Lloyd’s Register – Written evidence (ARC0048)

1. Summary
The objectives of this submission of evidence to the Select Committee on the Arctic are:

- To offer supporting data and insights on transit and destination shipping in the Arctic and, in addition, the characteristics of the UK registered Arctic shipping fleet.
- To contribute evidence on the technological challenges for future Arctic shipping activities
- To contribute evidence on the regulatory framework that will govern Arctic shipping
- To contribute advice, and views, on Arctic shipping to support consideration of the “UK dimension” by the Select Committee

Considering each objective in turn:

**Key points on supporting data and insights on transit and destination shipping in the Arctic:**

1. Very small numbers of ships use Arctic transits for voyages between ocean basins (*i.e.* Pacific and Atlantic basins) as an alternative shipping route to transits through the Panama or Suez canal
2. Shipping in the Russian Arctic is likely to increase, but will be mainly export shipping for dedicated natural resources projects. Transit of commercial ships through the Russian Arctic is likely to occur during the summer season only
3. The UK registered ice-classed fleet is small, with 119 ice classed ships, and just 8 ships potentially suitable for transiting the Russian Northern Sea Route independently in an average summer season

![Figure 1.1 % of Ice Classed UK Fleet](image1)

![Figure 1.2 Ice Classes assigned to UK flagged ships](image2)
Key points on the technological challenges for future Arctic shipping activities:
1. Technological challenges remain for efficient Arctic shipping with a significant build and operating cost premium associated with current generation of Arctic capable ships.
2. A combination of uncertainty of ice loads, and the development of much larger Arctic ship designs than hitherto, may lead to Arctic ships that are uneconomic in operation with reduced cargo carrying capacity and excessive hull structural steel-weights.
3. Dedicated, or specialised, ships designed for year round ice-going navigation, even those enhanced only for seasonal navigation in light ice conditions, are uncompetitive in build and operation costs when compared with open water shipping.

Key points on the regulatory framework that will govern Arctic shipping:
1. Canada and the Russian Federation have requirements that regulate Arctic shipping including seasonal limitations on ship operations in Arctic sea areas under their jurisdiction, primarily based on the ice strengthening standard (ice class) assigned to the ship.
2. International Maritime Organisation (IMO) finalised mandatory standards ("Polar Code") for Polar Shipping in 2014. The entry into force date will be 1st January 2017. The Polar Code is intended to supplement SOLAS\(^1\) and MARPOL\(^2\), and covers additional aspects of ship design and construction for international ships operating in the Polar Regions.
3. The Polar Code will require limitations to be recorded on the Polar Ship Certificate i.e. ice conditions and temperature limits of ship operations.

Key points on Arctic shipping to support consideration of the "UK dimension":
1. There may be direct economic and/or employment benefits to the UK from:
   a. An increase in Passenger Cruise Voyages in the Arctic
   b. Imports to the UK of natural resources from the Arctic
2. UK Arctic shipping experience and knowledge will be difficult to sustain if current low volumes of Arctic shipping prevail in future. A similar situation does, however, prevail for most other countries interested in the development of Arctic shipping.
3. Any initiative, as part of a "UK dimension" of Arctic shipping, may need to consider co-operation with other countries with interests in development of Arctic.

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\(^1\) International Convention for the Safety of Life at Sea, 1974 as modified by the 1988 SOLAS Protocol
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3. **Introduction**

3.1 **Objective**

The objectives of this submission of evidence are:
- To offer supporting data and insights on transit and destination shipping in the Arctic and, in addition, the characteristics of the UK registered Arctic shipping fleet
- To contribute evidence on the technological challenges for future Arctic shipping activities
- To contribute evidence on the regulatory framework that will govern Arctic shipping
- To contribute advice, and views, on Arctic shipping to support consideration of the “**UK dimension**” by the Select Committee

3.2 **About Lloyd’s Register**

Lloyd’s Register is a provider of marine classification services, helping ensure that internationally recognised safety and environmental standards are maintained at every stage of a ship’s life.

3.3 **Lloyd’s Register’s involvement with Arctic Shipping**

Lloyd’s Register publishes and maintains rules for design, construction and survey of ships, including specific rules for ships operating in ice (ice class ships) and ships intended to operate as icebreakers.

Accumulated practical experience with ships designed, constructed and operated for ice navigation forms the basis of our commentary and evidence to The Select Committee on the Arctic. Further detail about Lloyd’s Register’s involvement in Arctic Shipping is included in Appendix A.

4. **Arctic Shipping**

4.1 **Arctic sea ice and “choke” points: transit shipping obstacles**

*This section presents evidence of the environmental considerations (notably ice cover) relevant to Arctic shipping opportunities*

Recent measurements of the extent of Arctic sea ice, particularly the minimum extent in the summer have been used to suggest that the Arctic may soon become a viable transit route between the Atlantic and Pacific basins, and an alternative to the Panama and Suez canals. Figure 4.1 shows a plot of historical averages, including recent years, of the Arctic sea ice extent. The following points are highlighted:
- 2012 is the lowest ice extent on record, however 2014 data is closer to the 2000’s average
- Increase in variability of ice extent year-on-year
- The variability year-on-year is more significant in the summer time, in the winter there is less variability
- There is still significant ice coverage during the winter season
- Data on sea-ice extent is based on satellite observations that begin in 1979
With respect to the impact of the changing sea ice on shipping, the following observations are offered:

- The trend of less extent of ice in the summertime would suggest that the summer season is increasing for transit of open water ships (i.e. ships not specially designed to operate in ice). In 2013 the ice free season was approximately 40 days along the Russia Arctic transit routes.
- The variability of the summer season will continue to making long-term planning difficult for transits using the Arctic as a commercial shipping route.
- The consistent cover of ice in the winter will remain a hazard and block all but high specification (high ice class) ships transiting outside of the summer season.

Figure 4.2 shows three plots of sea ice extent for the 2014 season. The figure is intended to highlight the significant presence of ice during the mid-winter period. The middle plot in Figure 4.2 indicates the start of the “formal” summer shipping season on the Northern Sea Route. However significant ice remains on the route, effectively blocking entry and exit to the route for all but specialist ice class shipping. The right hand plot in Figure 4.2 shows the lowest ice extent for 2014 and shows open water for the Northern Sea Route, but with ice still keeping all but the shallow southern North West Passage route closed.

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4 Based on an analysis of Arctic Sea-Ice Monitor satellite image data
Right hand plot: Lowest ice extent for 2014 (26 September)

Figure 4.2 illustrates that the ice extent does not retreat uniformly from the shoreline of both the Northern Sea Route and North West Passage. In both sea areas there are also a number of shallow or constrained shipping channels that form “choke points” where, depending on the year, ice may remain longer than usual and prevent a passage.

A number of the more prominent “choke points” where ice may seasonally prevent a passage from opening are indicated in Figure 4.3:

The eastern end of the Northern Sea route is bounded by Novaya Zemlya, effectively providing two entrances, to the South through the Kara Gate or north of the island. Depending on ice conditions in the Kara Sea either one of these routes may be blocked, thus limiting transit of large vessels.

Towards the Western end of the Northern Sea route the New Siberian Islands present a limited draft passage South (through the Sannikov Strait) or North of the Islands, where the draft is deeper. Here too ice may remain against the islands, preventing access to the Northerly route for part of the navigational season.

Figure 4.3 Lowest ice extent for 2014 – showing an ice free Northern Sea Route, ice still in North West Passage

In the Canadian Arctic prevailing wind and current systems within the Arctic basin affect the amount of ice that is forced down through the straits in the North of the Archipelago. Straits such as the McClure can continue to be blocked or chocked by ice well into the summer months, leaving only the potential shallow southern route through Coronation gulf available for shallow drafted ships. These “choke points” will hinder shipping attempting to transit the various Arctic routes and mean that the start and end of the shipping season in the Arctic is unpredictable.

4.2 Arctic Shipping demands
This section presents evidence of the utilisation of the Arctic by commercial shipping
Shipping in the Arctic can be classified into two broad categories; destination shipping and transit shipping:

1. Transit shipping (or Trans-Arctic traffic) is typically defined as a ship voyage through the Arctic, where the origin and destination ports are outside the Arctic area.
2. Destination shipping is typically defined as a ship voyage or voyages either to or from a destination (port or terminal) within the Arctic area.

### 4.2.1 Transit and destination shipping

Decreased extent of Arctic ice in the summer months has prompted increased interest in using the Arctic as a shorter route for transit traffic between the Atlantic and Pacific basins, as an alternative to the Suez and Panama canals, so-called Trans-Arctic shipping routes.

There are three possible passages or routes for Trans-Arctic voyages:

- **North-West Passage** – through the Canadian Arctic, a set of three main routes through the Canadian Archipelago
- **North-East Passage** - through the Russian Northern Sea Route (NSR), defined as “a set of marine routes from the Kara Gate to Bering Strait”
- **Central Arctic Ocean** – the most direct route passing close to the geographic North Pole

Table 4.1 presents various categories of shipping and relates them to the various Arctic areas. Destination shipping occurs in all areas of the Arctic whereas transit shipping occurs either along the Russian Northern Sea Route or through the Canadian North West Passage. The categories of passenger ship cruises and export of natural resources (oil, gas, ore and minerals) in Table 4.1 are elaborated in the following sub-sections as they form the majority of destination voyages and are considered the most significant and relevant when considering commercial shipping in the Arctic.

<table>
<thead>
<tr>
<th>Shipping Type</th>
<th>Within EEZ of Arctic Council coastal state</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
</tr>
<tr>
<td><strong>Destination Shipping</strong></td>
<td></td>
</tr>
<tr>
<td>Passenger Cruise Ships</td>
<td>✔</td>
</tr>
<tr>
<td>Export of Natural resources</td>
<td>✔</td>
</tr>
<tr>
<td>Local re-supply</td>
<td>✔</td>
</tr>
<tr>
<td>Fishing</td>
<td>✔</td>
</tr>
<tr>
<td>Patrol / SAR</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Transit Shipping</strong></td>
<td></td>
</tr>
<tr>
<td>Northern Sea Route</td>
<td>✔</td>
</tr>
<tr>
<td>North West Passage</td>
<td>✔</td>
</tr>
<tr>
<td>Transpolar</td>
<td>✔*</td>
</tr>
</tbody>
</table>

Note: Estimate of EEZ (exclusive economic zone – typically 200 nautical miles from shoreline) for illustration purposes only, dependent on UNCLOS6 extended continental shelf claims.

