. J. (1997) Measurement, Modelling and Mimicry. Proceedings of the First International Manikin Forum. Keynote Address. Cord, Halifax, Nova Scotia.

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Technologies to enhance Survival	Enhanced lifeboat / raft technology and design	3 8 9 7	5 4 9 8	
	Technologies to combat heat loss	10 8 8 (10) 5	2 4 8 (1) 3	Again a focused scientific review of the literature could help answer this question Golden, F. St.C & Tipton, M. J. (2002) Essentials of Sea Survival. Human Kinetics, Illinois. ISBN 0-7360-0215-4. Tipton, M. J. (2006) Human physiology and the thermal environment. Chapter 12. In: Aviation Medicine (4th Edition) Edited by Rainford, D. P., Nicholson, A. N. & Gradwell, D. P. Arnold. Tipton, M. J. (2006) Thermal stress and survival. Chapter 13. In: Aviation Medicine. (4th Edition) Edited by Rainford, D. P., Nicholson, A. N. & Gradwell, D. P. Arnold. **What**: Temperature Activated Water (TAW) installation **Background**: The TAW installation operates as a mobile, efficient way to supply heat, electricity, and water, especially in emergency situations when other system fail. **Availability**: the TAW installation is currently available with limited production volume.
	Technologies to provide water and combat dehydration	4 8	2 4	Golden, F. St.C & Tipton, M. J. (2002) Essentials of Sea Survival. Human Kinetics, Illinois. ISBN 0-7360-0215-4

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		7 7	7 9	Tipton, M. J. (2006) Human physiology and the thermal environment. Chapter 12. In: Aviation Medicine (4th Edition) Edited by Rainford, D. P., Nicholson, A. N. & Gradwell, D. P. Arnold. Tipton, M. J. (2006) Thermal stress and survival. Chapter 13. In: Aviation Medicine. (4th Edition) Edited by Rainford, D. P., Nicholson, A. N. & Gradwell, D. P. Arnold.
	Enhanced flotation suits suitable for ANA conditions	4 3 9 5	6 7 9 7	
Collaboration between and regulations for ANA lifesaving stakeholders	Enhanced liaison between industrial developers and SAR practitioners	6 8 7 6	8 3 7 7	
	Increased numbers of sharing of helicopters to provide adequate coverage	- 8 6 (10)	- 8 6 (3)	Not really my area Icelandic Coast Guard and Arctic Command (Danish forces in Greenland) have established an agreement which includes “Standard Operation Procedures” for SAR in the Greenland / Iceland area. This SOP includes exchange/cooperation of SAR assets including Helicopters. **What**: SHERP Utility Task Vehicle

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		7 4	9 8	**Background**: SHERP is a much more affordable, truly all-terrain alternative to helicopters that travels in water at up to 6 km/h and does not sink. Two models are available to suit a large variety of needs and applications. **Availability**: Available now through the contact reference below. https://www.nordisksikkerhet.no/sherp-norway https://sherptheark.com
	Collaboration on how to meet "5 day" requirement of polar code	10 3 6 8	2 3 6 7	This is very important
	Common training of all crews/workers in ANA in lifesaving/survival issues	2 10 6 6	10 9 6 6	Almost impossible in my opinion…

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9.5.3 Communication Issues Priorities

Communication Issues

Prioritisation and Innovation Survey				
Need	**Sub-Category**	**Evaluate the importance/priority of the identified need on a 1-10 scale (10 being highest priority).**	**Evaluate the challenge in resolving the need based on the time, money and resources involved (on a 1-10 scale with 10 being the**	**Provide any sources of innovation that could be used to help solve these challenges.** These could be in the form of available products, services, and technology from recent projects, or emerging research developments. If possible, please give a suitable reference or weblink.

