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Offshore service vessels in high arctic oil and gas field logistics operations

Fleet configuration and the functional demands of cargo supply and emergency response vessels

Odd Jarl Borch

Nord universitet
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<tr><td>Sammendrag:
I rapporten ser en nærmere på de funksjonelle behov som bør ivaretas i forsyningskjeden for offshore servicefartøy knyttet til olje og gass operasjoner i arktiske farvann. En ser nærmere på spesielle utfordringer på felt i polarkode-områder med ekstra fare for is og ising, og med lite infrastruktur tilgjengelig. Det fokuseres både på godstransportbehov og på krav til fartøyers multi-funksjonalitet hva angår beredskapsfunksjoner.</td><td colspan="2">Emneord:

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Offshore logistikk
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<tr><td>Summary:
The report looks into the functional demands of offshore service vessels providing field logistics and safety and preparedness functions for offshore drilling rigs and installations. It elaborates on the operational demands in the Arctic waters, and reflect on the roles that offshore service vessels may play.</td><td colspan="2">Keywords:

Oil and gas operations
High Arctic regions
Offshore service logistics
Emergency preparedness
Vessel functionality
Fleet configuration</td></tr>
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PREFACE

This 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” is a result of the project *“Operational logistics and business process management in High Arctic oil & gas operations”* (OPLOG). This project has emphasized operational logistics management for oil and gas fields in the Arctic, with a special focus on innovative business process management in the supply chain of offshore exploration and exploitation.
The Oplog lead partner has been the Business School at Nord University in Bodo, Norway. Research partners have been Cyprus University of Technology, the University of Stavanger, the University College of Haugesund/Stord, the University of Southampton Solent, and UiT-The Arctic University.

The project is funded by the Norwegian Research Council and the industry partners DOF ASA, ENI Norway, Nor Supply Offshore, Troms Offshore, and Vard Design.

In this report, we look into the functional demands of offshore service vessels providing field logistics and safety and preparedness functions for offshore drilling rigs and installations. We take as the starting point the characteristics of different Arctic sea regions. We look at the demands of operations in different types of Arctic waters, and then discuss the functions that offshore service vessels may fulfill. We also reflect on the technological solutions available, including environment friendly engines, equipment, winterization and ice class demands in different areas of operation.

In the last part of the report we discuss the fleet configuration related to different sea areas. We reflect on the number of functions integrated into one vessel, versus several more specialized vessels, and the types of vessels to bring together, especially related to operational areas with limited infrastructure.

Comparisons are made between operations in different kind of Arctic waters in from Greenland and Norway to Northern Russia.

We thank the partners Vard design, ENI, Troms Offshore, DOF, and NSO Nor Supply Offshore for their crucial contribution to the project. A special thanks to Østen Mortvedt, founder and former managing director of Troms Offshore. Without his support this project would not have been realized.

Bodø, Norway, January 30. 2018

INNHOLD

EXECUTIVE SUMMARY

The Arctic sea regions hold significant amounts of oil and gas. Oil and gas exploration and exploitation in the Arctic face different challenges compared with operations in regions with a more pleasant climate and a well-developed infrastructure. The vulnerability of the Arctic nature also call for special measures for all commercial actors.

For offshore oil and gas operations in this region, transport of cargo and personnel may be challenging. Operations in the Arctic not «business as usual». The development of all the Arctic regions, although differing by various climatic conditions, have proved challenging as to the need for tailor-make and the related costs.

Thus, the shipping industry together with the rest of the maritime industry and the oil companies have to focus on finding the best-suited vessels for their offshore service efforts. Some areas are workable with modifications of present technology while other areas demand radical innovation and cooperation.

The special demands for the Arctic is also acknowledged by the governments and the petroleum authorities of the Arctic nations. More scrutiny and regulations are at hand. The oil and gas industry has to take additional steps to safeguard the operations including the field cargo supply, and create adequate SAR and oil response measures.

Logistics is about moving and storing goods or persons from one point to another on to a final destination. This includes tools for movement in several steps, intermediate points for storage/waiting, and tools for communication, coordination and control. Supply base locations and the fleet configurations represent an extra challenge the more they move towards the North and to the East from the Norwegian Barents coast line.

More tailor-made vessels are necessary for winter operations north of the present Goliat field. However, as tailor-made vessels for the Arctic regions are costly, and the market is limited, there is a significant risk for the shipping companies that the oil companies have to take into consideration in their chartering regimes.

The offshore shipping industry has to be entrepreneurial in meeting new demands through developing and operating vessels capable of serving in deep waters, areas with limited infrastructure and long distances to base, as well as manage extreme weather. Among the operating areas, the High Arctic waters may represent the most challenging arenas.. The most distinct High Arctic areas defined within the Polar code convention, in the Norwegian Barents Sea from The Bear Island and upwards where the risk of sea ice is present. ENI has at the Goliat field stimulated to significant R&D and knowledge sharing among the shipping companies involved. Further north, the need for joint R&D efforts in the whole supply chain is crucial.

When it comes to all-year operations, the complexity ad turbulence of the Challenging and Extreme Arctic regions make the functionality technology need “sky rocketing” compared with the close to shore operations in North Sea. The high complexity and volatility in an High Arctic environment demand a very broad resource base and the bundling of both high tech physical resources. Increased complexity due to a broad range of stakeholders, institutional arrangements and other factors call for a broader range of services including personnel transport, depot functions ice management, emergency landing platforms, and a number of units involved for emergency preparedness response.

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 multi-functional vessels high ice class, extra winterization, and comfort class notations, and a crew with additional education training and core competence. More costly vessels with ice class and icebreaker capacity have to be included even in summer operations. Winter operations demand 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.

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 implying mostly 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 multi-functionality of vessels and multi-competence personnel have to be included and trained in realistic environments

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 long planning and innovation period for the most challenging fields. The operators and the petroleum authorities should see to that significant R&D is taking place including the whole maritime value chain, with the goal of achieving a sustainable, safe and efficient operation in a region where there are no failure quota.

1. INTRODUCTION

Oil and gas regions in the Arctic. There are 19 geological basins making up the Arctic region, the main ones illustrated in figure 1 below. The main offshore activity has taken place in the Alaskan Northern Slope close to the Arctic Ocean, the Chukchi Sea and the Beaufort Sea, in the New Foundland region, the Barents Sea basin, and eastwards with significant Russian activity in shallow water, among others in the Pechora Sea.

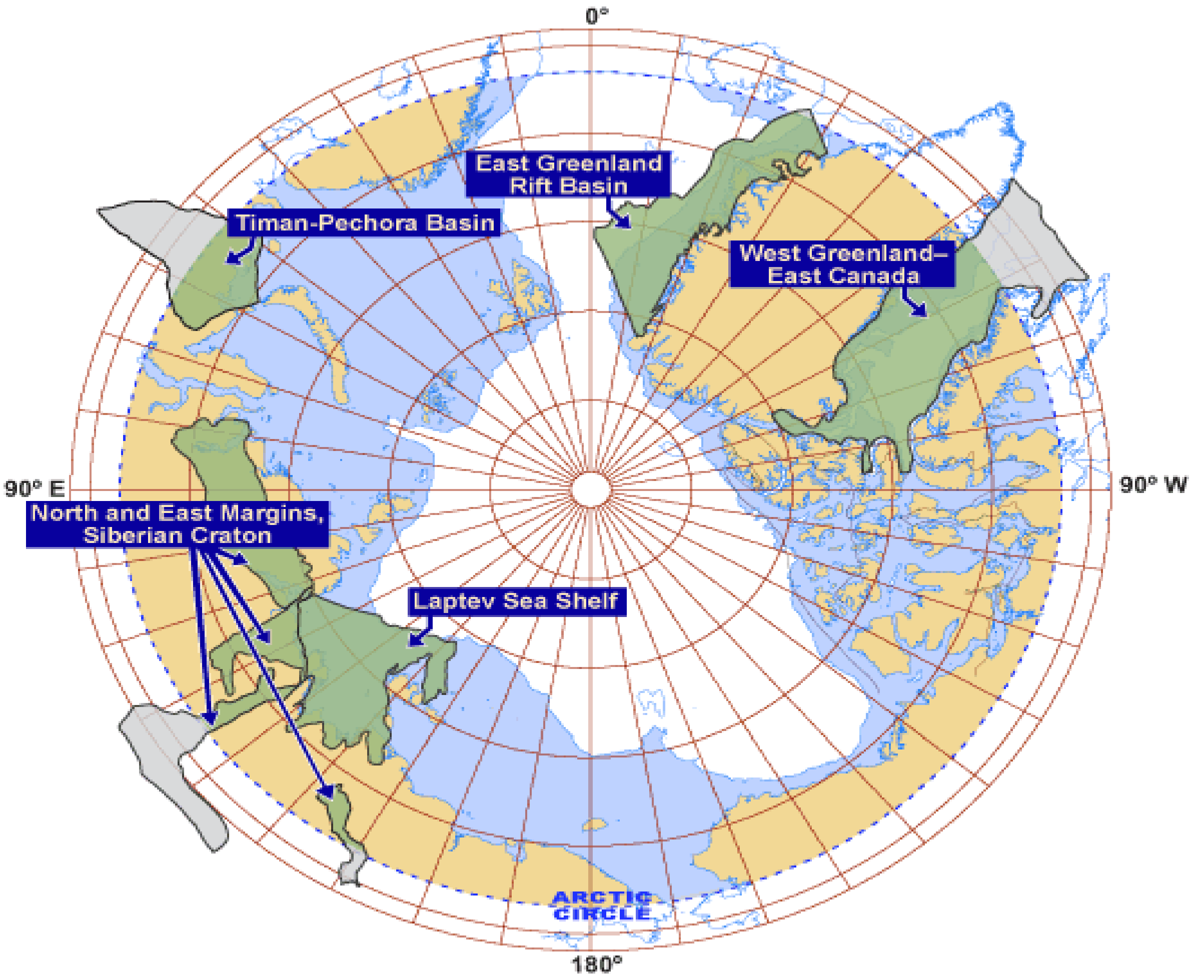


Figure 1. The Location of Arctic Basins (Source: USGS)

There have been an increasing interest in oil and gas exploration in the Arctic even though the interest for exploration and exploitation of petroleum resources in Arctic sea areas is fluctuating with the international petroleum prices. Several major players like Exxon Mobil, ENI, Shell, Statoil, Rosneft and Gazprom have significant experience from Arctic waters. We also find a broad range of newcomers such as the oil company Cairn with their operations on the West Coast of Greenland, and DEA and OEM in the Norwegian Barents Sea. In the Norwegian Barents Sea, there are 36 companies with ownership in licenses and 17 operators (2016).

Several of the offshore service vessel ship owners have experience from operations in the Arctic waters, and many of the offshore service vessel crews have experiences from Arctic fishing trawlers, research vessels, explorer cruise and coast guard. This experience is extremely important for a safe and efficient operation as stated in the new Polar code from the International Maritime Organization where this competence has to be formalized through specific courses.

The trend has been that the oil and gas industry is moving towards more challenging fields:

– From near coastal fields to more remote High Arctic fields
– From summer exploration, to all year production

For offshore oil and gas operations in Arctic region, transport of cargo and personnel may be challenging. Operations in the Arctic not «business as usual». The development of all the Arctic regions, although differing by various climatic conditions, have proved challenging as to the need for tailor-make and the related costs. The Arctic needs significant adaptation in technology and operational mode. Thus, the shipping industry together with the rest of the maritime industry and the oil companies have to focus on finding the best-suited vessels for their offshore service efforts. Some areas are workable with modifications of present technology while other areas demand radical innovation and cooperation. The special demands for the Arctic is also acknowledged by the Arctic governments, including the Norwegian Petroleum Authorities.

> *Good processes and optimal solutions is not achievable in the Barents Sea without cooperation between companies… not the least on transport solutions...*
> (Managing director Anne Myhrvold, The Norwegian Petroleum Safety Agency)

Also, the oil and gas industry has taken steps to safeguard the operations including the field cargo supply and create adequate SAR and oil response measures. However, as tailor-made vessels for the Arctic regions are costly, and the market is limited, there is a significant risk for the shipping companies that the oil companies have to take into consideration in their chartering regimes.

Continuous product improvement. To achieve a sustainable competitive advantage in Arctic operations the quality of the products has to be improved on a continuous basis through innovative and entrepreneurial action. The oil and gas industry and its suppliers have experience from offshore operations since its early start in the Mexican Gulf in the fifties. The next significant step was the start of operations in the North Sea that forced the invention of new adapted technology to the weather and wave conditions of this new exploration area. A significant contributor to the progress of efficient and safe transport has been the ship designers, yards and equipment producers together with the offshore service vessel industry developing more advanced service vessels increasing both the quality, speed and efficiency for the North Sea and Norwegian Sea. We now experience a similar step in the exploration of the Northern Arctic or High Arctic regions.

"Operations in the Arctic are complex and need more advanced technology. Successful operations depends on close cooperation between the operator and the suppliers of vessels" (HSEQ manager major oil company on Norwegian shelf)

Challenging waters and the need for innovations. The oil and gas industry has continuously moved the borders of operation into deeper water, more remote areas and areas with a lack of infrastructure in search for new oil and gas resources. For offshore operations, this has put a heavy strain on the maritime industry and especially the offshore service vessel industry serving oil and gas companies with logistics services stand by support, towing and complex underwater operations. The offshore shipping industry has to be entrepreneurial in meeting new demands through developing and operating vessels capable of serving in deep waters, areas with limited infrastructure and long distances to base, as well as manage extreme weather. Among the operating areas, the High Arctic waters may represent the most challenging arenas. We define High Arctic as areas north of the Arctic Circle where cold climate has a significant influence on the operation in the form of fog in the summer time, snow, darkness and icing in the winter time, and eventually sea ice both in the summer and winter time. The most distinct High Arctic areas defined within the Polar code convention, in the Norwegian Barents Sea from The Bear Island and upwards where the risk of sea ice is present.

Extensive research lies ahead.
We know a lot about conditions in the far North, and a great deal about what we need to know more on.

.. We will emphasize the robustness in every project...
We will in particular scrutinize the plans of the newcomers

(PSA-Petroleum Safety Authority Norway

Advanced technology. In the Arctic region, operations are challenging and costly due to special technology demands, the needs for extra capacity and redundancy for risk reduction. The lack of or distance to adequate infrastructure such as harbor capacity, suppliers with necessary stocks, air and land transport capacity and communication facilities make the supply chain a challenging arena, and the vessel may play a more important role than normal.

The IMO International Maritime Organization claim that ship operations in cold climate regions will require:

specially designed ships and equipment, as well as crew with special competence. The demands within the Polar code that shall provide "*Safety of navigation and prevent pollution from ship operations in Arctic ice-covered waters*
... is best achieved by and integrated approach which covers design, outfitting, crewing and operation".

..The guidelines recognize that safe operation in such conditions requires specific attention to human factors including training and operational procedures

The Polar code emphasizes design, outfitting, crew competence and operational routines, areas where not the least the Norwegian maritime cluster has been good in combining. Now we need an increased quality focus in providing specialized offshore products for the Arctic. Advanced systems to deal with multi-functionality, advanced technology to serve operations that are more complex and function in cold climate, and safe and sustainable operations with a broad range of stakeholders looking over your back. Research networks for the creation of competitive advantage from composite product packages should be in demand, In addition, close cooperation between maritime offshore customers and subcontractors, and the companies has to highlight the development potential of the offshore companies in increasing the dynamic capabilities of the offshore companies towards continuous concept improvement

At the Goliat field in the Southern part of the Norwegian Barents Sea the operator ENI started a broad range of R&D projects within HSE, environment issues, subsea technology, cold climate materials and processes, drilling, reservoir, technology, geology and operational management.

See: http://www.eninorge.com/no/Teknologi-og-innovasjon/Forskningsprosjekt---oversikt/

Central questions to be asked are:

1) What are the characteristics of the different Arctic sea areas?
2) What are the central offshore service challenges of these sea regions?
3) What functions have to be taken care of within the offshore service fleet?
4) What technology is available for the offshore service fleet in the different sea regions?
5) What functions should be integrated in each vessel?
6) What tasks should be covered by the pools of vessels hired in each field?
7) What are the innovation priorities as to functionality and technology?

2. OFFSHORE LOGISTICS

Logistics is about moving and storing goods or persons from one point to another on to a final destination. This includes tools for movement in several steps, intermediate points for storage/waiting, and tools for communication, coordination and control. The logistics system includes:

1. A supply chain including all the chains that a unit goes through on its way from A to Å
2. Means of transport moving the goods or persons from one point to another
3. Storage/hub functions serving as a buffer for units in transit
4. Systems for documentation and preparing goods and personnel for the transport including safety precautions
5. A unit carrier
6. Exchange of information between the different parts of the supply chain
7. Management, coordination and control of movements
8. Follow up laws, regulation and special procedures from governments and/or customer

The logistics system will vary according to cargo volume, distance, transport alternatives, frequency, time frame, how fast it should be delivered, sensitivity of unit transported, the need for tailor-made transport, and not the least the environment, including institutional arrangements, government laws and regulations, interest groups, etc.

The different phases of offshore oil and gas exploration, construction and production creates challenges as to transport and storage including shore supply base warehouse and inbound/outbound logistics, vessel transport capacity and routing, and storage capacity and inbound and outbound logistics on offshore platform/installation
The more complex, high cost the operation the more need for fast and timely deliveries. The logistics department of the operator has to calculate cargo needs based on actions involved, number of days of operation, the challenges of the reservoir, the size of the rig, the number of persons onboard, and the distances and working conditions for the platform supply vessel. In the Arctic waters, a special challenges is related to areas with long distances combined with bad weather (wind, waves and visibility), icing and ice. These conditions may lead to

planning problems, delays, and a need for a higher class of vessels. As a result of these conditions, there may be special regulations. Among others, the Polar code represent a factor that influence on the type of vessel that has to be chosen.

The different tasks to be performed within a logistics system are shown in the table below:

Supply chain management

- Movement of materials from source to end consumer at rig
- Domestic and international transportation/air and sea freight
- Warehouse and Storage
- Return freight handling
- Waste handling

Supply base management

- Accurate delivery of all materials from the supply base to the drilling location and vice versa
- Timely delivery of all materials from the supply base to the drilling location and vice versa
- Warehouse and yard management
- Materials management
- Crew change
- Waste disposal
- Provision of fuel
- Supply of provisions (water, lubes etc.)

Marine services

- Transshipment of materials /ship to ship transfers
- Mobilization and demobilization of rigs and vessels
- Provision of Manpower
- Vessel agency
- Chartering
- Provision of fuel

• Marine surveys Oil and Gas services • Safety inspections • Cargo Carrying Units (CCU's), • Manpower, fabrication, equipment rental and procurement. • Marketing, bidding, license provision, customs consulting and billing

Table 1. Offshore logistics tasks

Several actors are involved at the rig side including the oil company as operator, rig owner, and subcontractors. At the shore side there is the supply base operators and the cargo transport providers to and from the supply base. In between there are PSVs hired by the operating oil company taking care of the transport tasks and on some occasions temporarily serving as extra storage capacity for the rig Vessels hired on time charter where the oil company as charterer pays the bunker and harbor costs. The cost of hiring a PSV may vary from 100.000-250.000 NOK per day depending on the market, while the cost of the rig are several million NOK per day. One challenges with operations in the High Arctic is the need for special tonnage. This means that new vessels have to be designed at high cost and with high market risks in a period with financial difficulties. This may imply that the oil companies as operators may have to go for more long-term contracts than normal in other regions like the North Sea.

The creation of a new logistics platform for the High Arctic may result in significant extra investment costs. For the Johan Castberg field establishment of supply base services, consumption material, helicopter services, preparedness and supply vessels amount to 2,2, billion NOK (2016)[1]. In an offshore oil and gas, logistics system there will be several actors involved as shown in the figure below:

[1] Agenda Kaupang. Utbygging og drift av Johan Castberg. Samfunnsøkonomiske konsekvenser. Rapport 14.6.2017.