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5 Niini, M., Tustin, R.D., Future Possibilities for Trans-Arctic Shipping through the Central Arctic Ocean
6 UNCLOS – United Nations Convention on the Law of the Sea, for further discussion see Section 6
*Actual route of Trans-Arctic crossing may pass through Canada, Greenland, Russia, US, Norway and/or Iceland waters or international waters

**Table 4.1 Arctic Shipping Categories**

**4.2.2 Passenger Cruise Voyages**

Passenger cruise ship voyages have historically been infrequent in the Arctic due to cost and availability of suitably equipped ships. Recently, however, there has been an increase in cruise ship traffic in specific areas (Alaska and West Coast of Greenland), with notable recent interest in cruise voyages in more remote Arctic locations. Cruise ship size (passenger complement) in Arctic regions is also increasing.

Voyages usually involve tourist visits along Arctic coastlines with calls at numerous small ports for day-trips, bringing large volumes of people to remote areas. Figure 4.4 indicates cruise ship traffic patterns in the Arctic for the 2004 season.

![Figure 4.4 Passenger Ship traffic in the Arctic, 2004 season (after Arctic Marine Shipping Assessment, 2009)](image)

**Figure 4.4 Passenger Ship traffic in the Arctic, 2004 season (after Arctic Marine Shipping Assessment, 2009)**

Currently the majority of cruise ships are not ice strengthened and typical operations involve avoiding ice (often summer itineraries only). With respect to Passenger cruise ship voyages the following statistics are presented:

- 23 commercial cruise ships have transited the Canadian North West passage between 1984 and 2004 although most of these have been specialist smaller expedition style ships carrying less than 200 people (with some extent of ice strengthening and suitable for operating in ice covered waters).
- Between 2003 and 2008 the number of cruise ship calls at Greenland ports doubled.  

Recent news has indicated the prospect of larger cruise ships (1,000+ passengers) operating closer to ice or attempting sailings through the North West Passage.

**4.2.3 Export of Natural Resources**

7 Arctic Marine Shipping Assessment, 2009, Arctic Council

The Arctic is estimated to contain 66 billion barrels of conventional oil and 237 trillion cubic feet of undiscovered conventional natural gas according to the US Geological Survey\(^9\). In addition the Arctic area is rich in ore and minerals in particular Nickel and Zinc. Historic, current and near term Arctic natural resources projects are indicated in Table 4.2, with the associated ice capable shipping requirements (open water shipping demands have been omitted). The location of these projects is illustrated pictorially in Appendix E.

<table>
<thead>
<tr>
<th>Arctic Sea Area</th>
<th>Project Description</th>
<th>Resource</th>
<th>Start-up date</th>
<th>Close-down date</th>
<th>Shipping Season</th>
<th>Ice capable shipping demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Polaris, (Little Cornwallis Island)</td>
<td>Zinc</td>
<td>1981</td>
<td>2002</td>
<td>3 months</td>
<td>1 icebreaking bulk carrier</td>
</tr>
<tr>
<td></td>
<td>Raglan, (Deception Bay)</td>
<td>Nickel</td>
<td>1997</td>
<td>Current</td>
<td>8 months</td>
<td>1 icebreaking bulk carrier</td>
</tr>
<tr>
<td></td>
<td>Baffinland, (Milne Inlet)</td>
<td>Iron Ore</td>
<td>2015</td>
<td>NA</td>
<td>July-October</td>
<td>3 ice class bulk carriers*</td>
</tr>
<tr>
<td></td>
<td>Baffinland, (Steensby Port)</td>
<td>Iron Ore</td>
<td>2020*</td>
<td>NA</td>
<td>Year-Round</td>
<td>10-17 icebreaking ore carriers*</td>
</tr>
<tr>
<td>US</td>
<td>Red Dog (Alaska)</td>
<td>Zinc</td>
<td>1987</td>
<td>Current</td>
<td>July-October</td>
<td>23 ship calls/year</td>
</tr>
<tr>
<td>Russia</td>
<td>Norilsk Nickel Mine (Dudinka Port on Yensei River)</td>
<td>Nickel</td>
<td>1930s</td>
<td>Current</td>
<td>Year-Round since 2005</td>
<td>5 icebreaking container ships</td>
</tr>
<tr>
<td></td>
<td>Prirazlomnoye (Pechora Sea)</td>
<td>Oil</td>
<td>2014</td>
<td>Current</td>
<td>Year-Round</td>
<td>2 icebreaking oil tankers</td>
</tr>
<tr>
<td></td>
<td>Varandey (Pechora Sea)</td>
<td>Oil</td>
<td>2008</td>
<td>Current</td>
<td>Year-Round</td>
<td>3 icebreaking oil tankers</td>
</tr>
<tr>
<td></td>
<td>Yamal LNG (Sabetta Port, Ob River)</td>
<td>Natural Gas</td>
<td>2016</td>
<td>NA</td>
<td>Year-Round</td>
<td>12-16 icebreaking LNG carriers*</td>
</tr>
<tr>
<td></td>
<td>Noviy Port (Ob bay)</td>
<td>Oil</td>
<td>2014</td>
<td>Current</td>
<td>Year-Round from 2016</td>
<td>6 icebreaking oil tankers</td>
</tr>
</tbody>
</table>

*Estimate

**Table 4.2 Table on Export of natural resources requiring ice capable shipping support**

### 4.3 Arctic Shipping Statistics

This section presents evidence, in the form of statistics, on how the Arctic is used as a transit shipping route and an overview of environmental considerations (notably ice cover)

#### 4.3.1 Transit comparisons

The decrease in summer ice extent has led to an increase in summer transit traffic in the Arctic, notably through the Northern Sea Route. There have been very few commercial ship transits through the North West Passage, primarily because of the shorter summer season with open water.

Table 4.3 shows the first and last Arctic transits in 2012, to indicate the reality of the shipping window for Arctic ships (of any ice class). When compared to regulatory restrictions\(^10\) which, in principle, indicate a longer season of operation the actual season length is illustrative of year-

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\(^10\) See Appendix B
on-year variability of ice conditions, which will constrain and/or prevent ship transits. In summary: even if regulations indicate passage is permissible local ice conditions may prevent transit.

<table>
<thead>
<tr>
<th>Transit Route</th>
<th>Start (Actual)</th>
<th>End (Actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Sea Route (2012)</td>
<td>July</td>
<td>November</td>
</tr>
<tr>
<td>Northern Sea Route (2013)</td>
<td>July</td>
<td>November</td>
</tr>
<tr>
<td>North West Passage (2012)</td>
<td>No transits</td>
<td>No transits</td>
</tr>
<tr>
<td>North West Passage (2013)</td>
<td>September</td>
<td>October</td>
</tr>
</tbody>
</table>

**Table 4.3 Actual Start and end of the shipping season based on transit data**

Table 4.4 shows the number of transits made through the North West Passage in 2013 was 1, with 0 ships the year before. 2014 will see the first complete transit of a commercial ship unescorted (without icebreaker assistance) through the Canadian Arctic, although the passage is not ice free (the ship undertaking the transit was a Category A, Ice Class PC4\(^1\) icebreaking bulk carrier).\(^2\) Table 4.4 also shows a comparison of the number of transits (very small numbers of ships transiting) in the Arctic compared with those of the Suez and Panama Canals (very large numbers of ships transiting).

<table>
<thead>
<tr>
<th>Transit Route</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suez Canal</td>
<td>17224</td>
<td>16596</td>
</tr>
<tr>
<td>Panama Canal</td>
<td>14544</td>
<td>14544</td>
</tr>
<tr>
<td>Northern Sea Route</td>
<td>46</td>
<td>71</td>
</tr>
<tr>
<td>North West Passage</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 4.4 Number of ships using transit routes**

From Table 4.4 an increase in the use of the Northern Sea Route for transit traffic is shown with a 50% increase in the number of ships making the transit when comparing 2012 and 2013. Table 4.5 presents a comparison of sailing distances between Europe and Asia through the Northern Sea Route, compared with the Suez Canal and Panama Canal. The data indicates that distance savings can be made through the Arctic as far South into Asia as Shanghai, but destinations such as Hong Kong remain shorter through the conventional Suez route. When comparing Routes originating from Asia to markets on the NE Coast of the United States, distance savings can be made using the Northern Sea Route compared against both southern routes, although the actual mileage difference is often not significant.

<table>
<thead>
<tr>
<th>Sailing distance in nautical miles between</th>
<th>Rotterdam (Europe)</th>
<th>Halifax (NE Coast US)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Via Suez Canal</td>
<td>Via NSR</td>
</tr>
<tr>
<td>Yokohama</td>
<td>11212</td>
<td>7825</td>
</tr>
<tr>
<td>Busan</td>
<td>9907</td>
<td>8490</td>
</tr>
<tr>
<td>Shanghai</td>
<td>9612</td>
<td>8865</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>8859</td>
<td>9410</td>
</tr>
</tbody>
</table>

**Table 4.5 Distances between major ports by transit route (Icelandic Ministry of Foreign Affairs (2005))**

Figure 4.5 shows a comparison of cargo volumes carried through the Suez Canal compared with the Northern Sea Route in 2012 and 2013. The chart indicates that although there has

\(^{1}\) See Appendix D for description of polar classes
been some increase in cargo volumes carried through the Arctic, however the proportion is very small (less than 0.2%) when compared to southerly transit route through the Suez Canal.

Figure 4.5 Volume of Cargo shipped by Suez Canal and Northern Sea Route
Although some distance savings can be made using the Northern Sea Route as a transit route, the significant distance savings only occur when the transit originates from within Russian waters: Table 4.7 shows the distances from two major oil and gas projects in prospect in the Russian Arctic. The Yamal project will see a significant export of gas year around from within the Northern Sea Route itself, whilst Shtokman (although the project is currently on hold) would see shipping requirements from North of Novaya Zemlya. On-stream production from two fields in the Russian Pechora Sea (West of the Kara Sea and just east of eastern boundary of the Northern Sea Route), Varandey and Prirazlomnoye are similar distances from the markets in Table 4.7 as Shtokman.