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			most challenging)	
Enhanced Satellite Coverage and Capability in ANA region	Ensuring sufficient satellite coverage of ANA region	10 10 6	7 8 4	Integrate all available satellite sources, especially relevant to Polar orbiting satellites for Earth Observation and especially RADAR (SAR) sensors. Be ready to integrate upcoming missions. https://www.telespazio.com/en/news-and-stories-detail/-/detail/171219-the-first-second-generation-cosmo-skymed-satellite-has-been-launched-successfully?f=%2Fnews-and-stories-detail Exploit application platforms for value adding integrated services (e.g. SEonSE https://www.e-geos.it/#/hub/hubPlatforms/platform/platform-sense) Norwegian HEO (deployed in 2022) - https://spacenorway.no/home/ Megaconstellation (OneWeb from 2021, Starlink in the future) - https://oneweb.world/ Gallileo return channel (from 2020) - https://www.gsa.europa.eu/newsroom/news/galileo-return-link-service-declared-european-space-conference Polar Scout (2018) - https://www.gsa.europa.
	Communication Technology to ensure satellite data is accessible within required timescale	10 10 7	6 10 4	Some **Low Data Rate solutions** are currently available: o L-band constellations (Iridium, 66 LEO satellites) o VDES services, based on micro/nanosatellites (e.g. AISSat-1/2 and NorSat-1/2 satellites None of them is suitable to offer high throughput communication services as needed to support currently available applications ***Iridium NEXT*** *is replacing the original Iridium constellation. On January 11th, 2019 the last 10 Iridium NEXT satellites have been placed to low earth orbit (LEO), completing the new constellation.* *Constellation characteristic:* ▪ The system will maintain architecture of **66 LEO** (plus 15 spares: 6 in-orbit, 9 ground) ▪ near-polar orbit at an altitude of **780 km** ▪ Global coverage ▪ **L-band** phased array antenna for generating 48-beams each.

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				▪ **Ka-band** links will be also provided for communications with ground-based gateways and for ISLs. ▪ equipped with Automatic Dependent Surveillance-Broadcast (ADS-B) ▪ high-quality, truly mobile voice and data coverage over the planet's entire surface (including oceans, airways and polar regions) Data throughput of the order of **128 kbit/s to mobile terminals**, up to **1.5 Mbit/s to Iridium Pilot marine terminals**, and high-speed Ka-band service of up to **8 Mbit/s to fixed/transportable terminals** The Iridium NEXT could then better satisfy the need for mobile terminals connections, to allow the ship-owners sailing the Arctic areas to access/download products relevant to their surroundings and communicated with more stable performances. HEO: Inmarsat equipment needed - https://www.inmarsat.com/tag/space-norway/ Megaconstellation: Terminals unknown at the time
	AI and data analytics for processing of satellite data	8 6 5	7 5 5	Exploit Big data Processing methods and platforms, count on leading experts in the sector, e.g. CLEOS https://www.e-geos.it/#/hub/hubPlatforms/platform/platform-cleos
	Collaboration between satellite stakeholders to ensure maximal coverage and emergency preparedness and protection against cyber-threats	7 6 9	5 5 7	Lessons learnt from the existing services and European Agencies (EMSA, FRONTEX, Copernicus Emergency Services) and set the basis for efficient commercial services integrating all available data sources, customized for specific polar region's needs.

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	Systems and Training to allow effective satellite data usage by SAR and indigenous communities	10 7 8	3 5* 8	Industries shall provide training services relevant to the specific products and platforms and technology they provide, to local people, scientists, operators, decision makers. ** - about challenges, at least for indigenous training the main problem is the human capital at disposal and not time, money and resources. If we introduce this parameter, challenge evaluation rise to 10.* Communication technologies used for SAR should be based on technologies used in "daily life", so that the threshold for the users are low.
Enhanced Quality and Coverage of Broadband in ANA region	Broadband coverage of the ANA region	10 10 7	9 10 7	\\ Norwegian HEO and Megaconstellations should be able to provide backhaul for broadband. Local spreading networks (cabled/wireless) can be deployed when/where needed.
	Technology to allow Improved broadband speed In the ANA region	10 5 6	9 8 6	\\ Mobile systems (4G/5G) supported by satellite back-haul through HEO or LEO constellations. Dedicated broadband radio types, e.g. https://radionor.no/, https://www.kongsberg.com/maritime/products/bridge-systems-and-control-centres/broadband-radios/maritime-broadband-radio/
Improvements in local / on-vessel communications technology	Need for enhanced batteries with longer life for	9 8 10	8 5** 8	\\ *** - level is low since the world market will work in any case to improve life and other battery characteristics*