The managerial steps included in the field logistics are listed in the table below:

1. Coordination day-to-day activity operation
2. Platform management input delivery needs
3. Platform cargo lists/orders
4. Storage planning
5. Order to base effectuation
6. Inbound logistics to base form suppliers
7. Ship coordination – sailing orders
8. loading/discharging
9. Ship servicing
10. Outbound/inbound steaming
11. Safety zone operation
12. Coordination at base, within owner companies, and government agencies

Table 2. The offshore field logistics management chain

In this study, we will focus especially on the unit carriers and means of transport to a destination offshore. For offshore operations a floating rig, vessel or a fixed installation is the destination. On its way, the goods as well as persons may have used several types of transportation. The final leg must, however, use vessels or helicopters. For cargo transportation, the platform supply vessels play a central role including both dry and liquid bulk capacity in tanks, and deck cargo capacity. The platform supply vessel may also serve as a temporary storage due to limited storage capacity on the rig. The designated supply base for the field is the starting point for the PSV, but it may also be used for transport from other points of departure.

The platform supply vessel or more specialized vessels are also used for personnel transport especially when conditions are bad for helicopter flights. However, due to safety precautions, this type of transport is not very acceptable, but may be performed on certain occasions and locations.

The third logistic task related to a field is the emergency preparedness logistics. This includes transport of equipment and personnel to a site for example for search and rescue of people and oil response equipment. The vessels may also take part in the emergency response.

1. The operation may take place in very challenging waters
2. The need for fast mobilization and delivery
3. Equipment has to be carried from special depots
4. demanding transport of advanced equipment and personnel
5. the use of equipment and the operation may be very complicated and characterized by uncertainty and chaotic conditions
6. improvisation may be needed
7. the transport and operation may put heavy strain on the crew and other personnel
8. the operation may involve risk for the personnel involved
9. lack of infrastructure may hamper the response
10. Much coordination with other units and organizations are needed
11. Special standard operating procedures are to be applied
12. the operation may go on for a very long time
13. There will be a return cargo in the form of dead or wounded persons, and dangerous goods such as recovered crude oil

Table 3. Emergency preparedness logistics

The emergency preparedness managerial tasks included in an emergency operation is shown in the table below.

1. Surveillance-guarding and alarming
2. Mobilization of different tiers of response
3. Coordination of resources fleet-land base
4. Leaving control to specialized forces for oil recovery (in Norway: NOFO) and government agencies (MRCC, Coastal Administration, paramedics, police, fire brigades, etc.)
5. Running of SAR, ORO, evacuation, fire operations together with external actors
6. Evacuation and transport to shore
7. Lodging survivors and next of kin
8. Providing access for media
9. Normalization and evaluation

Table 4. The emergency preparedness managerial tasks

Based on the tasks above there has to be a calculation on the number of supply vessels needed. The table below shows the most important figures in this calculation:

1) Opening hours base –daily -week
2) Average percentage deck capacity used – from base
3) Average percentage deck capacity used – from platform
4) Average percentage bulk capacity used – from base
5) Average percentage bulk capacity used – from platform
6) Average number of hours for discharging and loading at base
7) Average number of departures from base weekly
8) Number of hastened deliveries per month
9) Time from base to platform
10) Distance from base to platform
11) Average number of hours for discharging and loading at platform
12) Average number of hours waiting time platform
13) Number of days delayed/stop because of bad weather a year
14) Number of days per year as back up for stand by vessel
15) Number of days per year active for preparedness exercises
16) Number of days per year away for maintenance/yard per year
17) Bulk capacity needed for each vessel
18) Deck capacity needed for each vessel
19) The number of vessels needed for contributing to platform supply duty

Table 5. Parameters for calculation of the number of vessels in a field operation

We will below discuss in further detail the functionality demands of the offshore supply vessel when taking part in these three different types of logistics systems. We will relate these tasks and functions to a special context that the logistics operations have to be adapted to, i.e. the Arctic.

3. THE CHARACTERISTIS OF THE ARCTIC SEA AREAS

3.1. THE ARCTIC CONCEPT

The Arctic concept is widely used with several area definitions. In this report we choose the geographical definition meaning the Arctic is the region above the Arctic Circle (latitude N 66°33′42,5″. This area in Norway includes much of the Norwegian Sea where the operators in the wintertime may experience polar lows with combinations of snow, strong winds.

In the further discussion, we call this region the Low Arctic. The High Arctic region is defined in Norway in the area around the Bear Island (Bjørnøya) and northwards, where the Polar code area defines this as an area of a special cold climate, with risk of severe icing and in some areas in the North and East ice in the Winter time and high density of fog in the Summer time. This area calls according to the Polar code for special precautions as to vessel capacities and well as added competence for the officers on board. Extreme Arctic is regarded as areas with much ice cover in the wintertime and inclusion of multi-year ice, including icebergs. This area is most challenging for industrial activity not the least for production installations dependent on a specific position.

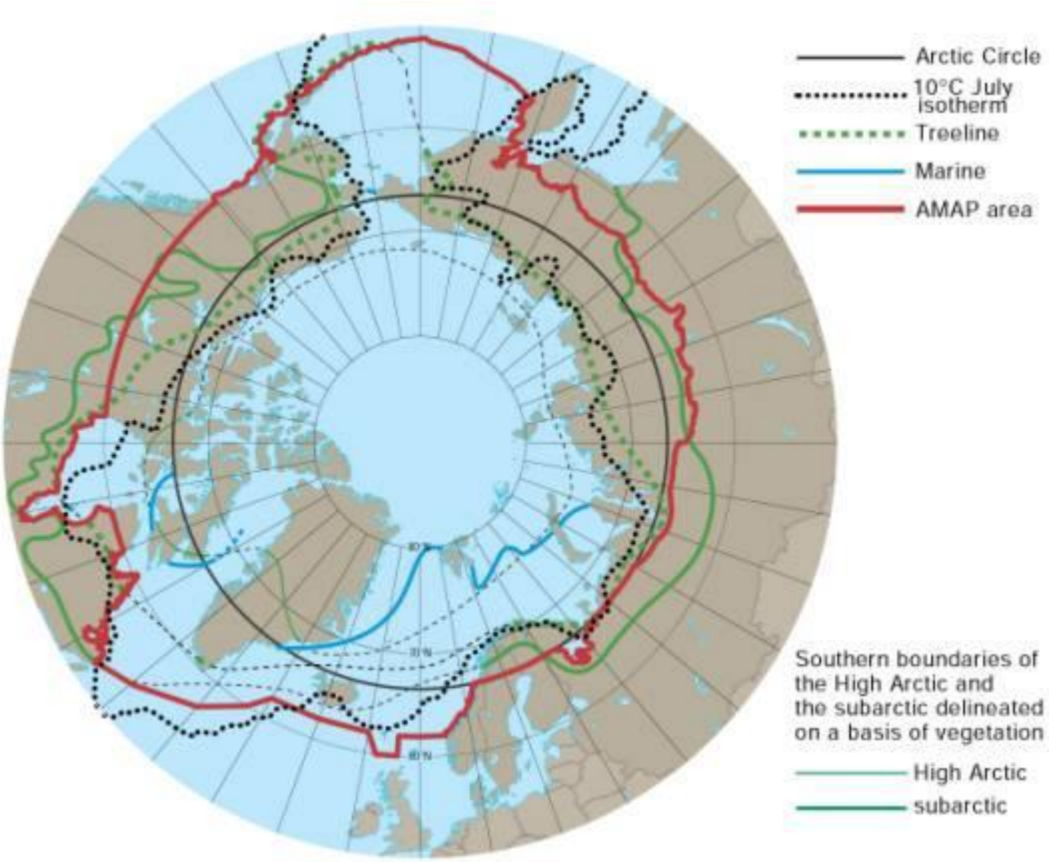


Figure 2. The climate zones of the Arctic

The characteristics of the sea regions depends very much on the longitude you are on, with the region in the Norwegian Sea and the Norwegian part of the Barents Sea as the less demanding areas. As an example, the Polar code region goes down to 58° N south of Greenland, but at 74°30’ in the Norwegian Barents Sea Bear Island-region. Then in Northern Russia, Alaska, Northern Canada and Greenland the ice conditions are much more severe and the infrastructure less developed than along the Arctic coast of Norway. Along the Greenlandic coast, ice appear in summer time along most of the east coast and from the Disco bay and northwards on the west coast.

3.2. THE ACTIVITY IN DIFFERENT PARTS OF THE ARCTIC

There are a broad range of stakeholders in the Arctic including several industries and interest groups. The shipping industry has been present in this area for centuries together with the fishing and seal hunting industry. The offshore oil and gas industry only has a forty year history in the region. The tourist industry also has a long history related to expedition arrangements. The cruise industry has expanded during the last decade. The research activity has also increased during the last years. The same is the situation with military presence.

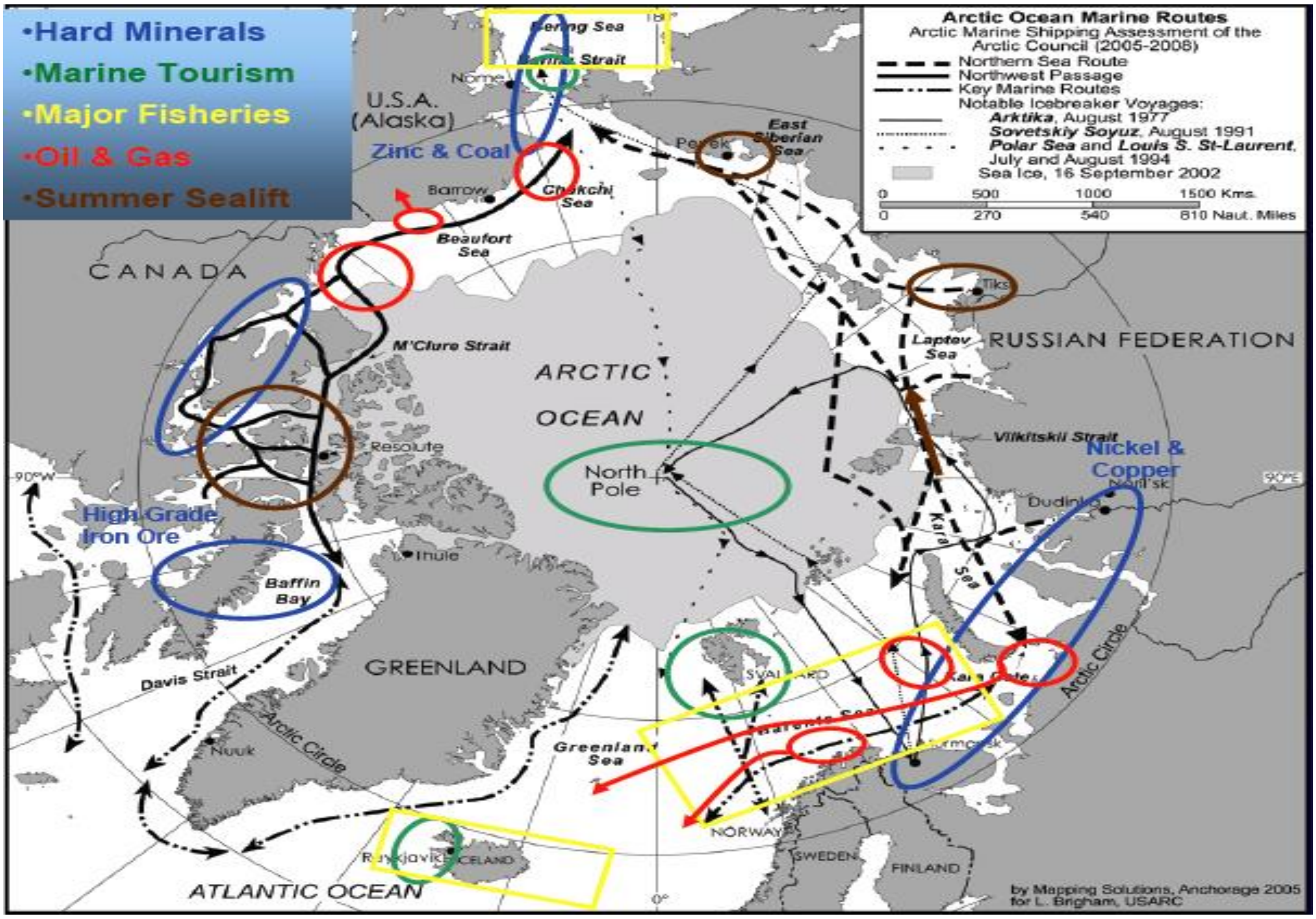


Figure 3. The commercial activity areas in the Arctic (Source: L. Brigham, USARC)

The red dots in the figure above shows the oil and gas activities the last five years in the Arctic. More exploration has taken place, for example around Greenland. The drilling of Cairn Energy on the west coast of Greenland and the Shell offshore drilling in Alaska have been stopped. The oil and gas field development taking place in the Barents Sea and the Northwestern part of Russia is going increasingly offshore (Tsvekova and Borch, (2017). The discovered and expected oil and gas resources in this region are shown in the map below.

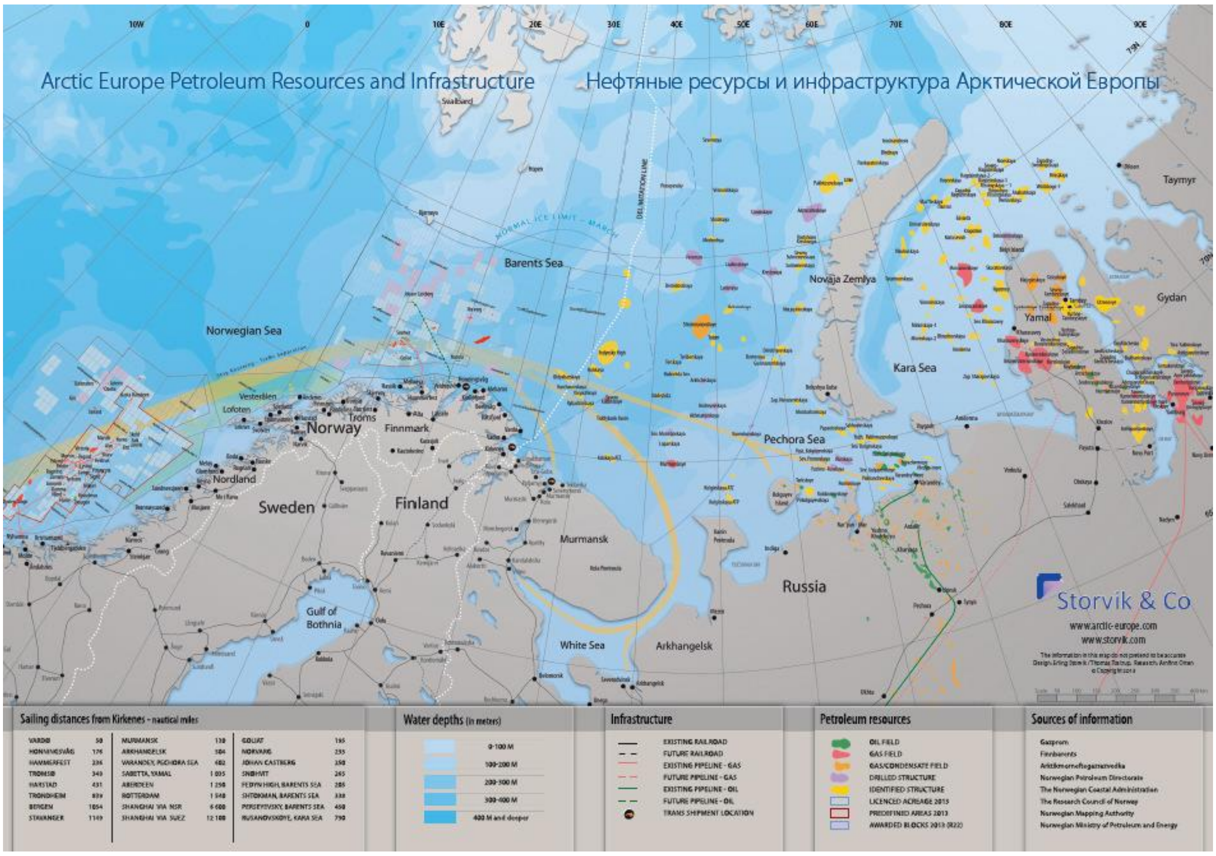


Figure 4. Areas of exploration in Arctic Norway and North-Western Russia (Source: Storvik & Co)

The most promising oil and gas region is in the Russian Arctic as shown on the map. This is also confirmed by the findings in the few holes that have been drilled offshore in Northern Russia. In addition, on the border between Norway and Russia, significant resources may be present.

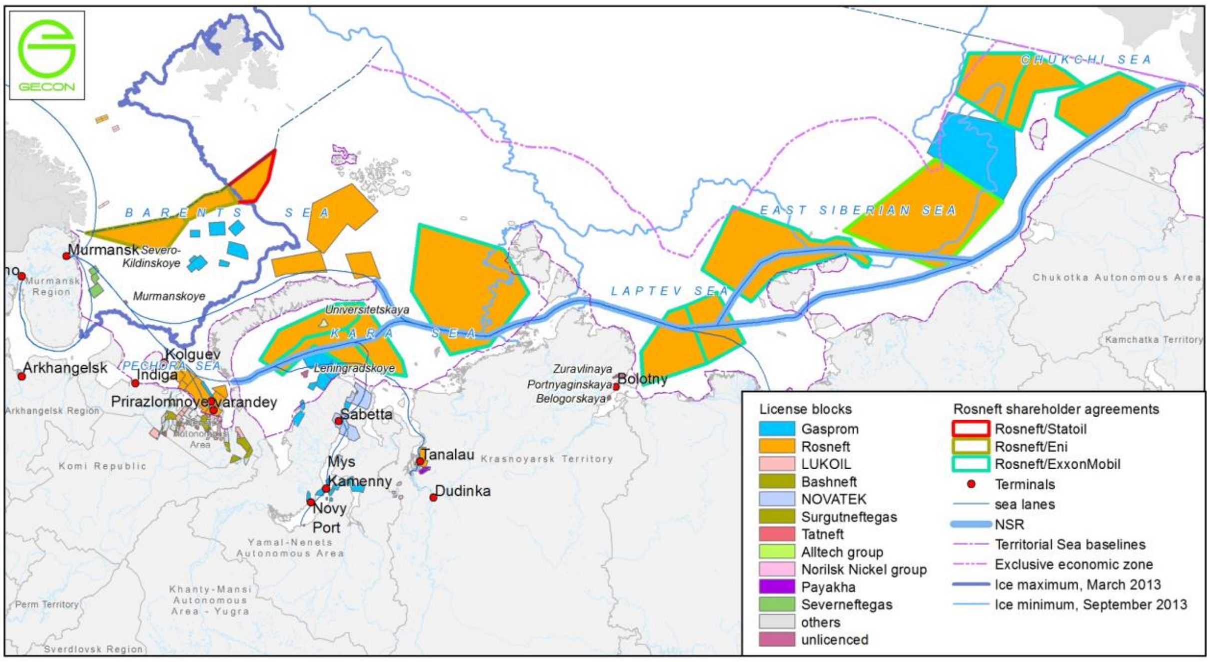


Figure 5. Oil and gas licenses in Northern Russia (Source: Gecon)

The figure above shows the licenses in Northern Russia where most of the activities offshore is at present close to shore. However, more activity is expected out to sea, with operations by both Gazprom and Rosneft. In the 2014 drilling campaign in the Kara Sea, most units including the drilling rig were Norwegian owned. This operation ended abruptly as the sanctions against Russia came into force. In the new exploration campaigns, drilling rigs from other countries are in operation, including a drilling rig from China.