<table>
<thead>
<tr>
<th>Sailing distance in nautical miles between</th>
<th>Shtokman (and Pechora Sea Oil)</th>
<th>Yamal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yokohama</td>
<td>Via Suez Canal</td>
<td>Via Suez Canal</td>
</tr>
<tr>
<td></td>
<td>12640</td>
<td>13340</td>
</tr>
<tr>
<td></td>
<td>Via NSR</td>
<td>Via NSR</td>
</tr>
<tr>
<td></td>
<td>5800</td>
<td>5360</td>
</tr>
<tr>
<td>Busan</td>
<td>12400</td>
<td>13100</td>
</tr>
<tr>
<td></td>
<td>5930</td>
<td>5500</td>
</tr>
<tr>
<td>Shanghai</td>
<td>12170</td>
<td>12870</td>
</tr>
<tr>
<td></td>
<td>6350</td>
<td>5920</td>
</tr>
</tbody>
</table>

Table 4.7 Distances between Russia Arctic Projects and markets

4.3.2 Transit limitations

13 Distances extracted from Arctic Energy Shipping Perspectives, Sovcomflot presentation to the Arctic Passion Seminar, 2011
One limitation on all transit routes between ocean basins which pass through shallow water, either channel water clearance or in the case of the Panama Canal lock sill clearance, is the allowable draft of the ship. Table 4.8 indicates these draft limitations.

It can be seen that once the new Panama locks are inaugurated both Arctic transit routes will have shallower draft restrictions on their inner passages when compared to transit through the Panama or Suez Canals. As indicated in Section 4.1 northerly routes in the Russia Arctic are available, however the seasonal window to access these routes varies with the ice cover year-on-year.

Furthermore it should be noted that, particularly in the Canadian Arctic, hydrographic charts of designated routes have limited data / accuracy. Although this poses little challenge when the water is ice free, when ice covered it is typical for ships to follow open water leads and take the path of least resistance in ice – a lack of reliable charting therefore restricts operation where deviation off designated routes to avoid harsh ice may result in the ship grounding.

<table>
<thead>
<tr>
<th>Transit Route</th>
<th>Maximum Draft</th>
<th>Maximum Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suez</td>
<td>20.1m</td>
<td>50m</td>
</tr>
<tr>
<td>Panama</td>
<td>12.04m</td>
<td>32.31m</td>
</tr>
<tr>
<td>Panama (new locks)</td>
<td>15.2m</td>
<td>49m</td>
</tr>
<tr>
<td>North West Passage*</td>
<td>14m</td>
<td>NA</td>
</tr>
<tr>
<td>Northern Sea Route</td>
<td>12.8m / 15m+*</td>
<td>30m</td>
</tr>
</tbody>
</table>

Table 4.8 Sea Route Size Limitations

Detailed notes on Table 4.8 data are provided as follows:

- 12.8m draft is the maximum through the Sannikov strait in the Northern Sea Route. A more northerly route (north of the New Siberian islands) allows for deeper drafts, but with a more limited window of ice free operation.
- The North West Passage is limited to 14m, but surveys of the passages are incomplete – therefore course deviations off the sounded channel (necessary for operation in ice) increase risk of grounding.
- Northern Sea Route beam limitations are related to the maximum width of the supporting icebreaker channel. Recent voyages of wider ships have taken place (in open water / light ice conditions) indicating that this requirement may be relaxed for summer season transits where close icebreaker escort is not required.

4.4 World and UK Fleet Statistics

This section presents evidence, in the form of statistics, on the volume and type of shipping in the Arctic and the available UK flagged fleet suitable for operation in the Arctic.

4.4.1 The world ice classed and Arctic fleet

Section 4.1 indicates that, with year-on-year variability, the ice free season in the Arctic is relatively short. Outside of the ice-free season ships require strengthening of the hull and machinery in order to operate in ice without damage (ice class). However, the number of ships in the world fleet (500 GRT or greater) that are ice classed is relatively small. Figure 4.6 indicates that about 8,600 ships, representing approximately 15% of the world fleet (500 GRT or above), have some extent of ice strengthening.  

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14 See further description and definition of ice class and ice strengthening in Appendix D
15 Data sourced from IHS Maritime Seaweb database
However, of these ships only about 6% (about 500 ships) could be considered Arctic cargo ships or icebreakers (Category A or B ships under the Polar Code), as Figure 4.7 illustrates. The data indicates there are a very small number of specialist ships capable of operating in Arctic ice-covered waters: We estimate about 120 Category A ships and 380 Category B ships.

The fleet of UK flagged ships of 500 GRT and above totals approximately 800 ships. Figure 4.8 indicates the percentage of these ships which are ice classed. Figure 4.9 indicates the breakdown of these ice classed ships by the ice classed assigned: The UK fleet consists of an estimated 119 ice classed ships, the majority of which are the lowest ice class (1C). The UK fleet consists of an estimated 8 ships that could, based on structural equivalence, be assigned a Category B under the Polar Code and potentially suitable for independent summer operations in Arctic waters with ice present.
The data in Figure 4.8 and Figure 4.9 shows that the number of UK flagged ships capable of operation in the Arctic outside of the ice-free season is small. Table 4.9 shows the top ten (by ship number registered under UK flag) ship owners and the number of ice class ships in their fleet: The largest fleet is that of the UK government as a number of Royal Navy auxiliary vessels are assigned an ice class (typically Ice class IC). It should be noted that the statistics presented include only ships registered under UK flag and does not include UK Crown Dependencies (Isle of Man and Channel Island)\textsuperscript{16} or Overseas Territories registered ships. Consideration has not been given in this report to UK-managed ships which are flying foreign flag. Consequently the contribution, influence and participation of UK shipping in the Arctic is potentially larger than indicated in this overview of the UK registered fleet only.

<table>
<thead>
<tr>
<th>Ship Owner</th>
<th>Ice Classed Ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom Govt</td>
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</tr>
<tr>
<td>Stena AB</td>
<td>8</td>
</tr>
<tr>
<td>Claus-Peter Offen Reederei</td>
<td>8</td>
</tr>
<tr>
<td>Knutsen OAS Shipping AS</td>
<td>6</td>
</tr>
<tr>
<td>Stolt-Nielsen USA Inc</td>
<td>6</td>
</tr>
</tbody>
</table>

\textsuperscript{16} See Shipping Fleet Statistics, Department for Transport
Table 4.9 Top ten UK registered ice-class ship owners

<table>
<thead>
<tr>
<th>Name</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial Shipping Ltd UK</td>
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</tr>
<tr>
<td>Ellingsen Shipping Group</td>
<td>4</td>
</tr>
<tr>
<td>Cairsbroke Shipping Ltd</td>
<td>4</td>
</tr>
<tr>
<td>Andrew Weir Shipping Ltd</td>
<td>4</td>
</tr>
<tr>
<td>Genzina AS</td>
<td>4</td>
</tr>
</tbody>
</table>

5. Arctic Technology

5.1 Technological advancements to support expanded shipping activities

This section presents evidence on key aspects of technology relevant to today’s Arctic shipping

5.1.1 The challenge of ice-going ship design

The main principle for all ice-going ship design is to minimise the amount of power required to break ice, while maintaining efficiency of operation in an open seaway. The fundamental dichotomy being that efficient icebreaking requires a relatively flat, full bow shape while an efficient bow for open water efficiency and sea-keeping requires a much finer bow form and hull lines. Higher engine powers are required for ships operating in ice because of the added friction between the ship and the ice and the momentum required to push the ship through ice.

5.1.2 The development of efficient ice-going ships

A detailed description on the development of efficient ice-going ships is provided in Appendix C. The principle developments can be summarized as follows:

- Prior to 1970s ice-going ship design was experienced based without engineering principles and practice for performance predictions
- The introduction of ice model basins in the 1970s and 1980s established rigorous methods of predicting ice-going performance and consequently saw significant improvements in hull form (ship shape) design of ice-going ships
- Advances in hull form design allowed for very efficient icebreaking forms, but at the expense of open water performance (flat, full icebreaking bows typically perform poorly in open water with higher open water resistance and fuel consumption, as well as degraded sea-keeping characteristics e.g. being prone to bow slamming in open water with increased discomfort to the crew).
- After this period of optimisation the efficiency of ice-going hull forms has now leveled out
- The introduction of azimuth thruster\(^\text{17}\) propulsion in the mid-1990s allowed for increased icebreaker efficiency (power and manoeuvrability) without the need for extreme hull form shapes
- Use of azimuth thrusters as a means of propulsion for icebreakers has become almost standard since the 2000s, allowing for a more effective balance between open water and ice-going power demands, although they are yet to be operated in extreme high-Arctic, thick ice conditions
- After an initial period of optimisation the efficiency of ice-going ships equipped with azimuth thrusters has also now leveled out

Two approaches currently exist for efficient ice-going ship design:

- High-powered shaft line ships with optimised icebreaking bow forms
- Azimuth-thruster equipped ships with moderate icebreaking bow forms

\(^{17}\) See Appendix C for explanation of Azimuth thrusters and icebreaking efficiency
In Figure 5.1 a number of icebreaking offshore support vessels are compared, all of which have similar performance points in ice (the ability to break 1.5m thick ice at 2 knots): Bollard Pull (thrust)/Beam represents a measure of efficiency, the lower the value the more efficient the ship is. The purpose of Figure 5.1 is to illustrate two key developments of ice-going ship efficiency:

- The first period between 1970s and 1990s involved optimisation of hull form shape for efficient ice operation.
- The second period, from the mid-1990s to present, involves optimisation of the use of azimuth thrusters for efficient ice operation.

The blue line, shaft line icebreaker designs, shows a decreasing bollard pull/beam value over time. This represents an increase in hull form effectiveness, with the final experimental concepts in the early 1990s being very efficient in ice (but with poor open water performance).

In the early 1990s a hiatus in icebreaker building occurred. The azimuth thruster concept was introduced to icebreakers in 1993, with some optimisation and learning from the first cases contributing to increases in efficiency in the 2000s.

![Illustrative Icebreaker Efficiency over time](image)

**Figure 5.1 Illustrative comparison of increasing icebreaking efficiency over time (offshore support icebreakers)**

The key conclusion from Figure 5.1 is that ice going ship development, unlike open water ship optimisation, has not been continuous and incremental, rather it has had step changes based on technology advances. It is to be noted that these step changes in technology have not been completely substitutional but rather complementary, with advances in icebreaking technology allowing for greater options and configurations of ship shape and propulsion configuration to suit specific operational profiles and needs: Efficient icebreaking ships equipped with shaft lines (not azimuth thrusters) continue to be built and operate effectively.

