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Interim Report on uptake of innovations and knowledge

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EXECUTIVE SUMMARY

The primary purpose of this deliverable report is to provide an interim account to define and classify innovation, and to show the uptake of innovation and knowledge in terms of the previously identified and prioritised needs. The uptake and barriers are classified in accordance with the mapping of Arctic and North Atlantic (ANA) safety and security need and priority sub-needs developed in ARCSAR Deliverable 2.1 (D2.1). These are replicated in the Annex and Table 1 of this report respectively. Innovations considered are in the form of available products, services, systems, approaches, solutions arising from projects, or emerging research developments. Where significant uptake has yet to occur or uptake has not occurred at the desired rate or level, the barriers to uptake are identified and classified.

Evidence of uptake of innovations of knowledge since the start of the ARCSAR project (specified as the past three years) and barriers to uptake was collected using multiple methods and sources from the ANA stakeholder community, represented by the ARCSAR network and their wider contacts in the ANA security and safety field, as described in Section 2. This resulted in the recording of 101 distinct sources of innovation or knowledge and information on the nature of the barriers to uptake across the need mapping categories from D2.1 (shown in the Table in the Annex). The analysis undertaken in Section 3 shows that the "communications" and "pollution and incident control" D2.1 need categories have the most reported innovations, whereas the "vessel structural and equipment" category has the least, possibly reflective of different technological maturity phases of these topics. Several innovation classification schemes are presented in Section 3, and the recorded innovations analysed according to two established paradigms in the innovation field. This resulted in the observations that the type of innovation varied across the D2.1 need categories, from the "pollution and incident control" topic which shows a predominance of "product-technological" type innovations through to the "personnel, education and training" topic which shows a predominance of the "process-administrative" type innovations. The majority of the innovations, as per normal in an applied field, are classified as "incremental" rather than "radical".

The barriers to uptake of innovations and knowledge are analysed in Section 5, where a gap analysis of the recorded innovations with respect to the priority sub-need mapping given in Table 1 is conducted. This is supplemented by an analysis of the feedback from the ANA stakeholders regarding barriers in each of the six D2.1 need categories. A set of potential barriers to uptake is developed, including the exceptional barrier of the ongoing Covid-19 pandemic in order to analyse the gaps and reported barriers. Whilst all barriers (technological, regulatory, political, financial, Covid-19), both analyses show the same conclusion, that the reported barriers of most concern are in the "regulatory" category, possibly compounded by political considerations. A second reported category of concern is that of "Technological: Required technology exists but practitioners are unaware of it or adequate training is not available."

The analysis of uptake of innovations and knowledge and barrier to uptake contained in this interim report is designed to inform and guide the remaining activities of the ARCSAR project and wider national and international ANA safety and security agendas.

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1 Introduction

1.1 ARCSAR WP2 Tasks

The initial stages of the ARCSAR project, carried out in tasks T2.1 and T2.2 and T2.5 to date, identified a range of Arctic safety and security needs and gaps in current knowledge, practice and provision through meetings, workshops and other practitioner engagement. The findings of these can be found in the ARCSAR documents deliverable 2.1 (D2.1) (Jones *et al,* 2020) and the fourth ARCSAR policy paper 4 (PP4, Cottle, 2020). This interim report will show the uptake of innovation and knowledge in terms of these needs, emphasising the priority need list classified in D2.1, replicated in Table 1. Where significant uptake has yet to occur or uptake has not occurred at the desired rate or level, the barriers to uptake are identified and classified. Additionally, arising issues since the start of the ARCSAR project, including the COVID-19 pandemic are discussed in the context of evolving Arctic and North Atlantic safety and security needs.

PP4 (Cottle 2020), titled 'Needs for Technology and Innovation in the Arctic North Atlantic', provided gaps in four thematic areas of technology, volunteer and community engagement, competence and network development. This data was collected in October 2019 when ARCSAR network members met for a Workshop on Innovative Emergency Response Solutions, Training and Knowledge Sharing in Reykjavik, Iceland.

Deliverable D2.1 (Jones *et al.,* 2020), 'Mapping of practitioner needs for Innovation and Knowledge Exchange in the ANA region', identified needs across six topics related to areas of the Polar code. These are

- Vessel structure and equipment (V)
- Life-saving appliances and sea and cold survival (L)
- Communication (C)
- Pollution and incident control (P)
- Navigation and voyage planning (N)
- Personnel, training and education (T).

This work characterised the types of practitioner needs under different thematic or operational areas, and established if the needs relate to innovation, research, knowledge, or collaboration. The brief descriptions and codenames used for the 75 obtained sub-needs can be found in the table of Appendix 1 (this table is a mapping between D2.1 and PP4).

The following ARCSAR tasks conducted after deliverable 2.1 (with some ongoing through the entire life of the project) supported this interim report:

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Task 2.3 Monitor and select innovations, research, and knowledge. Based on the mapping in Task 2.2, conduct an extensive search of practical and meaningful sources of innovations or knowledge. These could be in the form of available products, services, systems, approaches, solutions arising from projects, or emerging research developments.

Task 2.4 Establish innovation arena on the ARCSAR network platform. Based on the monitoring activities in Task 2.3, establish a user-friendly and highly functioning innovation arena as part of the ARCSAR network platform. The function of the arena will be to match innovations and knowledge with specific needs of practitioners and stakeholders. Monitoring and matching activities will continue throughout the project, with additional information gathered from project events, and through uploading of more needs and solutions on the arena by members of the ARCSAR network.

Task 2.5. Innovation and Knowledge Exchange Events. Hold an annual event for practitioners and stakeholders at the end of Year 1, 2 and 3 to facilitate exchange of information on innovations and knowledge and increase the likelihood of uptake. The first event will introduce the innovation exchange arena on the ARCSAR network and allow practitioners to become aware of innovation possibilities. Subsequent events on 'Innovation and Knowledge Exchange' will have different themes, and will facilitate continuous mapping of needs, monitoring of solutions, and providing a forum where practitioners can engage with innovation providers. Innovation providers will be invited to explain and demonstrate innovative solutions that match with the event theme (centred on specific needs) and to interact with practitioners. Knowledge transfer will be incorporated in several ways: peer-to-peer practitioner learning, learning from local communities including indigenous peoples, workshops face-to-face and on-line from specialists including practitioners, use of case studies and scenarios, and through table-top exercises. Tacit learning will be captured particularly from practitioners, local communities and voluntary groups. Meetings will involve key personnel within organizations involved in SAR- operations. Further innovation and knowledge exchange during year 4 and 5 will take place via the ARCSAR network platform. *Note that due to the disruption and travel restrictions caused by the Covid-19 pandemic, only two of the three innovation and knowledge exchange events have taken place before the date of this deliverable report, thus partially limiting the information available from this task. The outcomes of the third event will be captured in later deliverables D2.4 and D.2.5, the final report on uptake of innovations and knowledge and the ARCSAR practitioners' success stories and case studies book.*

Task 2.6 Monitor uptake of innovations and knowledge. Monitor uptake of innovations by practitioners, and extent of knowledge exchange, through surveys, focus groups, and one-to-one meetings during and following project events held in T2.5 and other relevant project activities. This will be continued throughout the project. Barriers to uptake will be assessed, and shared with practitioners, researchers, technology developers, solution providers in industry, and other stakeholders like policy makers and regulators.

Task 2.7 Report uptake of innovations and knowledge. Produce report on success of fast-tracking uptake of Innovations and Knowledge. This will be shared through stakeholder contact workshops and will form the basis for activities in WP3 to establish future priorities and futures. A position paper will be produced. Success stories of uptake by practitioners, and lessons learned will be promoted through

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the ARCSAR network platform and a case study book in order to meet a wider group of network members and practitioners. Barriers to uptake of innovations will be assessed and reported.

1.2 Prioritized Sub-needs

After gathering information to find and classify the sub-needs it was important, given the number obtained, to identify the priority gaps in Arctic security and safety. Table 1 provides the list of the 17 selected prioritized sub-needs and the relevant values used to acquire them. The values of importance and difficulty are (geometric) mean values obtained from surveying practitioners for 1-10 evaluations. A knapsack model was solved using a maximum size based on a proportion of the total difficulty values of all sub-needs. The difficulty value represents the experts' opinions on factors of time, financial element and other potential complexities. The goals of the model were to maximize the total importance value in the selected knapsack, while also selecting sub-needs from a balance of the 6 ARCSAR topic areas and also the categories the sub-needs were placed in. This sub-need categorisation was based on a 2x2 PICK decision grid (Possible, Implement, Challenge and Keep Back), which used the importance and difficulty values to place the sub-needs in the relevant grid quadrant. These two balancing goals effects can be seen in the table with the sub-needs being split fairly among the topics and the sharing between the categories of implement and challenge. The implement category signifies that the sub-need is of high importance and moderate difficulty, implying that it can be resolved in a short-medium term timescale. The challenge category signifies that the sub-need is of high importance and high difficulty, implying that it will need research effort over a medium-long term timescale in order to resolve it. The keep back category was excluded from selection as it contains sub-needs of high difficulty and low importance. Full details on this methodology can be found in Jones *et al* (2020).

This report on innovation barriers and uptake, while based on exploring the same six topics, is not focussed solely on priority sub-needs and hence provides relevant information across the whole set of sub-needs. However, as the prioritized sub-needs will be part of future ARCSAR collaboration work this report will look to identify anything of relevance to these specific areas.

Table 1: 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**

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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**
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**

2 Methodology for Evidence Collection

Given the range of topics for potential innovation relating to the ARCSAR project the task of gathering evidence was distributed amongst relevant partners. Having established working groups around the six topics the most suitable members involved in this task were challenged with collecting relevant information on uptake of innovations and barriers to uptake.

