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History of the Northern Sea Route

“History is a lantern to the future, which shines to us from the past”
V.O. Klyuchevskiy

1.1 FIRST VOYAGES
(V. Ye. Borodachev, V. Yu. Alexandrov)

The history of the exploration of the North is full of heroic spirit and tragedy—the voyages and expeditions that accompanied geographical discoveries—the history of scientific studies—organization of a system of stationary and non-stationary observations—creation of the scientific-technical support service for the Northern Sea Route (NSR)—all in all, the history of a fierce battle against the incredibly severe conditions of the Arctic.

It is challenging to comprehensively reconstruct the background to this history. The famous Norwegian polar explorer and scientist Fridtjof Nansen wrote: “We speak about the first discovery of the North—but how can we know when the first man appeared in the Earth’s northern regions? We know nothing except for the very last migration stages of humanity. What occurred during these long centuries is still hidden from us” (Nansen, 1911).

Indeed, we have some evidence on Pytheas, a Greek from Massalia, who between 350 and 310 BC reached England and then a “gloomy land” he called Thule, beyond which “there is no sea or land or air with some mixture of all these elements hanging in space” (Belkin, 1983). Such a perception of the earth’s northern regions was preserved for many centuries and only began to change in the 9th to 11th centuries with the appearance of first the Norsemen in the Barents and White Seas. Between 870 and 890 AD, more than a thousand years after the voyage of Pytheas, the Norwegian seafarer Ottar rounded the northern tip of Europe and explored the Barents and White Seas. The Norsemen also sailed to the mouth of Severnaya Dvina after Ottar: Eric Bodek in 920, Harald Grey Cloak in 965, Tore Hund in 1026, Haakon in 1090, and Ivar in 1222 (Henning, 1944).
The camps of Pomors,\(^1\) who actively developed areas of the White and Barents Seas hunting seals and walruses, appeared in the mouths of the Onega, Dvina and Pechora Rivers in the 10th century. In 1032 a team headed by the Novgorodian voevode\(^2\) Uleb made the first known sea voyage eastward of the White Sea and reached Kara Gate and Yugorskiy Shar (Belov, 1977). In the 12th century, Novgorodian merchants, developing the fur trade in Yugorskiy Land,\(^3\) seem to have crossed the Yamal Peninsula getting as far as the lower reaches of the Ob’ River. Throughout the 13th to 15th centuries the Pomors sailed into the Kara Sea, reaching it through the sea’s southernNovozemelsky Straits and Matochkin Shar Strait.

Among the achievements of the Norsemen and Pomors who sailed in the White and Barents Seas was the discovery of a number of islands including Novaya Zemlya and Spitsbergen. These voyages were highly risky because they were made onboard small wooden boats and without knowledge of climate, ice and navigation conditions. It was seafarers like these who were the first to accumulate knowledge about the nature of sea ice. Investigating winds and currents, tidal and other natural phenomena, they associated them with changes in sea ice state. For example, the appearance of fractures in ice as tidal currents changed from flowing to ebbing was called by the Pomors “ice divergence”. This term is still used in modern dictionaries. Seafarers got to know the basic ice-drift pattern in the Barents Sea. They also knew about ice export through the Greenland Sea. As part of their preparation for an expedition to the North Pole from the north shore of Spitsbergen, English explorers collected sea ice data from the Pomors.

### 1.2 VOYAGES IN THE 16TH–17TH CENTURIES


At the beginning of the 16th century, the dominance of Spain and Portugal over all known shipping lanes forced other European countries to search for alternative routes, mainly across the Nordic seas. It was at this time that a proposal to sail to China using the Northern Sea Route was proposed by Sebastian Cabot and a Moscow diplomat Dmitriy Gerasimov (Vize, 1939; Belov, 1970). Geographical knowledge of the Arctic at that time was rather vague, as can be seen from the map of the polar region published by a Dutch cartographer, Mercator (Figure 1.1). The contours of the mainland and archipelagos are significantly different from those of contemporary maps. The central Arctic was completely unknown and speculations about land there were quite common.

In the second half of the 16th century, Dutch and English merchants organized several expeditions to the Arctic with the aim of passing eastward through the polar ice. Ships under the command of Hugh Willoughby and Stephen Burrough reached the eastern Barents Sea. The Dutch merchant Olivier Brunel together with Russian

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\(^1\) The Pomors are a native Russian population living along the White Sea coast.