5.2 **Technological challenges for future Arctic shipping activities**

*This section presents evidence, in the form of data and derived opinions from recent Arctic shipping projects, on some of the technological challenges for commercially viable shipping in the Arctic*

5.2.1 **Uncertainty of ice loading for large ships**

The science concerning failure of ice (ice mechanics) and its use for engineering applications is still relatively immature and developing. Engineers and designers of ships instead have had to typically rely on semi-empirical methods, calibrated with full scale measurements of ship’s
structure exposed to ice, to determine design loads in order to dimension and size the ship’s structure to prevent failure when operating in ice. Although advances are being made in laboratory testing of ice failure, a significant reliance is still made on full scale testing data. It should be noted that full scale testing of ships in ice is exceptionally costly and consequently a limited data set is available for calibrating design loads. Classification societies, such as Lloyd’s Register, publish rules which prescribe the strength of ships for navigating in ice depending primarily on the thickness (and type) of ice. The IACS Polar Class Rules represent the latest scientific and engineering thinking on dimensioning ship structures in ice. These rules have been calibrated with the available data sets of full scale ship operations in ice. However, data sets used for calibration are from small icebreakers and moderate sized icebreaking cargo ships. For larger ships outside the calibration range the rule formulations (for design ice pressures which are used to define ice loads) are necessarily conservative, to account for uncertainty of ice loads on larger ships. Recent developments in Arctic shipping have seen a considerable increase in the size of icebreaking cargo ships, primarily to serve natural resource export projects, where economies of scale encourage large ship operations in ice. As the ship size increases, and as the Arctic is opened up to further projects which require ships to operate in thicker ice (or without icebreaker escort), the design loads increase exponentially due to uncertainty of ice loading. As the design load increases more steel structure is designed into the ship to prevent damage from conservatively (because of uncertainty) derived ice loads. The consequence of this increasing design load is an increase in hull lightship weight due to steel structure and a reduction in overall hull cargo carrying capacity. This makes the ships less efficient to operate and more expensive to build. In relatively thin thicknesses of ice the effect of ice load uncertainty is not significantly pronounced. However in relatively thick thicknesses of ice the effect of ice load uncertainty is pronounced. This uncertainty can be considered a significant technological hurdle that will require more full scale testing of large ships in relatively thick ice. Figure 5.2 shows a plot of the steel weight of a number of recent large cargo ship projects. The curve indicates the actual (exponential) increase in steel weight for ice strengthening with an increase in ship’s ice-going capability (as defined by permitted level ice thickness for ship operations). The straight line on the chart is intended to represent a desired, or ideal, situation where refinement in the understanding of ice loads on larger ships may, in the future, yield a more optimal structural design of reduced steel weight.
Figure 5.2 Increase in steel weight compared with icebreaking capability for large cargo ships

5.2.2 Efficient ship structures for large Arctic ships

The structural design of Arctic ships has not changed significantly since the mid-1980s. Structural design practice has followed a “tried and tested” approach, primarily because of the uncertainty regarding the ice load (as described in 5.2.1). However, as ship size has increased, the same approaches to dimensioning structure have been retained. As Arctic ships increase in size, and as the ice loads associated with operating these large ships in thicker ice remain relatively conservative, the applicability of current design practice is reaching its limit.

The nature of ice load is fundamentally different to that of wave loading and approaches to structural design of large Arctic ships have not been explored fully to allow for the most efficient arrangement and design to be adopted. The reduction in steel weight required for efficient Arctic ship design as shown in Figure 5.2 can therefore be considered to be a function of two required advances in Arctic technology:

1. Greater certainty of ice loads on larger ships (5.2.1); and
2. Improvements in structural design for large Arctic ships

Improvements in structural design are considered to encompass not only new configurations but also use of advanced materials. Current Arctic ship designs are utilising high strength steels up to the limit of what may be considered standard steel types in the shipbuilding industry. In order to address the need to develop more efficient and lighter structures to resist ice loads for larger ships new materials may have to be considered.

5.2.3 Competitive Arctic Ships

For some ship operations it may make economic sense, voyage for voyage, to use the Arctic as a transit route. But, as the previous sections have shown, there is only a small window in the summer months when open water vessels can operate, either independently or with icebreaker escort. Outside of this window, ships need an ice class, meaning extra power and a change in hull form shape, to enable operations in ice. Such vessels are not as fuel efficient as open water designs because hull form shape for icebreaking compromises hull form shape optimised for efficiency in open water.
Experience with higher first year ice-class ships (Finnish-Swedish ice class IA and IA Super) that are seasonally trading in the Baltic is that they are uncompetitive from an operating cost perspective when compared with modern open water ships that are optimized for fuel efficiency. Design for ship fuel efficiency in open water with satisfactory ice going performance is a significant challenge for ship designers to achieve an optimal balance of these two conflicting requirements for ship design. At present there is a widening gap in performance between ice-going and open water ships as fuel and energy efficiency improvement is driving and dominating the development of a new generation of open water optimised ships. The drive for fuel and energy efficiency is expected to continue in future, and is also being further supported by regulation for the mitigation of greenhouse gas emissions from ships, such that the performance gap between open water ships and ice class ships will widen further in future. Figure 5.3 shows a plot of the installed main engine power for small oil product tankers (with the same cargo carrying capacity) delivered from one shipyard over the last seven (7) years. The plot shows decreasing main engine power over time.

Figure 5.3 Comparison of installed engine power in Small Oil Product Tankers 2007-2014 (no ice class)
The decrease in engine power, shown in Figure 5.3, is possible because of energy saving (optimisation) methods that have been employed to reduce the power such as, for example, a de-rated lower power and slower RPM engine with a larger propeller and improved hydrodynamic efficiency. Figure 5.4 shows the same data (from Figure 5.3) compared with the same ship type (small oil product tankers) with an ice class (ice class IA). It shows that in recent years the efficiency of ice going ships (the power required) has remained stable. Comparing the two plots the diverging trend is apparent, where open water ships are becoming more efficient due to energy saving measures than ice class ships i.e. the operating cost penalty for an ice classed ship, when compared with a modern fuel efficient open water ships, is increasing.
The challenge facing owners and designers of ice class ships is how to balance the conflicting design characteristics of open water efficiency (and reduced operating cost) with required ice going performance (and increased operating cost).

If owners need an ice class for trading seasonally anywhere in the Arctic, the question remains: what are they going to do with their ships for the rest of the year? If they want to trade the whole year round, they may have to look at an extreme ice-breaking form and propulsion configuration that is only economical for particular projects or particular routes, where the ice-going performance can be optimized for exact conditions.

6. Arctic Shipping Regulations

6.1 Current international regulations

This section presents evidence on the current status of regulations relevant to Arctic shipping. In accordance with the UN Convention on the Law of the Sea UNCLOS article 234 authorizes coastal states within the limits of the exclusive economic zone (200 nautical miles from the coastal baseline) to adopt and enforce non-discriminatory laws and regulations for prevention, reduction and monitoring of marine pollution from vessels operating in areas covered with ice. Of the Arctic coastal states two countries have established national requirements that regulate shipping from different perspectives: Canada’s regulations focus on pollution prevention from ships; while the Russian Federation requirements are more safety and traffic related. Both of these countries’ requirements set out seasonal limitations on ship operations in Arctic areas under their jurisdiction, primarily based on the ice strengthening standard (ice class) assigned to the ship. Table 6.1 indicates the current relevant shipping regulations for the Arctic.
6.2 Polar Code
This section describes the current status of the Polar Code and its relevance to Arctic Shipping. Section 6.2.1 presents the status and commentary on the Polar Code as of October 2014, when this evidence was first submitted. Section 6.2.2 provides an updated status as of January 2015, following finalisation of the Code at the IMO in November 2014.

6.2.1 Polar Code Status October 2014
Work began in developing mandatory standards for Polar Shipping in 2009, with finalisation of the draft text anticipated in late 2014. The entry into force date is anticipated to be 1st January 2017.

The Polar Code is intended to supplement SOLAS\textsuperscript{18} and MARPOL\textsuperscript{19}, covering additional aspects of ship design and construction for international ships operating in the Polar Regions. In parallel, amendments to the STCW (Standards of Training, Certification and Watchkeeping) Code have included provision for training of seafarers on ships operating in Polar Regions. The technical content of the Polar Code mirrors best practices already adopted by experienced ship owners, ship designers and ship builders, principally:
- The effects of sea ice: requirements for ice Class, subdivision and damage stability
- The effects of icing: requirements for intact stability (ice accretion) and de-icing measures to ensure operability of equipment exposed to icing
- The effects of low temperature: requirement for operation of essential systems and equipment and provision of suitably habitable environment for the crew
- The effects of high latitude
- The effects of remote operations

It is the intention of the Polar Code to provide an international standard for shipping in Polar regions – to which owners may specify their ships, designers and shipyards may build their ships and insurers / ship charters may evaluate more accurately the suitability (and the risk) of ships engaged on Polar voyages. However, in the near future it is likely that national regulations will be retained, primarily because:
- as an international standard, not all local requirements will have been addressed
- some Arctic states will retain stricter standards / requirements above a minimum international standard for some aspects

The Polar Code is nearing finalisation. At present, one key issue with respect to the Polar Code that remains relates to ship limitations: The majority of other international shipping regulations set minimum standards for international trading. However, because of the diversity of environmental conditions within the Polar areas, setting a minimum standard (of construction and environmental protection) is a challenge as overly onerous requirements will affect the economics of operating ships safely. Consequently it is the intention that the Polar Code requires ship specific limitations to be recorded on the Polar Ship Certificate (specific to

\textsuperscript{18}International Convention for the Safety of Life at Sea, 1974 as modified by the 1988 SOLAS Protocol

\textsuperscript{19}International Convention for the Prevention of Pollution from Ships, 1973/1978
the ship and to the environmental conditions – primarily ice conditions and temperature – which the ship will operate in). However, although some have advocated a strict limit-based system (what some have termed a “strong Polar Code”\textsuperscript{20, 21}), the current Polar Code lacks the mechanism through which to set and enforce such limits. Primarily this is because of the technical complexity of developing a system that is based on seasonal and variable ice conditions but also because such a system would necessarily have to reconcile with (or at least accommodate) current national shipping regulations.