The focus is on all Arctic safety and security related innovation uptake, however we are reporting the findings based on the 20 needs categories obtained from D2.1. This allows innovations to be grouped easier than by comparing to all 75 sub-needs; where it is not possible to allocate an innovation to a specific need category they will be placed in a section for the related topic.

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The information has been gathered by ARCSAR partners from a variety of possible sources, as detailed in Figure 1. This includes their own knowledge of the subject matter, reviewing the literature, and through structured direct conversation with other relevant experts. These conversations will be of the form of meetings, focus groups, one-to-one discussions, and focussed survey depending on relationship with other experts and the timeframe for data collection.

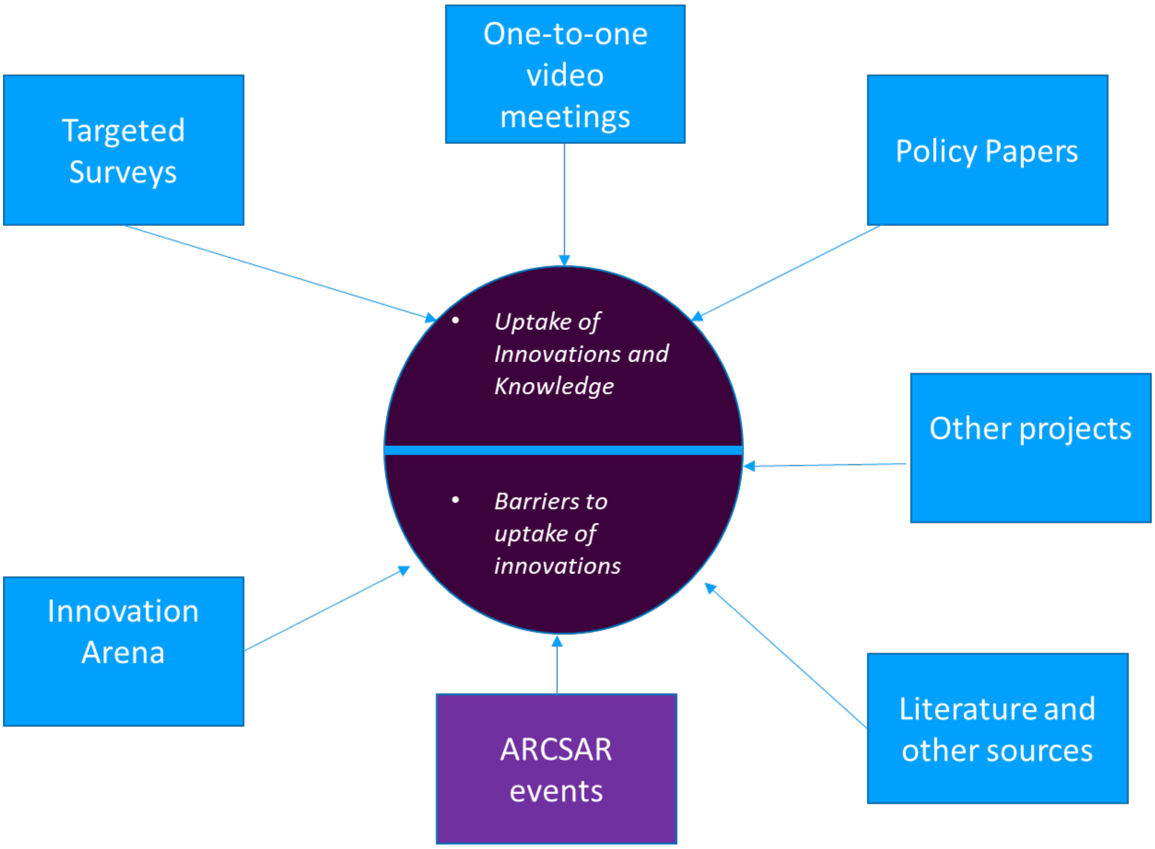

Figure 1: Sources of Information regarding Uptake of Innovations and Barriers to Uptake

Other sources of information for gathering evidence will be from ARCSAR Innovation Exchange Events, and the ARCSAR Innovation Arena. These are from work Package 2 tasks (T2.4, and T2.5) mentioned in the introduction. The first event in Iceland (October 2019) discussed the exchange of information on innovations and knowledge, while the second event in New Zealand (February 2020) was aimed at innovations and solutions for coordination and emergency response in remote areas.

Potentially information will also be sourced from the fifth annual joint Arctic Search and Rescue Tabletop Exercise (SAR TTX). Organized by the Association of Arctic Expedition Cruise Operators (AECO), the Icelandic Coast Guard (ICG) and the Joint Rescue Coordination Centre North Norway (JRCC NN) under the umbrella of the Arctic and North Atlantic Security and Emergency Preparedness Network (ARCSAR) with funding from the European Union’s Horizon 2020 research and innovation programme. A fully virtual event in which participants were invited to play out a scenario in which an expedition cruise vessel temporarily loses steering and grounds on a submerged shelf in a remote part of the Arctic.

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3 Innovation Evidence

This section presents the analysis of evidence of uptake of innovation on a case-by-case basis, with classification given into the Deliverable 2.1 Need Categories where appropriate. A brief context of each source of evidence or knowledge is given in each case, with analysis of the recorded innovations and their uptake taking place in Section 4.

3.1 Vessel Structure and Equipment Innovation Evidence

SafePASS starting August 2019 is an EU-Horizon 2020 project for the next generation of life saving appliances and systems. They aim to provide 'an integrated solution that provides passengers tailored evacuation assistance, assists the crew by enhancing their situational awareness and ability to handle de-skilled equipment, while incorporating fail-safe processes for the evacuation procedure' (http://www.safepass-project.eu/project) (V2A, V2B)

Martec, a partner of the **MONALISA 2.0 project**, demonstrated a test installation on the cruise ship Ruby Princess connected in real-time from Alaska. **The People Tracking System** ensures a quick response to ship emergencies in terms of rapid automatic detection of crew presence in sensitive areas.

A number of new (starting 2018) regulations and amendments for all vessels (new, bulk carriers, cargo), to SOLAS, Polar Code, MARPOL and other conventions: https://marine-offshore.bureauveritas.com/sites/g/files/zypfnx136/files/media/document/Navigating-Statutory-Requirements-2018.pdf (V3C)

3.2 Lifesaving Appliance and Sea and Cold Survival Innovation Evidence

Number of companies offering assistance with PWOM (**Polar Water Operation Manual)** as a paid service. Realistic and relevant planning is supposed to be done through preparation of this manual. Also publication of more information on how to prepare a detailed PWOM. (For example: https://safety4sea.com/wp-content/uploads/2019/11/ICS-OCIMF-Guidelines-for-the-Development-of-a-Polar-Water-Operational-Manual-2019_11.pdf) (L1A)

The three SARex exercises (2016–2018), based on the initiative of the Norwegian Coast Guard and the University of Stavanger, were aimed at studying the gaps between the functionality provided by the existing **SOLAS** (International Convention for Safety of Life at Sea) **approved safety equipment** and the functionality required by the Polar Code. (L1D)

Polar Bear Hair-like wearable fabric:
(https://onlinelibrary.wiley.com/doi/abs/10.1002/adma.201706807) (L2B)

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PPE including dry suits and natural fiber have changed in recent years, with the use of merino wool in this field for both under gloves, and socks making significant changes and work even when wet.

The use of the **Savior Stretcher** (https://www.saviourmedical.com/saviour-stretchers) enables casualties to be lifted, carried in confined space using rope systems, and most importantly the victim with a lifejacket on can by traversed safely in water. The first of its kind.

New reflective material which (Orafol) have developed for SAR operations. The study examined the potential to exploit retro reflective materials to increase the conspicuity of aircrew in a rescue scenario. It includes a review of the capabilities of the aircraft equipment used for Search and Rescue (SAR) in a maritime environment and the underlying concepts relating to conspicuity. A high fidelity field trial was then conducted to evaluate the performance of modified immersion suit in a simulated SAR mission. Recommendations are made on how standards for immersion suit design may be evolved in the future.
https://www.easa.europa.eu/sites/default/files/dfu/EASA_REP_RESEA_2017_2.pdf

Thermal under garments and **new waterproof zips** (YKK), drysuits, and thermal accessories including thermal gloves and skull caps.

Research into human behaviour and decision making when cold
It is well established that exposure to extreme environments, such as cold, reduce physiological and cognitive performance. Cold stress can quickly overwhelm human thermoregulation with consequences ranging from impaired physical performance to death. Recently Yang and colleagues (2021) have demonstrated that exposure to cold air (-10°C) has a significant effect on short-term memory (decreased by 33%), psychomotor ability, and sensorimotor speed. Similarly, exposure to water temperatures below 10°C have been shown to impair memory, reaction time (simple and choice), attention, and decision making – for a detailed review see Jones et al (2017). What is less well understood is how cold environments alter human behaviour and complex logistical decision making. This should be the focus of empirical research moving forward. (L1C)

Research into how well laboratory mannequin tests reflect actual conditions
Laboratory manikins are useful in quantifying thermal exchanges of the human-clothing-environment system and in simulating human thermophysiological behaviours. Unfortunately, existing manikins typically do not take into account the body movement/posture during simulations and this may greatly affect the precision of simulation results (Wang, 2018). In addition, manikins are typically not reliable when simulating a water leak within personal protective clothing. As a result using immersion thermal manikins to provide a single overall measure of clothing insulation will not necessarily distinguish between immersion suits which provide quite different levels of protection for humans exposed to cold water (Balmi and Tipton, 1996). (L1D)

3.3 Communication Issues Innovation Evidence

USCGA Cubesat: In 2018, the U.S. launched two very small satellites, known as **CubeSats**, as a part of the Polar Scout mission with the Department of Homeland Security (DHS). The two CubeSats, named Kodiak and Yukon, would pick up on test signals of emergency position-indicating radio beacons

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(EPIRBs) for 18 months or more. CubeSats, which are often about the size of a shoebox, and smallsats, which typically clock in at about the size of a mini-fridge, have proliferated in recent years, especially in research. Continued barrier of making it into orbit (ie technology fail). (C1A)

Use of **drones to raise Height of Eye**

(i) Possible use of drone as iridium relay if in a place with limited comms, we use drones for ice recognizance and photography.