	usage in ANA region			Some input could be provided by https://www.ntnu.edu/employees/pedro.torre who was checking battery available for Arcic operations for ArcticABC project (https://ieeexplore.ieee.org/document/8604603)
	Technology to allow enhanced communications through water in ANA conditions	5 5 0(1)	5 10*** 0(1)	\ **** - not sure what this means. I am answering supposing that you are not talking about submarine cables but about real open path communication in a water environment*
	Multi-national isotope detection system and response protocols	8 4 7	5 ??**** 4	\ ***** - no sufficient information from my side* World Meteorological Organization?
	Enhanced radio communications coverage	9 10 8	6 5 ***** 6	\ ****** - cost and energy can be low, advantages very high. Very relevant benefit/cost ratio* HF as a back-up communications if satellites go off line is vital. Proficiency in HF communications is decreasing by use of satellite communications. In our work we try to focus on enhanced radio communication coverage. Some links that may be of your interest are: https://www.ntnu.edu/ie/smallsat/ntnu-smallsat-lab#/view/about Use of manned and unmanned vehicles as a relay-nodes or data-mules. E.g. Resources: **Communication relay using flying vehicles – an ArcticABC project example**: 1) ArcticABC project: http://www.mare-incognitum.no/index.php/arcticabc) 2) Ice-node description https://ieeexplore.ieee.org/document/8604603 3) Communication enabler tests:

				https://www.norceresearch.no/en/insight/verdens-forste-passasjerfly-for-miljoovervaking-er-norsk 4) Real life validation https://www.facebook.com/groups/1118134231531920/permalink/3941664885845493/ **Survery on communication using unmanned vehicles:** Zolich, A., Palma, D., Kansanen, K. et al. Survey on Communication and Networks for Autonomous Marine Systems. J Intell Robot Syst 95, 789–813 (2019). https://doi.org/10.1007/s10846-018-0833-5, link: https://link.springer.com/article/10.1007/s10846-018-0833-5 **Example of multisystem cooperation using a prototype Norwegian communication technology:** https://ieeexplore.ieee.org/document/7996481 **Tracking underwater tags:** https://ieeexplore.ieee.org/document/8232099 https://ieeexplore.ieee.org/document/8593659 **Long-endurance unmanned vehicle and a buoy example that c an be use as a communication gateway:** https://ieeexplore.ieee.org/document/8962768 https://ieeexplore.ieee.org/document/7485493 **Assessment of 5G and IoT over satellite:** https://www.researchgate.net/publication/337464987_An_assessment_of_IoT_via_satellite_Technologies_Services_and_Possibilities **Enabling the Internet of Arctic Things With Freely-Drifting Small-Satellite Swarms:** https://ieeexplore.ieee.org/document/8533329 **Future concepts:** https://www.ntnu.edu/ie/smallsat/iot-for-remote-areas

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9.5.4 Pollution and Incident Control Priorites

Pollution and Incident Control

Prioritisation and Innovation Survey

Need	Sub-Category	Evaluate the importance/priority of the identified need on a 1-10 scale (10 being highest).	Evaluate the challenge in resolving the need based on the time, money and resources involved (on a 1-10 scale	**Provide any sources of innovation that could be used to help solve these challenges.** These could be in the form of available products, services, and technology from recent projects, or emerging research developments. If possible, please give a suitable reference or weblink.

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			with 10 being the most challenging)	
Technology for dealing with oil spills and pollution	Autonomous technology capable of operation in dangerous and harsh conditions.	8 6 7 8	2 9 8 8	Center for Autonomous Marine Operations and Control Systems: https://www.ntnu.edu/amos/about-amos Norwegian Coastal Adm (NCA) Action plan -2018-2023), ID 2.3 x Underwater unmanned systems would work but have not a sufficient autonomy and remain very expensive... Do you investigate gliders? Remotely Piloted Aircraft Systems (RPAS) for detection and/or verification of oil spills. The use of drones is expanding, but most often limited in range and flight time. The Norwegian Coastal Administration (NCA) has purchased 5 quadcopter drones, operated from 5 vessels of the Norwegian Coast Guard. Includes Infrared sensors (gives day and night capacity) for verification of oil pollution on water. The inventory also includes sulphur-sniffer sensors and a nuclear radiation sniffer sensor.