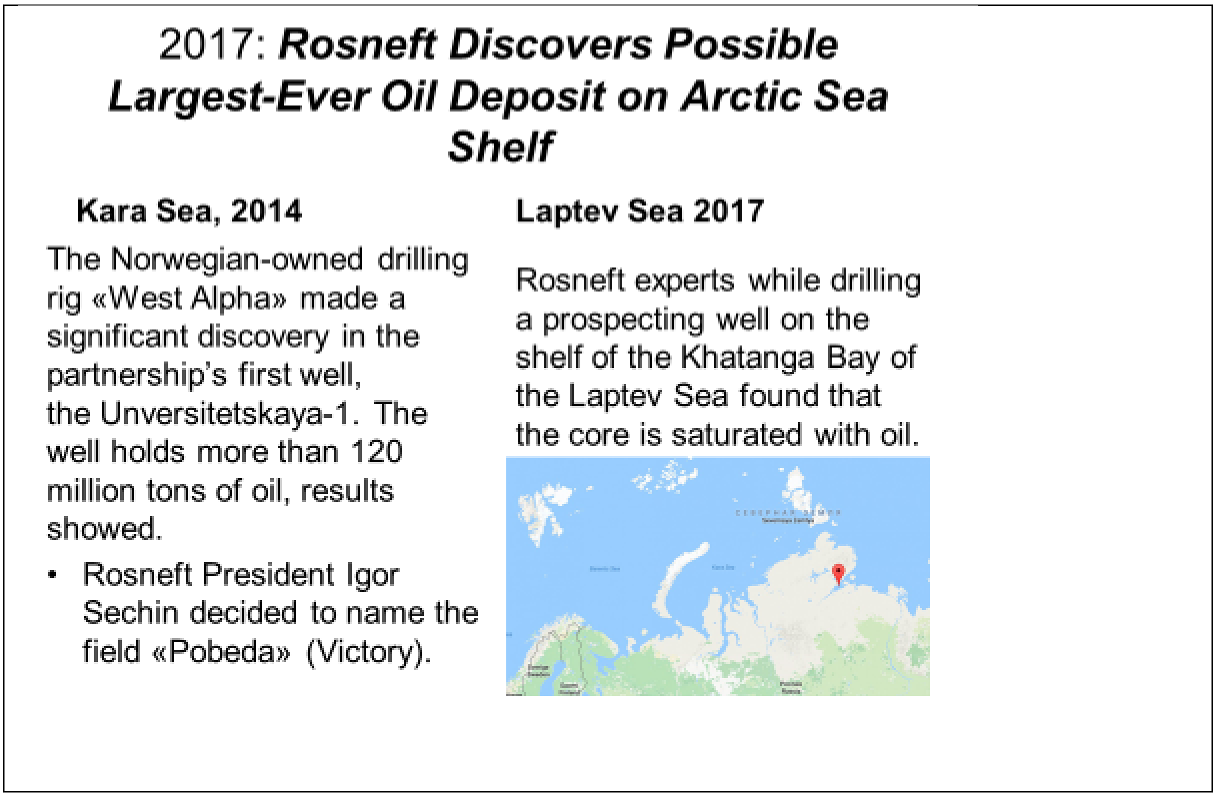
The list below shows the drilling program for the dominating Russian companies Rosneft and Gazprom.

RUSSIA – NEW FIELDS AND DRILLING CAMPAIGNS OFFSHORE	
ROSNEFT:	GAZPROM
2014: Kara Sea 2017: Kara Sea 2018: Barents Sea (Fedynsky area) 2019: Kara Sea	2015: Kara Sea 2018: Kara Sea 2019: Barents Sea

Table 6. Offshore drilling activity in Northwestern Russia up to 2020.

We see that the drilling in the Kara Sea has high priority by both Gazprom and Rosneft. Drilling in the Russian part of the Barents Sea will commence in 2018. Both ENI and Statoil have ownership in the Russian part of the Barents Sea. Increasing the drilling activity in these demanding areas implies that there are good prospects for oil in these licenses.

This drilling campaign by Rosneft in the Kara Sea in 2014 was successful, and so was the drilling in the Laptev Sea in the summer 2017 as shown in the cut below.



The interests in the 23rd license round in the Norwegian Barents Sea as well as the drilling plans and the immediate success in the Russian North West indicate that the activity in the Arctic region of Norway and Russia will see more offshore activity. . The very successful oil company Lundin claims that they have significant focus on their Barents Sea licenses in the years to come.

"We regard the Loppa High license in the Barents Sea as our new core area"

Jan Vidar Markmanrud, Lundin at the Oil and Gas Preparedness Conference, Bodø Norway, May 2017

In total, we see a significant increase in willingness to explore their licenses in both the Norwegian and the Russian Arctic. With a move away from the coast and out in more distant and more exposed fields there have to be a focus on the technology needed, especially when it comes to winter operations.

3.3. THE CONTEXT - SPECIAL CHALLENGES IN ARCTIC OPERATIONS

The reflections above indicate that there is a significant activity level in the Arctic region, moving into the High Arctic. At the same time, the Arctic is representing large differences in operation conditions. In the table below some of the main dimensions for categorizing, the different sea areas are described.

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
7. Waves
8. Visibility
9. Low temperatures (fog, icing, ice)

Table 7. Arctic field logistics challenges

The dimensions above are linked to different operational factors that must be followed up by vessel technology and operational competence.

3.3.1. Lack of knowledge

Limited knowledge may relate to lack of general research in the area, lack of personnel with education and experience from the region, and limited predictability. Limited predictability is very much about the difficulties in predicting the weather. The Polar lows in wintertime is difficult to forecast, the same is with fog and drifting of ice.

The Polar code claim more education and experience from operations in polar waters by the crews, but only to a limited extent. Knowledge on complex operations and use of advanced tools in challenging and put a strain on the personnel. Therefore, an increased effort to learn more about the demands related to sailors in offshore service operations and on rigs is needed. The vessels have to be better prepared for the unknown with more specialized personnel, more manning, and better equipped.

> *"I will not go up there again. It is too much stress as to situations that may come out of the blue. Ice growlers are floating, it is fog, and we cannot see this type of ice on the radar. If something happen rescue is far away.*
> *All this uncertainty and the increased complexity are too much without more advanced ships and more empowered crew and organization"*
> Master with experience from supply operations West Greenland

The citation above shows that this type of operational areas demands thorough preparations, including a focus on the stress that the crew are exposed to.

The following factors should be considered as a potential challenge:

1. Lack of research in the area on natural condition in field areas 2. Communication limitations effects 3. Limitations as to weather forecast 4. Lack of crew with experience from the region 5. Need of advanced vessel technology properly tested in the region 6. Uncertainty about laws and regulations and their supervision 7. Military and environmental sensitivity 8. Psychological stress

Table 8. Arctic field knowledge gaps

The knowledge gap implications for the OSV companies are shown in the table below. The companies should do more research with a systematic collection of analyses of their field experiences. Close cooperation with researchers could help in the internal processes and to the dissemination of knowledge.

➢ Active own research within the companies

➢ Bringing researchers into the field ➢ Test facilities on board the vessels ➢ More education and training of crew, including on board simulators ➢ High degree of redundancy on board ➢ Advanced navigation instrumentation

Table 9. Arctic knowledge gap response

At the Goliat field, the operator ENI demanded the vessel owners to be active within research, and to share the experiences with the other participants in the operation. ENI took part in a broad range of R&D projects logistics and operational processes in the supply chain.

3.3.2. Vulnerability of the environment

The vulnerability of the environment is about the capability of nature to recover from human influences, and the rareness of the animals, birds and other species that are present in the region. The immense focus on environment protection and the role of the Arctic in global climate change means that the areas with special importance will be well protected. The implications are that there have to be special safety measures from the start, the vessels have to be designed to withstand strain, including hull integrity in case of collisions. The emissions have to be as close to zero as possible, and the vessels have to be extra equipped, not the least with engine fuel solutions that give less air pollution and risk of oil spill. It also means that the vessel has to be designed and well equipped for environmental spill recovery operations.

As the emission to sea and waste disposal, challenges are dealt with, the air emission and noise challenges are still a problem. The noise challenges have been an important problem on the rig and onboard the vessels, recently there have been a discussion on releasing noise to sea, where the exposure of mammals to extreme noise is regarded an environment problem.

The Arctic Council committee for protection of the Arctic Maritime Environment discussed at its meeting in September 2017 how the noise from the propellers and seismic had negative impact on the whales. WWF called for more research and a discussion on restrictions to avoid this kind of negative impact in certain areas. Arctic Council, PAME-Protection of the Marine Environment working committe meeting, Helsinki, Sept 2017.

The following factors should be considered as a potential challenge:

- Emission to sea and air from drilling units and service vessels
- Accidents ending in pollution
- Noise in compartments
- Propeller noise

The emission to air includes NOx and CO_2, and soot. This emission has gradually been reduced by vessels that are more efficient. Use of LNG as fuel reduces the CO_2 emission significantly. Still, however, this is a major problem to de be dealt with in the High Arctic.
Among the implications for the OSV capacities are:

- ➢ Hull integrity
- ➢ Zero emission to sea through waste treatment facilities
- ➢ Engines using fuel causing lowest possible emission to air
- ➢ Storage capacity for garbage
- ➢ Oil spill response capacity on board
- ➢ Reduction of noise through better propeller system and electricity as fuel

Table 10. Environment vulnerability response

Operations in the Arctic will demand more efforts the longer into the High Arctic region the activity takes place, and especially when it comes to winter activity. This includes higher ice class for the hulls, capacities for treating waste on board, more fuel efficient engines with dual fuel (LNG) and increased battery capacity, a hull design that reduces energy in transit, and more local capacities locally for oil spill response.

3.3.3. Range of stakeholders

The number of stakeholders in a region may vary according to the presence of resources, conflicting interests as to exploitation as well as heterogeneity in culture and values. As for values, the shareholders may feel that operations in Arctic water is too risky. The insurance companies definitely has as word to say about Arctic operations. Most underwriters do not accept ventures outside known routes and above 70 degrees. This means they have to be both consulted and the premiums may be significant.

There may for example be different interests between commercial interests, environmentalists, scientists, endogenous people's traditional way of living, military and the oil and gas industrialists. Other industries such as the fishing industry may find there are conflict of interest as to sea areas, and the tourism industry focusing on nature and explorer tourism do not want to any types of industrial activity along their routes.

Stakeholder complexity:

- Shareholders
- Insurance companies
- Other industries with conflicting interests in the Arctic
- Environmental organizations negative to oil and gas industry
- Endogenous people feeling a threat to traditional way of living
- People using the same region for leisure activities
- Other governments claiming right to area
- Dispute between local and national government

The number of stakeholders mean that there have to be a special focus on the investments in taking care of other industry interests, for example through SAR and oil spill recovery capacities. There will also be focus on the robustness of the whole operation, for example related to track record of negative incidents. This means that the vessels have to be state of the art, well equipped and with back up capacities both to convince the other stakeholders of their robustness, to contribute to other industries if possible and well prepared if something should go wrong. This also includes destructive action of some sorts, demanding a focus on security installations.

During the drilling operation by Cairn at Greenland, the Greenlandic home rule government was strongly in favor of this drilling. It created valuable jobs, especially for younger well educated Greenlanders. And striking oil would give valuable income for the Greenlandic government making it possible to fulfill its ambitions towards full independence from Denmark. The government also claimed that the drilling was very safe, as it followed the Norwegian North Sea Rules.

However, the environment organizations of Greenland was against it and Greenpeace arranged a demonstration against the drilling hampering the drilling for two days. Many of the endogenous people was also against. The International Inuit Association made a vote against drilling at a meeting in Nuuk.

The implications for the OSV capacities are shown in the table below.

- Safe navigation tools
- Lowest possible emission to air
- Zero emission to sea
- Environment friendly fuel
- Hull integrity against leakage of oil products and sinking
- Oil spill recovery capacities
- Security measures against destructive action

➢ Functions that may serve the local communities of the region

Table 11. Stakeholder complexity response

3.3.4. Infrastructure variability

The infrastructure dimension is in particular linked to a) cargo and personnel transport capacities in and out of the region, b) availability of service infrastructure such as harbor and service facilities, including yards, spare parts, supplies and fuel, c) government infrastructure such as navigation systems including accurate charts, positioning tools, telephone and broadband communication, and d) emergency preparedness infrastructure such as search and rescue capacities such as hospitals, AWSAR helicopters and sea-going rescue vessels, oil spill response capacities, and e) decision infrastructure such as local government with the necessary jurisdiction as to law enforcement, permissions, f) joint government-industry efforts for finding good solutions locally, etc.

The implications could be that the campaign has to be self-sufficient as to what it needs for a very long period. This means that it needs storage capacities, installations otherwise bought ashore, such as hospital capacity, and the opportunity for the vessels to serve as helicopter hubs and depot ships.

One critical element is communication infrastructure. There are limited and/or unstable broad band communication capacity for the internet when you move North. This has implications both for commercial operation and for emergency response. Satellite telephone is available but may also prove unstable. For SAR operations HF band maritime radio is the main tool north of 70 degrees. Here the vessel has to be equipped with the most advanced tools for satellite communication. The operator has to think out solutions using the platform as a communication link.

For the drilling activity in the Kara Sea, the closest supply base was in Murmansk, 72 hours sailing from the drilling site.

In the Disco Bay drilling by Cairn, the company had arranged for a smaller supply base for minor goods in the harbor of Aasiat, a narrow harbor just deep enough for the PSVs. The transit time from Aasiat to the field was about 15 hours. However, larger equipment and supplies such as chasings had to be brought up by the PSVs from Nuuk 360, approx. 30 hours away. In addition, transport time by air was time consuming and packages might take very long time, among others due to much fog at the inland international airports.

The following factors should be considered as a potential challenge:

- cargo and personnel transport capacities in and out of region
- intra-regional transport systems
- density of harbor and service facilities
- access to spare parts, supplies and fuel
- navigation systems
- phone and broadband communication
- SAR capacities
- Oil spill response capacities

The implications for the OSV capacities are shown in the table below.

- Loading capacity vessel (deck, tank and passenger capacity)
- Speed
- Advanced navigation tools, including ice radar
- Additional communication capacities through satellite communication and platform links
- Helicopter platforms and fueling arrangements
- Depot storage capacities
- Hospital facilities
- SAR and oil spill capacities

Table 12. Infrastructure variability response

3.3.5. Winter darkness

The winter darkness influence on the capacities of the vessel to operate, among others searching for ice in water. It very much would influence on the crews ability to cope with challenging work. There is a need to follow up on the amount of sleep for the crew and the conditions for relaxation on board. This means that the comfort on the vessel is crucial with limitations of noise and vibrations that may influence on the sleep of the crew. There has to be extra light on board and opportunities for light treatment. Other welfare opportunities have to be present, for socializing and internet communication and for contact with family and friends.

The following factors should be considered as a potential challenge:

- Challenges for navigation and operation
- Lack of daylight
- Combination of darkness and coldness
- Noise and vibration that increase fatigue and reduce sleep quality

The implications for the OSV capacities are shown in the table below.

- Night navigation tools
- Strong search lights
- Illumination of vessel
- Reduced noise and vibration in vessel
- Comfort in cabins and social zones
- Welfare facilities
- Added crew for reduced time of duty

Table 13. Winter darkness response

3.3.6. Cold climate and weather conditions

The cold climate is related to low temperatures, the presence of high density fog, especially in the summer time, snow and ice, and a risk of icing on the vessel. Snow and wind combined will influence on the workability on board. Polar lows may come suddenly and influence on vision, the conditions on deck, increased waves and operability of the vessel. Combinations of wind, waves, low temperature and high humidity may combine both atmospheric and marine icing on the superstructure. This may cause stability challenges, challenges as to deck machinery, equipment, and work on deck, ice on antennas causing navigational or communication problems, and access to evacuation and firefighting equipment.

Snowdrift may add to this. Severe coldness and sea ice may cause additional challenges for operation and call for extra strengthening of the vessel and icebreaker capacities. Risk of icebergs on rig collision course may demand ice management capacities including extra towing strength.

The combination of warmer wind and cold sea may bring fog in the spring and summer months, providing navigational problems and risk of collisions, especially combined with sea ice. In addition, very strong winds may appear in such zones, as experienced from Greenland.

> *"We did not plan for extreme weather during transit in spring time. This was even worse than the North Sea in wintertime. Out of the storm the vessel faced a large belt of potential dangerous ice growlers in the operation area. This gave us an indication on the challenges the ships and the crew was facing"*
>
> HSEQ manager, shipping company with supply vessel at West-Greenland

The implications for the OSV capacities are shown in the table below

- Ice class hull
- Winterization of vessel
- Cover of superstructure
- Low temperature design properties for equipment and materials
- Equipment for removing ice
- Electrical heating of windows, decks, valves, etc.

Table 14. Cold climate response

The risk of significant sea ice and icebergs is shown at the IMO chart describing the area where the Polar code is at work.

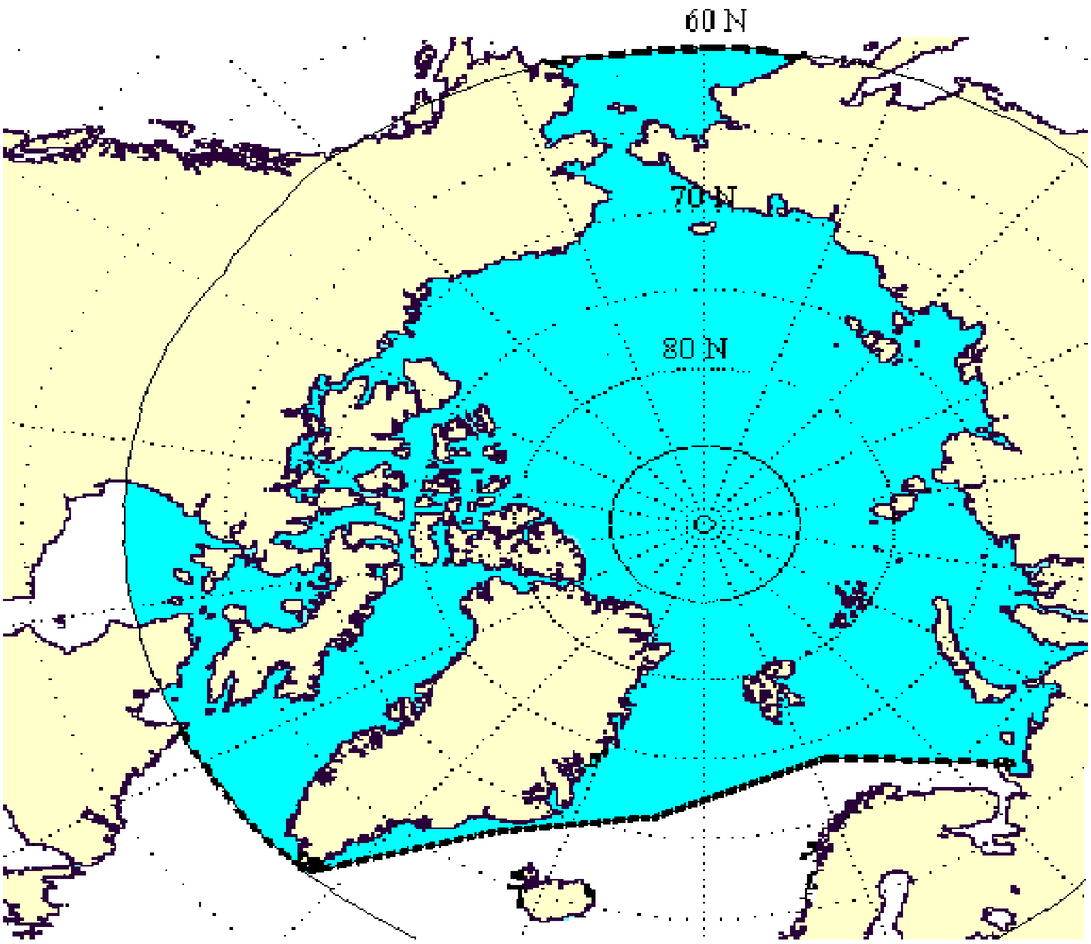


Figure 6. The Polar code region based on ice conditions in the Arctic (Source: IMO)

4. TOWARDS A CATEGORIZATION OF THE ARCTIC SEA REGIONS

As discussed above there will be many variations when it comes to the Arctic region, and it is important to divide between them and between the challenges and thus capacities and competences needed. For example, the wave conditions in the Norwegian Sea and the Barents Sea may be better than in the North Sea. However, fog, polar lows and risk of icing and finally sea ice together with lack of infrastructure and long distances from nearest harbor or base to the fields may create other more severe challenges in the Northern regions. There have been some efforts for categorization of the Arctic.

4.1. THE NATURE AND THE MARITIME WORKING CONDITIONS

4.1.1. The Norwegian Barents Sea and North Western Russia

The sea regions from the South western Barents Sea is getting gradually worse the longer East and North you go.