The draft Polar Code is to be further refined at MEPC67 in October 2014 (Marine Environment Protection Committee – IMO’s committee on preventing pollution from shipping) and MSC94 (IMO’s Maritime Safety Committee) in November 2014. The following paragraph presents commentary that is relevant to the draft Polar Code as of September 2014. Developments at the IMO leading to the completion of the draft Code text (anticipated in November 2014) may affect the relevance of the following commentary and should be validated against the final draft code text:

Outstanding issues relating to the certification and limitations for operation in Polar waters will be discussed at MEPC67 and MSC94. Proposals developed by IACS and a number of Arctic states to introduce a system for linking ice conditions with ice class – effectively a risk based system for determining if a ship can operate in specific ice environments based on its structural strength and survivability – are to be presented.\textsuperscript{22} However, it should be highlighted that such a system is only proposed as guidance and not as a mandatory traffic restriction tool. The implications of this are that there is still no common mandatory standard for regulating the passage of ships in ice areas, even with the onset of the Polar Code – it will be up to coastal states, flag states, insurers and operators to require/use an appropriate system for determining in what conditions ships may operate. At the outcome of MSC94 in November it is anticipated that this issue will be concluded.

6.2.1 Polar Code Status January 2015

The Polar Code text is now complete. The entry into force date of January 1\textsuperscript{st} 2017 has been confirmed. As of January 1\textsuperscript{st} 2017 all ships operating in Polar Waters (above 500 grt) will be required to carry a Polar Ship Certificate.

Although the Polar Code text was completed at MSC94 in November, the key outstanding issue – relating to a standard system/approach for determining limitations for operating in ice – remained incomplete: There was insufficient time at MSC94 to consider the proposal of such a system (POLARIS – Polar Operational Limit Assessment Risk Indexing System) as submitted by IACS for inclusion in the Polar Code. Instead a further Correspondence Group, reporting to MSC95 (which will meet in June 2015) was set up to consider POLARIS, and other methodologies for assessing operational limitations, as an IMO Circular. A reference was included in the final Polar Code text to “Guidance developed by the organization” as a means to link the expected IMO Circular developed by this correspondence group with the Polar Code itself.

It is anticipated that the Correspondence Group outcomes will include a generic set of requirements for methodologies to assess (and set) ship limitations with respect to ice operations as well as an example of such a methodology (which is likely to be based on the POLARIS proposal from IACS submitted at MSC94).

\textsuperscript{20} The case for a strong polar code, Friends of the Earth international, 2011


\textsuperscript{22} MSC94/3/7 POLARIS – Proposed system for determining operational limitations in ice
Therefore, although the Polar Code text is now complete, there is still ongoing work at the IMO to refine procedures, methodologies and guidance that will enable the Polar Code to be implemented consistently. It is anticipated that this will be complete by the conclusion of MSC95 in June 2015. Until this work is complete there remains a certain level of uncertainty in terms of how ship-owners and ship designers are to prepare for the 1st of January 2017 entry into force date.

7. Arctic Shipping developments and the UK

This section presents evidence and offers advice, and views, on the influence of Arctic shipping developments on the UK to support the consideration of the “UK dimension”.

The two categories of Arctic shipping are considered most significant and relevant as described in the previous sections, namely: Passenger Cruise Voyages (section 4.2.2) and Export of Natural Resources (section 4.2.3). Advice, and views, are offered on the potential for a “UK dimension” from an expansion of Arctic shipping in these two shipping categories.

7.1 Passenger Cruise Voyages

Although passenger numbers in Arctic cruises are still relatively small (about 50,000 passengers in 2012) the number passenger cruise voyages to the Arctic is, however, increasing. UK & Ireland citizens are the second most numerous passengers on cruise ships with just over 8% of total cruise passenger numbers. See global passenger data in Table 7.1 from Cruise Line Industry Association (CLIA) statistics from 2013. Furthermore, Southampton is one of five European ports in the top 20 ports of embarkation for cruise passengers globally (the others being Barcelona, Copenhagen, Genoa and Venice).

<table>
<thead>
<tr>
<th>Country</th>
<th>2013 Passengers</th>
<th>Global Passenger Share</th>
<th>5 Year % Change</th>
<th>2013 Passenger Source Rank</th>
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<tbody>
<tr>
<td>United States</td>
<td>11,016</td>
<td>51.7%</td>
<td>15.1%</td>
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</tr>
<tr>
<td>UK &amp; Ireland</td>
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</tbody>
</table>

Table 7.1 – Top Ten CLIA Cruise Passenger Source Market Overview (2013 Passenger estimates (000’s))

Considering the above, there may be direct economic and/or employment benefits to the UK from an increase in Passenger Cruise Voyages in the Arctic in the case of one or a combination of the following:

1. UK registered cruise ships operating for Passenger Cruise Voyages in the Arctic
2. UK ports of embarkation for Passenger Cruise Voyages in the Arctic
3. UK domiciled specialist tour and expedition cruise operators

Considering UK & Ireland passenger numbers, and port of embarkation statistics, it could be anticipated that increased numbers of UK & Ireland citizens will travel to the Arctic for
Passenger Cruise Voyages. Furthermore some of the cruise ships employed for these voyages may also fly the UK flag. A UK port of embarkation is quite feasible and probably for Passenger Cruise Voyages to the Arctic as northern UK ports are closer in voyage distance to Arctic cruising destinations than most other popular European ports of embarkation. Finally it is also quite conceivable that specialist Arctic tour and expedition cruise companies may be established in the UK & Ireland to access a potentially large (the 2nd largest global share of cruise passengers) pool of cruising customers.

7.2 Export of Natural Resources

Direct economic and/or employment benefits to the UK from an increased export of natural resources from the Arctic could be anticipated in the case of one or a combination of the following:

1. UK import of natural resource cargoes from the Arctic
2. UK registered commercial ships employed to load natural resources from ports in the Arctic for export
3. UK port trans-shipment of natural resource cargoes from the Arctic

Depending upon the terms of the agreements (between the cargo buyer and cargo seller) there is a possibility that UK buyers of natural resources from Arctic projects could be responsible for the provision of specialist Arctic shipping. Such a scenario (the cargo buyer providing the shipping) is quite common for LNG cargoes where long term agreements for the purchase of large volumes of LNG cargo (i.e. multiple shipments per year) are essential to justify huge investments in infrastructure, e.g. land side terminals and gas processing plant. The LNG cargo buyer in such a scenario is typically an international oil company and dedicated shipping is often purpose designed and built for long term employment.

This is possibly the most realistic (albeit highly dependent on attractive commercially terms for any LNG to be imported from the Arctic) future scenario that we can conceive where UK registered commercial ships might be employed to load natural resources from ports or terminals in the Arctic, that is, an international oil company buying LNG cargoes under a long term agreement from a natural resource project in the Arctic, and employing dedicated UK registered shipping for import of the LNG into the UK.

A second scenario of natural resource imports could be envisaged where Arctic minerals are imported to the UK on dedicated, purpose designed and built, high specification Arctic commercial ships.

This is another realistic (albeit again highly dependent on attractive commercially terms for any minerals imported from the Arctic) future scenario that we can conceive where UK registered commercial ships might be employed to load natural resources from ports in the Arctic, that is, a UK importer buying Arctic mineral cargoes under a long term agreement from a natural resource project in the Arctic, and employing dedicated UK registered shipping for import into the UK.

A final scenario of a UK port being developed for trans-shipment of natural resource cargoes from the Arctic could also be a future Arctic shipping scenario with direct economic and/or employment benefits to the UK. As an example Yamal LNG (a project for exporting gas from Russia’s Yamal Peninsular) has reached an agreement in April 2014 for a Belgian LNG receiving terminal at Zeebrugge to act as a winter season LNG trans-shipment port (transfer of LNG cargoes from dedicated Arctic LNGs for the Yamal LNG trade to conventional LNG ships employed in world-wide trade).
In addition to the above scenarios for operations of Arctic shipping to/from UK ports and/or on UK registered ships there are possibilities for additional accumulated benefits to the UK from an increase in Arctic shipping through the provision of services by specialist service providers and specialist equipment and materials suppliers based in the UK to global shipping entities involved in Arctic shipping.

This may include, but is not restricted to, the following:

1. Specialist ship management services
2. Insurance and underwriting service provision, such as, for example, specialist insurance for operations in Arctic seas provided by London based underwriters
3. Technical services providers, such as, for example Classification and Certification services from Lloyd’s Register
4. Specialist suppliers of equipment and materials, such as, for example UK suppliers of specialist abrasion resistant external hull coatings for operation in ice

Notwithstanding the beneficial possibilities of future Arctic shipping for the UK, as described above, it should however be noted that Arctic shipping volumes are currently exceptionally small, as described in transit statistics in section 4.3.1. Arctic shipping is then small scale (when cargo volumes are compared with global shipping volumes) and it is a niche activity undertaken by a small number of specialist shipping providers. Currently the main providers of Arctic shipping are entities that reside within the Arctic state of the shipping project or Arctic destination ports, for example, Fednav of Canada or Sovcomflot of Russia.

Within the UK the only specialist shipping providers, albeit for Antarctic destinations (not Arctic destinations), are government owned operations for science i.e. British Antarctic Survey or security i.e. Royal Navy Ice Patrol. Other than government Antarctic operations there are UK based staff with some Arctic shipping experience and knowledge in the marine operations and assurance staff of International Oil Companies such as, for example, Shell and BP. In addition there may possibly be some Arctic shipping experience in UK based ship owner and ship management companies.

Overall though the extent of Arctic shipping experience and knowledge within the UK is both difficult to assess and quantify, and will also be difficult to sustain if current low volumes of Arctic shipping prevail in future. It should, however, be noted that a similar situation prevails in most other countries with interests in development of Arctic shipping (even for some states with Arctic territorial waters).

Arctic shipping technology providers, i.e. specialist ship designers, ice model basins and specialist equipment suppliers, typically supply services globally for Arctic shipping projects. Currently there are only a very small number of these specialist technology providers, most notably in Finland where a small cluster of Arctic shipping technology providers exists. Note that none of these providers is a UK based entity. In the case of dedicated Arctic shipping, to be purpose designed and built for UK trade, it is anticipated that the employment of existing Arctic shipping technology providers (outside of the UK) would be necessary.