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				However, we think there is still a gap between how common types of drones are used (on the scene of an accident), and what is today solved by use of satellites and manned aircraft (remote sensing of large geographical areas). Problem: how to solve remote sensing tasks with the use of autonomous or remotely piloted systems, with minimum loss of the flexibility that manned aircraft provides (use of controlled airspace, airport handling, turn-around capability at airports, short notice diversion to other airports, cargo/personnel pick-up and delivery etc.). RPAS systems also used during trials to drop an igniter device for in-situ burning of oil on water. Other areas of use to be further investigated. Within the oil and gas industry, a wide range of sub-sea systems are used. Some specially developed for dealing with spills from wells (e.g. sub-sea chemical dispersion systems). https://www.iogp.org/blog/news/five-years-on-oil-spill-project-achieves-industry-step-change/ USCG R&D projects

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		7 7	8 9	
	Technology for detecting oil under ice	10 8 6 8 5 8 (in and under ice)	8 ? 9 8 8 8	Norwegian Coastal Adm (NCA) Action plan -2018-2023), ID 2.3 x Interesting option, but is a remote technology already identified from planes or satellites? Can a small disposable payload dropped by a plane make its way across the ice??? Relevant links: https://www.iogp.org/blog/news/five-years-on-oil-spill-project-achieves-industry-step-change/ https://www.sintef.no/projectweb/jip-oil-in-ice/ USCG R&D projects

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	Development of user-friendly "Arctic tool box" for oil spill management	10 (10)	8 (1)	Norwegian Coastal Adm (NCA) Action plan -2018-2023), ID 2.4 x **What**: Temperature Active Water (TAW) instalation **Background**: TAW is a technology that alters the pressure and temperature of any type of water (pure, salt, brackish, etc.) w/o any additives to produce a special vapor-droplet mixture that has been proven to be very effective, amongst its many applications, in cleaning engineering and technological equipment of oil and gas residue. TAW also has significant potential as an extremely effective and environmentally friendly way to clean up oil spills at sea. **Availability**: the TAW installation is currently available with limited production volume. Extremely complex as Arctic environment is still largely unknown and very harsh while being also very fragile. Experience from warmer/calmer seas (e.g. Gulf of Mexico) would not help

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		8	10	Arctic Council Working Group EPPR (articles, projects, publications): https://arctic-council.org/en/about/working-groups/eppr/
		6	4	https://oaarchive.arctic-council.org/handle/11374/3
		8	6	Arctic ERMA is an online mapping tool that brings together the available geographic information needed for an effective emergency response in the Arctic. Arctic ERMA supports the efforts of the Arctic Council's Emergency Prevention, Preparedness, and Response Working Group as a platform for data sharing. https://response.restoration.noaa.gov/resources/maps-and-spatial-data/arctic-erma
		7	8	Ongoing efforts to fund Active engagement in US Arctic communities
			7	

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		9 (coupled with training for first responders in remote locations)		
	Satellite data analysis tools for oil spill management	8 10 8 8	2 ? 6 6	Centre for Integraded Remote Sensing and Forecasting for Arctic Operations https://cirfa.uit.no/ Same questions as above when facing ice cover Alteration of sea roughness by oil only proven detectable by SAR radar when sea states are smooth enough (<SS3 typically) EMSA satellite services: CleanSeaNet is a European satellite-based oil spill and vessel detection service which offers assistance to participating States. http://www.emsa.europa.eu/csn-menu.html Kongsberg Satellite Services (KSAT): https://www.ksat.no/no/ About oil in ice:

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		5 9	9 7 - Transboundary issues continue as well as timely info sharing	https://www.ksat.no/news/news-archive/2020/ice-information-in-the-arctic/ https://response.restoration.noaa.gov/resources/maps-and-spatial-data/environmental-response-management-application-erma
	Need for enhanced pollution monitoring sensors	8 8 7 8	5 ? 6 8	Same questions as above when facing ice cover Disposable sensors will raise the concern of heavy metals of their batteries Visual classification of oil on water: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/open-water-oil-identification-job-aid.html https://www.bonnagreement.org/activities/aerial-surveillance