The DNV's Barents 2020 project suggested that the Barents Area should be divided into 8 sub-areas dependent on the areas' physical characteristics (Eide, DNV). The most distinct dividing line is sea ice or not.

i) Spitsbergen - usually ice every winter
ii) Norwegian Sea - generally ice free
iii) Franz Josef Land - usually ice every winter
iv) North East Barents Sea - usually ice every winter
v) Novozemelsky - in between
vi) Kola - in between
vii) Pechora - usually ice every winter
viii) White Sea - usually ice every winter

Figure 7. Division of the Barents Area into sub-areas dependent on the physical characteristics (DNV's Barents 2020 project)

The DnV division shows that ice is a challenge in all the areas except zone II. However, also in the Northern part of zone II there may be ice challenges and not the least challenges of icing.

The organization of oil companies with ownership in licenses in the Arctic divides the Norwegian part of the Barents Sea into

- South East
- South West

The South East region is rather large and includes areas that are quite North in the Barents Sea in the North Eastern part of the 23rd license round. In this region, sea ice may appear in wintertime.

DnV-GL has later developed an Arctic Risk Map showing the challenges in different areas in different parts of the year to assist decision-makers in choosing the best solutions for operation. It includes an Environmental vulnerability index that is location and season specific, showing the environmental vulnerability of marine resources with respect to oil spill (https://maps.dnvgl.com/arcticriskmap/). The risk maps serve as a good starting point for assessing the risk in specific sea areas.

Building upon an assessment of broad range of challenges Nielsen (2016) categorizes the Barents Sea into four different regions based on the following dimensions:

- coldness

- Darkness
- Ice
- communication
- meteorology and forecasting

A drawing of the regions is given below:

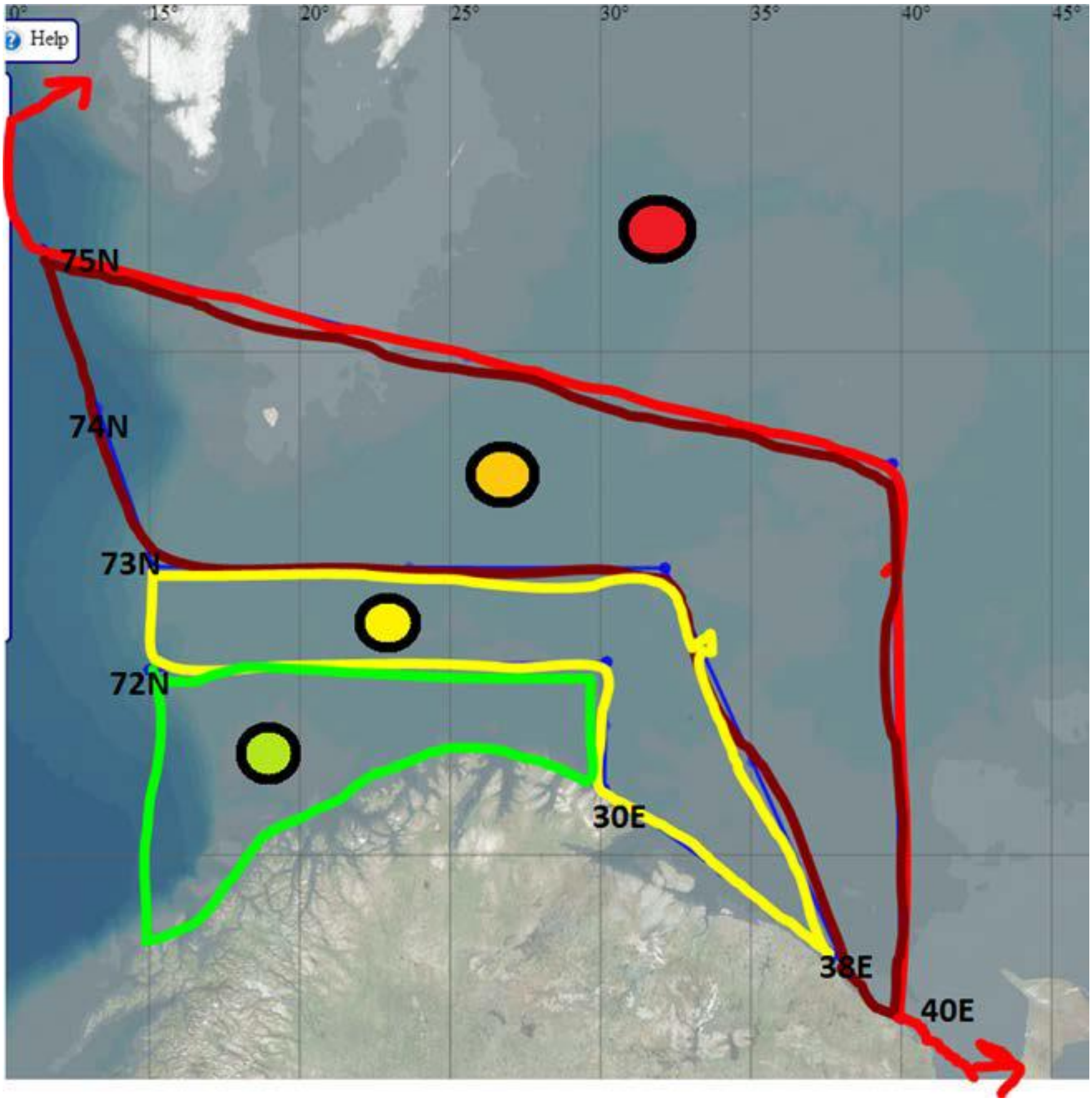


Figure 8. Areas of different challenges in the Barents Sea (Source: Nilsen, 2014)

Area 1: *South –West Barents* (Green)

In the South-West Barents Sea up to 72 degrees north and eastwards to 30 degrees, East the winter temperature is starting to be a problem, together with winter darkness. The meteorological data is quite good, even though Polar lows represent a problem for the PSVs at times. The infrastructure with the Polar base in Hammerfest is quite good, even though passenger transport has its limitations in and out of Hammerfest airport.

Area 2: Middle –West Barents Sea. (Yellow)

This area stretches up to 73 degrees North in the western Barents Sa but declines down to 58 degrees North to the Russian coast line when one goes from approx. 32 degrees East to 38 degrees East. In this area there may be up to 10% chance of icebergs in the North Eastern part, at 73 degrees north of Kirkenes.

The transport time starts to be significant with long distances from the base in Hammerfest and with helicopter from helibases like Kirkenes or Vardø. The waters are getting deeper, and the communication coverage is getting worse. In this area, one still lacks empirical data that calls for precautions taken in operations.

This area is characterized by:

- almost no ice
- a small chance of small-scale icebergs
- up to 200nm distance to supply base (Hammerfest)

Area 3: *North–East Barents Sea (*Orange)

This area stretches from up to 75 degrees N in the west and from the Russian coastline up 74 degrees N in the East. In this area, there is a 10-20% probability of icebergs. The distances from land base is very high, making both cargo and crew transport a challenge. High ice strengthening and vessels for ice management may be necessary in the wintertime. In this area, there is also limited met data and other empirical data needed for operation.

	Norwegian Sea	
Annual middle wind at 100 m height	10,5	9,5 m/s
Extreme wind speed with 100 year period of return	34 m/s	31 m/s
Extreme value wave height with 100 year period of return	16,5 m	14 m
Top period in wave specter with 100 year period of return	18 s	17 s
No of days (middle) with icing, 2-4 cm/hour Less than	0,1	5
No of days (middle) with icing, 0,7-2 cm/hour	0,1	27
Lowest air temp. (°C) with 100 year period of return	-8	-30
Lowest surface temp (°C) with 100 year period of return	6	0-1
Probability of sea ice	--	Annually?
Probability of ice bergs		1 pr 100 year
Winter season		Oct-April
Visibility under 1000m		8 % of the year

Table 15. Comparison of weather parameters between the Norwegian Sea 6716N_0517E versus the North Eastern part of the Barents Sea, 7347N_3553E (Korpfjell) (Source: ProActima, 2016).

The table above shows how the wind may not represent the largest problem. However, the combination of wind and low temperatures very much increase the risk of icing. In addition, the visibility is reduces because of fog in the summer time and snow in the wintertime.

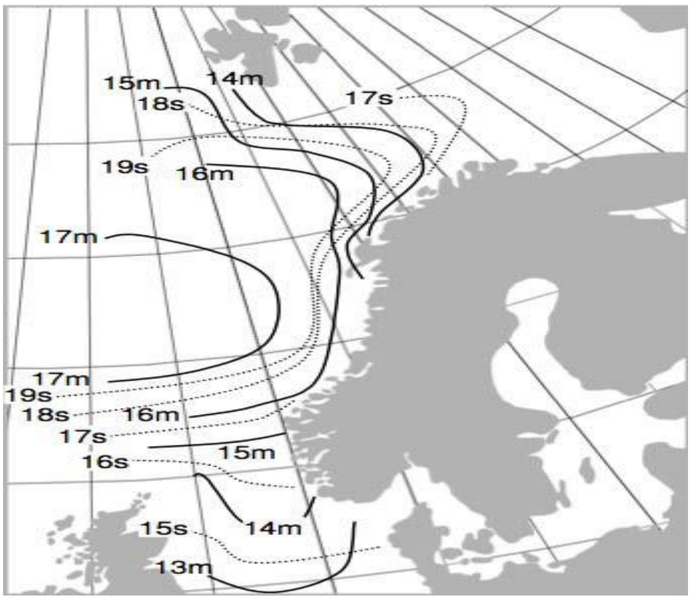


Figure 9. Peak wave height on the Norwegian Shelf.

The table above shows that the wave's height in the Norwegian Sea and the Western part of the Barents Sea are quite similar and significant higher than in the North Sea.
The table below shows the severity index for the Northeastern regions, especially when going into Russian sector where the sea temperature is decreasing and the risk of ice increases.

Area 4: *Extreme Barents (*Red).
In this region, there is up to fifty percent change of icebergs and one is close to the sea ice ridge. The met data is limited and the communication challenges is significant. The distances from land makes logistics very difficult. Combinations of wind, reduced visibility and icy bits from multi-year ice make sea traffic extremely challenging.

The presence of challenges in this area are:

- Ice up to nine months a year
- Risk of multi-year ice
- Large icebergs
- Up to 550 nm distance to supply base

The ice ridge has been subject to much political discussion as it has been fluctuating over time. The tables below shows how the ice ridge has been fluctuating over the years, but for the last years have mostly been shrinking.

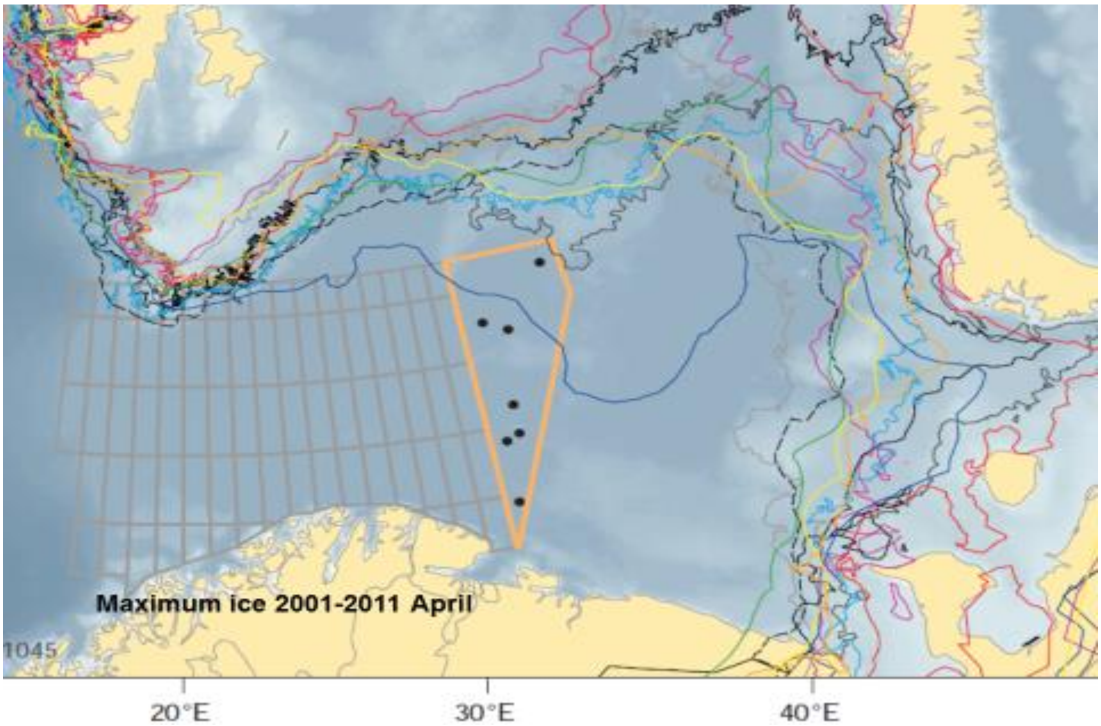


Figure 10. Ice observations in the Month of April 2001-2011.

During the last 30- year period, there have been ice into what is described as North East Barents several winters, and south of the Bear Island. In the last years, however, the previous figure shows that this has occurred seldom and the ice ridge have move several nautical miles to the North. The Government has defined the ice edge as north of the northern delineation of the 23rd license round at 74° 30’ north. The oil companies define the closest limit as 50 km from the observed ice ridge that brings the line further up north. The environmental organizations, however, want the ice ridge to be set at the southernmost position where ice is observed the last 30 years, as shown in the first ice table.

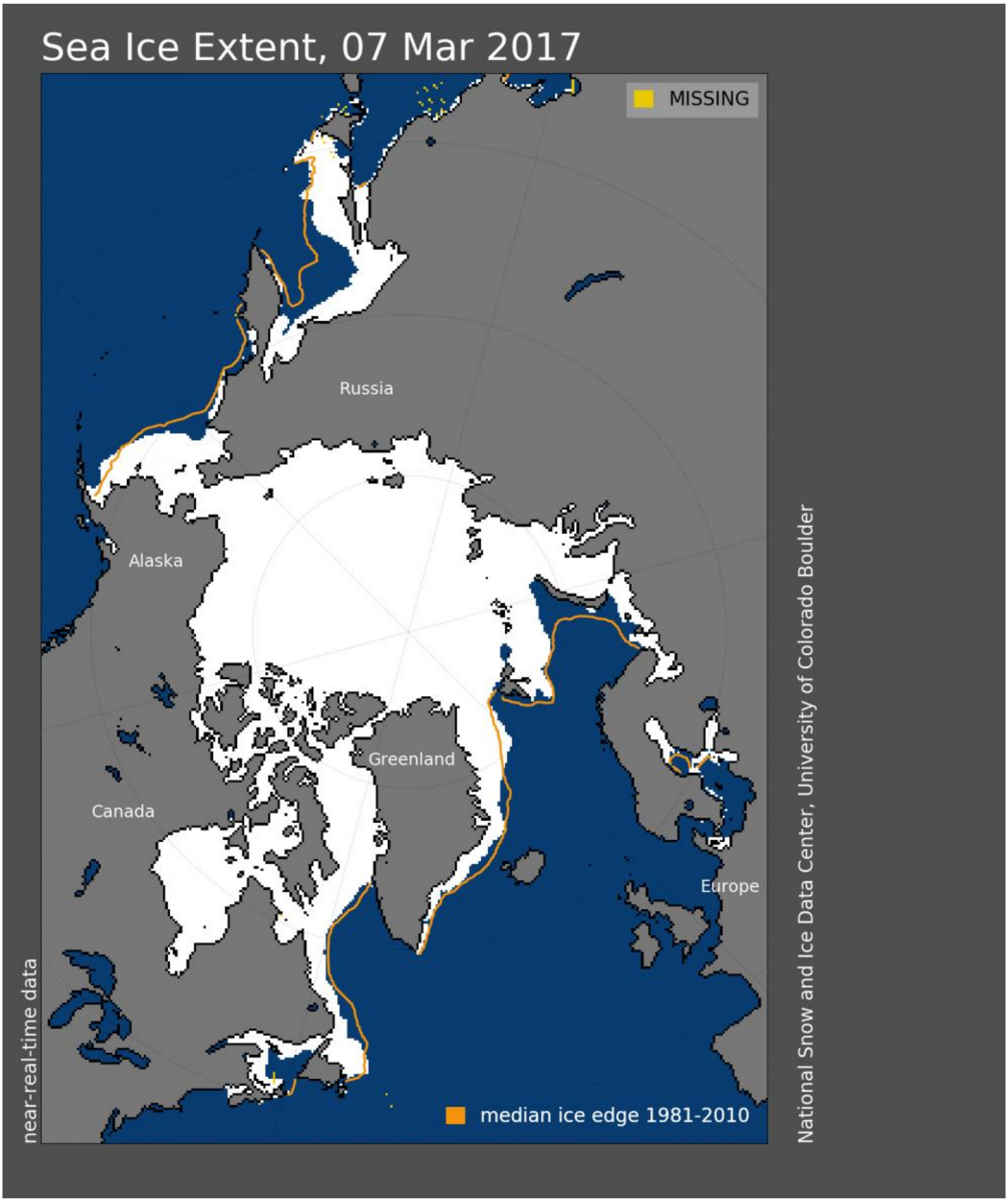


Figure 11. Arctic sea ice on March 7, 2017. (Source: National Snow and Ice Data Center)

4.1.2. Greenland

The conditions on the west coast of Greenland is as complex as in the Barents Sea. There are many aspects related to the inland glaciers of Greenland causing large fluctuations in temperature, and much sea ice.

The table below lists some of the climatic challenges at the west coast. At the east coast, the situations are even worse, with more sea ice, more polar lows and stronger currents along the coast.

EXAMPLE: WEST-GREENLAND

Weather:

- Mean air temperatures below 10° C all year round. The coldest month is February and the warmest month August (in the coastal area: July)
- Fog or polar lows are common features near the South West and South Greenland shores
- in the long and narrow fjords strong local winds may occur in sunny days
- Frequency of fog increases during May and peaks in June/July, when the temperature contrast between the cool sea surface and the relatively warm atmosphere is at a maximum. It fades out in late August.
- The frequency of fog in July is 20-30 % of the total time over the coldest parts of the sea area Less visibility than 0,5 nm 20-30%of the time in June and July

Ice:

- Broad continental shelf with depths less than 500 m
- Fylla basin outside Disco Bay has optimal condition April - June, also July - August – some ice bergs
- Icebergs and growlers originating from glaciers occur in the entire region, but the density of icebergs is normally low, increasing towards the Cape Farewell area to the south
- sea ice normally covers most of the Davis Strait north of 65° N
- Warm northwesterly West Greenland current opens the coast line, in areas close to the Greenland coast, a flaw lead (open water or thin ice) of varying width often appears between the shore or the fast ice and the drift ice as far north as latitude 67° N.
- Baffin bay basin with depth above 2000 m and ice cover 6-9 month
- Sea ice breaks and head towards Baffin bay
- Icebergs from Disko bay and Melville bay drift in northwest direction produce, 10-15,000 icebergs per year
- Iceberg with length up to 200m have largest depth 250-300m, length 50m means depth of 40m.
- Floating ”growlers” and icy bits
  - Multi-year ice out of Disco bay and Isfjorden at Ilullissat.
- Medium-sized ice bergs coming out of Disco bay and heading north and west with speed up to 3 knots in storms
- Also to be found on the South West coast
- Winter pack ice (west ice) in small first year ice floes (20-100m diameter) and 70-150cm thick

Table 16: Weather and ice conditions on the West Greenland Sea line

The table above shows the generally lower sea temperature causing fog in the summer time from May to August and ice in the winter.

The west coast may be divided in two parts, the South West Greenland area, with mostly open water and little summer ice. The Mid- and North-West Greenland area with a large amount of ice bergs, floating icy bits and fog challenges in Summer and sea ice in the Winter. The number of ice bergs and floating multi-year ice is causing challenges both for drilling rigs and the transport, from the Disco bay and North.

4.2. THE SOCIETY AND THE SOCIAL DIMENSION

The discussion about the definitions of the ice ridge in the Barents Sea illuminates some other challenges of this region that is the number of stakeholders or interest groups. Different political parties may disagree on where the limit should go. The growing strength of environmentalist organizations means there are more conflict the higher north one goes. Every failure will be scrutinized and used against the campaign, as Shell experienced in Alaska after the grounding of the rig Kullug in 2012.