7.3 Summary of expected impact development of Arctic Shipping on UK interests

In summary on the “UK Dimension” of any increase in Arctic shipping:

1. There may be direct economic and/or employment benefits to the UK from an increase in Passenger Cruise Voyages in the Arctic
2. There may also be direct economic and/or employment benefits to the UK in the case of import to the UK of natural resources from the Arctic
Although there is some Arctic shipping experience and knowledge within the UK it is difficult to assess and quantify, and will also be difficult to sustain if current low volumes of Arctic shipping prevail in future. Any initiative, as part of a "UK dimension" of Arctic shipping, may need to consider co-operation with other countries with interests in development of Arctic. Such an approach is considered to be more realistic than consideration of any UK national initiative for Arctic shipping.

8. Concluding Remarks

The objectives of this submission of evidence to the House of Lords Arctic Committee are:

- To offer supporting data and insights on transit and destination shipping in the Arctic and, in addition, the characteristics of the UK registered Arctic shipping fleet.
- To contribute evidence on the technological challenges for future Arctic shipping activities
- To contribute evidence on the regulatory framework that will govern Arctic shipping
- To contribute opinions on the “UK Dimension” of any increase in Arctic shipping
- To contribute advice, and views, on Arctic shipping to support consideration of the “UK dimension” by the Select Committee

Considering each objective in turn:

**Supporting data and insights on transit and destination shipping in the Arctic**

**Key points:**

1. Very small number of ships use Arctic transits for voyages between ocean basins (i.e. Pacific and Atlantic basins) as an alternative shipping route to transits through the Panama or Suez canal
2. Shipping in the Russian Arctic is likely to increase, but will be mainly export shipping for dedicated natural resources projects. Transit of commercial ships through the Russian Arctic is likely to occur during the summer season only
3. The UK registered ice-classed fleet is small, with 119 ice classed ships, and just 8 ships potentially suitable for transiting the Russian Northern Sea Route independently in an average summer season

**Background, or driver, of key points:**

- Even with a reduction in sea ice extent, ice conditions will remain variable and will continue to be a risk to non-specialized shipping in all but the summer season. Variability of Arctic sea-ice conditions annually and year-on-year will continue, limiting the operational season and opportunities for liner traffic to use Arctic transits as an alternative to current trade routes
- Draft (ship-size and cargo carrying capacity) restrictions due to shallow waters in much of the Arctic reduce the possibilities for large ships to navigate in the Arctic and as a consequence reduces achievable economies of scale in comparison with other shipping routes for movement between ocean basins (i.e. in comparison with transits through the Suez and Panama Canals)
- Statistics presented include only ships registered under UK flag and do not include UK Crown Dependencies (Isle of Man and Channel Island) or Overseas Territories registered ships. The contribution, influence and participation of UK shipping in the Arctic is potentially larger than indicated in this overview of the UK registered fleet only.

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23 See Shipping Fleet Statistics, Department for Transport
Contribute evidence on the technological challenges for future Arctic shipping activities

Key Points:
1. Technological challenges remain for efficient Arctic shipping with a significant build and operating cost premium associated with current generation Arctic capable ships.
2. A combination of uncertainty of ice loads, and the development of much larger Arctic ship designs than hitherto, may lead to Arctic ships that are uneconomic in operation with reduced cargo carrying capacity and excessive hull structural steel-weights.
3. Dedicated, or specialised, ships designed for year round ice-going navigation, even those enhanced only for seasonal navigation in light ice conditions, are uneconomic in build and operation costs when compared with open water shipping.

Background, or driver, of key points:
- A fundamental driver of hull form design for ice-going ships is to minimise the amount of power required to break ice. To maintain efficiency of operation in an open sea there is a fundamental dichotomy in that efficient icebreaking requires a relatively flat, full bow shape while an efficient bow for open water efficiency and sea-keeping requires a (much) finer bow shape.
- A limited data set, from full scale measurements of ice loads on ships in ice, is available for calibrating and determining design loading of ships due to hull-ice interaction. A combination of uncertainty of ice loads, and the development of much larger Arctic ships than hitherto, is possibly leading to excessive conservatism in design loads and structural design of Arctic ships. This is shown in a plot of the steel weight of a number of recent large cargo ship projects. The curve indicates the actual (exponential) increase in steel weight for ice strengthening with an increase in ship’s ice-going capability (as defined by permitted level ice thickness for ship operations). The straight line on the chart is intended to represent a desired, or ideal, situation where refinement in the understanding of ice loads on larger ships may, in the future, yield a more optimal structural design of reduced steel weight.
- The trend for energy efficiency for open water ships, coupled with relatively high installed power requirements for Arctic and ice class ships, is leading to a divergence in hull performance such that Arctic and ice class ships are becoming (even more) uneconomic from consideration of build and operating costs when compared with open water ships. This is shown in trend comparison for installed main engine power between ice-going, and open water, designs of small oil product tankers – where higher installed engine power directly relates to capital cost at build and operating cost (i.e. fuel oil consumption) in service.
Figure 8.1: Increase in steel weight compared with icebreaking capability for large cargo ships

Figure 8.2: Comparison of installed engine power in small product tankers (ice class 1A and no ice class)
Contribute evidence on the regulatory framework that will govern Arctic shipping

Key Points:
1. Canada and the Russian Federation have requirements that regulate Arctic shipping including seasonal limitations on ship operations in Arctic sea areas under their jurisdiction, primarily based on the ice strengthening standard (ice class) assigned to the ship.
2. International Maritime Organisation (IMO) finalised mandatory standards (“Polar Code”) for Polar Shipping in 2014. The entry into force date will be 1st January 2017. The Polar Code is intended to supplement SOLAS\(^{24}\) and MARPOL\(^{25}\), and covers additional aspects of ship design and construction for international ships operating in the Polar Regions.
3. The Polar Code will require limitations to be recorded on the Polar Ship Certificate i.e. ice conditions and temperature limits of ship operations.

Background, or driver, of key points:
- The Polar Code text was finalised at MEPC67 in October 2014 (MEPC = Marine Environment Protection Committee – IMO’s committee on preventing pollution from shipping) and at MSC94 (IMO’s Maritime Safety Committee) in November 2014.
- One key outstanding issue relates to limitations: The majority of other international shipping regulations set minimum standards for international trading. However, because of the diversity of environmental conditions within the Polar areas, setting a minimum standard (of construction and environmental protection) is a challenge.
- Further work at the IMO is continuing to establish an appropriate standard/methodology for setting limitations for operating in ice through a Correspondence Group. This Correspondence Group will consider proposals submitted by IACS at MSC94 (POLARIS = Polar Operational Limit Assessment Risk Indexing System). The conclusions are to be discussed at MSC95 in June of 2015.

Contribute advice, and views, on Arctic shipping to support consideration on the “UK dimension”

Key Points:
1. There may be direct economic and/or employment benefits to the UK from:
   a. An increase in Passenger Cruise Voyages in the Arctic
   b. Imports to the UK of natural resources from the Arctic
2. UK Arctic shipping experience and knowledge will be difficult to sustain if current low volumes of Arctic shipping prevail in future. A similar situation does, however, prevail for most other countries interested in the development of Arctic shipping.
3. Any initiative, as part of a “UK dimension” of Arctic shipping, may need to consider co-operation with other countries with interests in development of Arctic.

Background, or driver, of key points:
- Based on passenger number statistics alone it could be anticipated that increased numbers of UK & Ireland citizens will be travelling to the Arctic for Passenger Cruise Voyages
- Depending upon the terms of agreements (between the cargo buyer and cargo seller) there is a possibility that UK buyers of natural resources from Arctic projects could be responsible for the provision of specialist Arctic shipping
- Other than government (British Antarctic Survey and Royal Navy Ice Patrol) Antarctic operations there are UK based staff with some Arctic shipping experience and knowledge in the marine operations and assurance staff of International Oil Companies such as, for example, Shell and BP. In addition there may possibly be some Arctic shipping experience

\(^{24}\) International Convention for the Safety of Life at Sea, 1974 as modified by the 1988 SOLAS Protocol
in UK based ship owner and ship management companies. Overall though the extent of Arctic shipping experience and knowledge within the UK is difficult to assess and quantify.

8. References
2. Future Possibilities for Trans-Arctic Shipping through the Central Arctic Ocean, Niini, M., Tustin, R.D., Proceedings of ICETECH, 2010
3. Arctic Marine Shipping Assessment, Arctic Council, 2009
5. Arctic Energy Shipping Perspectives: Arctic Voyage of SCF Baltica – First Step in Regular Oil Products Trade to Asia, Sovcomflot presentation to the Arctic Passion Seminar, 2011
8. POLARIS – Proposed system for determining operation limitations in ice, MSC94/3/7, IMO, 2014
11. Fleet data and statistics are extracted from the IHS Maritime Seaweb database, www.seaweb.com

APPENDIX A: Lloyd's Register’s involvement with Arctic Shipping
Lloyd's Register has evolved from the original classification society supporting the shipping industry to a multi-industry compliance, assurance, risk and technical consultancy services organisation. Lloyd’s Register remains a leading provider of marine classification services around the world, helping ensure that internationally recognised safety and environmental standards are maintained at every stage of a ship’s life
Lloyd's Register publishes and maintains rules for design, construction and survey of ships, including specific rules for ships operating in ice (ice class ships) and ships intended to operate as icebreakers.
Lloyd's Register’s recent work on the development of ice class Rules and Regulations is significant. Having been the first class society to fully adopt the new IACS (International Association of Classification Societies)26) Polar Class Rules (IACS UR I), we have undertaken detailed analysis of these Rules to first validate, and then expand upon these Rules – with particular focus on their application to icebreakers intended for use in more harsh/aggressive ice conditions. We have also published the first dedicated set of Rules for Stern First Ice Class Ships (commonly known as Double Acting Ships (DAS™)27). Lloyd’s Register is the current IACS (International Association of Class Societies) representative to the IMO Polar Code working group.

26 See www.iacs.org.uk
27 DAS and Double Acting Ship are Trademarks of Aker Arctic Technology Inc – the originators of the design concept for ships equipped with azimuth propulsion units and designed to operate stern first in ice
Since 1977 over 1,000 ships, totalling some 11 million gross tonnes, have been built to Lloyd’s Register’s ice class notations: Our involvement includes approving the design; supervising construction and in-service survey, highlights of our experience include:

- MV Arctic, icebreaking bulk carrier – over 35 years of operation in the Arctic
- Icebreaker fleet built for the Canadian Beaufort oil industry exploration program in 1980s - ships that are still in operating today, mainly in other ice-covered areas
- MT Tempera / MT Mastera, the first and largest icebreaking double acting tankers – now with over 10 years of operational experience

Of the 127 icebreakers in the world the number that are designed and built to Lloyd’s Register class (26) is second only to Russian Register (40 icebreakers). Lloyd’s Register class icebreakers and ice-going vessels operate in all sea-ice areas: Antarctic, Baltic, Canadian Arctic, Russian Arctic, Sakhalin. Through this fleet, LR has built up a considerable breadth of knowledge regarding icebreaker design, and the through-life performance of their structures and systems.