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		5 7 – more critical in remote areas	9 8	There is a need for further investigation on sensors for determining thickness of oil on water. Also there is a need for sensors to support the prediction of spread of diesel oils on water. Ultimately, there is a need for sensors to determine the type of oil (viscosity) on water.
	Enhanced technology for oil recovery under ANA conditions	10 8 8 8	10 ? 7 8	Current floating barriers require smooth sea states (<SS2) not met most of the time in arctic. Have you identified workable solutions? www.syke.fi/projects/mospa2018 Arctic challenges include a wide range of factors like darkness, ice, low temperatures etc. Few resources and large geographical areas give logistical challenges.

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		6 6	7 8 - greater distance for assets and industry responders	Further investigation on enhanced technology for oil recovery and effective in-situ waste handling is needed.
Enhanced and Standardised International Arctic Pollution Regulations	Standardised regulations for prevention of oil spill	8 10 9	8 2 6	Evident way ahead but difficulty to enforce compliance in such remote exploitation sites, in particular in Russia Referring to IMO regulations, and working groups ongoing within IMO (Pollution Preparedness and Response - PPR): http://www.imo.org/en/OurWork/Environment/PollutionResponse/Pages/Default.aspx

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		9 8	3 8– challenges to authority and jurisdiction	
	Enhanced international agreements treatments and commitments relating to nuclear facilities and vessels in the ANA region	8 9 4 -	4 5 7 -	Already initiated with international cooperation in Mourmansk for old soviet-era nuclear subs, evident way ahead but difficulty to enforce compliance in such remote exploitation sites, in particular in Russia Referring to ongoing work within the Arctic Council EPPR expert group on radiation https://eppr.org/expert-groups/radiation/ Defer

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	Demilitarisation strategies in the Arctic region	4 7 4 -	10+ 9 8 -	Increasingly difficult with the evolving Russian sea confrontation doctrine (multiplication of SSN and SSBN patrols closer to EU and US coasts) No Comment Defer
	Regulations on heavy oils in the Arctic region	10 10	5 7	Should come first from agreements under IMO on the reduction of ship exhausts air pollution (the polar route is not today a route for tankers, the main risk is ship tanks and bunkers). The lighter fuels used to de-sulphur the exhaust are also less polluting as presenting a larger evaporating fraction. Because of the sensitive environment of Arctic, an agreement to use lighter sulphur-free fuels should be reachable

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		9 7 -	8 8 9 – presence to ensure compliance	IMO regulations and ongoing work: http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/default.aspx Effective Polar Code implementation to address compliance and enforcement of shipboard spills
	Further development of international decontamination strategies and technologies	4 8 10	4 9 – cost, distance, and technology challenges 10	Unclear (depolluting the sea, or simply the bunker tanks and cooling waters?) Relevant topics: Common Arctic procedures for waste handling and decontamination on site Common regulations for settling of recovered oil/water on site

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	Ensuring all vessels covered by Polar Code or similar regulations	10 6 10	4 7 4	Not workable: the ice melting will probably limit the applicability of the polar code to the winter period, allowing normal cargo ships on the polar routes in summer IMO regulations and ongoing work: http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/default.aspx Review of PC application underway at the IMO
Research to understand Arctic pollution and how to respond to it	Skills assessment of new competences needed to deal with Arctic pollution incidents	10 4 7	8 4 6	(too vague to be assessed) Relevant topics:

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		9 10	8 6 – new training requirements for response teams	Further studies on response methods in Arctic environments (e.g. burning/ dispersion/ mechanical recovery) Relevant articles: https://oaarchive.arctic-council.org/handle/11374/105 Basic skills needed for response in Arctic conditions (knowledge/training) Response to hazardous and noxious Substances (HNS) incidents in the Arctic https://www.itopf.org/knowledge-resources/documents-guides/hazardous-and-noxious-substances-hns/
	Classification of Arctic pollutants and their consequences	8	8	Unclear: which pollutants could appear arctic-specific???