\(^2\) A voevode is a military leader, ruler of Slavic nations.

\(^3\) This corresponds to the present region on the border between the Barents and Kara Seas.
Figure 1.1. Map of the Arctic by Gerhardus Mercator (1512–1594). The map was modified several times and published in 1606 with Spitsbergen drawn on it. From Drivenes and Jolle (2004).

seafarers made a sea voyage from the mouth of the Pechora to the lower Ob’, while the expedition commanded by Arthur Pet and Charles Jackman sailed across Yugorskiy Shar Strait to the Kara Sea (Vize, 1939). At the end of the 16th century, three expeditions were organized to the Arctic under the command of Willem Barents. During the last of these, explorers rounded the northern tip of Novaya Zemlya where their ship was trapped in ice and damaged in the bay called Ledyanaya Gavan’ (Ice Harbor). After a severe winter they continued and eventually reached the Kola Settlement, but at great cost: Willem Barents died on the way and was buried on the northern island of Novaya Zemlya (Vize, 1939).

After Barents’s voyages, interest in the Northeast Passage decreased considerably. However, at the end of the 16th century Russia began intense exploration of Siberia and the Far East, and the Asian continent from the Urals to the Pacific Ocean
Figure 1.2. Map of the northern coast of Russia made by Isaee Massa in 1611.
was spanned in slightly more than a half-century (1581–1641). The northern lands and seas were claimed by Russia, who took the leading role in the development of Arctic shipping. This contributed to the development of “overseas” trade, concentrated in the 16th and 17th centuries in the only seaport, Arkhangelsk. During this time a continuous flow of cargo was transported along the Severnaya Dvina (Belov, 1956).

At the end of the 16th century, shipping along the coast of the Arctic Ocean became significantly more active. Pomors and manufacturers made voyages from the White Sea to Novaya Zemlya and Spitsbergen. Between 1610 and 1619 no fewer than 16 or 17 ships sailed annually along the Ob’ and Taz Rivers to Mangazeya. However, use of this route was banned by the Moscow Government in order to prevent foreign penetration into Siberia, causing a lot of harm to the development of shipping in the north (Rudnev and Kulik, 1915). From data gathered in Russia, Isaac Massa published in 1611 a map of the Arctic coast (Figure 1.2), depicting the Ob’ Delta, the Yamal Peninsula, and also the mouths of the Yenisey and Pyasina, where sea mammals were hunted. In the 17th century, Russian seafarers passed through the most difficult part of the Northeast Passage along the Taymyr Peninsula coast and rounded Cape Chelyuskin (Belov, 1977).

In the first half of the 17th century, Cossacks sailed to what they termed the “Icy Cold Sea” along Siberian rivers. The main voyages of Cossack seafarers were made from Yakutsk and Zhirinsk along the Lena River to the sea and then to the Kolyma River along the coast (Figure 1.3).

![Figure 1.3. Eastward advances of the Russians in Northeast Asia in the 17th century: (1) I. Rebrov (1638), (2) I. Perfiliev (1637), (3) I. Rebrov (1633), (4) D. Zyryan (1642), (5) D. Zyryan and M. Stadukhin (1643), (6) I. Ignatyev (1646) and (7) S. Dezhnev (1648).]
Typically, as many as ten ships sailed together in these voyages. In the 15 years following 1633 the Cossacks discovered the mouths of all major rivers flowing to the Laptev and East Siberian Seas. Simultaneously, settlements appeared along the coast between the Lena and Kolyma, which, however, did not exist for long (Khmyznikov, 1937).

In 1646 the first attempts to pass by sea to the east of Kolyma were undertaken by Ivan Ignatyev, who sailed to Chaunskaya Bay along the coastal polynya. The advance of Russian seafarers along the Eurasian Arctic coast ended with the voyage of Simon Dezhnev. In 1648, the Russian ships under his direction sailed from the Kolyma to the Pacific Ocean and discovered the Bering Strait 80 years earlier than the Bering expedition. The northeastern cape of Chukotka discovered by Dezhnev, was named after him in 1898 (Vnukov, 2000).