(ii) **RPAS drones** continue monitoring ship emissions in Danish waters. http://emsa.europa.eu/news-a-press-centre/press-releases/item/3970-rpas-drones-continue-monitoring-ship-emissions-in-danish-waters.html (Innovation arena) (C1A)

Iridium Next, constellation was completed in January 2019 (66 satellites), with a global coverage (https://directory.eoportal.org/web/eoportal/satellite-missions/i/iridium-next) See press release: https://investor.iridium.com/2020-12-15-Worlds-First-Truly-Global-Real-Time-Maritime-Emergency-Service-Launched-by-Iridium (C1A)

Fleet Broadband & RescueNet, Iridium Distress Alerting – GMDSS, tracking USCG MH60 via aircraft tracking websites (C1A)

Svalbard, located between mainland Norway and the North Pole. These areas are known to be plagued by unreliable network coverage with vessels experiencing regular outages in satellite connectivity. Multraship (a Dutch towage and salvage company) recognised it was critical to bridge this gap in communication to maintain its high standards of service and safety. Not only did its fleet need a guaranteed, always-on internet connection they could rely on to operate safely, but the company also needed to support the speeds required to sustain a data-hungry operating environment. Delivering the high data speeds enabled by the Global Xpress Ka-band network, combined with the proven reliability of Inmarsat's FleetBroadband L-band service, Fleet Xpress gave **Multraship** the perfect solution – **ultra-high-speed connectivity with guaranteed 99.9% availability anywhere in the world**." (https://www.inmarsat.com/en/news/latest-news/maritime/2021/frontm-signs-up-as-new-inmarsat-fleet-connect-dedicated-bandwidt.html)

"This collaboration enables ship owners and operators to undertake **real-time telemedicine and video conferencing**, troubleshoot mission critical issues, and access e-learning for improved crew welfare." (https://www.inmarsat.com/en/insights/maritime/2019/pacific-gas-case-study.html) (C1B)

Satellite Geospatial services can support in risk prevention and sea/ice conditions monitoring; new satcom capabilities allow to receive all data and information on-board the vessels for Situational Awareness purposes. (C1B)

IMO amendment: Maritime cyber risk management in safety management systems (https://marine-offshore.bureauveritas.com/sites/g/files/zypfnx136/files/media/document/Brochure_Statuory_Requirements-2021-1009.pdf). (C1D)

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"**Fleet Xpress service**. Fleet Xpress will open a reliable 24/7 communication link between the vessel and shore-based teams with high-speed always-on connectivity from anywhere in the world. Pacific Gas is also integrating cyber security solution Fleet Secure Endpoint to meet International Maritime Organisation (IMO) 2021 cyber risk regulations and protect its fleet from cybercrime at sea." https://www.inmarsat.com/en/about/technology/our-roadmap.html) (C1D)

"**SMARTIce** is a climate change adaptation tool that uses both Indigenous knowledge of sea ice and satellite data to provide communities near real-time information about sea ice thickness and local ice conditions. This project may not have started out as co-production but evolved and is now a collaborative project with Indigenous organizations. www.smartice.org. Just last month it received a Canadian government grant of more than CA$670,000 to make travel over sea ice safer in Inuit regions while continuing work on gathering real-time data on ice conditions." (https://www.cnet.com/features/on-the-frontlines-of-climate-change-communities-are-using-tech-to-keep-tradition-alive/) (C1E)

LEO-based broadband constellations featuring large numbers of small satellites (the so-called "megaconstellations"), OneWeb, Telesat, Iridium NEXT (Network Survey response) (C2A)

"The Canadian Space Agency is looking into **expanding telecommunications above the Arctic**, the Finnish meteorologists say, and could be a good candidate for adding a weather-tracking satellite or imager as well." (https://www.arctictoday.com/continuous-satellite-coverage-arctic-predict-extreme-weather-around-globe/; https://polarconnection.org/oneweb-satellites-arctic/) (C2A)

2019 Arctic Council Task Group on connectivity and telecommunications infrastructure (C2A)

The United States Coast Guard Research and Development Center and representatives from GATR Technologies deployed an **inflatable Ku band satellite dish** on Anvil Mountain near Nome, Alaska, that enabled internet access to remote locations in Alaska during the annual Arctic Chinook search and rescue exercise. (C2B)

"The **VDR Float Free capsule** is a combined EPIRB and a storage unit with an EPIRB battery capacity of 168 hours at -20*C. This VDR Float Free capsule can also be fitted with a heating bracket so to protect and reduce icing." (Innovation Arena) (C3A)

New Regulation: All ships shall have on board a **receiver** for a recognized global navigation satellite system or a terrestrial radio navigation system. Operators include, for example, GPS (USA), Galileo (EU), GLONASS (Russia) and BeiDou (China). (https://www.dnvgl.com/news/imo-maritime-safety-committee-189482) (C3A)

"It was only late last year that the **first truly high-speed internet reached the high Arctic**, in the form of a satellite system serving the needs of the German research vessel RV Polarstern. The multi-state expedition teams housed on that ship, which is currently in the Central Arctic Ocean, north of Svalbard, have been able to make use of internet speeds of over 100 Mbps (megabits per second) to transmit data findings and communicate with the rest of the world." (https://overthecircle.com/2020/04/05/the-internet-in-the-arctic-crucial-connections/) (C3D)

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2019 **Arctic Council Task Group** on Connectivity and Telecommunications Infrastructure (C3D)

The Unites States Coast Guard Research and Development Center and personnel from ComTech Communications installed a **rooftop radio system** during the 2018 exercise in Port Clarence, Alaska. The system is part of a network that can transmit voice and data signals over distances up to 48 miles and will provide responders with important cellphone coverage during the Arctic Chinook search and rescue exercise. The RDC will test a mobile version of the **Next Generation Incident Command System**, a disaster response organization tool that can be downloaded to any computer or smartphone. U.S. Coast Guard photo.

The Coast Guard Research and Development Center has also developed **deployable mobile line-of-sight radio transmitters**, that will provide internet connections to disaster response command posts during a search and rescue exercise in remote areas of the Arctic (C3D)

i911 accurate caller locations (Network member survey response) (C3D)

"On our new rescue helicopters we have **mobile MC capture or mobile phone base station**, so they can actually ... When they come to an area where you don't have mobile phone coverage it can establish mobile phone coverage." (Knowledge and Innovation Event Response) (C3D)

Mackenzie Valley Fibre Optic Project (Completed) - Government of Northwest Territories. Consortium of Ledcor Developments, LTS Infrastructure Services Limited, and Northwestel Inc., completed construction of 1,154-km fiber optic link between High Level and Inuvik in 2017, with connections to six communities in the Mackenzie Valley.

Enhanced Satcom Project - Polar (W6369-180123/B) (Proposed) The Canadian military wants to build a new satellite constellation that would provide 24-hour satellite communications for the Arctic region as early as 2028-29. The program would likely include at least two satellites in an elliptical orbit. Canadian Armed Forces would operate the constellation, but the military plans to cooperate with international allies to help offset the cost of the program. Already, Canada has verbal commitments from the United States, Denmark and Norway to serve as partners on the program. RFI released in 2018.

Quintillion Subsea Cable System - Phase 1 – Completed construction of 1,182 miles of submarine fiber optic cable trunk between Nome and Prudhoe Bay, Alaska with branches into the Alaskan communities of Nome, Kotzebue, Point Hope, Wainwright, Utqiagvik and Prudhoe Bay. Concurrently laid 505 miles of terrestrial fiber parallel to the Dalton Highway between Fairbanks and Prudhoe Bay, Alaska. Phase 2 – Asia, is planned to extend the backbone cable from the Nome branching unit west to Asia, with options for additional branches into Alaska. Phase 3, is intended to extend the subsea system east of the Prudhoe Bay, Alaska branching unit to Canada and on to the United Kingdom. Phase 3 will connect to Northern Canadian communities and will provide a secure low latency route from Europe to Asia.

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Nunavik-Hudson Bay Fiber Optic Project (Proposed) Kativik Regional Government. Installation of an underwater fiber optic cable from Chisasibi to Puvirnituq, with branches off to Kuujjuaraapik, Umiujaq, and Inukjuak. Contract awarded to Alcatel Submarine Networksin 2020. Extension to the remaining communities in Nunavik currently being planned.

Iqaluit Fiber Optic Connection - Government of Nunavut. Plan calls for construction of a 1,700-km fiber optic cable to connect Iqaluit with Nuuk, Greenland. The Government of Nunavut will design and execute the project, which should be completed by 2023. The Government of Canada will provide $151 million to support the project, while the Government of Nunavut has already committed $30 million. Potential for later extension to other communities in Nunavut.

Iridium NEXT (Completed) Iridium has replaced its existing constellation by sending 75 Iridium NEXT satellites into space on a SpaceX Falcon 9 rocket over 8 different launches. On January 11th, 2019 at 07:31 am PST (15:31 UTC) a flight-proven SpaceX Falcon 9 rocket launched from Vandenberg Air Force Base and delivered the final 10 Iridium® NEXT satellites to low earth orbit (LEO). All 10 satellites have successfully communicated with the Iridium Satellite Network Operations Center and are preparing to undergo initial on-orbit testing. The Iridium satellite constellation is unlike any other in orbit and is the only communications network with pole-to-pole coverage of the entire planet. It is comprised of six polar orbiting planes, each containing 11 crosslinked satellites totaling 66 in the operational constellation, creating a web of coverage around the Earth.