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		6 8 8	3 6 7	No Comment US joint research into the impacts of dispersants in the Arctic
	Research into the effects of a nuclear incident in the Arctic	5 7	5 6	Unclear: please categorize the type of nuclear incident (the fusion of a naval reactor core has no common measure with the release of radioactive cooling water or the loss by a submarine or an aircraft of an unexploded nuclear warhead! Satellites disintegration also possibly involves small nuclear generators) Relevant links: https://eppr.org/expert-groups/radiation/ https://www2.dsa.no/en/

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		4	7	
Pollution Incident Data Sharing	Pollution risk and incident data sharing and analysis	10 10 8 8 8 8	10 1 6 6 6 8 – challenges wrt info sharing capacity	There are already international agreements under IMO and EU to share airlines and maritime incidents http://www.imo.org/en/OurWork/MSAS/Casualties/Pages/Reporting.aspx so this is mainly an issue of compliance and sub-register for Arctic See sub-category "Development of user-friendly "Arctic tool box" for oil spill management" above. Best practices for ship detentions under PSC, and JCPs

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	Further definition of acceptable response times	10 6 5 9	10 9 5 8	Purely theoretical! You should revert it into a plan for pre-deployed response assets: how many needed to keep response time below 10 days/5days/2days etc This should be based on risk and emergency preparedness analysis.
	Need for prevention measures and protocol for dealing with fire on a nuclear vessel			Why so specific? Fire on board a nuclear sub or ice breaker is not a main risk of reactor fusion! Nuclear reactors are at risk in case of major structural accidents (e.g. grounding or collision at high speed, but SSBNs and icebreakers are slow). Fire on board is a major risk for all ships which can result into the loss of cargo and fuel, and the pollution impact is higher with big cargo ships than any other type of vessel. Nuclear vessels have crews extremely well trained including fire-fighting and a very high safety culture. Referring to ongoing work within the Arctic Council EPPR expert group on radiation.

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		8 7 4	7 6 7	https://eppr.org/expert-groups/radiation/ Exercise (possibly) upcoming in Norway in 2021

9.5.5 Navigation and Voyage Planning Priorities

Navigation and Voyage Planning

ARCSAR
Arctic and North Atlantic Security and Emergency Preparedness Network

Prioritization and Innovation Survey				
Need	**Sub-Category**	**Evaluate the importance/priority of the identified need on a**	**Evaluate the challenge in resolving the need based on the time, money and resources involved (on a**	**Provide any sources of innovation that could be used to help solve these challenges.** These could be in the form of available products, services, and

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		1-10 scale (10 being highest).	**1-10 scale with 10 being the most challenging)**	technology from recent projects, or emerging research developments. If possible, please give a suitable reference or web link.
Enhanced ice mapping and navigation systems	Automated system to avoid and investigate alarms	7 4 9 10 7	7 4 8 10 7	www.aari.ru www.marnav.dk www.martecpolar.com www.nautinst.org/publications Training of bridge personnel in using correct radar properties Further development of radar technology for use in ice conditions Direct Access to AARI website Digital Photos and Ice Map
	AI and data analytic tools and apps for advanced ice and route condition forecasting	8 10 10 10 8	8 4 7 8 8	www.aari.ru www.marnav.dk www.martecpolar.com www.nautinst.org/publications Project Extreme earth (MetNo) Software "Ice assist" Polaris (MSC 1519) Further development of systems where observations may be included and shared Need 72h ice forecasting Direct Access to AARI website Digital Photos and Ice Map

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	Technology to ensure systems are not weather affected	8 8 5 10 7	8 3 5 9 7	www.aari.ru www.marnav.dk www.martecpolar.com www.nautinst.org/publications Norsat 3 Further improvement of rapid tasking and delivery of SARScenes. Service "Iceeye" TRANSAS - 4000
	Emergency port identification system and associated logistics planning	5 5 5 10	5 7 6 9	www.marnav.dk www.martecpolar.com www.nautinst.org/publications SAR resources available real-time for users in arctic Availability of emergency ports and logistical useable given the ice condition Might be a challenge to gather different national data in a common system NSRA website and duly updated list of contact