During the 2012 drilling season, Noble was the operator and bare boat charterer of the drillship and the conical-shaped Kulluk*, which ran aground off the coast of Unalaska when it broke free from its tow in bad weather en route to Seattle. The* Noble Discoverer *suffered failures with its main engine, its propeller shaft and other equipment and Noble negligently discharged machinery space bilge water from the drillship into Broad Bay, Unalaska, creating a sheen on the water. Greenpeace Arctic, which has been a vocal campaigner against Shell's ambitions in the Arctic, said the charges were the clearest indicator yet that Shell failed to manage its contractors safely. "Letting Shell back into such a precious and risky environment as the Arctic would be sheer madness, yet that's what Shell wants to do next summer," said Greenpeace campaigner Ian Duff.* (Frontier Energy, Dec 2014)

U.S. President Barack Obama on Tuesday banned new oil and gas drilling in federal waters in the Atlantic and Arctic Oceans... The ban affects 115 million acres of federal waters off Alaska in the Chukchi Sea and most of the Beaufort Sea and 3.8 million acres in the Atlantic from New England to Chesapeake Bay. Reuters, Dec 21, 2016

In addition, the Barents Sea is a political sensitive area, not the last the Spitsbergen region. The military tension is also present with the main submarine navy of Russia operating in this region. The military and political sensitivity increase as one goes eastward towards Novaja Zemlja. In the Russian sector, the Northern Fleet of the Russian navy has wide authority as to direct traffic and define activity types. In addition, the oil and gas production is regarded as a strategic important aspect for both Norway and Russia, and it is important to be present in the areas at both sides.

The very strict military requirements at Novaya Zemlya were challenging for the planning and operation in the Kara Sea. Even if this island, with its many sheltered bays and fjords, was situated only 50nm away from the drill site, no preparedness role could be planned for here. Both the remoteness and the military regime led to the planning conclusion that no helicopter should be used in the operation…. some of the service vessels experienced conflict with naval vessels, forcing them to change course and route between the drill site and Murmansk. This served as a limiting factor for preparedness planning and was considered as both a political risk and a safety issue (Ice Pilot participating in the Kara Sea operation 2014).

The stakeholder dimension in Greenland may be as important as in Norway, with tension between Denmark and the home rule government, as well as between endogenous groups and the rest of the population. In addition, the environmentalist organization and the tourist industry are mobilizing against the oil and gas industry

4.3. THE COMBINED INFLUENCE OF NATURE AND SOCIETY

The discussion above shows that there are many challenges related to both nature and society when it comes to Arctic operations. In this chapter, we takes this a step further and reflect on the consequences. In order to compare the sea regions the factors discussed in the former chapter is gathered into two main categories, that is complexity and unpredictability. Complexity is about the numbers of factors that have to be taken into consideration, and their mutual influence on each other. An environment where many influence factors are present and they are strongly interlinked is regarded as a high complexity environment.

Degree of unpredictability relates to whether there are factors coming up that you do not know are coming, and that it is difficult to predict the outcome. A polar low is for example difficult to predict, and direction and strength is difficult to decide upon, even when it has appeared. The casual relations between action and outcome may also prove difficult to understand.

Factors that are leading to complexity are shown in the table below.

- Distances between supply base and field
- Lack of supplies locally as to spare parts and other necessities
- Limited harbor and yard capacity
- Limited air and road transport capacity
- More steps within the supply chain
- Broader set of activities that each vessel has to perform
- Broad set of government rules on safety and environment
- More ISO notations demanded by oil companies
- More external links to sub-suppliers
- Interest groups
- Government regulations

Table 17. Operational complexity

Factors that may lead to increased unpredictability are shown in the table below.

- Weather –polar lows and limitations in meteorological data
- Ice (first year, growlers and ice bergs)
- Several companies involved - Inter-organizational dependency
- Human factors -limited skills/fatigue
- Lack of knowledge as to area characteristics
- Limited met data
- Different interest groups
- Political tensions
- Security threats- terrorism, piracy
- Environmental extremism
- Emergency-search and rescue resources and outcome
- Communication loss

Table 18. Operational unpredictability

The factors below illuminate the challenges of operations in different geographical areas based on both nature and society context. For example, the Lofoten region may not prove challenges when it comes to natural conditions, but the number of stakeholders and political tensions may both increase complexity and the unpredictability or dynamism in the operation.

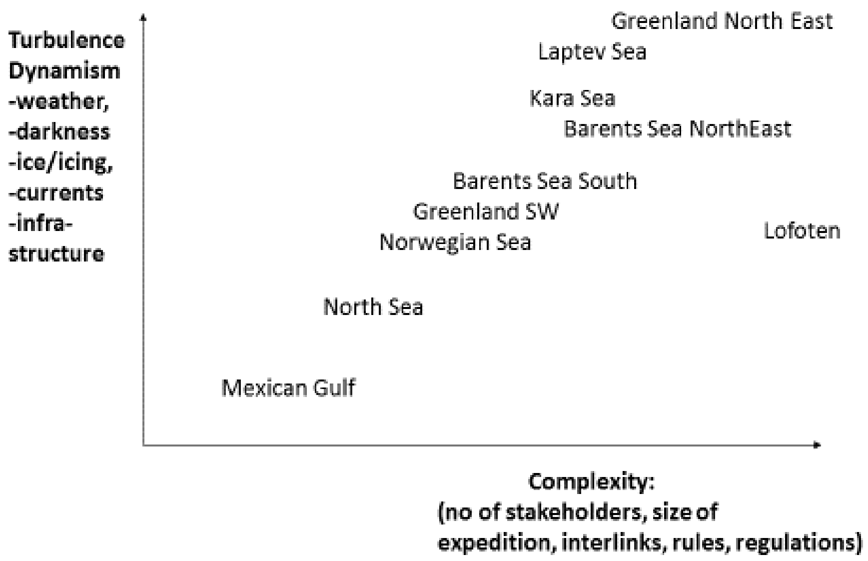


Figure 12. Complexity-predictability categorization of the different sea regions of the Arctic.

The figure above shows that Greenland North East is one very challenging area due to nature, with unpredictable weather, current in the sea, ice and fog. In addition, there is no infrastructure in the region, and large areas on the coast are national parks. The Kara Sea is challenging due to very long distances to base, military sensitivity and due to heavy ice in the wintertime and icebergs in summer time.

The North Eastern Barents Sea may not have the same challenges as to weather compared with East Greenland. However, the complexity as to number of interest groups, political and military sensitivity and number of special demands for operation in this area may be as high. A combined high complexity and high dynamism (turbulent) environment may be called an extreme, Arctic environment.

An extreme environment is characterized by:

1. A high probability of one or more unexpected situations to appear
2. Where the consequences of unexpected situations may be serious as dealing with such situations may surpass the capabilities of the organization to map, avoid or reduce the negative consequences to an acceptable level
3. The personal, material or economic consequences may prove destructive for the assets involved

The area on the North East coast of Greenland may be regarded as an example of an extreme environment. The same will be true for the area in the North Eastern part of the Barents Sea eastwards towards Nova Zemlja. The gigantic gas field of Stokman is an example of field that could be regarded as on the edge to extreme Arctic.

- Field context
  - Large production volumes
  - Very long distances to base (600 km)
  - Winter ice of various thickness (prepare for 2m first-year ice)
  - Ice bergs in Summer time
  - Subject to harsh and unpredictable polar storms
  - Extreme HME-challenges in coldness and darkness
- Challenges of offshore service operations
  - All year stand-by in ice
  - All year supply in ice
  - Towing of ice bergs
  - De-coupling and towing of installations due to ice threats
  - fighting of pollution and rescue in icy waters

Table 19. The Stokman field as an example of an Extreme Arctic environment.

New sea areas that are on the threshold of being explored such as the Laptev sea and eastwards in Northern Russia have much of the same characteristics that make them very challenging as operations areas.

4.4. TOWARDS A GENERIC CATEGORIZATION OF THE ARCTIC REGIONS

Above we have given some reflections on the context of the Arctic regions and some detailed criteria for a categorization. The table below sums up the discussion above and the efforts towards categorization presented. The table represents a starting point for a reflection on the technology and the operational competence needed in the different sea areas. We have followed some of the categorization discussed for the Barents Sea. However, the Extreme Barents Sea has been divided into Challenging Arctic and Extreme Arctic.

	"Mid- Arctic"	«On the edge» Arctic	«Challenging Arctic»	Extreme Arctic
Example area:	Middle-west Barents Sea Castberg)	North East Barents Sea (Hoop-plateau)	(Greenl W Kara Sea)	(Greenland E Baffin bay N Stokman)
Design temperature	-18	-25?	-30?	-40?-
Polar lows risk	+	++	+++	++++
Low visibility risk	+	++	+++	++++
Icing risk	+	+++	++++	++++
Sea ice risk	+- (Very low possibility)	+ (Risk of winter ice+ice bergs)	++ (Ice bergs+ winter ice)	+++ (Ice bergs+ ice)
Distances to base	240km	350km	500-1000	600-1500
Infrastructure limitations	+	++	+++	++++
Stakeholder conflict	+	++++	++++	++++
Workability (with present technology)	Summer and winter	Summer Partly winter?	Summer	Summer

Table 20. A generic categorization of Arctic offshore oil and gas environments

5. THE OFFSHORE SERVICE FLEET AND ARCTIC FUNCTIONALITY

5.1. THE RELATIONS BETWEEN CONTEXT AND FUNCTIONALITY DEMANDS

In the previous chapter, we have described the challenges of the Arctic as to both nature and weather conditions, and societal, social and political aspects such as infrastructure, interests and stakeholder conflicts. In a chapter we look into the implications of the working conditions in the different regions as to functional demands for the offshore service vessel fleet, especially related to cargo operations, stand by emergency tasks and ice management.

The figure below shows how the different factors influence on the functions the vessels have to fulfill and the configuration of the vessels and their equipment.

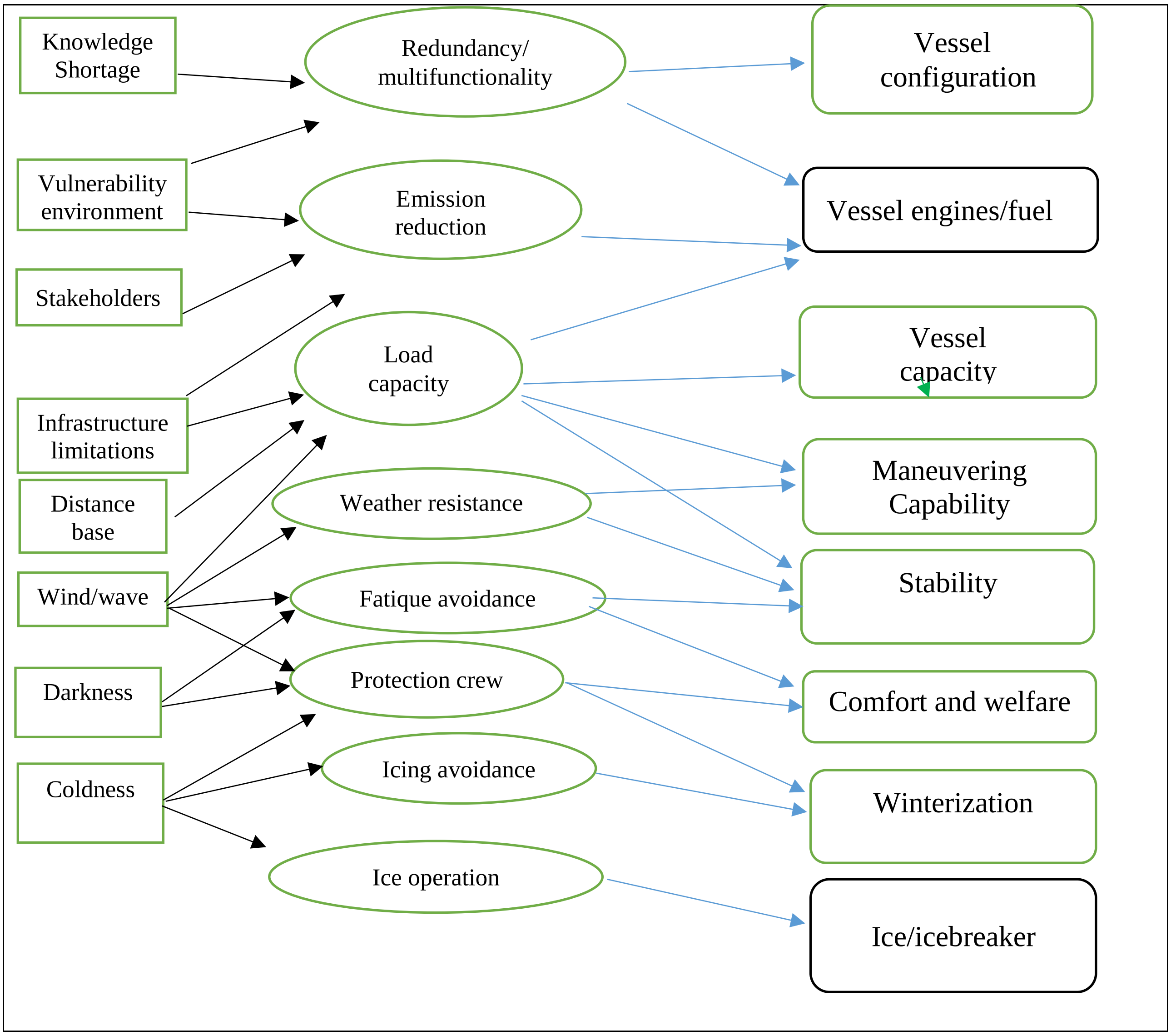


Figure 13. Operational context, functional demands and technology

The lack of knowledge of the conditions in a region, the vulnerability of the environment as to external influence, and the variability of interests including conflicting interests between stakeholders make risk avoidance and assurance more critical. This have implications for the tools and equipment of the vessel as well as the crew competence and size. Good communication and navigation capacities are crucial.

Infrastructure limitations as well as distance between supply base and rig/installation means larger cargo capacity and increased size of the vessel, or number of vessels. The wind aspect influence on the opportunities for delivering cargo, the wave resistance of the ship to avoid weather damage, and the protection of the crew. The wind aspect has implications for both the maneuvering capability related to engines, dynamic positioning etc., the stability of the vessel, and crew fatique.

The winter darkness may demand more protection for the crew as to light and facilities on board. It implies both better equipment, more skilled and trained personnel and not the least a high comfort onboard to reduce vibration and noise, and welfare facilities.

The coldness demands both better protection of crew, more advanced safety equipment, and significant efforts in winterization of the vessel to avoid ice on the superstructure, the functioning of all deck equipment and launching and use of SAR and oil spill recovery capacities.

The coldness may lead to ice that have significant consequence for the ice strengthening of the hull, and in the worst case to the need of icebreaker class. This results in another design of the hull with less sea going abilities as well as more costly engine and propeller systems. Also, running the ships with extra winterization and engine capacities have added fuel consumption consequences. The extra costs of both winterization and higher ice class are significant.

5.2. THE FUNCTIONALITY DEMANDS

The challenges of operating a vessel under severe conditions include keeping service speed and time limits, risk of damage to ship and crew, risk of collisions with other ships, complicated maintenance processes and repairs, reduced accessibility to installation/platform, complicated positioning keeping, and removal of ice from installations, difficult evacuation of vessel, difficult rescue operations and firefighting, complicated oil spill response. In this section, we discuss the different demands to functionality of the vessels in question.

5.2.1. Redundancy and multi-functionality related to preparedness

(1) Long distances and limited infrastructure call for robustness of the vessels and equipment involved. However, failures appear. This means that there have to be spare parts available on board together with high competence as to repairs. This also implies spare parts to be used between the vessels in the operation. The stand by vessel is, for example, vulnerable in this respect.

(2) Communication challenges is becoming more severe the longer north you go. This means that there have to be alternative channels of communication, understanding of the different antennas needed, for example for receiving corrections signals for the GPS and DP related systems.

(3) The remoteness create challenges as to emergency response. Distances from harbors and depots are long, and the capacities as to helicopter will be reduced the longer from an airport the operation is taking place. That means redundancy when it comes to emergency equipment is important.

This implies extra MOB and fast response daughter craft boats, with easy ways to launch the boats. It include hotel and hospital capacities.

(4) Oil pollution response is an extra challenge because of the vulnerability of the environment. This calls for extra capacities for both oil spill recovery including skimmers and lenses that may withstand high waves and icing, dispersant and other response capacities. In addition, the equipment has to be adapted to collecting oil in ice. It also has to be protected from icing. This may imply that traditional boom systems have to be supplemented with brush systems. Such systems have among others been tested out at the new Finnish coast guard vessel Tuva.

(5) Emergency towing capacities is a fourth multi-functionality that may be added to both EPRV and PSVs for helping other vessels with problems and the rig as well. This may also include towing of smaller icebergs, working together with larger anchor handling and towing vessels.

(6) An important dimension is the role of depot and hotel vessel. The PSVs may temporarily serve in this role along the rig. However, with longer distances and risks of bad weather for a longer time, a more long-term depot function may be needed. Such a vessel should have large deck space and preferably a heavy lift crane that may take supplies from other vessels.

(7) The lack of knowledge in the regions means that there has to be a more continuous collection of data from the site. The fifth dimension thus include facilities for systematic collection and registration of data, for example met data, ocean data, wave and vessel response, etc. this calls for installing different types of sensors on board.

(8) The vessels may also serve as a backup for the rig. Special functions that may be installed is systems for drilling fluids and mud mixing, as well as treatment and storage of drill cuttings, spare parts capacity

(9) As many people may be stuck for a time in transit, there is a need to have as hub function, where the vessel may serve as a landing and fueling site for the helicopters to and from the rig. This also implies extra cabin capacity on board serving as a hotel for the stranded personnel to and from the rig, or personnel serving as a backup if the helicopter transport is hampered by bad weather.

(10). With very long transfer hauls for helicopters there may be a need for the OSVs to serve as hubs and tanker stations, especially in case of fog. This is also important in case of accident and SAR operations. This means that the vessel needs helicopter landing platforms with heavy helicopter capacity and fueling station.

As to the role of OSVs in emergency preparedness to SAR and oil spill prevention in the High Arctic, I think we are not fully prepared. There is a way to go to be able to meet those challenges, but I think we just have to take the best equipment we have, the best people we have, and we have to do the best out of it. Maybe adjust operations in line with what kind of resources you have.

Manager, shipping company.

5.2.2. Emission reduction

The vulnerability of the Arctic means that there should be a minimum footprint from each vessel. The number of conflicting stakeholders may increase in the Arctic area, with a special increase in environmentalists skeptical to oil and gas exploration in general, and in the Arctic in particular. There will therefore be many interest groups including the regional and national governments focusing on this side.

(1) Garbage or any emissions to sea and any other forms of sea pollution should never appear, and mistakes or mishaps will be discovered soon. In general, there will be no failure quota.

(2) A greater focus and restrictions also comes to air emission. There will be a focus on NOx, Co2 and zoot. The answers to these questions are low emission fuels such as LNG or hydrogen, and electrical or other types of soft-going engines. Still there will be a need for hybrid gas-diesel fueled

vessels for practical and safety reasons. However, the industry should work hard to reduce any type of emission and pollution.

(3) A new area of pollution is noise not only for the crew but also for the mammals that are very much present in Arctic waters. There is a significant focus by environmentalist groups on the welfare of mammals, especially the larger whales. Sea noise pollution has been raised as a problem within the Arctic Council committee for maritime environment PAME and will probably be a point of discussion in the years to come.

(4) Anti-fouling coatings may have a negative impact on the environment. There is research going to avoid coatings through using other types of anti-fouling, among others through cathodic protection.

5.2.3. Load capacity

(1) Deck and tank load transport is the basic job for the platform supply vessels serving as the "work horses" for the rigs and installations. For the long distance fields, the capacities of the PSVs are important, including both deck and tank capacities. The capacities will depend on the number of vessels that are to be used, and whether it is exploration or production activity, where the latter means less cargo volume.