EISCAT 3D Radar System - EISCAT_3D will be a radar system for the scientific study of the Earth's atmosphere and ionosphere. Using separate stations in Norway, Sweden, and Finland, based on phased array technology, EISCAT_3D will be able to make three-dimensional measurements of the plasma densities and temperatures and the direction of motion of that plasma, among other things. This will provide scientists a more comprehensive view of the important physical processes. The radar, to be built across Norway, Sweden and Finland by the European Incoherent Scatter Association (EISCAT), should come online in 2021. The new radar system will be set up at Skibotn in Norway, near Kiruna in Sweden, and near Kaaresuvanto in Finland.

Space Norway Satellites - The project is based on a system of two satellites providing coverage 24 hours a day in the area north of 65 degrees N latitude. Both satellites will be launched in late 2022 on a SpaceX Falcon 9 rocket into a Highly Elliptical Orbit (HEO), which will provide full coverage from 65 degrees North, which in practical terms is the area North of the Arctic Circle. Each of the two satellites will carry multiple payloads, and the system is scheduled to be operational for at least 15 years with users able to switch between current geostationary satellites and the HEO satellites. Each satellite will have a mass of 2000 kg and provide 6 kWatt power through their sun arrays. The ground station will be established in North Norway and ensure Norwegian control of this critically important capability.

The Copernicus initiative (formerly GMES; Global Monitoring for Environment and Security), an initiative to create an autonomous European earth observation system.

FinnHEMS' medical and emergency helicopters communication system. FinnHEMS has six bases in Finland, the northern-most one is in Rovaniemi and the southern-most one is in Vantaa. Thus, FinnHEMS helicopters use the same location system as Lapland Safaris. The map software is in the

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memory of terminal devices and business phones, so it does not require an internet connection and does not crash during use. In addition, the accuracy of the terrain maps is sufficient for their operations.

3.4 Pollution and Incident Control Innovation Evidence

NorLense NO-T-1000-S High speed oiltrawl - a fast current boom system that is a containerized one-person-operated system with single point inflation of the boom part. The collection/storage bag also has the function of separating the water from the oil. (https://www.norlense.no/oil-spill-recovery/high-speed-sweep-system/) (P1A)

FLIR thermal camera imaging for detection of oil (https://www.flir.co.uk/instruments/oilandgas/), which is based on the differences between oil and water in temperature, thermal reflection and thermal emissivity. Thermal imaging cameras can not only be used at the time of an accident. They can also be very useful for monitoring oil spills during the oil transfer from oil storage bunkers to oil tanker vessels and vice versa. Thermal imaging cameras are also valuable tools for coastguard or other law enforcement agencies. They can track vessels that are illegally polluting our seas by cleaning their oil tanks in open water. (From application story https://www.flirmedia.com/MMC/CVS/Appl_Stories/AS_0042_EN.pdf) (P1B)

The **NOFI Current Buster Technology** represents a revolution in oil spill containment systems and holds an international patent. It has the unique ability to collect and concentrate spilled oil in current exposed waters or when being towed at high speed. The system is designed with a unique built-in separator to separate contained oil from water, and to retain the oil inside the separator. (https://www.allmaritim.com/en/products/oil-spill-response/high-speed-systems/nofi-current-buster-series) (P1A)

RPAS 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.

"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.)." *Quote from a National Costal Administration Agency.*

RPAS systems are 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. (P1A)

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Within the oil and gas industry, a wide range of sub-sea systems are used. Some are 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/

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 (P1C)

JIP Oil in Ice - The objective of the program is to develop knowledge, tools and technologies for environmental beneficial oil spill response strategies for ice-covered waters.
https://www.sintef.no/projectweb/jip-oil-in-ice/ (P1B)

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/
KSAT's Oil Spill Detection Service: Oil spill detection monitoring by satellite enables a much larger area to be monitored, at a fraction of the cost, compared to surveillance by aircraft, vessel, buoy, or platform radar. https://www.ksat.no/earth-observation/environmental-monitoring/oil-spill-detection-service/
https://www.ksat.no/news/news-archive/2020/ice-information-in-the-arctic/ (P1D)

NEPTUNE EPPR project looking into the possibility of expedition cruise vessels and operators becoming part of the oil spill preparedness and response in the Arctic. This was announced in June 2020. https://www.seatrade-cruise.com/news/aeco-norwegian-coastal-administration-get-funding-oil-spill-response-project

The Grace project focussing on developing, comparing and evaluating the effectiveness and environmental effects of different oil spill response methods in a cold climate. In addition, they developed a system for the real-time observation of underwater oil spills and a strategic tool for choosing oil spill response methods. The final conference report from 2019 can be found at https://www.grace-oil-project.eu/en-US/Final_conference

Circumpolar Oil Spill Response Viability Analysis; COSRVA is intended to provide more science-based decision-making in Arctic oil spill response contingency planning. An additional benefit of the study is the identification of components or methods used in response countermeasures that could be optimized through additional research and development. https://arctic-council.org/en/projects/cosrva/
Technical Report: https://oaarchive.arctic-council.org/handle/11374/1928

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The expanding of **NOR Coastguard capacity** and responsibility regarding towing readiness in Norwegian AOR given by the Norwegian Coastal Administration.

Blue Impact's prototype vessel "Vorax" disperses oil into small biodegradable particles with water jets, removing the need for chemicals https://oceanautonomy.no/oil-spill-cleanup-without-chemicals/

Lamor & Arctia study effectiveness of oil spill response applications in ice. The Arctic Sternmax skimmer will be the oil recovery system used in the joint study developed by Arctia shipping, the Lapland Rescue Department and Lamor. The skimmer, designed by Lamor, is installed on the stern of the vessel.
https://www.lamor.com/news/lamor-arctia-study-effectiveness-of-oil-spill-response-applications-in-ice

"Equipment is currently being upgraded through an **Environmental Response equipment modernization project**, purchasing new equipment, but not necessarily new technology." *Quote from a national Coast Guard.*

Other recent developments, reported from multiple sources, include MBR, ODR, working on implementing a **helicopter dispersant bucket (helibucket) system**

Canada is leading a $40+ Million **Multi-Partner Oil Spill Research Initiative** examining many aspects of spill response science including better understanding the use of dispersants, decanting, in situ burn, oil translocation and oil spill decision support tools.

Policy and protocol recent advances: Marine Protected Areas, Environmental Response Equipment Modernization, Increased monitoring of cruise ship activity.

Outfitting (*a national coast guard*) existing fleet vessels and new vessels with enhanced ER equipment, and Volunteer marine monitors in the Arctic observe and report only.

Heavy fuel oil ban in the Arctic leading to more use of MGO /MDO, but the 0.5% global Sulphur cap, might have led to a new type of fuels (VLSFO) with other properties like high pour point giving more challenges to oil response especially in cold climates

3.5 Navigation and Voyage Planning Innovation Evidence

"For our national meteorological institute in particular we've got sea ice and iceberg hazards, there exists **an ice watch program** which is trying to bring more in situ observations into the **automated satellite classification forecast** middle data sets. It would allow more of a link to the people on the ground, so in the case where someone on the ground needs a situational awareness report the system to send in a photograph of conditions and have someone at the other end respond with the interpretation of what's going on and particularly types of ice and the ice bergs." (Quote from Innovation and Knowledge Exchange Event).

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International Ice Patrol is continuing to develop **models to improve icebergs reports** based on satellite surveillance, satellite imagery and image analysis into operational processes and data streams.

BeiDou Navigation Satellite System - The third iteration of the system promises to provide global coverage for timing and navigation, offering an alternative to Russia's GLONASS, the European Galileo positioning system, and America's GPS. In late 2018 this Chinese navigation satellite system started providing global services with the launch of the third generation BeiDou system (BeiDou-3).

Innovation for AI and data analytic tools and apps for advanced ice and route condition forecasting:

ExtremeEarth EU Horizon 2020 project based on state-of-the-art technologies from the research areas of Remote Sensing, Deep Learning, Big Data, Distributed Systems, Semantic Web and Linked Geospatial Data http://earthanalytics.eu/index.html (N1B)

Polaris (MSC 1519) Guidance on Methodologies for Assessing Operational Capabilities and Limitations in Ice https://www.imorules.com/MSCCIRC_1519.html (N1B)

Innovation for technology to ensure systems are not weather affected:

Norsat 3 - The AISSat and NorSat constellation, Norway has acquired a unique and highly useful tool for assuring surveillance of the vast maritime areas in the north (N1C)

ICEYE company is tackling this crucial lack of actionable information with world-first aerospace capabilities and a New Space approach. ICEYE's radar satellite imaging service, with coverage of selected areas every few hours, both day and night, helps clients resolve challenges in sectors such as maritime, disaster management, insurance, finance, security and intelligence. https://www.iceye.com/company

TRANSAS - 4000 Transas is a global market leader in ship & fleet operations solutions that include bridge infrastructure, digital data and electronic charts services, and applications for access to the real-time information https://www.wartsila.com/transas (N1C)

A Comprehensive Proposal for Shipping Corridors in Canada's Arctic a new policy proposal from The Pew Charitable Trusts, contains eight recommendations to address these shipping-related challenges in the Canadian Arctic https://www.arcticcorridors.ca/2017/11/09/a-comprehensive-proposal-for-shipping-corridors-in-canadas-arctic/ (N2A)

MarineTraffic is the world's leading provider of ship tracking and maritime intelligence. Building on a base of data gathered from our network of coastal AIS-receiving stations, supplemented by satellite receivers, apply algorithms and integrate complementary data sources to provide the shipping, trade and logistics industries with actionable insights into shipping activity (https://www.marinetraffic.com/en/ais/home/centerx:-12.0/centery:25.0/zoom:4) (N2B)

PAME Arctic Ship Traffic Database (ASTD) project has been developed in response to a growing need to collect and distribute accurate, reliable, and up-to-date information on shipping activities in the Arctic https://www.pame.is/projects/arctic-marine-shipping/astd (N2B)

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Indigenous Peoples of the Arctic
https://www.arcgis.com/apps/Cascade/index.html?appid=2228ac6bf45a4cebafc1c3002ffef0c4
(N2D)

Alaska Native Place Names
https://www.uaf.edu/anla/collections/map/names/ (N2D)

3.6 Personnel, Training and Education Innovation Evidence

New training courses: Polar waters basic training and Polar waters advanced training. Range of enhanced courses offered by national coast guards.