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		5	5	
Enhanced collaboration between ANA stakeholders in Navigation field	Creation of Navigational ship areas of corridors	10 4 6 8 6	10 5 5 7 6	www.aari.ru www.marnav.dk www.martecpolar.com www.nautinst.org/publications Many countries have begun to establish ship corridors. Political priorities might affect the processes Data Exchange traffic between ships and...
	Creation of (electronic) platform for sharing past and current ship and route information	10 8 6 9 6	10 6 6 9 6	www.aari.ru www.marnav.dk www.martecpolar.com www.nautinst.org/publications OLEX and Arctic web is in use for sharing ship and route information Barents Watch might be a suitable platform for information Band width might hamper information sharing COP for navigation/SAR/ports/Ice WX conditions AIS Visual aids

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	Resilience plans for navigation in case of Arctic incident	10 9 8 10 6	10 2 6 8 6	www.marnav.dk www.martecpolar.com www.nautinst.org/publications Risk based approach to navigational planning and real time available SAR resources. Buddy ships SLOT times for shipping All equipment located onboard ice-breakers
	Maps that incorporate indigenous community names	8 2 6 2 6	8 2 4 - 6	www.marnav.dk www.martecpolar.com www.nautinst.org/publications
	Dissemination of available technology to all ANA stakeholders	5 - 8 5	5 - 4 9	www.marnav.dk www.martecpolar.com www.nautinst.org/publications

		7	7	
	Liaison between product developers and ANA end-users to ensure correctly developed and used technologies	8 8 8 7 6	8 2 4 8 6	www.marnav.dk www.martecpolar.com www.nautinst.org/publications One country must be in lead if a common system is established from ARCSAR. User forum/steering group to ensure information between partners Leadership by AARI and NSRA
Enhanced navigation technology	Assistive drone technology	10 4 6 0 (1) 7	10 2 8 10 7	Krylov-centre.ru www.marnav.dk www.martecpolar.com www.nautinst.org/publications Might be used as a communication link Weather dependant Have been tested in many arctic projects Not applicable due to distance

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	Enhanced ANA vessel traffic management systems	10 8 7 10 8	10 5 8 10 8	www.marnav.dk www.martecpolar.com www.nautinst.org/publications Dependant on improved communication and bandwidth in the arctic Warnings/ais/nav information presented from traffic services Alternative ice-breakers of Rosatomflot

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9.5.6 Personnel, Training and Education Priorities

Personnel, Training and Education

Prioritisation and Innovation Survey

Need	Sub-Category	Evaluate the importance/priority of the identified need on a 1-10 scale (10 being highest).	Evaluate the challenge in resolving the need based on the time, money and resources involved (on a 1-10 scale with 10 being the most challenging)	**Provide any sources of innovation that could be used to help solve these challenges.** These could be in the form of available products, services, and technology from recent projects, or emerging research developments. If possible, please give a suitable reference or weblink.

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Development and Delivery of Training Material	Advanced, age appropriate training for crews of vessels (including small vessels)	6 6 5 10 7	8 7 8 5 6	Online courses, Simulator training and exercise, Computer based training Online courses Simulator training and exercise Computer based training Standardisation I.e. video from AECO and Lufttransport: https://vimeo.com/365038803 Mandatory in Iceland; http://www.icesar.com/search-and-rescue/sar-at-sea/maritime-safety-and-survival-training-centre
	Development of advanced, ANA training materials for SAR teams	5	8	Online courses, Simulator training and exercise, Computer based training

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		5 5 10 8	7 5 5 6	Online courses Simulator training and exercise Computer based training Standardisation ACGF, train the trainers course. Could be possible to develop this further. https://www.arcticcoastguardforum.com/news/arctic-train-trainers-course
	Training and technology to fill the language gap	6 6	8 7	Online courses, Distributed and inter-connected simulator training and exercise, Computer based training Online courses Simulator training and exercise Computer based training

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		7 5 10	5 5 6	Standardisation
	Specific training to deal with nuclear incidents	7 7 10	8 7 5	Arctic Council EPPR WG reports RADSAR project reports RADEX TTX scenario and reports ARCSAFE reports Arctic Reihn 2021 (EU project) See ARCSAFE project. https://iasc.info/communications/news-archive/538-meeting-report-emergency-prevention-preparedness-and-response-meetings-june-2019