(2) For remote fields, passenger transport capacities may also prove important. The combinations of strong winds and large distances, and is summer time fog may hamper helicopter transport. Transport by vessel may prove the only solution. This was the case in the 2015 Kara Sea drilling where the crew change took place by PSV transport between the drilling site and the base in Murmansk.

(3) As tanker vessels, the PSVs and AHTV may carry different types of fuel. One type of cargo may be helicopter fuel with a helicopter deck as the tanker station.

5.2.4. Weather resistance

(1) Weather resistance is firstly about the vessel's seakeeping abilities being able to advance in bad weather and keep up operations in wind and wave conditions. It is also about keeping the loads safe in case of bad weather. Among others, the cargo rails of the PSVs have been higher to protect the containers and the deck crew.

(2) For the crew there should be efforts to make the conditions easier to reduce the challenges of staying both on deck, work in other parts of the vessels in high seas, and swell.

(3) An important capability of a field logistics vessel is to keep up the positioning along the rig for loading. This means that both the hull and the superstructure has to be designed to reduce the wind and wave pressure. The larger the vessels, the more challenging this will be.

(4). the vessel should have the best instruments and support available for route planning to reduce the strain on the vessel and the crew during transit and operation.

5.2.5. Fatigue resistance

In winter, time working in the Arctic means darkness most of the day. Together with stormy weather and challenging operations, this may cause fatigue problems where the crew becomes exhausted. Winter depressions may also be a problem.

(1) The vessel has to be equipped with the necessary light and tools to reduce the strain on the crew during working hours. It also has to be equipped with cabins and welfare zones that gives maximum opportunity for relaxing.

(2). Opportunities for systematic training is important to avoid fatigue and stress. Fitness facilities should have a central place on board.

5.2.6. Protection crew

(1) The crew should have the best of equipment to restrict coldness and to keep up the safety, especially on deck.

(2) The rescue equipment and firefighting equipment has a central role on board and has to be prepared for both storage and use under icing and freezing conditions. The equipment should be adapted to be used with winter clothes on.

5.2.7. Icing avoidance

(1) The vessel has to be designed to avoid areas from freezing because of atmospheric ice as well as spray from the sea. As much of the vessel as possible has to be closed in.

(2) Critical passages as the gangways and windows have to be heated to secure good overview and safe passages on board. Valves that are to be used should be protected and preferably heated.

(3) The Polar code emphasizes the protection of firefighting as well as private and collective rescue equipment from freezing.

5.2.8. Operation

(1) The vessels has to have an ice class according to the area where they are expected operate, and the worst conditions that may appear. That means a higher ice class than has been normal up to this day that is ICE C. there are only a few ice classed supply vessels in the world, most of them in Russia. Out of 35 platform supply vessels working in Russian icy waters in 2015, 20 had ice class above lowest ice class Ice class 1C. Two of them was from Viking Supply. In total, there were only around 50 PSVs/AHTVs with Ice class C or above[2].

(2) The design of the vessel should be made to balance between a) a slender hull, lighter weight and propulsion efficiency to increase speed and reduce fuel consumption and emission, b) seakeeping capability and noise and vibration reduction and c) strength for operating under ice conditions. This is especially a challenging task when it comes it icebreaker capabilities.

(3) There is a need for equipment that may provide the vessel with information as to both stability and pressure on the hull. Ice Load Monitoring systems may be installed to provide continuous info and to be used in research as to what strain different types of ice and weather contribute to. This may include sensors in the hull to register the global and local stress on the hull.

(4) Navigation tools for the Arctic have to be added including strong searchlights, infrared cameras, and ice radar systems. One significant challenge is for the radars is to discover icy bits and growlers with a very small part above the surface. Especially in waves and fog that reduce visibility this is a significant challenge in areas with multi-year ice.

[2] Fearnly Offshore Supply, 2015.

The vessel also needs advanced systems for collecting, storing and analyzing weather, waves, ice inclusion and coverage, hydrographic, oceanographic, and other hazards of importance for route and operational planning. This is especially important when the vessel is to conduct ice management removing icebergs or crushing ice floes threating the rig. Radar imagery from satellite radars may help detecting “hidden” multi-year ice and the drift patterns of icebergs. Access to “big data” with historical information may provide a platform for better risk assessments.

This means that there have to be necessary satellite communication capacities. This has been a significant problem from 70 degrees and above. More satellites in high orbit may solve this problem

One problem with navigation and especially for DP operations close to the rig is the lack of precision as to gyro, GPS and communication. The correction signal for the GPS (DGPS) is weak when you are far up North, and has to be compensated by other positioning tools at the rig. Satellite compass should be included on high degrees and are obligatory north of 80 degrees according to the Polar code.

There have to be a consideration of a closer coordination and control of vessel navigation from shore control centers. Installations for remote control of the vessels has to be considered.

6. VESSEL TECHNOLOGY IN ARCTIC OFFSHORE LOGISTICS

6.1. GENERAL CONDITIONS

The discussion in the chapter above shows that the climatic conditions as well as the other important parameters like long distances to the base and a lack of infrastructure calls for service ships supporting platforms and installations that are robust and meet the demands of these regions.

Offshore service vessels are largely exposed to rough conditions at sea. Much of the oil and gas activity today is in the open waters. High wind and waves will appear together with a heavy rain, fog, and currents. In the Arctic environment the same conditions may appear. In addition, there are other challenges that may cause problems for the mariners. These are ice, icing and extreme darkness together with storms created by the polar lows, all mixed with long distances and limited infrastructure. For the construction and operation of service vessels, this may imply increase focus on both the construction of the ship, the vessel functionality and the operational demands.

The ship owner together with the designers, yards and equipment producers has to develop adapted technology for the Arctic waters. As for now, the fleet available for the operation in this area is limited. On the economy and finance side, more in-detail economic calculation and risk evaluation, including political risk are needed. This means that the investor companies and banks need to develop stronger links to operators in this region. On the management side, the ship operating companies and the oil companies operating the fields has to build on shore operational management with broad understanding of jurisdiction and (maritime) culture. There is a need for special navigational qualification on board of the ships; ice pilot/ice management and special HME, environment and quality management. There has to be a focus on the safety and cooperation with the authorities and other ships, awareness of endogenous people and their local interests, and a total quality management approach within the whole organization.

6.2. THE MAIN TECHNOLOGY AREAS AND REGULATIONS

In the previous chapter, we have described how different types of functionality have implications for technology development. Areas of technology improvements are the hull, engine and propellers, cargo capacity and storage facilities, deck machinery and equipment, bridge equipment, the superstructure and the interior.

The technological development when it comes to offshore service vessel has accelerated since the first types appeared in the Mexican gulf in the fifties. Not the least has the operations in the North Sea and the involvement of Norwegian design companies, yards, equipment producers and experienced and demanding ship owners and crew contributed to a fast implementation of new technology.

The list below shows some of the significant innovation areas within the OSV vessel design

1. new hull designs for stable operations and seaworthiness in high waves and wind
2. improved cargo capacity both on deck and in tanks as the vessels have continuously been longer and broader
3. higher cargo rails to increase cargo capacity and protect crew and cargo
4. more engine power
5. more energy friendly engines with electro motors and Diesel-LNG-high efficient generators
6. Battery technology
7. Azimuth (360 degree) and thrusters (side propellers) for improved maneuvering
8. Dynamic positioning systems for keeping position on site
9. Improved view from the bridge
10. Integrated navigation systems
11. Satellite Communications
12. Surveillance and remote-control of technical systems
13. Advanced winches and towing capacity
14. SAR and oil spill response facilities integrated

Table 21. Vessel configuration design

In addition to the industry innovators, the maritime and petroleum government bodies together with the oil companies as demanding customers have been drivers in pushing the maritime industry forward. In addition, the classification societies have followed suit by introducing new standards and notations that would provide the vessels with the necessary classification and certificates, as well as regimes for inspection and control.

Class notations from a class society includes independent technical standards for design, construction and survey of ships, and control with verification that the vessel comply with these standards.

Among the regimes and standards that have followed the industry are:

- The International Maritime Organization conventions (COLREG, SOLAS, MARPOL, STCW)
- Flagg state laws and regulations
- The IACS The international Association of Classification Societies classification rules
- Classification Society notations
- Industry standards, such as G-OMO – guidelines for offshore marine operations
- Insurance company guidelines
- Company standards and manuals
- Field specific standards as manifested in tenders
- Vetting standards as practiced by inspectors
- Sea region standards

Table 22. Laws, regulations and standards of importance to the OSV fleet

The Polar code represents a very specific regulation regime for the Arctic region. Almost all side of vessel technology and operation are looked into. The table below

Vessel design and construction

- **Three categories:**
  - A) Medium first year ice-70 cm to 120 cm thickness (1A Super, Polar class 6)
  - B) Thin first year ice -0.3-0,7 m thickness (Polar Class 7/ice class A,B,C)
  - C) Open waters- ice conditions less severe than A and B (ice concentration less than 1/10)
- **Intact stability with top side icing**
  - Sufficient stability in ice accretion (more layers of ice) on superstructure
  - Stability calculations have to show the icing allowance
- **The structure**
  - The (hull) structure has to resist both global and local structural loads
- **Materials**
  - Have to use materials strong enough for the vessel's polar service temperature (at least 10°C below the lowest MDLT for the intended area and season of operation in polar waters.
- **Ice strengthening**
  - Rudder/ stock
  - Hull
  - Propeller/ shaft
  - Sea chest arrangement
  - Ballast water anti freezing

Table 23. The Polar code focus on design and construction

The Polar code first defines three types of vessel according to what type of sea ice conditions they may enter. Second, they focus on the amount on ice on the deck and superstructure that the vessel should manage without losing stability. Third, the hull has to withstand the pressure from ice and the load on the hull of ramming ice. Finally, there is a focus on the strength of different parts of the underwater facilities such as the rudder and propellers to withstand the ice and freezing water. This includes the ballast water and the intake of cooling water for the engines.

One of the challenges of the Polar code is the assessment of risk related to the different sea areas as a platform for polar water operation manual. Within the IMO framework, efforts have been made to create a Polar Operational limit assessment risk indexing system (POLARIS) that may serve as a platform as to both construction and operation.

6.3. THE TECHNICAL CONFIGURATION OF A SUPPLY VESSEL FOR THE ARCTIC

In the previous chapter, we categorized the main technological areas of improvement within the following areas:

1. Vessel configuration –inclusion of utilities/ equipment
2. Vessel engines and fuel
3. vessel size and loading capacity
4. Maneuvering capability/DP
5. Vessel stability
6. Comfort and welfare
7. Winterization
8. Ice operation

6.3.1. Vessel configuration –inclusion of utilities/ equipment

Vessel configuration is about the utilities that the vessel should bring with it to serve the field optimally.

(a) Depot facilities with equipment for spare parts with a lot of storage capacity has been discussed. The vessel also has to have high redundancy with back up capacities if critical equipment fails. To serve as a depot ship also implies larger space at deck and under deck. It also means that the vessel should have extra crane capacity.

(b) Search and rescue (SAR) capacities are critical as one get longer from the coastline and especially as the capacity of the AWSAR rescue helicopters are stretched. The SAR capacities is about the pickup capacities of persons from the sea, including the number and size of MOB boats, fast going covered daughter crafts and persons one may accommodate on board, and hospital capacity. One important issue is the safe rescue of lifeboats and man over board (MOB) boats in high waves. Taking in these boats on the stern has been launched as a new solution.

For the search tasks use of UAV drones turns up as an important solution.

For Emergency Response and Rescue Vessels there are certain demands as to capacities, such as speed of picking up people in the sea. The table below shows the Norwegian Oil and Gas Association recommendations for response in defined situations of hazards or accident

(DSHA), and BASEC (Barents Sea operators) recommendations for the more remote parts of the Arctic.

DHSA	Norwegian Oil & Gas Ass.	Recommended for more remote Arctic	Resources
Man overboard from rig	8 min	8 min	Stand by vessel
Personnel in sea after helicopter accident	120 min (21 pers.)	4 hours	Helicopter Supply vessels
Personnel in sea after emergency rig evacuation	120 min		Stand by vessel Helicopter Supply vessels
Rescue from lifeboats		24 hours	Helicopters Other vessels
External assistance illness/accidents	60 min		Helicopter
Evacuation illness/accidents	180 min		Helicopter
Risk of collision	50 min		Stand by vessel
Fire with need of external assistance	Field specific		Standby vessel Supply vessels
Acute oil spill	Field specific Goliat :SBV 120min Goliat PSV1: 8 hrs Goliat PSV2: 13 hrs	Field specific: Korpfjell SBV 120 min PSV1: 13 hrs PSV2: 30 hrs	Standby vessel Supply vessels Specialized oil response vessels

Table 24. The response capacities recommended on Norwegian Continental Shelf (Source: BASEC, Hauge, Statoil, 2017).

The table above shows that there will be challenges as to response time in the Challenging Arctic like Korpfjell. The rig may have 100-150 persons on board. The sailing hours from the depots in Hammerfest is 24 hours with an economic speed of 12 knots, and a little less with max speed of 15-16 knots. The helicopter transport is around 2-3 hours with distances to

nearest hospital in Kirkenes around 270 nm or 500 km. Emergency speed for the SAR helicopter is around 140 knots per hour. The mobilization time for the SAR helicopter is normally 45 minutes, but 15 min when helicopters are in transit. The hours above are under ideal conditions. However, fog and waves may create significant delays. The new AWSAR AW 1010 Rescue helicopters located at Banak will significant improve the capacity. There is limitation as to data transfer capacity for example for telemedicine purposes. The bandwidth are as low as 4 Mbps, which is not sufficient. There is a need for more capacity both on the rigs and especially on the stand by vessel.
The classification notation from DnV-GL is STAND-BY, and is especially made for Rescue operations and standby services in harsh weather conditions.

The Norwegian Maritime Directorate (NMD) has made instructions to class societies as to stand by vessels, with criteria for capacity for taking care of people after they have been rescued that have been a kind of industry standard.

The instructions include:

- Number and location of rescue boat
- Recovery of persons from the sea directly into the vessel
- Room for survivors
- Field of vision from command position
- Means for communication between treatment room and doctor on shore
- Helicopter winching zone
- Side scuttles and blind covers
- Blind covers for windows in wheelhouse
- Breaking strength of towing wire

As an example, fulfilling the criteria for 100 rescued persons gives the notation NMD RESCUE CLASS (100).

Reflections:

The designs above have made for the North Sea. One may consider whether there should be and extra categories with additional equipment for the challenging Arctic, for example as to comfort and winterization.

For other vessels like a PSV that do not have a Stand-by class there may be specific technical demands for each field they want operate set by the petroleum authorities and the oil company. For the Challenging and Extreme Arctic, capacities close to the Stand-By notations should be considered. Extra sea going capacities may be available to fill in for helicopter limitations. The high communication capacity for emergencies and telemedicine should be central criteria for the stand by vessels.

(c) Capacities for oil spill response is about removing oil spill that may harm the environment. This can be done by collecting it, burning the oil on site, or spread the oil so that it sinks through dispersants.

Oil spill recovery operations is about platforms for using skimmers for collecting oil, facilities for receiving and tank capacities for storing it, running oil booms, and dispersant capacity. Mostly, the PSVs do not have this capacity on board, but have to go shore, unload proceed to a depot, load the equipment and then transit to the site for oil recovery. As shown in the table above, this takes time both for making the equipment ready at base, transport it (11 hours from Hammerfest to Korpfjell distance 340 nm), and make it ready on site (min 2 hours).

The extra notation from DnV-GL for occasional handling, storage and transportation of oil with flash point below 60ºC recovered from a spill of oil in emergencies is OILREC.

NOFO the Norwegian Clean Seas Association for Operating Companies have made a special standard vessels taking part in oil recovery operations on the Norwegian Continental Shelf.

This includes tanks with heating, loading and discharge systems, deck layout for oil recovery equipment and skimmers, and systems for boom towing. This standard is called NOFO 2009.

Reflections:

Within challenging Arctic areas and on onwards with long distances there will be a need for having much of the ORO capacity on the site, and added capacity for SAR. This means that oil booms, skimmers and dispersants should be stored on board

.

(d) Capacity for firefighting is also an import additional configuration. There have to be pump systems as well as top side equipment for delivering water and foam. There also have to be protection from radiation, and capacities for continuing fighting large fires and
Cooling of structures. This includes larger water pumping capacity and more comprehensive firefighting equipment. There will be different notations for different capacities.

The extra notation from DnV-GL for fire-fighting capacities is FI-FI with three categories, were Fi-Fi III is the most advanced category.

Reflections:

For the Challenging Arctic as much capacity as possible may be needed, with special adaptation for operation in very low temperatures.

(e) Helicopter landing facilities are important both for SAR operations and for serving as an extra hub capacity in case of bad weather or accidents. This means that the vessel has to be equipped with helicopter deck for larger helicopters with fueling opportunities.

The extra notation from DnV-GL for helicopter landing decks is HELDK with Heldk F as the most advanced category.

Reflections:
Helideck has been regarded an unnecessary cost for PSVs closer to shore. Only offshore construction vessels and ERRVs are equipped with helideck For Challenging Arctic one may reflect on having this capacity for all vessels in operation.

f) Hotel capacities may be an important part of serving as a hub. This means extra cabin and catering capacities. In addition, the vessel needs bridging arrangements for personnel to safely transfer from the rig to the vessel. This calls for extra innovations as to safe transfer system that is workable under tougher conditions including icing.

e) Security is an important element that has come up. The ERRVs have a special role in surveying the sea area around the rig and guarding the 500 m safety zone. With more controversy about oil and gas activity and the general increase in violent action and terror, there may be an extra need for added facilities on the vessels for surveillance, protection of personnel and also to serve as an action platform for special forces in case of violent action. This may imply both extra sensors, communication systems, strengthening of part of the superstructure, and special rooms as safe heavens dedicated for the purpose.

Reflections:
All the extra functionality above for PSVs and AHTV take space from the primary tasks of these type of vessels. This means that the vessels may include more functions than normally that will mean a larger size or a compromise with the cargo capacity. Another solution is to combine the basic installation on board with storing the additional equipment on a specialized depot and hotel ship on site.

6.3.2. Vessel engines, fuel and emission

The vessels emission to sea and air is a very critical point in the Arctic. The low footprint objective will be stronger and stronger. This means that air pollution and noise as well as sea pollution from garbage, coating, grease etc. is areas where the vessel will be scrutinized.

Fuel consumption and emission is related to a broad range of issues including:

- Vessel size and weight
- Hull design
- Hull coating and cleaning
- Optimized propeller systems
- Engines and fuel types
- Energy optimization
- Motor adjustments and maintenance
- Exhaust cleaning technologies
- Heat recovery
- Efficient route planning
- Economic speed

The most significant change in emission comes from the choice of fuel type. The solution to this challenge is engines with low emission fuel, especially reducing fuel oil to a minimum. The first alternative is the use of gas fuel, such as LNG or hydrogen.

The highest effect comes with the use of electricity from renewable power, or from fuel cell technology. Fast charging systems for charging in harbors, or for example from the rig/installation should be in place if they can provide energy with lower emission. The development of the electrical ferry *MF Ampere* is an example of applied fast charging and offshore technology. Statoil has demanded batteries installed in several PSV on long-term contract. The construction of the new Hurtigruten expedition vessel *Roald Amundsen* may represent a step further into using batteries in combination with diesel engines. Running rig operations with a combination of one generator with back-up power coming from batteries may significantly reduce the emission.

At the same time, having enough fuel of high quality with tank capacity enough for long distances and necessary cargo call for compromises. LNG, for example, have few fueling points, and the tanks on board is voluminous. For the Challenging Arctic regions, duel fuel engines using both diesel and gas seem to be the solution. For diesel and gas, engines advanced catalytic or other systems should be installed to reduce emission to a minimum.

Reflections:

The accelerating development of battery technology gives new opportunities for loading in harbor, and storing electricity on board with additional battery capacity. Accumulating as much battery capacity on board as possible due to space and weight will probably be an important solution. Running on battery will also remove another problem that is reducing the noise exposing both to the crew and to the surroundings.