Training developed for joint regular exercises with involvement of internal staff and external stakeholders. (T1B)

Complex training on board vessels, operating in the Arctic, based on the seafarer training as an individual person who is responsible for the certain operations during his watch (personal skills training) and training the same person as a team-player (in this case crew-members are considered as a vessel control subsystem and every crew-member is the unit of this sub-system) that allows training collective skills and provide high efficiency of vessels' operation and crew survival in the case of emergency in the Polar waters;

Technology aimed on enhancing training and awareness:

ELSAR (electronic SAR training) as a moodle-platform, which is in the last steps of development;

Polar code bridge simulators and training course for watchkeeping or chief officers and masters of ships operating in polar waters in a distance learning format;

SAR-varsling (SAR-notification) system that connects 11 units and JRCC. SAR-varsling is performed immediately when the situations is considered as rescue operation;

Nødnett (Emergency Net) is a digital nationwide multi-agency public safety network in Norway that provides reliable communication for SAR-professionals and volunteers; (https://www.nodnett.no/en/)

AECO's vessel tracker and contact list which enables expedition vessels to see and contact each other directly while sailing in the Arctic;

Marine training simulators with integrated cloud technology

EPPR online manual guideline for risk assessment

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Trainings for ship-handling manoeuvring under ice conditions, towing under ice conditions

AR technology applied to explore potential safety improvements within passage planning and route monitoring for vessels operating within the Arctic (www.sedna-project.eu/about/innovations/safe-arctic-bridge/). There is no yet formal uptake, but the technology will be presented by the Lloyd's Register at IMO in February 2021

SAR personnel from different entities **visiting expedition cruise vessels**, while at shore, and learn about their capabilities, equipment and SOPs is one of innovative solution to communicate with stakeholders; (T1B)

Joint Arctic SAR TTX, what have already been established as recurring events is a good example of innovative tool aimed to enhance dialogue and collaboration between sectors; (T1F)

Arctic Council EPPR WG reports (https://oaarchive.arctic-council.org/handle/11374/3) (T1D)

ARCSAFE Project - Promoting Cooperation in Maritime Emergencies Potentially Releasing Radioactive Substances **(https://eppr.org/projects/arcsafe/)** (T1D)

RADSAR is a sub-project of ARCSAFE. The objective of the project is to identify possible challenges and further improve national and international emergency preparedness and response related to SAR operations in a radiological hazardous environment in the Arctic. The final report from RADSAR was accepted as a Ministerial deliverable for the Arctic Council Ministerial meeting 2021. The report will be published after the Ministerial. Summary status report for ARCSAFE: https://oaarchive.arctic-council.org/handle/11374/2395 (T1D)

RADEX TTX - ARCSAFE project conducted RADEX 2019 table top exercise in 2019. RADEX 2019 was an international exercise related to rescue operations in radiological hazardous areas and with risk for radioactive contamination at sea in the Arctic. (T1D)

Nordlab - Nord University preparedness management lab an arena for situational awareness and risk assessments, as well as education, research, exercises and tests related to sea, land and air-based emergency response. https://www.nord.no/en/about/faculties-and-centres/business-school/research-centres/nordlab (T1E)

Exercise Barents 2021 is an exercise that will be held to enhance cooperation between Norwegian and Russian SAR and oil spill response agencies. The exercise is held annually to implement the Bilateral Agreement between Norway and Russia. (T1F)

Arctic Coast Guard Forum Exercise Polaris 2019 was one of the largest international Search and Rescue exercises organized in the Baltic Sea in recent years. The exercise also focused on searching for missing persons, ship fire incidents and emergency towing. https://www.arcticcoastguardforum.com/news/arctic-coast-guard-week-marks-end-finnish-chairmanship-arctic-coast-guard-forum (T1F)

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Arctic Reihn (Radiation Exercise in the High North) exercise 2021. The Directorate for Radiation Protection and Nuclear Safety (DSA) is planning, on behalf of the Ministry of Health and Care Services, a national nuclear preparedness exercise to test and verify the emergency response capability in the event of a nuclear or radiological accident in Northern Norway https://www.regjeringen.no/no/dokumenter/meld.-st.-9-20202021/id2787429/?ch=7 (T1F)

Enhanced involvement of **indigenous partners and local communities in SAR activities**: (T4A):

"Finally, the importance of local engagement was a consistent theme in responses …, with implications and suggestions for a number of stakeholders, including volunteers, government officials, policy makers and tourism operators. Establishing cultural competencies that respect local traditions was also seen as important … participants also emphasized the importance of building effective relationships with local communities before incidents occur. This can include **strategies to reduce the strain that is placed on these communities by increased tourism**, and concern for the emotional distress experienced by volunteer responders." (Cottle, 2020)

Canadian Coast guard **"community boat"** example of enhanced involvement of indigenous partners and local communities in SAR activities. https://www.canada.ca/en/canadian-coast-guard/news/2019/08/government-of-canada-partnering-with-indigenous-coastal-communities-to-enhance-marine-safety-across-the-country.html. (T4A)

Also for volunteers: **Arctic Rescue Guide Course**
https://blogi.eoppimispalvelut.fi/arcticguide/course/arctic-rescue-guide/

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4 Classifying and Analysing Innovation Uptake

The term 'innovation' gets to be confused with other terms such as 'improvement', 'invention', and 'novelty'. Kogabayev and Maziliaukas (2017) provide a differentiation between 'innovation' and other closely related terms as shown in Figure 2.

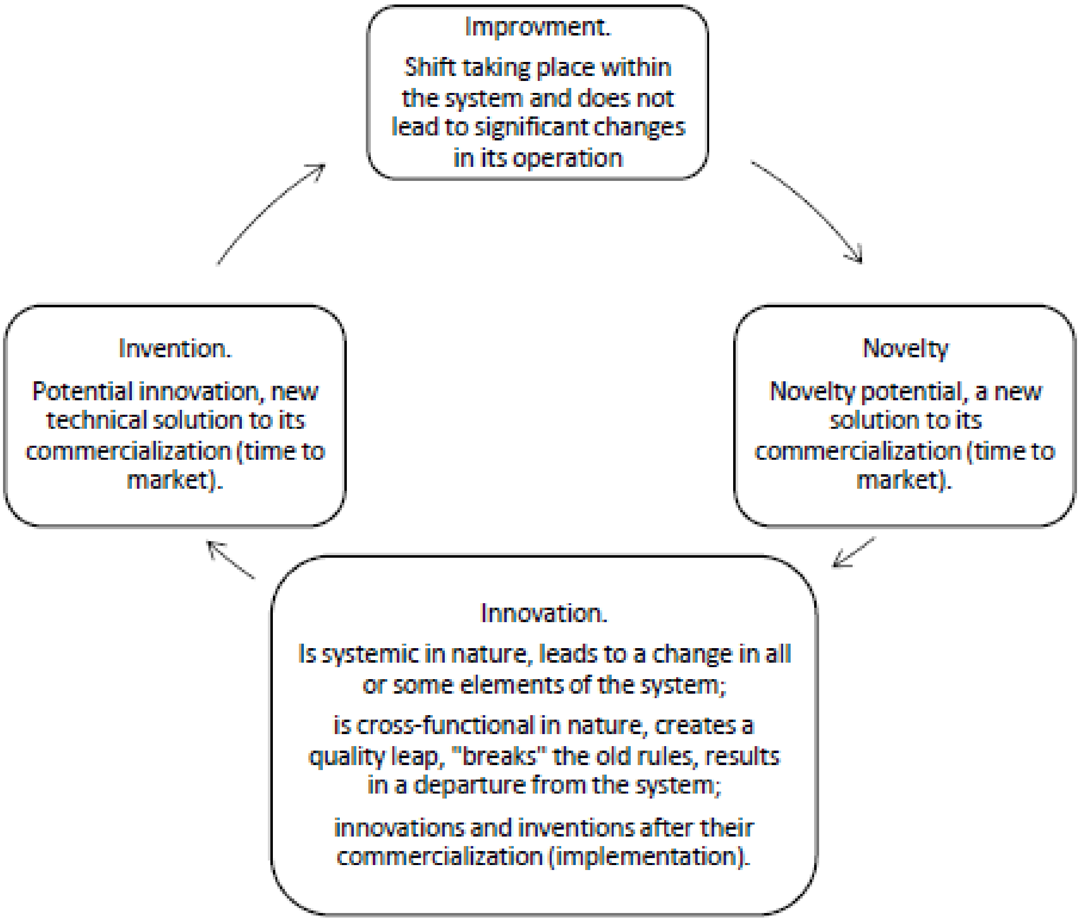

Figure 2: The concepts of 'improvement', 'novelty', invention', and 'innovation'.

4.1 Classifying Innovation Types

With discovered innovations it would be useful to have a system for classification the types of innovation.

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According to Rowley et al (2007), one of the early models of types of innovation was that proposed by Knight, 1967. He suggested that there were four different types of innovation:
(1) Product or service innovation, concerned with the organization's new product or service offerings.
(2) Production-process innovation, referring to the changes to organizational operations and production; this is also usually initiated by technological advancements.
(3) Organizational structure innovation, concerned with the organization's authority relations, communication systems, or formal reward systems
(4) People innovation, relating to changes to the people (staff) within an organization, including changes in staffing levels, personnel, job roles, cultures, and behaviours.

Cooper (1998) then proposed a multidimensional integrative model of innovation as shown in Figure 2.