In the last 5 years, we have been involved in a number of key Arctic Shipping Projects:

- The delivery of the latest two icebreaking supply vessels for Sakhalin Service
- The acceptance into class of the Canadian Coast Guard’s flagship icebreaker
- The approval of the design for the Canadian Coast Guard’s new icebreaker to Polar Class 2 – the highest PC class yet to be approved
- The delivery of two Double Acting Arctic Shuttle tankers for the Russian Arctic
- The approval of the first icebreaker equipped with podded propulsion forward and astern
- The approval of the first dual fuel / LNG icebreaker
- The approval of the first icebreaker / Antarctic research vessel to be built in China

APPENDIX B: SUPPORTING INFORMATION – ARCTIC SHIPPING STATISTICS

B1. Transit seasons – duration and variability

Table B1 to Table B4 indicate the regulatory seasons for Arctic Shipping along the Northern Sea Route and through the North West Passage. These are based on the interpretation of Northern Sea Route Administration and Transport Canada regulations.

The following should be noted when comparing and interpreting the tables:

- The Northern Sea Route declares Easy, Average and Hard seasons. These are based on the severity of the ice conditions at the start of the season. Canadian Arctic regulations do not differentiate and only set specific dates. However in milder seasons operators can utilise an alternative system of on-sight ice condition assessment to determine if operations are permissible.
- The Northern Sea Route regulations differentiate between independent and escorted navigation. The Canadian Arctic regulations do not, as icebreaker escort is not provided in the Canadian Arctic for commercial shipping (independent navigation is assumed).
- The North West Passage is not one passage but a number of alternative routes through the Canadian Archipelago, each route has different draft restrictions and may be open or closed depending on the movement of the Arctic pack and how the pack ice moves into the Archipelago. The easiest route has been assumed to be open for the purposes of comparison.
- Ship Category definitions follow those in the Polar Code

28 “Icebreaker” being defined as ships with a primary function of icebreaking, and not counting cargo ships or icebreaking tugs and harbour duty vessels. In general this equates to vessels of Polar Class PC5 or above.
29 Canadian Arctic Ice Regime Shipping System (AIRSS)
30 See Appendix D
The Northern Sea Route regulations only allow for vessels with no ice strengthening to operate independently when the water is ice free (marked with an *)

<table>
<thead>
<tr>
<th>Transit Route</th>
<th>Ship Category</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Sea Route</td>
<td>Category C (No ice class)</td>
<td>Not Allowed*</td>
<td>Not Allowed*</td>
</tr>
<tr>
<td></td>
<td>Category C</td>
<td>July</td>
<td>November</td>
</tr>
<tr>
<td></td>
<td>Category B</td>
<td>Year-Round</td>
<td>Year-Round</td>
</tr>
<tr>
<td></td>
<td>Category A</td>
<td>Year-Round</td>
<td>Year-Round</td>
</tr>
</tbody>
</table>

Table B1 Independent Operation, Mild Ice year

<table>
<thead>
<tr>
<th>Transit Route</th>
<th>Ship Category</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Sea Route</td>
<td>Category C (No ice class)</td>
<td>Not Allowed*</td>
<td>Not Allowed*</td>
</tr>
<tr>
<td>North West Passage</td>
<td>Category C</td>
<td>Not Allowed</td>
<td>Not Allowed</td>
</tr>
<tr>
<td></td>
<td>Category B</td>
<td>Not Allowed</td>
<td>Not Allowed</td>
</tr>
<tr>
<td></td>
<td>Category A</td>
<td>Year-Round</td>
<td>Year-Round</td>
</tr>
</tbody>
</table>

Table B.2 Independent Operation, Average Ice year

<table>
<thead>
<tr>
<th>Transit Route</th>
<th>Ship Category</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Sea Route</td>
<td>Category C (No ice class)</td>
<td>July</td>
<td>November</td>
</tr>
<tr>
<td></td>
<td>Category C</td>
<td>July</td>
<td>November</td>
</tr>
<tr>
<td></td>
<td>Category B</td>
<td>Year-Round</td>
<td>Year-Round</td>
</tr>
<tr>
<td></td>
<td>Category A</td>
<td>Year-Round</td>
<td>Year-Round</td>
</tr>
</tbody>
</table>

Table B.3 Icebreaker Supported Operation, Mild Ice year

<table>
<thead>
<tr>
<th>Transit Route</th>
<th>Ship Category</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Sea Route</td>
<td>Category C (No ice class)</td>
<td>Not Allowed</td>
<td>Not Allowed</td>
</tr>
<tr>
<td></td>
<td>Category C</td>
<td>Not Allowed</td>
<td>Not Allowed</td>
</tr>
<tr>
<td></td>
<td>Category B</td>
<td>July</td>
<td>November</td>
</tr>
<tr>
<td></td>
<td>Category A</td>
<td>Year-Round</td>
<td>Year-Round</td>
</tr>
</tbody>
</table>

Table B.4 Icebreaker Supported Operation, Average Ice year

In general it can be seen that the North West Passage is closed to traffic, even high ice-classed icebreakers, during the wintertime according to Canadian Regulations. The Russian Northern Sea Route does remain open for year-round shipping for high ice class (Category A ships). It is
also to be noted that the Northern Sea Route only allows for independent operation of non-ice strengthened ships in ice free water: The definition of ice free water would typically mean that even during the summer months an icebreaker escort may be required.

APPENDIX C: SUPPORTING INFORMATION – ARCTIC TECHNOLOGY

C1 Detailed description of the historical development of ice-going ships

The science of optimising a hull form for ice began in the 1970s with the introduction of model scale ice basins for testing of hull forms. Prior to this, effective hull forms were derived from full scale experience.

Development of new ship designs with hull forms refined in model scale enabled a significant reduction in the installed power of ice-going ships, increasing their efficiency and economy. The 1980s saw a large program of investment and development in icebreaker technology, both with respect to hull form shape and provision of auxiliary systems to aid icebreaking, primarily by reducing the friction between the ice and the ship (e.g. low friction paint, heeling tanks, air bubbler systems, water deluge systems). Figure C1 shows the performance of a number of icebreakers and icebreaking cargo ships compared. The figure uses a standard set of comparison metrics\(^{31}\): The y-axis is a measure of thrust per metre beam; the x-axis is the achieved ice thickness broken at a constant 2 knot speed. A number of trends are highlighted to illustrate the development of ice-going ship efficiency in recent years:

1. Green marker points: Kigoriak (1979) and Robert Lemeur (1984) have the same ice performance point; however the installed power in Lemeur is approximately 30% less. The increase in efficiency is due to optimised hull form shape and inclusion of a number of auxiliary friction-reducing measures (low friction paint, water-deluge system), all advances in technology developed in the early 1980s

2. Red Marker points: Kapitan Sorokin (1977) was a series of Arctic icebreakers, originally built with conventional “wedge” shape bows. During the 1980s the bow section of two of the class of ships were replaced, one with a unique “cutting/shearing bow”\(^{32}\)(New Sorokin, 1991) and one with an extreme (shallow angle) conical bow (Kapitan Nikolayev, 1990). These new bow forms were proven to increase the icebreaking efficiency by 50-65% respectively, although at a cost to their performance in open seas.

The period of development between the late 1970s and the 1980s therefore saw an increase in ship icebreaking efficiency. However, primarily because of the downturn in oil price, and subsequent reduction in the economic viability of Northern oil and gas projects, investment (and engineering) associated with Arctic Technology declined. Reflecting on the progress and experimental programs in the 1980s, designers from 1990s onwards have had a wide range of hull form solutions to select from, depending on the operational profile of the ship, principally the amount of time the ship is intended to operate in ice and the amount of time the ship is intended to operate in open water.

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\(^{32}\) Thyssen-Waas bow concept
C2 Development and use of azimuth thrusters for ice-going ships

The 1990s saw a new approach to addressing the challenge of icebreaking vs. open water efficiency but focused on propulsion technology rather than hull form shape. Bow propellers have been used on icebreaking ships for a number of years, prior to the 1990s the most recent adoption of bow propellers on icebreakers was the Sisu class icebreakers designed in Finland (2 propellers at the bow, 2 at the stern), the main advantage being that the water flow into the pulling propeller (at the bow) causes a pressure drop under the ice sheet ahead of the ship; which reduces buoyant up thrust on the ice sheet and promotes ice breaking by bending.\textsuperscript{33}

A development from the observed effects of bow propellers was the concept of using directional thrust to enable a more efficient process for ice channel breaking. This evolved into a project between the Finnish Maritime Administration (FMA) and Kvaerner Masa Yards (KMY) focusing on improving Baltic icebreaker capability and resulted in the first installation of an Azipod\textsuperscript{34} (Azimuthing Poded Drive), on ‘Seili’, owned by the FMA, in 1990. Figure C2 illustrates an Azimuth thruster.

\textsuperscript{33} Methods and Approaches for the Classification of ships designed for stern first operation in ice, Proceedings of Icetech 2008

\textsuperscript{34} A poded electric main motor and steering device driving a fixed pitched propeller at variable rpm. The pod can azimuth infinitely through 360 degrees by means of hydraulic motors and the system is designed to preferentially use a pulling propeller when in the normal ahead mode.”
Figure C.2 Azimuth Thruster installed on an ice-going cargo ship

As the azimuth thruster provides 360 directional thrust it was found that, with the unit located at the stern of the ship the ship can proceed in ice “stern first” with the stern (and the propeller) facing the oncoming ice. The beneficial effects of stern first operation from propeller and hull ice interactions are described below:

- **Ice sheet bending and breaking** - the water flow into the pulling propeller causes a pressure drop under the ice sheet ahead of the stern; which reduces buoyant up thrust on the ice sheet and promotes ice breaking by bending.

- **Flushing of ice ridges** - by azimuthing the pod adjacent to the keel of an ice ridge the variable flow of water promotes the erosion, or flushing, of the ice ridge keel.