6.3.3. Vessel size and loading capacity

Both platform supply vessels and the anchor handling and towing vessels are taking part in the transport to and from rigs. Capacities are related to deck space for carrying containers, chasings, pipes and other drilling equipment. The tank capacity is related to different types of special bulk cargo with a sophisticated valve and pipe loading and discharging system. As tank load, they carry fresh water, fuel oil, dry and liquid drilling mud and flammable liquid as methanol. The vessels have since the seventies been longer and longer meaning larger deck and tank capacities, with a deck area around 1200 m2. For vessels with firefighting equipment, there are also tanks for firefighting foam.

As return cargo, different types drilling waste, used waters and sewage water is carried.

Reflections:

For Challenging Arctic increased capacities should be considered, taking into consideration whether the increased capacity will demand a vessel that is so large it will be difficult to maneuver alongside the rig.

6.3.4. Maneuvering and positioning capability

A critical point for the supply vessels is their station keeping capabilities especially when close to the rig. This means that there have to be abundant of engine power and advanced dynamic positioning systems. A critical point here is the sensors needed to keep position especially the signals for the GPS system. This may represent a challenge when it comes to correction signals. The correct antennas and system at the rig for having positioning signals is of utmost importance.

The DP-systems are sensible, and different types of redundancy are built in case of damage on sensor, the system or the maneuvering desks, and redundancy as to engine capacity and thruster systems.

The DnV-GL extra notations for dynamic positioning is DYNPOS in the categories AUT, AUTR and AUTRO, related to the standards DPS1-DPS3.

Reflections:
As the DP systems are of critical importance for operations, extra backup systems are critical in the Arctic. For supply vessels, the normal level of quality has been DPS 2 or AUTR. For the challenging Arctic, very separate systems for DPS 3 level may be considered.

6.3.5. Vessel stability

For sea areas with high waves and much wind, the seagoing capabilities are of utmost importance. It is a question about speed in high waves, the safety and comfort of the crew, and taking care of sensitive cargo. Thirdly, there is the risk of ice on the top side that may severely reduce stability. The most important is the stability when loading/discharging cargo to and from the rig

Stability is about slamming when meeting waves, vertical and horizontal movements, role and pitch. In particular, it is about the risk of having sea into the desk during transit and cargo operation.

To be classified as a supply vessel you have to fulfill stability and floatability demands. .In general a supply vessel and anchor handling and towing vessel will have very high stability. With higher cargo, rails for supply vessel and stronger towing winches for AHTVs the stability may, however, be challenges. With ice on the superstructure, this may create extra challenges as to stability.

At the rigs, the operators have general limitations as to wind and waves for the PSV to operate into the rig, for example max. 12 ms. With more tailor-made vessels one may create more specific demands for each vessel related to a specific rig/installation, based on the characteristics of the vessel, waves, wind, current and ice and type of loading that is taking place

The DnV-GL extra notation for a supply vessel will be SF.

Reflections:
The weather conditions, icing, and ice conditions means that the vessel for the Mid-Arctic should and beyond should have extra stability, fulfilling the Polar code, and also for the sake of the crew welfare. There should be an evaluation of each vessel as to stability when operating close to a specific rig, to learn more about the capacities and operational limitations.

6.3.6. Comfort and welfare

The welfare of the crew is a very important aspect when it comes to the Arctic. Working for a long time in bad weather and in darkness put a heavy reduce sleep quality and create fatigue challenges for the operation.

There have been a development in improving facilities on board for the crew including day mess, and for reducing vibration and noise in the living quarters.

This has to be developed further into more noise- and vibration isolated cabins, and more comfort in every part of the vessel.

It will also include installation of welfare rooms, including training facilities.

TV and internet coverage is necessary to keep the relations to the social network and society. This means advanced satellite communications available.

The DNV-GL extra notation for noise, vibrations and indoor climate is COMFORT in three categories, where (1) is the best.

Reflections.
For vessels in the Challenging and Extreme Arctic extra comfort and welfare, arrangements should be made beyond this class, including both more cabin noise and vibration isolations, wider space and more welfare rooms, in addition to satellite links for internet capabilities.

6.3.7. Winterization

Making the vessel ready for snow and icing conditions is critical for Arctic operations. This means that all vital parts of the vessel have to be protected, with coverage, electrical heating, etc. this also means extra generator capacity. Central areas of heating are wheelhouse windows, staircases, bulkheads, drain pipe systems, vent pipes, drain gates, evacuation hatches, as well as the MOB boat hangars.

The Polar code is emphasizing winterization for avoidance and removal of ice for keeping up the stability of the vessel in case of icing conditions. There also have to be equipment for removal of ice including hot water/steam, and manual equipment. In addition, the lifesaving and navigation equipment has to be certified for low temperatures.

The certification is related to how long one could operate in freezing temperatures and to what low temperatures the vessel and its equipment is designed for. We are here talking about the daily average temperature (DAT) that critical parts such as hull, safety equipment, cargo handling equipment for cargo should withstand.

The extra notation of DnV-GL is WINTERIZED with three different categories: Basic, cold, and Polar. Category POLAR means that the vessel can operate in extreme cold climate all year-round.

Reflections:

For vessels in the Challenging and Extreme Arctic, one may discuss the high but flexible degree of winterization, with adaptions according to temperatures and icing conditions. Winterization down to minus 30 degrees is needed for the Challenging Arctic and -45 for Extreme Arctic.

6.3.8. Ice operation capabilities

The Challenging as Extreme Arctic represent additional ice challenges in the form of sea ice and icebergs. With low visibility, this represents an extra challenge. Much focus has been laid on the extra demands necessary for meeting ice in open waters and operate under conditions with high ice density. The presence of large amounts of hard multi-year ice represents the most critical challenge. In addition, for the rig ice management in the form of breaking up ice floes and towing icebergs may call for extra considerations. There is also a challenge that is designed for ice breaker capacities may give extra costs for fuel, and also less sea-going capabilities in high seas.

(1) Ice class. A certification for operating in ice demands a focus on both the hull strength and the propeller and rudder systems. In addition, the challenges for the intake of cooling water for engines is important and avoiding the ballast water from freezing. The vessel needs extra engine capacity and extra demands as to stability.

Baltic		Polar Class	
		PC1	Year-round operation in all Polar waters
		PC2	Year-round operation in moderate multi-year ice conditions
		PC3	Year-round operation in second-year ice which may include multi-year inclusions
		PC4	Year-round operation in thick first-year ice which may include old ice inclusions
		PC5	Year-round operation in medium first-year ice which may include old ice inclusions
1.0 m first year ice	ICE-1A*	PC6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
0.8 m first year ice	ICE-1A	PC7	Summer/autumn operation in thin first-year ice which may include old ice inclusions
0.6 m first year ice	ICE-1B	-PC1 to PC6 may be assigned additional notation ICEBREAKER	
0.4 m first year ice	ICE-1C		

Table 26. The Baltic (Swedish-Finnish) and IACS class notations for operating in ice

The Finnish- Swedish ice rules covers different types of first year ice from ICE 1C to ICE 1A Super, with 1C 1C) includes operation in first year ice with max Ice thickness of 0.4 m and 1A Super an Ice thickness of 1.0 m with operations only in Summer and Autumn.

The International Association of Classification Societies (IACS) has made a new category going from PC7 to PC 1 where PC 7 is equivalent with ICE 1A. From PC 5 you may operate all year round with thicker and more multi-year ice.

If you have ice class from PC 6 (1A*) and better, the vessel may have additional notation icebreaker if it fulfills special icebreaker requirements. Note that Baltic class ICE 1A and 1A* are not totally similar to polar class PC7 and PC6. For the last ones they have to be strong enough to withstand inclusions of old ice while the Baltic class is for first-year ice only.

The three Polar code categories relate to the IACS categories as follows:

IMO Polar code categories	Description	IACS ice class categories
Category A	Designed for operation in polar waters in at medium first year Ice, which may include old ice inclusions.	Polar ice classes PC5 - PC1. Russian Arc 3- Arc 1
Category B	designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions.	Polar ice classes 7 to 6 Baltic Ice class 1A and 1A* Russian Arc 5 and Arc 4
Category C	Designed to operate in open water or in ice conditions less severe than those included in Categories A and B.	Baltic Ice class 1C and 1B Russian Arc 1-3 No ice class

Table 27. Polar code categories for operating in polar code waters and equivalents.

We see that the Polar code is a much more coarse-grained categorization than the class notations. One may expect that IMO may come up with more detail especially on the category C areas.

(2) Ice navigation instrumentation is vital in operating in ice. This imply ice radar capacities, infrared cameras, and satellite image systems. Advanced computer systems may combine these sensors into images that may help identify ice in open water, ice bergs and multi-year ice mixed into ice floes, etc. this means that extra antennas and both hardware and software have to be developed and implemented, and satellite communication capacities for taking down large amount of met and satellite image data have to be installed.

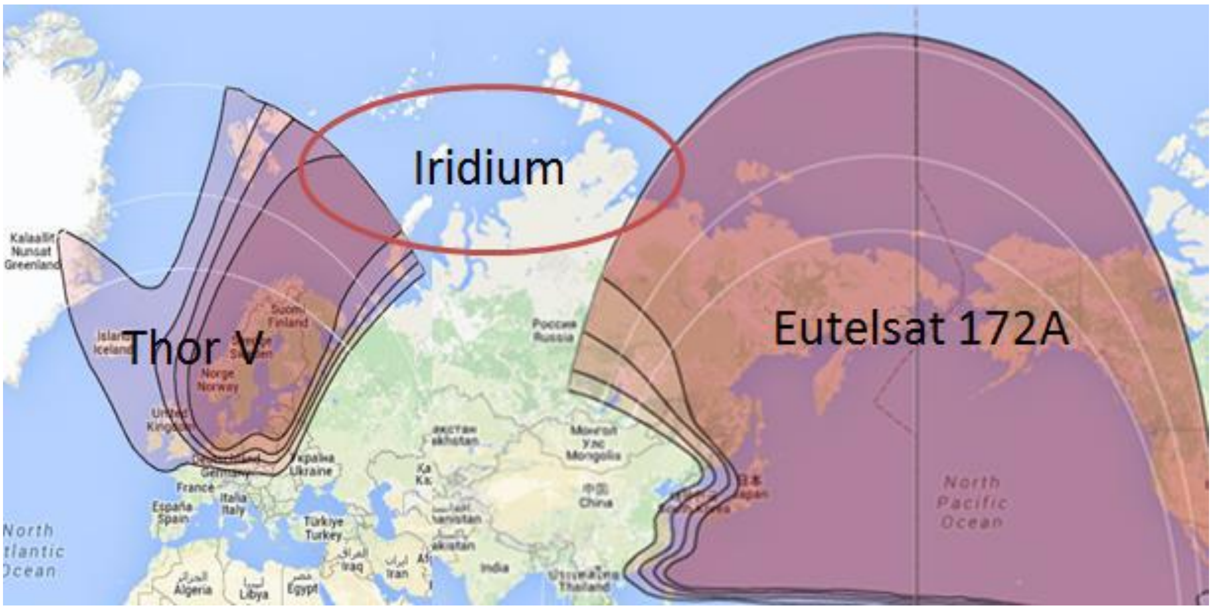


Figure 14. Satellite communication coverage in the Arctic (Source: Viking Supply)

The winterization, ice class and instrumentation is vital for safe operations in the Challenging and High Arctic. Winterization and high ice class is costly, Polar class and icebreaker class have implications for the hull and will reduce both seaworthiness and increase fuel consumption. The investment costs may increase by 250%. Anti-ice heating may represent up to five mill extra in cabling and generators. Ice class 1A super means several millions extra in steel. A high ice class will therefore have negative effects on many of the other parameters, and should be considered if needed. In Challenging and Extreme Arctic a high ice class towards PC 6 (ICE 1A Super) should be considered to take care of the

The table below summarizes the demands within the different sea areas:

	Low Arctic	*Medium Arctic*	*Challenging Arctic*	*Extreme Arctic*
Ice class	*Low Ice1C-1B*	*Ice 1B -1 A*	*ICE 1A Super (PC6) -PC 5*	*PC5-PC4*
Ice breaker AHTS		*First year ice(PC4)*	*PC3*	*PC3*
Winterization	*Low*	*High*	*Polar (-30)*	*Polar (-45)*
Comfort	*High*	*Highest*	*Highest*	*Highest*
FIELD LOGISTICS				
Cargo capacity	*Moderate*	*Large*	*Large*	*Extra large*
Hotel capacity	*Limited*	*Large*	*Extra large*	*Extra Large*
PREPAREDNESS:				
SAR	*High*	*Very high*	*Very high*	*Advanced ice*
Oil Recovery ORO	*Medium*	*High*	*Very high*	*Advanced ice*
Security	*High*	*High*	*High*	*High*
Towing	*Limited*	*Increased*	*High*	*Very high*

Table 28. Technical demands in different areas of the Arctic

We see from the table that the demands for the vessel increase as we enter the High North and icing and icy waters. As for ice class, we are talking about breaking 1m ice in summer autumn operations (ICE 1A Super (PC6) or PC 5- breaking 1m ice all year round.

Darkness and rough weather means that more emphasis has to be laid on the welfare of the crew. In addition, the distance from the supply bases and the necessary infrastructure call for more redundancy and more functionality built into the vessels. The distances also imply that the vessels should be larger, with new functions built in. The challenges of Challenging and Extreme Arctic call for innovation related to technology solutions and crossover in functionality between the vessel types, in particular the PSVs, AHTVs and the ERRVs. We may also look at the development of a new type of hub vessels, serving as helicopter hubs, depot and hotel vessel on or close to the site. More specialized vessels for oil recovery operations may also be an option.

The dilemmas of the Challenging and Extreme Arctic vessels are imminent in conflicting demands as shown in the table below.

DESIRES:	DILEMMAS:
High Power for Ice Breaking and Ice Management	Increase in emissions, noise and vibrations
Hull lines for Ice Breaking	Reduction in speed, seakeeping capabilities, stability and comfort
High ice class propellers	Reduction propulsion efficiency and increased fuel consumption
Additional weight because of ice strengthening	Reduced speed and increased fuel
Winterization through electrical cables etc.	Increased generator capacity and fuel consumption
Low emission engine solutions with LNG and battery fueling	Less tank capacity
Under deck oil response equipment	Less tank and LNG/battery capacity
Additional SAR and oil response installations (daughter craft, etc.)	Reduced deck space for cargo
High ice class, winterization and comfort for Challenging and Extreme Arctic	50 % increase in building costs

Table 29. Challenges of making more robust and multi-functional vessels for the Arctic.

We see the dilemmas above making it difficult to meet even more advanced requirements as to reduced emissions, better winterization, and increased safety and crew comfort when making the high ice class/icebreaker class. In addition, the increased preparedness and hotel/hub functionality means reduced cargo capacity. The implications are that there have to be much innovative efforts to reduce these dilemmas, and to discuss more specialized vessels in the more challenging environments.

7. THE VESSEL TYPES AND CAPACITIES

As discussed, an important aspect of the preparation for operation in the Arctic environments is the need for the development of the vessel types tailor made for the area. Today, we face the same situation as in the sixties in the North Sea. Ships were brought form the Mexican Gulf that were not suited for the North Sea. This has to be avoided in the North. The main types of vessels that service offshore oil and gas operations are:

1) Offshore service vessels
   a) Supply vessels (PSV),
   b) anchor handling and towing vessels (AHTV)
   c) Stand by rescue vessels (ERRV)

In the following, we relate to the different categories of vessels, the crossover of functionality and reflect on a new type of vessels in the regions, that is a depot and hub vessels.

7.1. Platform service vessels (PSV)

A PSV has a central role in transporting goods, food, cement, liquids and personnel to and from offshore installations and platforms. The characteristics of the PSV are: The PSV has such characteristics as large deck space for different types of hard cargo, high cargo rails, a broad set of tanks in hull, advanced pumping systems connecting the different tanks, cabin facilities for extra passengers, advanced dynamic positioning systems to keep position close to platforms, oil recovery capacity.

In order to operate in the Arctic conditions, PSVs have to be made for transport of a broad range of products on deck such as containers, pipes. Bulk cargoes in tanks may include cement, barite, bentonite, brine, base oil, water based mud, recovered oil, drill cuttings, wastewater.

As discussed in the previous chapter the platform supply may have multipurpose functions also accommodating and transporting people, SAR, security, oil recovery, and firefighting. There have been a significant development in capacity of the PSV's. This includes the tank capacity, also, these vessels may have extra crane capacity helping with depot functions and taking heavy lifts.

As discussed, we need more tailor-made vessels as we enter the Challenging and Extreme Arctic. So far, we have developed PSVs for the low and Mid-Arctic.

An example of a mid-Arctic PSV is Troms Arcturus, with a large loading capacity, including a deck area of almost 1200m2; she has ice class 1C as most of the modern PSVs, basic winterization, moderate comfort class and installation for oil spill recovery operations. In addition, she has systems for connecting to land electricity and charging.

Figure 15. Troms Arcturus, Troms Offshore

Specifications: Length, Overall: 310.5 ft. 94.7 m, Beam: 68.9 ft. 21 m, Depth: 27.9 ft. 8.5 m
Maximum Draft: 23 ft. 7 m, Light Draft: 11.5 ft. 3.5 minimum Height: 92.5 ft. 28.2 freeboard: 5 ft. 1.5 m, Displacement: 9,080 lt 9,220 MT, Deadweight: 5,520 lt 5,610 MT, Clear Deck Space: 300 x 57 ft. 70.1 x 17.5 m, Clear Deck Area: 12,700 ft^2 1,180 m^2, Deck Strength: 2,050 lb. /ft^2 10 t/m^2
Class Notations: DNV: +1A1, ICE-C, WINTERIZED BASIC, OILREC, SF, LFL*, COMF-V(2)
C(3), E0, DYNPOS-AUTR, NAUT-OSV(A),CLEAN DESIGN, DK(+), HL(2.8)

An example of a new generation of icebreaker platform supply vessels is a new build in Finland. In 2017, Arctech Helsinki finalized the first of four vessels commissioned by SCF Group for operation at the Sea of Okhotsk at Sakhalin. The icebreaking platform supply vessel with standby, SAR and ORO functionality is named Gennadiy Nevelskoy and will work for Sovcomflot.

Figure 16. MV Gennadiy Nevelskoy, SCF Group
Gross Tonnage: 8.400 Net Tonnage: 2.500 Power: 21 MW, Length, overall: 104,4 m, Breadth: 21 m, Classification: Russian Maritime Register of Shipping. Customer: Sovcomflot KM(*), Icebreaker6, AUT-1, OMBO, FF3WS, DYNPOS-2, ANTI-ICE, ECO, Winterization(-35), Supply vessel, Oil recovery Ship, Special purpose ship

The vessel may operate in 1m ice, and it has winterization down to minus 35 degrees. It fulfills the IMO tier 3 requirements for emission. It is designed for low sea noise levels.
A vessel like this are suited for the Challenging Arctic and may operate in Extreme Arctic.

Additional requirements regarding the PSV characteristics for operation in the Arctic are presented in the table below.

Operational tasks:

- Transport from base to platform/other vessels with cargo and passengers
- Extra storage on field
- Standby functions
- Security surveillance
- Ice management
- Rescue operations
- Oil recovery
- Towing operations
- Hotel ship +150
- Heavy lift

Class notations:

- Polar class PC 4 or 5
- DP 2 or 3
- Comfort V(1) and N(1)
- Winterized – Arctic A(-45)
- FiFi III
- Evacuation/rescue Group B ERRVA rules
- NOFO oil recovery rules with extra ORO for ice

Deck equipment:

- Cover over deck area
- Remotely steered hose connections
- Automatic container release hooks
- Towing winch
- Rescue boat/daughter craft
- Fire fighting
- Oil recovery- ORO operations
- Hotel gangway
- Helideck
- Heavy lift crane
- Rig gangways
- Safe havens

Engine:

- Hybrid energy (diesel/LNG/fuel cells)
- 15-20000 kW (20-27000 hk)
- Azimuth main propellers
- Azimuth retractable prop. (2-3 pieces)
- Ballast water cleaning
- Heating all tanks
- Heating deck/rails
- High steam capacity on deck
- Exhaust to sea/exhaust gas recirculation (EGR)

Table 30. Specifications for High Arctic platform supply vessels

7.2. Anchor handling and towing vessel

An AHTS is a service vessel for towing platforms and other floating installations, for placing their anchors in precise locations, and removing obstacles. This may imply placing and pulling anchors at very high deeps up to 2-3000 meters. The largest anchors for permanent anchoring may have a diameter of 5-6 meters and height up to 15 meters. The weight of the anchors and the long chains means that the operations may prove challenging in heavy sea and strong winds. This type of vessel is characterized by good stability, large deck space for anchors, chains, wires, bows, chasers and grapnels, towing pins and quarter-pins at deck to control the wires at the cargo rail, very strong heave-compensated winches, strong engines, high pollard pull capacities, precise positioning systems for location of anchors.