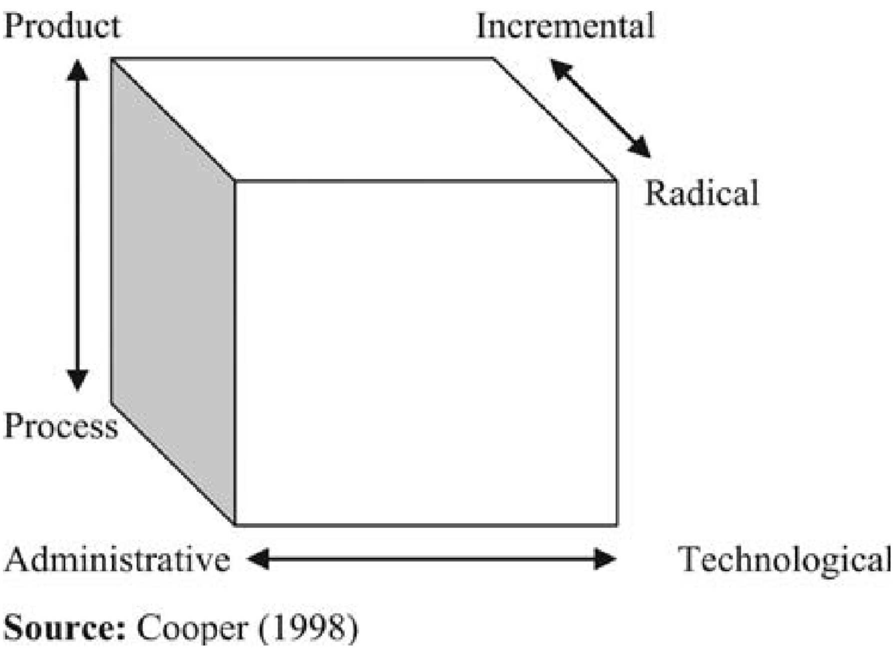

Figure 3 Multidimensional classification of innovation

The work of Rowley et al. (2011) integrated previous frameworks into a mapping tool that clarifies the various terminologies of innovation types. They ultimately produce the figure 4:

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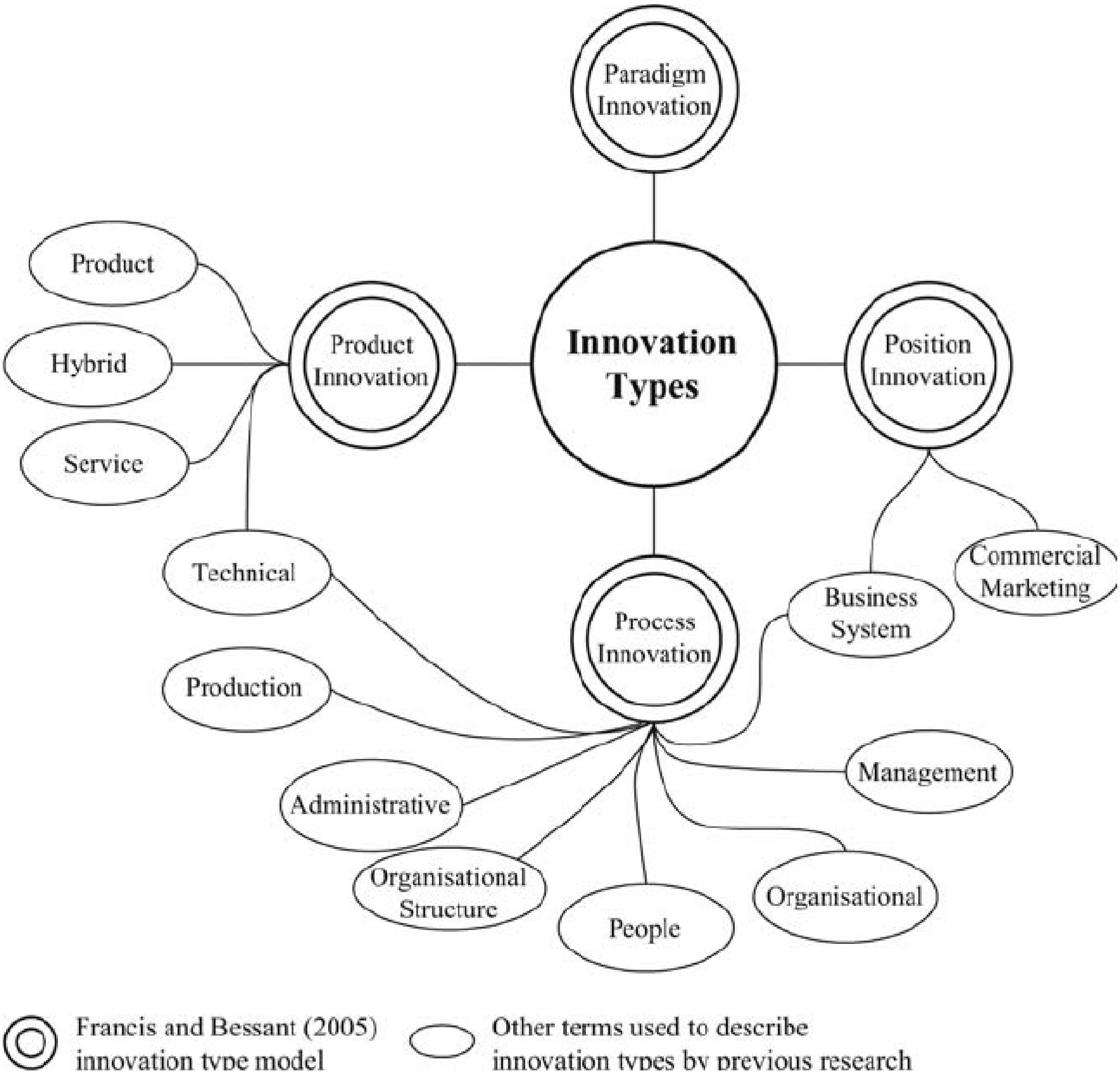

Figure 4: Innovation types.

The four main innovation types; Product, position, process, and paradigm are taken from the model of Francis and Bessant (2005). In the product innovation grouping hybrid innovation is a mix between service and product innovation. The process innovation category has two distinct natures: technical, or organisational (administrative based). Position innovation has been described as commercial or marketing innovation and to some extent business system innovation, which overlaps with process innovation as these deal with both the administrative and marketing side of the operations. There exists a further overlap between product and process innovation with the area of technical innovation. Finally, paradigm innovation, or discontinuous innovation, is when there is a shift to something completely different leading to new innovations in the other areas.

A further classification of innovation is provided in the following table (taken from Davydenko, 2011). This classification scheme will allow us to measure the level of uptake for innovations. The

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‘Classification Signs’ of intensity, pace, scope, and effectiveness provide the measures of the level of uptake and are the most useful. This report being an interim report on the innovation uptake these concepts of maturity, significance, and reach will not be fully known at this point, but it is important to start capturing these measures.

Table 2: Innovation Classifications

Classification Sign	Classification Categories of Innovation
Applications innovation	Managerial, organizational, social, industrial, agricultural, etc
Segmentation, targeting and positioning (STP) process, resulting in innovation	Scientific, technical, technological, engineering, manufacturing, information
Intensity of innovation	"Boom", uniform, weak, mass
Pace of implementation of innovations	Fast, slow, decaying, growing, uniform, abrupt
Scope of innovation	Transcontinental, transnational, regional, large, medium, small
Effectiveness of innovation	High, stable, low
Efficiency innovation	Economic, social, ecological, integrated

The remaining innovation signs (application, STP, and efficiency) may become of more importance when reporting on innovation at the end of the project if a fuller innovation classification is required.

4.2 Analysis of Uptake of Innovation and Knowledge

Section 3 demonstrates a significant level of uptake of Arctic SAR Innovations and enhancement of knowledge in recent years (the surveys and interviews specified the last three years, roughly corresponding to the start of the ARCSAR project), with a 101 distinct innovations listed. A definitive classification of uptake of ANA SAR innovations and knowledge is premature at this interim stage of the ARCSAR project. Nevertheless, this section attempts to draw out some key observations regarding the nature of the innovations and knowledge reported in Section 3 with a view to (i) guiding activities in the latter half of the ARCSAR project, (ii) providing a basis on which to compile the final report on uptake of innovations and knowledge (Deliverable 3.4, due at the end of the project) and (iii) guiding the selection and development of practitioner success stories and case studies (Deliverable 3.5, due at the end of the project.

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In terms of volume of individual innovations reported for actual or potential uptake, the communications and pollution and incident control categories show the greatest individual volume. The volume of **communications** innovation is perhaps reflective of the level of recent technological advancement moving through to actual systems uptake in the field of Arctic communications, together with the recognition of the high importance of enhancements in this field. The importance is demonstrated by, for instance the highly ranked priority sub-needs of *"C1A: Ensuring sufficient satellite coverage of ANA region (Importance: 8.434)"* and *"C1B: Communication Technology to ensure satellite data is accessible within required timescale (importance 8.879)"*. Perhaps a potential future barrier, given the level of satellite systems and solutions reported is the co-ordination of different systems in order to produce single coherent sources of information to aid decision making. Some of the reported innovations report movement in this direction.

The volume of **pollution and incident control** innovations and sources of knowledge is indicative of the high importance placed on the need for innovation in this topic by practitioners in ARCSAR workshops (Jones *et al,* 2020). The responses in this topic area seem to focus on oil and chemical spill response, which aligns with the priority sub-needs such as *"P2A: Standardised regulations for prevention of oil spill (importance 8.769)"* and *"P3B: Skills assessment of new competences needed to deal with Arctic pollution incidents (importance 7.591)"*. However, the focus of the reported oil spill response innovations tends to the product-technological category, whereas the priority sub-needs tend to the process-administrative categories, with the exception of reported innovations such as Arctic ERMA and Neptune EPPR. The other major incident category highlighted in ARCSAR workshops, nuclear incident response, is less represented in the reported innovations.