As a result of expeditions in the 16th and 17th centuries, during which mainland shores, islands and encountered rivers were discovered and described, knowledge of the real length of the Northeast Passage, coastline of the Eurasian Arctic seas and ice conditions was significantly expanded. “All north coast of Eurasia, excluding probably part of Taymyr, was passed by the Russian seamen before 1650 and this achievement really belongs to the Russians” (Armstrong, 1996).

1.3 FROM THE 18TH TO THE EARLY 20TH CENTURY
(V.Y. Alexandrov, V.Y. Borodachev, I.Y. Frolov)

1.3.1 Expeditions and geographical discoveries
As a result of Peter the Great’s reforms, Russia became a powerful sea state, necessary to support and protect regular shipping to its territories in the Far East and necessary for the development of foreign trade. This is the reason much attention in the first half of the 18th century was devoted to exploring the coast of Eurasia from the White Sea to Kamchatka. In 1728 an expedition headed by V. Bering onboard Svyatoj Gavrill passed to the north of Kamchatka, discovered the Komandorskiye and Aleutian Islands and found that Asia did not connect with America. The Great Northern Expedition, commanded by V. Bering, obtained the most important geographical discoveries and scientific results in 1733–1743. It surveyed the coast of the Arctic Ocean and divided it from west to east into four sectors: (1) to the west of the Ob’, (2) between the Ob’ and Yenisey, (3) between the Yenisey and Lena, and (4) east of the Lena, each of which were studied by individual teams

The ships of the two western teams were able to pass from Arkhangelsk to the Yenisey, perform a survey of part of the coastline and conduct observations of tides and currents. Exploration of the most difficult segment of the Northeast Passage between the Yenisey and Lena, around the Taymyr Peninsula, was carried out both from the western and from the eastern sides. In spite of this, attempts to round Taymyr from the sea were unsuccessful and inventory of a significant part of the
peninsula coast was made from land. During this work, S. Chelyuskin in 1742 reached the northern tip of Eurasia later named after him, Cape Chelyuskin. The eastern team passed by sea from the Lena to the Indigirka, then to the Kolyma River, and described the coast. In summer of 1741 in an attempt to pass further eastward, the expedition's ships reached Cape Bolshoy Baranov, where they encountered compact, thick ice.

In general, the Great Northern Expedition is a worthy member of the most effective expeditions in the history of earth's exploration. It described and mapped almost the entire coast of the Arctic Ocean and discovered Alaska. Based on the collected data, M.V. Lomonosov compiled in 1763 a map of the polar regions, which correctly described the coast of the Eurasian Arctic. Using the same data he also determined some regular features that form the natural conditions of the Arctic Ocean (Lomonosov, 1952). Maps, sailing directions, data of depth measurements, and information on ice conditions were widely used by the following generations of seafarers. These voyages also showed that ice conditions along the NSR during the period 1733–1743 were considerably more severe than in the 17th century and at present. All ships were frequently trapped in ice yet they continued to sail to their various destinations for many years. In spite of enormous efforts, they were unable to pass along the coast of the Taymyr Peninsula and exit to the Pacific Ocean. It was obvious that wooden ships could not make such voyages along the NSR.

Nevertheless, attempts to master the Northeast Passage continued. Based on the hypothesis of “open sea” in the northern polar area, M.V. Lomonosov proposed a plan to sail to the Pacific Ocean across the Pole. In 1765–1766 six ships under the command of Admiral V.Ya. Chichagov twice attempted to do so but both times they were stopped by the ice and returned to Arkhangelsk.

Attempts to sail along the NSR from the Pacific Ocean to the west began more than 200 years later than in the European part. In 1778, James Cook’s ships Resolution and Discovery passed through the Bering Strait and sailed westward, but near Cape Schmidt compact sea ice blocked their way. The next year this expedition was headed by Clark, after Cook’s death, and made one more attempt, but once again it was unable to pass farther than Cape Schmidt. This was interpreted in England as conclusive proof of the impossibility of using the NSR (Vize, 1939). After that, no further attempts were made until the middle of the 19th century.