- **Lower frictional resistance in ice** - with the propeller pulling, the water flow from the propeller washes along the length of the hull. The water flow reduces the friction between the hull and the ice by lubrication.

Ships designed for stern first operation in ice can be optimized for heavier ice conditions going astern, enabling the bow of the ship to be optimized for open water (for example using a bulbous bow) or light ice conditions. A superior open water performance may be achieved when compared with a ship with an icebreaking bow, as well as a comparable ice-going vessel designed for bow first operation in ice. The use of azimuth thrusters therefore has two principle benefits:

- Increased maneuverability in ice (the primary reason for using azimuth thrusters on icebreakers)
- The ability to optimise the ship’s hull form for open water conditions when operating ahead and ice conditions when operating stern first (the primary reason for using azimuth thrusters on Arctic cargo vessels)

Table C1 provides data extracted from Figure C1 for a number of Arctic icebreaker and cargo ship designs with similar installed engine power. The increase in efficiency in Arctic icebreakers (shaft lines) is evident and mainly due to improved hull form shape. The increase in ice performance (at the same installed power level) for Arctic cargo ships shows the improvements that can be made when using Azimuth thrusters as part of stern first operation.
<table>
<thead>
<tr>
<th>Ship Type</th>
<th>Date</th>
<th>Propulsion type</th>
<th>Ice performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctic icebreaker</td>
<td>1970s</td>
<td>Shaftline</td>
<td>1.45m</td>
</tr>
<tr>
<td></td>
<td>1990s</td>
<td>Shaftline</td>
<td>2.2m</td>
</tr>
<tr>
<td></td>
<td>1990s</td>
<td>Shaftline</td>
<td>2.4m</td>
</tr>
<tr>
<td>Arctic cargo ship</td>
<td>1980s</td>
<td>Shaftline</td>
<td>1.0m</td>
</tr>
<tr>
<td></td>
<td>2000s</td>
<td>Azimuth</td>
<td>1.65m</td>
</tr>
</tbody>
</table>

Table C.1 Improvements in ice-going performance for similar powered icebreakers and Arctic cargo ships

Considering the commentary provided above it is to be noted that, as with the hull form developments in the 1980s, the successful use of Azimuth thrusters has given Arctic ship designers another option to select from when considering how to optimise the ship for its operational profile (amount of time in ice vs time in open water etc.). Successful shaft line and Azimuth thruster equipped Arctic cargo ships have been built and are in operation today. Furthermore there are two key technology challenges for the application of azimuth thrusters for large, high Arctic ships that are yet to be fully addressed:

- Power density: The amount of power (and therefore delivered thrust) from an azimuth thruster where the electric motor is located outside of the hull is currently limited
- Multi-year ice: The ice loads on the propeller and the azimuth thruster itself (which will experience ice load impact when operating ahead and stern first) are relatively untested in harsh high-Arctic conditions in strong multiyear ice.

Both issues are being addressed in an incremental, step-by-step progression, with higher powers and more harsh operating conditions planned for the near future.

APPENDIX D: ICE CLASS DESCRIPTIONS

To protect ships when navigating in ice, suitable strengthening of the ship is required. This is achieved by a special set of classification rules; the ice class rules. Ice class rules provide standards for additional strengthening of the hull structure and propulsion machinery, and often requirements for increased engine power to enable the ship to force its way through the ice.\(^\text{35}\)

Ice class rules are a strengthening standard: An additional level of strength for the hull structure and propulsion machinery is provided depending on the ice class selected. Categorisation of ice classes are normally made by assumed thickness. The assumptions regarding the ice thickness determine the loads to be applied to the structure. Currently three significant ice class rule sets are used:

- Finnish Swedish Ice Class Rules – published by the Finnish and Swedish administrations for application to ships trading in the seasonally ice covered waters of the Baltic (first-year ice): The majority of classification societies have incorporated these rules into their own standards.
- Russian Maritime Register of Shipping (RMRS) ice categories – a set of ice classes that form the basis of traffic restrictions for operation on the Northern Sea Route.
- International Association of Classification Societies (IACS) Polar Class Rules – developed over a 10 year period by collective input from a number of classification societies to form a set of standard rules for ships operating in Polar waters (presence of multi-year ice).

\(^{35}\) See Factors Influencing the Choice of an Ice Class, Design and Construction of Vessels Operating in Low Temperature Environments, RINA, 2007
These rules were developed to complement, and are directly referenced in, the IMO Polar Code and are now incorporated into IACS member’s rules. It is important to note that the ice class rules do not require certain ice classes for certain operational areas (with the exception of the Russian Maritime Register of Shipping, the ice categories of which are directly interrelated with Russian Northern Sea Route regulations). In addition, it has generally been the ship owner that selects what he considers a suitable ice class for his intended operations, not the classification society insisting on a specific level of strengthening (ice class is considered an optional classification notation).

The majority of the sea areas that experience ice conditions that are under the jurisdiction of national administrations do, however, have some form of shipping regulation / control system, which functions to limit the amount of high (damage) risk ships operating in ice covered areas. The main limiting criteria used by national administrations for operation is a certain ice class, dependent on the prevailing ice conditions.

Table D1 and D2, overleaf, respectively show ice classes for the IACS Polar Class Rule and Finnish Swedish Ice Class Rules and a nominal value for level ice thickness associated with each ice class.

<table>
<thead>
<tr>
<th>Polar Class Notations</th>
<th>Ice Description</th>
<th>Nominal design level ice thickness*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1</td>
<td>Year-round operation in all Polar Waters</td>
<td>&gt;4m</td>
</tr>
<tr>
<td>PC2</td>
<td>Year-round operation in moderate multi-year ice</td>
<td>3-4m</td>
</tr>
<tr>
<td>PC3</td>
<td>Year-round operation in second-year ice which may include old ice inclusions</td>
<td>2-3m</td>
</tr>
<tr>
<td>PC4</td>
<td>Year-round operation in thick first-year ice which may include old ice inclusions</td>
<td>1.2-2m</td>
</tr>
<tr>
<td>PC5</td>
<td>Year-round operation in medium first-year ice which may include old ice inclusions</td>
<td>0.9m-1.2m</td>
</tr>
<tr>
<td>PC6</td>
<td>Summer/autumn operation in medium first-year ice which may include old ice inclusions</td>
<td>0.7m-0.9m</td>
</tr>
<tr>
<td>PC7</td>
<td>Summer/autumn operation in thin first-year ice which may include old ice inclusions</td>
<td>0.5m-0.7m</td>
</tr>
</tbody>
</table>

**Table D.1 Ice Class Notations – Polar Class**

<table>
<thead>
<tr>
<th>Finnish Swedish Ice Class</th>
<th>Nominal level ice thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA Super</td>
<td>1.0</td>
</tr>
<tr>
<td>IA</td>
<td>0.8</td>
</tr>
<tr>
<td>IB</td>
<td>0.6</td>
</tr>
<tr>
<td>IC</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**Table D.2 Ice Class Notations – Finnish Swedish Ice Class**

Notes on table D1 and D2:
- PC6 is considered equivalent to IA Super (if engine powering requirements are met) but the equivalency is not reciprocal
- PC7 is considered equivalent to IA (if engine powering requirements are met) but the equivalency is not reciprocal
- Nominal/design level ice thickness does not set absolute limits on ice operation, but is the design value

Various other ice classes exist in addition to the above published by different classification societies. For first year ice classes (ships operating in ice that melts during the summer) there is an agreed set of equivalencies between ice classes. For multi-year ice classes (ships operating in ice that survives the summer and is significantly harder than first-year ice) there is no accepted equivalence.

### D2 Polar Code Categories

The Current draft Polar Code divides ships operating in Polar waters into three categories. The applicability of requirements within the Polar Code is then based on the Category assigned to the ship. Polar Code ship categories are described in terms of World Meteorological definitions of ice conditions and are given in Table D3. Within the draft Polar Code the Categories are related to the IACS Polar Classes – the relevant polar classes are also presented in Table D3.

<table>
<thead>
<tr>
<th>Polar Ship Category</th>
<th>Ice Description</th>
<th>Ice Class required</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category A</strong></td>
<td>A ship designed for operation in polar waters in at least medium first-year ice, which may include old ice inclusions</td>
<td>PC1 – PC5</td>
</tr>
<tr>
<td><strong>Category B</strong></td>
<td>A ship not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions</td>
<td>PC6 – PC7</td>
</tr>
<tr>
<td><strong>Category C</strong></td>
<td>A ship designed to operate in open water or in ice conditions less severe than those included in categories A and B</td>
<td>Other ice class rules and ships notice strengthened</td>
</tr>
</tbody>
</table>

*Table D.3 IMO Polar Code Ship Categories*

### D3 Ship type and ice class definitions

A variety of terminology exists for use when describing ice-going ships. The following provides a brief explanation of the most common terms. These are not official definitions, but may be considered as guidance when evaluating different ship types and capabilities.

**Ice class** – any ship assigned an ice class that operates in ice.

Low ice class ships (IC to IA Super, PC6, PC7) typically operate in ice channels created by an icebreaker or are supported by icebreakers.

High ice class ships (Polar Class ships, PC5 – PC1) typically operate independently in ice without the support of icebreakers.

**Ice-strengthened** – typically used to refer to low ice class ships.

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26 See HELCOM Recommendation 25/7
**Icebreaker** – ships specifically designed to operate aggressively in ice, which may include ramming of heavy ice features and close maneuvering in ice. Icebreakers may be assigned a high ice class but typically have increased strength levels above the ice class minimum to reflect the heavy loading from aggressive operations.

**Icebreaking cargo ship / Arctic cargo ship** – ships carrying cargo which typically operate independently in ice. Arctic cargo ships are typically assigned a high ice class.
APPENDIX E: Arctic Oil, Gas and Mineral Major Projects

Key: Dashed lines represent seasonal export, solid lines represent year-round export
Arctic Oil, Gas and Mineral Major Projects: Existing and Near Future

- Milne Inlet: Iron Ore Export
- Amaguliak: Oil Export
- Deception Bay: Nickel Export
- Prirazlomnoye: Oil Export
- Varandey: Oil Export
- Yamal: Gas Export
- Norilsk: Nickel Export

Key: Dashed lines represent seasonal export, solid lines represent year-round export, yellow markers represent near future export projects

19 January 2015