The categories with a moderate volume of reported actual or potential innovations are Vessel and Structural Equipment, Life-Saving Appliance and Cold and Sea Survival, and Navigation and Voyage Planning. Of these, the least voluminous category is **Vessel and Structural Equipment**. Considering that two of the three priority sub-needs in this category relate to standardisation and collaboration and of the "implement" PICK category (i.e. important but less challenging), it is possible that Arctic practitioners are not focussed on this category as a focus for technological innovation. Nevertheless, innovations in administration (new regulations) and technology (a ship people tracking system) have been reported.

The **Life-Saving Appliance and Cold and Sea Survival** shows a dual response to innovation and knowledge production in this field. Firstly, new research results are being generated in response to the sub-needs of *"L1C – Research into human behaviour and decision making when cold"* and *"L1D – Research into gap between lab/mannequin tests and ANA realities"* , albeit with the Covid-19 pandemic slowing progress for this category of laboratory type research, as discussed in Section 5. The second response is more immediate uptake of technological innovations, some of which are linked to the two priority sub-needs in this category, *"L2B – Technologies to combat heat loss"* and "*L3C – Collaboration on how to meet "5 day" requirement of polar code"*. The latter (L3C) is also supplemented by various SAREX and AECO-TTX multi-national simulation exercises which facilitate process innovation.

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The **Navigation and Voyage Planning** category shows a relatively modest level of reported innovations. The innovations reported tend towards the technological, with an emphasis on the interface with the communications topic. However, there are some reported innovations aimed at the highest priority sub-need N1B*: "AI and data analytic tools and apps for advanced ice and route condition forecasting, Importance level 9.146"* and the priority sub-need "N1C – Technology to ensure systems are not weather affected". There are few reported process innovations across the broad N2 *"Enhanced collaboration between ANA stakeholders in Navigation field",* with some evidence of individual country-level initiatives.

The **Personnel, Training and Education** category shows a intermediate level of reported innovations. Due to the nature of topic and consequent ANA needs, the topics shows a predominance of process and administrative type innovation. There is evidence of design and usage of relevant training solutions on a trans-national as well as a national level, although there is not yet evidence of innovation uptake across all the sub-needs of the broad T2 *"Technology to enhance training and awareness"* need category. There is also significant innovation with respect to the priority sub-need of T4B *"Enhanced sharing of results of ongoing SAR projects within ANA SAR community"* through ARCSAR and other trans-national projects and fora. However, this has not yet led fully to evidenced process innovation uptake in the form of new trans-national regulations and policies. The specific priority sub-need T4C *"Enhanced liaison with hospitals for emergency incident planning"* also does not yet show evidence of uptake of innovation.

With respect to the innovation classification scheme of Cooper (1998) illustrated by Figure 3, a range of innovations across each of the three dimensions (product-process, administrative-technical and incremental-radical) can be seen, however this is not spread equally across each dimension nor amongst the six need categories. As alluded to in the analysis conducted of this section, different need categories will naturally require different profiles of innovations in order to meet their identified needs. It is also helpful to consider the analysis of Cottle (2020) which divides ANA SAR needs into the broad categories of "situational awareness" and "technological", as illustrated by the right side of the mapping Table in the Appendix. The communications category is perhaps the most balanced in this respect as it requires technological product innovations to take place in order allow for an increase in situational awareness mainly process innovations to be possible. Thus, the communications topic can be seen to have a balanced range of process-product innovations and administrative-technological topics.

An example of a necessarily less balanced category is personnel, training and education, which is largely process and administrative dominated, although with the occasional technological training solution proving an exception to this rule. Utilising the Francis and Bessant (2005) paradigm given by Figure 4, the process innovation for personnel, education and training can be seen to include elements of organisational, people, structural, and administrative innovation – with a significant representation of innovate systems or products designed to train personnel, and hence falling into the "people" sub-category. An example of the opposite type of category is pollution and incident control, where a large number of potential and actual product and technological innovations have been identified. This is a positive development, but does not negate the continued need for innovation in the administrative

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and process categories. The pollution and incident control product innovations appear to be spread across the Francis and Bessant (2005) product, hybrid and service sub-categories, with a slight bias towards products over services. The remaining need categories of life-saving appliance and cold and sea survival, navigation and voyage planning and vessel and structural equipment have less innovations to assess in order to derive a pattern, but examples of both product and process and administrative and technological innovation can be found in each of these three need categories, with a slight bias towards product-technological innovation.

Considering the third innovation category of Cooper (1998), incremental-radical, the vast majority of the listed innovations are of an incremental rather than a radical nature, as can be expected in a field where safety and security is of paramount importance. Arguably, the closest to radical innovation can be found in the communications section where several radically different, new ways of achieving communication may fall into this category. There is also potential for some of the new knowledge in the life saving and cold and sea survival and the AI-based ice-forecasting methods in the Navigation category to lead to radical new ANA SAR solutions.

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5 Analysis of Barriers to Uptake of Innovations

Whilst Sections 3 and 4 have listed and analysed the potential and actual innovations in Arctic and North Atlantic safety and security, they have also revealed some need areas and gaps where there exist barriers to the uptake of innovations. This Section further identifies and analyses these barriers. The findings are important for guiding the focus of activities in the remainder of the ARCSAR project, particular where the barriers to the uptake of innovations pertain to a sub-need found to be of high importance in the Deliverable D2.1 need mapping D2.1. The identified barriers will provide part of the framework by which the Deliverable D2.4 (the final report on uptake of innovations) can assess the progress achieved during the ARCSAR project and the future innovation challenges in the field. The identified barriers also should be interest to the wider Arctic safety security field.

Barriers to potential uptake of innovations can be due to technical, cultural, financial, political, and other factors. In terms of technology factors this may mean no such things exist or are not yet ready to be used in the real world. Other factors may include industrial practitioners being unaware that a relevant technology exists. An exceptional potential cause of barriers that has occurred during the ARCSAR project is the ongoing COVID-19 pandemic. The effects of this pandemic have been a barrier to all aspects of society. Work that is reliant on people interacting physically (for example, search and rescue training) has been halted. Meetings and events, which were not able to be held virtually, have also been prevented. Research that is dependent on close human interaction has similarly been drastically slowed or halted. The effect of the pandemic has also brought up the importance of prioritising issues related to remote access, and remote communication across the globe and especially in the Arctic, and it has also raised the importance of innovations related to needs of venerable types of people especially the elderly. Hence, it is expected that innovations in these areas will be accelerated.

The above considerations lead to the following broad need categories of barrier:

- Technological: Required technology does not yet exist
- Technological: Required technology exists but is not yet sufficiently mature to be used
- Technological: Required technology exists but practitioners are unaware of it or adequate training is not available.
- Regulatory: Required technology or process cannot be implemented because it has not been regulatory approved / regulations for its enforcement do not exist
- Financial: Required technology or process is too expensive to widely implement
- Political: Required process or technology cannot be implemented for local, national or uber-national political reasons
- Covid-19 (exceptional): Required process or technology cannot be implemented due to the ongoing Covid-19 pandemic.

A complicating factor in the above is the multi-national regulatory environment of the ANA region, which means that one or more of the above barriers could be relevant in some Arctic nations but not in others.

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A gap analysis of the priority sub-needs given in Table 1 against the uptake of innovations listed in Table 1 yields a few key areas that are not demonstrating uptake of innovation and knowledge. The most significant observation regarding the priority sub-needs that have not yielded evidence of uptake of innovation and knowledge is the predominance of **regulation, standardisation and collaboration** type sub-needs (V3D, L3C, P2A, P2F, P3A, T3C, T4B and T4C)[1]. This indicates that significant barriers to uptake may lie in the regulatory and political categories, which has a significance within any beyond the ARCSAR project. A word of caution is this respect is that the absence of evidence does not definitively mean that uptake does not exist, simply that it was not found amongst the evidence sources listed in Section 2, which include liaison with a significant number of ANA SAR stakeholders. Furthermore, the converse to the above finding is that there exists at least some evidence of uptake across the other, more technology focussed sub-needs since the commencement of the ARCSAR project, particularly in the communications, navigation and voyage planning and pollution and incident control fields. This is a positive finding, although further technological developments are still required to fill many sub-needs across all categories and the need to effectively share and enforce relevant technologies through enhanced co-operation and regulation to overcome barriers is evident.

Individual evidence from SAR stakeholder interviews and collected feedback points to the barriers listed above being in existence at some level in an overlapping sense to inhibit the uptake of innovations and knowledge to some degree. In resonance with the analysis in the previous paragraph the area of **regulatory challenges** was a highlighted issue. Concerns raised include the level of clarity of regulations, as summarised by the following comment:

"Slowness - policy development, time to participate/populate new systems"

"Regulations (non-existent, ambiguous)"

The comments regarding regulations were a mixture of international, and (lack of) transnational regulatory concerns. For instance, the comments:

"Biggest barrier in (country name redacted) at the moment has to do with legislated restrictions on the use of dispersants, in situ burning, decanting and oil translocation. The … government continues to explore options to add these tools to the ER toolbox in (country name redacted)."

and *"International regulations/mandates needed to encourage compliance – at this time standards are old or not updated."*

[1] Regulation, standardisation and collaboration sub-need definitions with lack of evidence of uptake of innovation:
V3D: Enhanced collaboration between vessel owners and SAR and industrial stakeholders;
L3C: Collaboration on how to meet "5 day" requirement of polar code
P2A: Standardised regulations for prevention of oil spill
P2F: Ensuring all vessels covered by Polar Code or similar regulations
P3A: Skills assessment of new competences needed to deal with Arctic pollution incidents
T3C: Standardised protocol for incident investigation and implementation of lessons learned
T4B: Enhanced sharing of results of ongoing SAR projects within ANA SAR community
T4C: Enhanced liaison with hospitals for emergency incident planning

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Illustrate the concerns raised.