In the 18th century, there were several expeditions to the islands and the coast of the Arctic Ocean. In 1741, Savva Loshkin made an outstanding voyage around Novaya Zemlya and proved that the prevailing concept in cartography of the 16th to 18th centuries of a giant Novaya Zemlya was incorrect. A couple of decades afterwards, the expedition of Fedor Rozmyslov made a survey of Matochkin Shar Strait. In 1760–1762 a Yakutian merchant Nikita Shalaurov sailed from the mouth of the Lena to Cape Shelagskiy and tried to round the northeast tip of Asia. Based on conducted measurements he issued a map depicting the shore between the mouth of the Lena and Cape Shelagskiy that was highly accurate for that time (Vize, 1939). In 1764, Shalaurov sailed eastward again, but 53 sailors onboard the Vera, Nadezhda, and Lubov' perished trying to overcome the ice of the Chukchi Sea. In 1787 the

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4 The Yakuts are one of the nations living in the northeastern part of Russia.
Northeastern Expedition, led by Joseph Billings and Gavriil Sarychev, began to explore the coast of the Chukotka Peninsula and land to the north of the mouth of the Kolyma. The explorers onboard the *Pallas* and *Yasashna* attempted three times to pass eastward, but each time ice stopped them in the vicinity of Cape Bolshoy Baranov. Some 4 years later the Northeastern Expedition made a further attempt to sail westwards from the Bering Strait onboard the *Slava Rossii*, which they built in Kamchatka, but again without success. However, a map of the north coast of Chukotka was made by questioning the indigenous people (Pasetsky, 1983).

At the beginning of the 19th century a number of important expeditions were carried out in the northeastern Arctic. Yakov Sannikov investigated Stolbovoy, Faddeyevskiy, and Novaya Sibir’ Islands. The expedition of the college registrar, M.M. Gedenstrom, made a transit from Novaya Sibir’ Island to the mouth of the Kolyma, reported for the first time the existence of the Siberian Polynya, and made a survey of the coast between the mouths of the Yana and Kolyma Rivers (Vize, 1939). While on Kotel’nyy Island, Gedenstrom saw in the northeast “a dark-blue color quite similar to the one sometimes visible above a distant land.” Thus, the legend about the hypothetical “Sannikov Land” was born, one which existed for more than 100 years. During 1820–1823, the expedition headed by a naval officer P.F. Anjou made the first reliable map of the New Siberian Islands. At the same time, a team under naval lieutenant F.P. Wrangel made an instrumental inventory of the coast from Cape Shelagskiy to Kolyuchinskaya Bay and tried to find the land said to be located, from rumors, to the north of Cape Shelagskiy (Tammiksaar, 1998). The existence of this land was confirmed when, in open water some 25 km from its southwestern tip, Wrangel marked it on the map. Later, this island was observed from the *Gerald*, and was completely mapped by T. Long’s American expedition onboard the *Rogers* in the second half of the century.

Several important expeditions were made to Novaya Zemlya: by F.P. Litke (1821–1824), P.K. Pakhtusov (1834–1835), and A.K. Tsivol’ka (1837–1839). Under severe conditions, surveys of much of the west and east shores of the southern and northern islands of Novaya Zemlya were made. These expeditions paid a lot of attention to oceanographic, ice, meteorological, and other studies, but were however rather separate regarding synchronous coverage of water areas and time of observations. In 1870 a Norwegian manufacturer E. Johannessen for the first time after Loshkin rounded Novaya Zemlya. On the basis of this voyage the Norwegian meteorologist Henrik Mohn made a map of the northern part of Novaya Zemlya, which differed significantly from previous maps (Vize, 1939).

Although the existence of land to the northeast of Novaya Zemlya had been long advocated, this area in the middle of the 19th century was indicated by a white spot on the map. In 1873 the unknown land was discovered by the Austro-Hungarian expedition under the command of Karl Weyprecht and Julius Payer onboard the *Tegetthoff*, when transported along by drifting ice. The next year, the explorers surveyed and mapped a significant portion of the archipelago which they named after the Austrian Emperor Franz-Josef. After that, the expedition of Leigh Smith onboard the steam yacht *Eira* discovered the islands Nordbruk, Bruce, George Land and Alexandra Land, and the expedition of Frederick Jackson sailed through the
British Channel and mapped a number of new islands to the west and east of this strait (Vize, 1939).