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		5 4	8 4	
	Enhanced development of Arctic simulators	7 8 8 10 5	8 8 1 5 5	NORLAB, Nord university https://www.nord.no/no/om-oss/fakulteter-og-avdelinger/handelshogskolen/senter/nordlab https://www.nord.no/no/om-oss/fakulteter-og-avdelinger/handelshogskolen/senter/nordlab Already existing. I.e. NORDLAB: https://www.nord.no/en/about/faculties-and-centres/business-school/research-centres/nordlab

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	Further live exercises to train for different types of incidents	7 7 10 10 7	8 8 10, this is costly and many exercises already exist 2 6	ARCSAR livex 2021 Exercise Barents 2020 and 2021 Arctic Coast Guard Forum exercise Polaris Arctic Reihn exercise 2021 ARCSAR livex 2021 Exercise Barents 2020 and 2021 Arctic Coast Guard Forum exercise Polaris Arctic Reihn exercise 2021 Exercise Barents, Barents Exercise, ACGF exercises, SAREX Svalbard exercises, other national and international. Perhaps would be good to have smaller exercises to train specific things, i.e. making camp after evacuation etc.

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				Several live exercises but need for international exercises is recognized by member states of ACGF, to name some: https://www.arcticcoastguardforum.com/
Technology to enhance training and awareness	Age appropriate multi-media technology for emergency situations	7 7 10 10 7	5 7 5 2 7	Apps Social media App Telemedicine would be good to develop further. Need good training. With increase traffic of passenger vessels come new challenges, age of passengers is one of those.
	Collection of information from crew and passengers	8 8	5 8	Need to further develop using new technology as Smartphone APPs and personal tracking devices Apps and tracking

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	involved in ship abandonments	10 10 6	5 2 6	Finnish Red Cross bracelet technology. (look at notes from the Innovation and Knowledge exchange workshop)
Regulations to enhance safety	Formal certified courses for Arctic crew vessels	8 8 10 8	5 5 10, need further regulation 8	IMO certified courses Online courses, Distributed and inter-connected simulator training and exercise, Computer based training IMO certified courses Online courses, Distributed and inter-connected simulator training and exercise, Computer based training POLARCODE, but perhaps need further regulation AECO requires some additional courses from their partners

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		7	8	Would most likely have to come through IMO.
	Regulations to ensure compulsory medical care insurance for all ANA passengers	N/A N/A 1 10 7 8 5	N/A N/A - 5 9 6 6	Don't know the requirement Not applicable
	Standardised protocol for incident investigation and implementation of lessons learned	8	8	Need system for systematic identification and implementation of lessons identified and lessons learned. Arctic Lessons Learned Arena based on the ARCSAR Innovation Arena

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		8 10 10 7	8 5 5 5	Need a holistic system for identifying, processing, implementing and testing “lessons learned” Iceland has such a body, see: http://www.rnsa.is/en/
Enhanced ANA stakeholder communication	Enhanced involvement of indigenous partners in SAR activities	8 7 10	8 7 3	Bring forward and systemize tacit knowledge exchange from indigenous groups and local knowledge from local communities Systemizing knowledge, Overcoming language barriers See Canadian Coast guard example. https://www.canada.ca/en/canadian-coast-guard/news/2019/08/government-of-canada-partnering-with-

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		5 8	5 5	indigenous-coastal-communities-to-enhance-marine-safety-across-the-country.html Also for volunteers: Arctic Rescue Guide Course https://blogi.eoppimispalvelut.fi/arcticguide/course/arctic-rescue-guide/ Local knowledge, most likely, can only increase possibility of a rescue in SAR cases.
	Enhanced sharing of results of ongoing SAR projects within ANA SAR community	8 8	3 9	Use of Social media Use of the ARCSAR web page and Innovation Arena Use of the Arctic Council EPPR WG web page We'll soon need a project to coordinate all the other projects…

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		10 10 7	1 1 4	 Biannual NAMRCC meetings have been for several years, the last one in Halifax in 2019.
	Enhanced liaison with hospitals for emergency incident planning	7 6 10 10 6	5 5 1 2 5	Include relevant hospitals in projects and seminars Inclusion in projects

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