Another key point raised by ANA SAR stakeholders was the need for enhanced training in order to take advantage of existing and emerging technologies. This need was evidenced across multiple categories and aligns to the third "Technological: Required technology exists but practitioners are unaware of it or **adequate training** is not available." barrier, with some overlap with the financial barrier. Typical comments with regard to this concern are represented by the following comments:

"Technical understanding or training in how to use the technology - people in the area of "users" are not up to speed in safety and design. The value of research with support from manufacturers is important.

Training - cost (both money and time), access, who is responsible for conducting or monitoring training?"

and

"The different crews need time to learn how to use all technical support systems. An e-learning tool is underway, but in a stressful everyday job, finding time to learn all the potential in these systems is a challenge."

To conclude the analysis of barriers, it can be seen from both the gap analysis and the analysis of individual SAR stakeholder responses that the barriers in the category of regulatory (with some overlap of political) are of greatest concern. The SAR stakeholders also highlight the barrier of access to adequate training. The other barriers (technological, financial, Covid-19) are also mentioned, but to a lesser extent.

Since this this interim report is focussed on showing the uptake of innovation and knowledge in terms of the priority needs given by Table 1 using the PICK method of coding and the overall need classification from D2.1 that is replicated in the Annex of this report. Hence, it is important to continuously map emerging and future innovations together with respect to the initial coding and update it accordingly.

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ANNEX

ARCSAR D2.1 to PP4 Mapping

Table 3: ARCSAR D2.1 to PP4 Mapping

D2.1 Need Category	D2.1 Sub-Category	PP4 Gap	PP4 Sub-Category	D2.1 Match
V1 – Enhancements in vessel design (1)	V1A – Pro-active vessel design and construction to minimise likelihood and impact of emergency incidents	Competence training	Training practicalities	T1, T2, T3
V2 – Enhanced vessel equipment (1)	V2A – Ensuring accessibility of lifeboats/rafts at all times		Training maintenance	
	V2B – Standardisation of requirements (including maintenance schedules) for life saving equipment	Competence Information sharing	Industry relationships and information sharing	V3, L3
	V2C – Enhanced vessel based mass or individual marine rescue equipment		Data accessibility and information sharing	
V3 – Collaboration between vessel and SAR stakeholders (1)	V3A – Formation of a "buddy" rescue system for vessels		Emergency response competence and combined exercises	
	V3B – Learning and transference from other sectors (e.g. offshore energy)		Sharing best practises, lessons learned	

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	V3C – Clarification on points of regulation for vessels	Cultural Competency	Volunteer motivation	T4
	V3D – Enhanced collaboration between vessel owners and SAR and industrial stakeholders		Volunteer competencies and management	
L1 – Understanding and mapping of Survival in ANA region (1)	L1A – Research into mapping of actual realistic survival times by category (age, vulnerability, location, conditions)		Cultural competencies	
	L1B – More nuanced survival planning with respect to type of vessel and incident		Local knowledge and relationships	
	L1C – Research into human behaviour and decision making when cold	Competence Regulations and standards	Operator standards and training	L3
	L1D – Research into gap between lab/mannequin tests and ANA realities		Training standards - tourism and tourists	
L2 – Technologies to enhance Survival (1)	L2A – Enhanced lifeboat / raft technology and design		International standards and competencies	
	L2B – Technologies to combat heat loss	Competence knowledge and experience	Resource awareness	C1
	L2C – Technologies to provide water and combat dehydration		Infrastructure and equipment capabilities	

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	L2D – Enhanced flotation suits suitable for ANA conditions		Arctic knowledge and experience	
L3 – Collaboration between and regulations for ANA lifesaving stakeholders (2)	L3A – Enhanced liaison between industrial developers and SAR practitioners	Volunteers	Volunteer training	
	L3B – Increased numbers of sharing of helicopters to provide adequate coverage		Volunteer motivation	
	L3C – Collaboration on how to meet "5 day" requirement of polar code		Volunteer management	
	L3D – Common training of all crews/workers in ANA in lifesaving/survival issues	Local community engagement	Benefits to community	T4
C1 –Enhanced Satellite Coverage and Capability in ANA region (7)	C1A - Ensuring sufficient satellite coverage of ANA region		Relationship building	
	C1B – Communication Technology to ensure satellite data is accessible within required timescale		Respect for local community	
	C1C – AI and data analytics for processing of satellite data		Local strain	
	C1D – Collaboration between satellite		Local knowledge and experience	

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	stakeholders to ensure maximal coverage and emergency preparedness and protection against cyber-threats			
	C1E – Systems and Training to allow effective satellite data usage by SAR and indigenous communities	Volunteer and local community - operating picture	Operator resource	C3, T3
C2 – Enhanced Quality and Coverage of Broadband in ANA region (1)	C2A – Broadband coverage of the ANA region		Limited resource and infrastructure	
	C2B – Technology to allow Improved broadband speed In the ANA region		Resource awareness, single platform	
C3 – Improvements in local / on-vessel communications technology (2)	C3A – Need for enhanced batteries with longer life for usage in ANA region		Incident management, coordination, combined training	
	C3B – Technology to allow enhanced communications through water in ANA conditions	Volunteer and local community - information sharing	Situation awareness	C1
	C3C – Multi-national isotope detection system and response protocols		Data sharing	
	C3D – Enhanced radio communications coverage		Data accessibility	

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P1 – Technology for dealing with oil spills and pollution	P1A – Autonomous technology capable of operation in dangerous and harsh conditions.	Network inefficiencies	Too much duplication of work	T2, T4
	P1B – Technology for detecting oil under ice		Resource awareness	
	P1C – Development of user-friendly "Arctic tool box" for oil spill management		Need single platform for knowledge	
	P1D – Satellite data analysis tools for oil spill management		Large complicated networks	
	P1E – Need for enhanced pollution monitoring sensors		Institutional memory, maintenance and lessons learned	
	P1F – Enhanced technology for oil recovery under ANA conditions	Network - communicatio n issues	Stress hindered communication	C1, T1
P2 – Enhanced and Standardised International Arctic Pollution Regulations	P2A – Standardised regulations for prevention of oil spill		Excessive incident communication	
	P2B – Enhanced international agreements treatments and commitments relating to nuclear facilities and vessels in the ANA region		Insufficient communication	
	P2C – Demilitarisation	Network development -	Standardized rescue language	T1

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	strategies in the Arctic region	shared understanding		
	P2D – Regulations on heavy oils in the Arctic region		Different understandings and perspectives	
	P2E – Further development of international decontamination strategies and technologies		Different languages	
	P2F – Ensuring all vessels covered by Polar Code or similar regulations		Different frequencies and platforms	
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	Network - information sharing	Information sharing and knowledge transfer	C1, T1
	P3B – Classification of Arctic pollutants and their consequences		Training and capacity building	
	P3C – Research into the effects of a nuclear incident in the Arctic		Efficient dissemination of knowledge	
P4 – Pollution Incident Data Sharing	P4A –Pollution risk and incident data sharing and analysis		Accessible information	
	P4B – Further definition of acceptable response times	Technology - Funds	Funding money	
	P4C – Need for prevention measures and protocol for dealing with fire	Technology - data sharing	Accessible satellite data	C1

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	on a nuclear vessel			
N1 – Enhanced ice mapping and navigation systems (1)	N1A – Automated system to avoid and investigate alarms		Training in data interpretation	
	N1B – AI and data analytic tools and apps for advanced ice and route condition forecasting		Data sharing	
	N1C – Technology to ensure systems are not weather affected	Technology - resource awareness/ lessons learned	Simulators, artificial intelligence	L1, C1, C3, N2
	N1D – Emergency port identification system and associated logistics planning		Passenger tracking system	
N2 –	N2A – Creation of Navigational ship areas of corridors		National SAR database with assets	
	N2B – Creation of (electronic) platform for sharing past and current ship and route information		Experience database/ lessons learned	
	N2C – Resilience plans for navigation in case of Arctic incident	Technology - passenger safety	Two way communication	V1, V2, C1
	N2D – maps that incorporate indigenous community names		Lifeboats	
	N2E – Dissemination of		Better positioning system	

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	available technology to all ANA stakeholders			
	N2F – Liaison between product developers and ANA end-users to ensure correctly developed and used technologies		Evacuating/ transferring passengers	
N3 – Enhanced navigation technology (1)	N3A – Assistive drone technology	Technology - communication capabilities	Drones	L2, C2, N1, N3
	N3B – enhanced ANA vessel traffic management systems		Improved interfaces/ integration	
T1 – Development and Delivery of Training Material (7)	T1A – Advanced, age appropriate training for crews of vessels (including small vessels)		Cell coverage and potential	
	T1B – Development of advanced, ANA training materials for SAR teams		Ground proofing	
	T1C – Training and technology to fill the language gap		Improved imagery/ hydrographic data	
	T1D – Specific training to deal with nuclear incidents		Satellites and radar	
	T1E – Enhanced development of Arctic simulators			

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	T1F – Further live exercises to train for different types of incidents			
T2 – Technology to enhance training and awareness (2)	T2A –Age appropriate multi-media technology for emergency situations			
	T2B – Collection of information from crew and passengers involved in ship abandonments			
T3 – Regulations to enhance safety (2)	T3A – Formal certified courses for Arctic crew vessels			
	T3B – Regulations to ensure compulsory medical care insurance for all ANA passengers			
	T3C – Standardised protocol for incident investigation and implementation of lessons learned			
T4 – Enhanced ANA stakeholder communication (3)	T4A – Enhanced involvement of indigenous partners in SAR activities			
	T4B – Enhanced sharing of results of ongoing SAR projects within ANA SAR community			

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	T4C – Enhanced liaison with hospitals for emergency incident planning			

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