The first voyage to successfully pass through the NSR was conducted by a Swedish scientist A.E. Nordenskjöld, who was supported and financed by the Russian goldmine owner A.M. Sibiryakov, Swedish King Oscar II, and manufacturer O. Dikson. The voyage was made onboard the *Vega*, which on 30 July 1878 departed from the Kara Sea together with Sibiryakov’s ship *Lena*. During August both ships under favorable ice conditions passed Dikson, rounded Cape Chelyuskin and—following along the coast of Taymyr, which turned out to be located much more westward than in the data of the Great Northern Expedition—reached the mouth of the Lena (Vize, 1939). From here, the *Vega* continued her voyage alone. East of the Medvezh’i Islands, the ice conditions sharply deteriorated and the ship moved eastward along the flaw polynya. Particularly heavy ice was observed near Cape Schmidt and on 29 September the *Vega* had to overwinter to the east of Kolyuchinskaya Bay. In summer of the next year the ship took just 2 days to reach the east cape of Asia. Thus, the first passage from the Atlantic to the Pacific Ocean along the NSR was made without loss or ship damage. The route of the *Vega* is shown in Figure 1.4. In spite of the successful voyage, Nordenskjöld believed that shipping between Europe and the mouth of the Yenisey in the west and between the Pacific Ocean and the mouth of the Lena in the east had greater importance than through-voyages. “This route as far as the ice regime near the shores of Siberia is known will hardly ever have any actual importance for trade” (Nordenskjöld, 1936).

In 1879–1891 the De-Long expedition onboard *Jeannette*, organized by the owner of the *New York Herald* G. Bennett, attempted to reach the North Pole. After drifting from Gerald Island and discovering the archipelago, named later after De-Long, the ship was crushed by the ice and sank 800 km northeast of the mouth of the Lena. The expedition reached the mainland by sledge and in boats. Some expedition members were able to save themselves; however, De-Long and another group froze to death in the Lena Delta. The drift of the *Jeannette* demonstrated that the “open sea” hypothesis was ungrounded.

During this period some scientists believed that Greenland stretched far to the north to the central Arctic. This is shown in a map from the renowned German geographical publication *Petermans Geographische Mitteilungen* (see Figure 1.5).

On 24 June 1893 the Norwegian Fridtjof Nansen set out on one of the most daring and exciting research expeditions the world had ever seen. Its aim was to drift across the North Pole in a ship frozen in the ice. The expedition of Fridtjof Nansen onboard the *Fram* was scientifically justified and carefully prepared. The rounded shape of the ship hull was specially designed so that at compression by ice the ship was simply lifted upward by the ice, rather than crushed and sunk. Entering the Kara Sea on 4 August 1893, the *Fram* almost immediately encountered drifting ice and it took to the middle of August to pass the northern coast of Yamal. During the course of further navigation in open water, the expedition discovered Sverdrup and Scott-Hansen Islands. To the east of the Nordenskjöld Archipelago the ship sailed into heavy ice; however, it was able to pass Cape Chelyuskin and much of the Laptev Sea, sailing along the shore. In its easternmost reach, the *Fram* headed northward and on 20 September 1893
Figure 1.4. The route of the first through-sailing in the Northern Sea Route by Nördenskjöld onboard Vega. From Mountfield (1974).
Figure 1.5. The map of the Arctic Ocean published by the *Petermans Geographische Mitteilungen* (Germany) in 1869. From Drivenes and Jolle (2004).
reached the ice edge in the vicinity of 78° N, from where it began its historical drift in which it reached latitude 85°56′ N (Nansen, 1898). The most important results of this were the discovery of the deep Polar Basin and that the ice drifted to the right of the wind due to the effect of the Coriolis force. Nansen also found for the first time that water depths between 200 to 600 m had an above-zero temperature and constituted a continuation of the Gulf Stream into the Arctic Ocean.

The end of the 19th and beginning of the 20th centuries are characterized by the renewed interest of the Russian Government in Arctic studies. In 1894–1897 the Hydrographic Expedition headed by A.I. Vilkitskiy made a detailed survey of Ob’ Bay and the Yenisey Gulf and charted the first safe courses through their mouths (Vize, 1939). In 1898–1904 the region from the west of Ob’ Bay to the Norwegian border was also explored (Barr, 1991). At the turn of the century, the Emperor’s Academy of Science organized a polar expedition headed by Edward von Toll onboard the schooner Zarya, the purpose of which was to conduct studies in the Laptev Sea and in the New Siberia Islands and to search for the rumored land to the north of this archipelago. It was highly significant in mapping the coast and made a considerable contribution to meteorology, ice research, geology, geophysics, botany, and zoology. Unfortunately, Toll himself perished during the traverse on foot from Bennett Island to the New Siberian Islands.