The anchor handler has as its main task to tow into position and secure the anchors of platforms of drilling ships. Most AHTVs are also equipped for serving as cargo ships both with deck and tank cargo. In addition, they may serve in oil recovery operations, and search and rescue.

In the Challenging and Extreme Arctic, it will with its very high engine power have the task of towing icebergs and performing ice management together with the standby vessels. A very important part of its task is to tow away rigs or installations if icebergs of the ice threaten them. A broad range of AHTVs has been made for the Low and Mid-Arctic.

Figure 17. Skandi Iceman, DOF Group

VARD AH 12 (2013), LOA 93,6m Class specifications. DNV +1A1, Offshore Service Vessel AHTS, SF, E0, DYNPOS-AUTR, COMF-V(3) C(3), CLEAN DESIGN, OILREC, WINTERIZED BASIC, FIRE FIGHTER I & II, NAUT OSV (A), DK(+), HL(2.8), TMON, ICE-1B, SPS

Skandi Iceman is an example of a Mid-Arctic AHTV offshore service vessel class, ice class 1B, accommodation for 60 persons fire-fighting II notation that implies a heavy fire-fighting capacity, Oilrec class and in compliance with NOFO 2009 oil recovery preparedness capacity, and NMD rescue approval with capacity for saving 300 passengers.

As for Challenging and Extreme Arctic we need AHTV with icebreaker class. Several AHTVs have been built, especially for serving in Russian waters. In addition, the vessels Vidar and Balder Viking are example of this type.

Figure 18. Balder and Vidar Viking are sister ships and examples of icebreaker AHTV.

Examples of earlier generations and specifications for a further development of an icebreaker AHTV for the Extreme Arctic are presented in the table below.

	Fennica 1994	Antarctica-borg 1997	Fesco Sakhalin 2005	Balder Viking 2000	Pacific Endeavour 2006	"Extreme Arctic» prototype
Owner	Finstaship	Wagenborg Offshore	Fesco, Vladivostok	VikingSupply ships Kr.sand	Swire Pacific Offshore	
Design Yard	STX Finland cruise	Kværner Masa Yards Helsinki	Aker Finnyards	KMAR 808 Havyard Leirvik	UT758Ice Aker Søviknes	
Hull	Polar 10	Double hull Baltic Ice 1A Super	Double hull Icebreaker ice-10	Icebreaker ICE-10	Ice-10 DAT 35	Icebreaker Polar 3
Length o.a.	116	65	100	83,7	91,5	100+
Breadth	26	16,4	21,2	18	19	
Draft/draught	8,4	2,9	7,50	6	5,09 max 8,2	
Depth	12,5	4,4	11	8,5	10	
Gross tonnage	9088	1453	6882	3382	4992	6-7000
Deadweight	4800	650t	4300t	2528	4482	
Service speed	16	13 3kn 60cm ice	15	12-16	12	15
Helicopter	Helideck 19m	no	No	No		Helideck 21m2
Cargo deck area	1100m2	350	730m2	603	780	12-1300m2
Offshore crane	150t+20t			12+3t	5t +20t	50t
Multipurpose functions	Supply/tug/ Installations	FiFi 1	FiFi 1 Salvage,	tug	Stand by 150 Tug	FiFi, Stand by, Ice managem.
Towing/anchor Bollard pull	230t	32t		201		500t
Pollution prevention			Oil rec	No		Oil recovery
Interior						Comfort (V)(C) 1
Tank capacity	5200m3 inc fuel/ballast		1500t cargo load	4500 inkl fuel/ballast		Superior
Engine	Diesel electric	Diesel electr.		4x MAK= 13440kW		Diesel and LNG-

	4 ABB 14500kW	2x1950kW				electric, +battery
Propulsion	Fixed pitch 3 stk bow thrusters 1150kW	Azipod 2x1650kW Double action Bow thruster 150kW		1 tunnel 1200 +azimuth 2400kw +stern 1200kw		Azipull, Dual action
Dynamic positioning	DP22			Autr SDP21		DP3
Navigation/ communication	+ Multi-sensor radar	+ Sonar satcom	NAUT-OC			Sonar, Ice Radar Adv. Sat. com

Table 31. The specifications of several generations of AHTVs with icebreaking capabilities

For the future, the development has to be taken into more functionality. An example is a prototype made by Aker Arctic.

Figure 19. Aker Arctic Prototype icebreaker anchor handling and standby vessel

This prototype has icebreaker capacities, is well winterized, and has fire fighting and oil response equipment to be able to serve as standby vessel with a capactity to host 200 persons.

7.3. Emergency Response Rescue Vessels (ERRV)

This type of vessels is made to serve as the “watch dog” and safe heaven for the offshore installation. They are controlling the 500 m control zone around the platform. They also serve in transporting people, they represent a safety measure in case of fire, need for evacuation and fighting pollution from the installation. This type of ship has such characteristics as good sea going capabilities, firefighting capacity, oil recovery systems, high passenger capacity, hospital. This type of vessels may be developed further for the Challenging and Extreme Arctic.

The ERRV Esvagt Aurora below was built for the Goliat field in the south of the Norwegian Barents Sea with the PSV Stril Barents with LNG fuelled engine serving as a backup. These two vessel types may be further developed for the Mid-Arctic regions.

Figure 20. ERRV Esvagt Eurora built for the Goliat field.

Esvagt Eurora 2012 – Zamakona Shipyard, Bilbao, Spain - Ulstein SX123 Design. DNV-GL, #1A1 ICE-1C WINTERIZED BASIC Tug Standby Vessel(S) Fire Fighter I and II OILREC SF COMF-V(3) DEICE-C E0 DYNPOS-AUTR NAUT-OSV(A) CLEAN DESIGN HL(2.5) BIS, NMD (Norwegian) Rescue - in compliance with up to 320 survivors.

The Challenging Arctic stand-by vessel needs capacity for operations in such areas as safety and security around installations, general rescue operations, anchor handling, ice management, helicopter operations, oil combat and recovery operations, firefighting, back up for supply vessel. For rescue operations, there is a need for large hospital and cabin facilities for temporary treatment and accommodation. IR camera and flying drones for search and localization of man over board and thickness of oil spill is necessary.

For emergency, towing one may need strong anchor handling winch. As for the ice management, it is related to ice surveillance and clearing the water especially for icebergs, berry bits and growlers that may represent the highest risks. This means that the stand by vessel may have ramming capacities. For towing icebergs a bollard pull of 250 tons and 2-3000 m 83mm wire may be needed.

As for the oil combat, NOFO oil recovery facilities are needed.

As for the fire fighting, this may mean the most advanced equipment similar to DnV notation FiFi 1.

As a backup vessel for the supply vessel, there is a need for some tank capacity and transfer systems. A stand-by vessel with such capacities may have a length from 90-110 meters.

7.4. The hub and depot vessel

The discussion above shows that we for especially the Challenging and Extreme Arctic are in need for extra capacities due to long distances and transport disturbing weather conditions. We have shown how one may put more functions on board the present type of vessels, the PSV, AHTV and ERRVs. There is a consideration about to what extent you can build multi-functionality into a vessel before it becomes a “multi-useless” vessel.

An alternative that has been followed in both the West-Greenland and Kara sea operations is to have a specialized hotel and depot vessel.

This vessel may provide extra storage capacity, accommodation and transport for rig crew change, and serve as a backup hub and fuel point for helicopters. It may also have an important job as first line oil recovery operation capacity, and play a role in SAR operations. They may also serve as back up for the ERRV. The table shows some of the capacities for a High Arctic hub and depot vessel.

- Ice class PC 6
- Winterization Arctic -30
- Large accommodation capacity 150 pax
- Large covered cargo storage capacity
- Fast going 15+ knots
- Very high stability --limited heave and roll
- Very high positioning capability-reference systems
- Highest comfort and welfare class
- Rescue class
- NOFO class oil recovery
- Hospital
- Mobile broadband systems
- Large type AWSAR helicopter platform
- Oil boom hangar
- Rig gangway solutions
- Heave-stabilized crane for personnel lifts
- Heavy lift cargo crane
- Environment-friendly – low emissions

Table 32. Specifications for a hub and depot vessel for the High Arctic

This means that these type of vessels should have much of the same capacities as an ERRV, extra deck space and accommodation, heavy lift crane, and gangway systems for safe transit between the vessel and the rig.

8. FLEET CONFIGURATION

We have in the former chapter discussed single vessel type capabilities. We have shown the range of functionalities that may be added into the traditional types of vessels, and launched the hub and depot vessel as a new alternative. The table below shows some of the functions that have to be taken care of by the fleet.

1. Platform supply
2. Waste treatment and transport
3. Anchor handling
4. Emergency towing
5. Ice breaking and ice management
6. SAR- Stand by emergency response and rescue
7. ORO- Oil spill recovery
8. Personnel transport
9. Depot
10. Hotel
11. Helicopter hub
12. Evacuation

Table 33. Functions that may be combined- areas of multi-functionality

One has to find the optimum solution to reduce both vessel investments (CAPEX) and the costs of running the vessels (OPEX). On a time charter, the oil company will pay for the much of the variable operating costs including fuel.

As we have seen, the more functionality that is introduced and not the least higher ice class the investment costs will increase significantly, and the same with the operating costs of maintenance and crew. However, the costs of delays in delivering critical cargo and crew to the rig is often much higher if the whole drilling campaign or production is delayed.

The drilling master and supervisors together with the storekeeper have to decide upon the key parameters:

- Speed of vessels
- Cargo capacity and costs of each unit
- Visiting frequency (daily or less frequent)
- Types and volume of deck and bulk cargo to be transported
- SAR response time in case of rig problems, helicopter crashing or vessels in distress
- 1st and 2nd line response time and volume demands set by the petroleum authorities and the operator

This has to be seen in relation to the delays and down time due to weather, ice, icing, maintenance and technical problems. This means that there also have to be key performance indicators as to:

- Running in bad weather
- Positioning in bad weather along the rig
- Low collision impact with rig
- Costs of not having deliveries
- Fuel costs per hour
- Emission/environment costs
- Other operating costs
- Investment costs

In the drilling campaigns that have been performed in waters characterized as Challenging and Extreme Arctic we have seen a pattern of creating a fleet of vessels that have some overlapping functions, and provide the necessary capacity within each function and a backup.

Figure 21. Fleet configuration during exploration drilling Disco Bay, West-Greenland in 2010.

At West Greenland, the Cairn campaign included Nordica, Balder, Loke and Vidar Viking to perform ice management, towing, anchor handling, supply duties and other general support tasks. Loke Viking was also dedicated to emergency response and oil recovery preparedness duties. Esvagt Don and Connector were hired to perform stand by duties. Troms Vision served as depot and hotel ship plus crew and cargo transport to installations. Finally, Troms Pollux, Troms Artemis and Olympic Poseidon provided supply duties, and served as emergency response in case of SAR and oil spill recovery.

It was a challenging task to anticipate the capacities needed based on the distances and lack of infrastructure in the area.

In Greenland, the first year we started up, in my opinion the operators had not done their homework in preparing the operation… "Then we asked them if they have a medical team and diving support. What if you need a diver for West Greenland? Because if you are in Aberdeen then there is no problem. You can make a call, and you will have diver within an hour, they have services there… They discovered that facilities in West Greenland were far more western than they expected. Therefore, they needed to ship a lot of equipment. And if you are sailing in a good weather from the northern coast of Europe up to West Greenland, it takes about 8-10 days. Good weather sail. It means that if you have a vessel up in West Greenland, the vessel should go back to the continent to bring a container. And it was around 3 weeks until the vessel was back again. So then you have to do a really hard logistics thinking. They, of course, needed more vessels than they expected." "The fog also brought them problems for the crew change on installations. The helicopters were not able to fly, and then…

Norwegian Ship Owner contributing with vessels to the Disco Bay drilling.

The citations above show the logistics problems for summer operations in Extreme Arctic. In the Kara Sea, the distances were even longer, and the sea ice was lying for a longer time than expected.

". Due to the new area of operation and high safety margins, a massive fleet of vessels was mobilized for the operation. A total of 13 vessels (+ rig) took part on a regular basis… They had to wait till August 3rd before the drilling rig could enter through the Kara gate . Lacking regional port facilities forced all supply services and crew changes to operate out of new offshore base in Murmansk, which is the closest alternative, 850 nm from the drill site. This resulted in a minimum 8 days roundtrip time for the service vessels…. Helicopters could have been very helpful for ice reconnaissance and personnel transfer, but were excluded based on a safety evaluation and Russian legal issues. Ice Pilot participating in the Kara Sea drilling.

In the Kara Sea in 2014, Rosneft as operator followed much of the same pattern as Cairn outside the Disco Bay at Greenland, with the MPSV Island Crown as the depot and hotel vessel.

Figure 22. Fleet configuration drilling Kara Sea 2014 (Source: Borch & Kjerstad, 2016)

At west-Greenland, the distance from the field to the Aasiat base was 162nm with a normal transit time of 15 hours. In the Kara Sea lacking regional port facilities forces all supply services and crew changes had to operate out of the supply base in Murmansk. The distance was 850 nm from the drill site. This resulted in a minimum 8 days roundtrip time for the service vessels. Helicopters were not allowed, so passenger transport was a time consuming task.

We see from the fleet configurations above that operations in Challenging and Extreme Arctic call for more vessels and more overlap. For each field there have to be a discussion on how to combine different vessels. The examples above where from summer drilling campaigns. Winter operations will be a much more challenging task.

9. CONCLUSION

In this report we have showed that Arctic operations call for a thorough understanding of the characteristics of the sea regions one wants to operate. When it comes to all-year operations the complexity ad 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. 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.

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. 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.

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 multi-functionality of vessels and multi-competence personnel have to be included and trained in realistic environments

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.

LITERATURE

Agenda Kaupang. Utbygging og drift av Johan Castberg. Samfunnsøkonomiske konsekvenser. Rapport 14.6.2017

Andreassen, N., Borch, O.J., Kuznetsova, S. & Markov, S. (2015) Emergency management in maritime mass evacuation operations - the case of the high Arctic. Paper presented at the joint WMU-IMO-Arctic Council International Conference on Safe and Sustainable Shipping in a Changing Arctic Environment ShipArc-2015 conference, 25-27 August 2015, Malmø,

Arctic Council Working Group "Protection of the Arctic Marine Environment" (PAME). (2009). Arctic Council Offshore Oil and Gas Guidelines report.

Arctic Council Working Group Emergency Prevention, Preparedness & Response (EPPR). Field Guide for Oil Spill Response in Arctic Waters.

Barents Sea Exploration Collaboration (BASEC) SSEPA Barents Sea 23 R Area Report - SSEPA Barents Sea (23 R - South East). DnV, 2016.

Berg, T.E., Ø. Selvik and B.O. Berge. 2015. Defining operational criteria for offshore vessels. MTEK.

Borch, O.J. 2012. Demand for offshore service vessels in the Arctic. Working Paper, University of Nordland, Bodo, Norway.

Borch, O.J. (red.). 2016. Fartøyledelse og kontroll av skipets drift. Fagbokforlaget, Bergen.

Borch, O.J. & Kjerstad, N. 2016. Offshore oil and gas operations in ice infested water - resource configurations and operational process management. Paper presentated at the joint WMU-IMO-Arctic Council International Conference on Safe and Sustainable Shipping in a Changing Arctic Environment ShipArc-2015 conference, 25-27 August 2015, Malmø, Sweden.

Borch, O.J.; Solesvik, M. Partner selection versus partner attraction in R&D strategic alliances: The case of the Norwegian shipping industry. International Journal of Technology Marketing 2016; Volume 11. (4) s. 421-439.

Borch, O.J. & Andreassen, N. 2015. Joint-Task Force Management in Cross-Border Emergency Response. Managerial Roles and Structuring Mechanisms in High Complexity-High Volatility Environments., in Weintrit, A & Neumann, T. (Eds) "Information, Communication and Environment: Marine Navigation and Safety of Sea Transportation", CRC Press 2015 ISBN 978-1-138-02857-9, pp. 217-224.

Borch, O.J. & Solesvik, M. 2015. Innovation on the Open Sea: Examining Competence Transfer and Open Innovation in the Design of Offshore Vessels. Technology Innovation Management Review September 2015 (Volume 5, Issue 9).

Borch, O.J. & Batalden, B. 2014. Business process management in high turbulence environments – the case of the offshore service vessel industry. Maritime Policy and Management, Vol.42, Issue 5.

Borch, O. J.; Solesvik, M. 2013. Collaborative Design of Advanced Vessel Technology for Offshore Operations in Arctic Waters. Computer Science 2013; Volume 8098 (1). ISSN 0302-9743.s 157 - 160.

Borch, O.J M. H. Westvik, S. Ehlers, and T. E. Berg, 2012. Sustainable arctic field and maritime operation. In Proceedings of the Offshore Technology Conference, Houston, USA 3-5 Dec. 2012

Frontier Energy. Several editions.

Gribkovskaia, Victoria, Trond Johnsen, Haakon Lindstad, Eirik Uthaug 2016. Evaluation of upstream logistics system concepts for offshore operations in remote areas. Proceedings of the ASME 2016 35th International Conference on Ocean, Offshore and Arctic Engineering June 19-24, 2016, Busan, Korea.

Jenssen, J.I. & Randøy, T., 2006. The performance effect of innovation in shipping companies. Maritime Policy & Management, 33(4), 327-343.

Marsh Risk Management Research (2014). Arctic Shipping: Navigating the Risk and opportunities.

Marchenko, Nataliya; Borch, Odd Jarl; Markov, Sergey V; Andreassen, Natalia.
Maritime safety in the high north - Risk and preparedness. ISOPE - International Offshore and Polar Engineering Conference. Proceedings 2016, Volume 2016-January. s. 1233-1240

Marchenko, N.A. Borch, O.J, Markov, S. and Andreassen, N. 2015. Maritime activity in the high north – the range of unwanted incidents and risk patterns. In Proceedings of the 23rd International Conference on Port and Ocean Engineering under Arctic Conditions, June 14-18, 2015, Trondheim, Norway.

Kristiansen, S., 2004, Maritime transportation: safety management and risk analysis. (Oxford: Butterworth-Heinemann).

Nilsen, L. 2014. Lecture on Arctic challenge. Oplog Hurtigrute-conference, Norway.

ProActima report for the Petroleum Safety Authority Norway: *“Overview of measures specifically designed to prevent oil pollution in the Arctic marine environment from offshore petroleum activities».*

Kheiri Pileh Roud, Ensieh; Borch, Odd Jarl; Jakobsen, Uffe; Marchenko, Nataliya.
Maritime emergency management capabilities in the arctic. ISOPE - International Offshore and Polar Engineering Conference. Proceedings 2016; Volume 2016-January. s. 1241-1248

Schmied, J., Borch, O. J., Roud, E. K. P., Berg, T. E., Fjørtoft, K., Selvik, Ø., & Parsons, J. R. (2017). Maritime Operations and Emergency Preparedness in the Arctic–Competence Standards for Search and Rescue Operations Contingencies in Polar Waters. In The Interconnected Arctic—UArctic Congress 2016 (pp. 245-255). Springer International Publishing.

Special Committee report to the Ministry of Transportation 2015: *«The Norwegian oil pollution preparedness - prepared for the future? (Ly-utvalget) (In Norwegian)*

The SARINOR projects: www.sarinor.no

The MARPART projects: www.marpart.no

Tsvetkova, A. & Borch, O.J. 2018. New offshore oil and gas fields on the high Arctic Norwegian and Russian continental shelf - logistics challenges and offshore service vessel demands. To be published.

Aas, B., Halskau, Ø & Wallace, S.W., 2009. The role of supply vessels in offshore logistics. Maritime Economics & Logistics 11(3), 302-325.