The strategic importance of the NSR increased after the Russian–Japanese War of 1904, and surveys of the Arctic coast were continued. In 1909 the Lena–Kolyma and Chukotka Expeditions mapped the shoreline between the Lena and Alazeya Rivers and made a survey of the coast between the Kolyma River and Cape Dezhelev. Of large importance to the hydrography, oceanography, meteorology, and navigation of the Arctic was the Hydrographic Expedition to the Arctic Ocean in 1910–1915 onboard the icebreakers Taymyr and Vaygach, which arguably made the most important geographical discovery of the 20th century—the Severnaya Zemlya Archipelago. In September 1916 the Russian Government officially claimed these lands as part of the territory of Russia (Gramberg and Ushakov, 2000). Arriving in autumn of 1915 to Arkhangelsk, the ships completely traversed the NSR from east to west. Similar to Nordenskjöld, they were unable to complete navigation during one summer, which did not speak well of a possible use of this route for practical shipping. However, the expedition made the first hydrographic description and issued navigation maps for the entire length of the NSR. In 1912, Brusilov onboard the Syvayatya Anna and Rusanov onboard the Geraskes made an attempt to pass along the NSR from west to east, but both voyages ended tragically.

By the beginning of the 20th century the shores of the islands and the mainland had been surveyed and hydrographic work accomplished, all of which resulted in the publication of navigation maps of Russia’s Arctic seas. Observations of the ice cover of the seas made by the expeditions were episodic. However, it was proved that the Arctic seas were not 100% covered with sea ice and their ice regime was not the same from year to year. The first books summarizing the results of sea ice studies were published by Kolchak (1909) and Lesgaft (1913). The conditions for provision of accident-free shipping along the NSR were gradually prepared, but these achieve-
ments were not able at the time to solve all the problems facing the development of regular navigation in the ice of the Arctic seas.

1.3.2 Beginning of trade shipping

Beginning in the second half of the 19th century, trade shipping began to develop in the Kara Sea—especially, around the mouths of the Ob’ and Yenisey Rivers—exporting Siberian mineral resources and importing industrial goods. Ships of the Swedish polar explorer Nordenskjöld in 1875 and 1876 delivered goods from Tromsø to the mouth of the Yenisey. Without exception all the cruises of the English Captain Viggins (in 1874, 1876, 1878, 1884, 1887, 1888, 1889, 1890, 1893 and 1894) achieved similar results (Vize, 1939). In general, during the period 1876–1900, 60% of the cruises along the Kara Sea Route were successful, and ships transported 21,000 tons of cargo (Arikainen, 1984). During the period 1901–1910, no commercial voyages were made due to the absence of customs facilities and high insurance rates, except for 1905 when the Northern Sea Expedition escorted ships from Europe to the Yenisey. In 1911, voyages were resumed and were carried out until 1919 (see Table 1.1).

From 1911 in the eastern part of the NSR, 2,300 tons of cargo were transported from Vladivostok to the Kolyma River, and an attempt was also made to sail between the mouths of the Lena and Yana Rivers (Arikainen, 1984).

The development of shipping cargo along the Kara Sea Route necessitated the development of technical facilities to support this. In order to explore the Arctic Ocean and bring about cargo ship communication with the Ob’ and Yenisey, the Russian Admiral S.O. Makarov proposed using a polar icebreaker approved by the Marine Ministry of Russia. The Yermak constructed by A. Vitvort had a deadweight of about 9,000 tons and was equipped with an engine of 10,000 hp. However, after her not quite successful Arctic voyages in 1899 and 1901, confidence in the use of icebreakers to penetrate the central Arctic was undermined and the Yermak was relocated

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Table 1.1. Number of ships and volume of shipping along the Kara Sea Route in 1901–1919. From Arikainen (1984).
to the Baltic Sea. The Russian icebreaking fleet was only increased during the First World War. The flotilla formed in Arkhangelsk numbered 24 icebreakers by 1917.

The voyages and expeditions set out the principles for the future organization of Arctic shipping. V. Rusanov in 1911 wrote that this required special organization: much finance, technical capabilities, icebreakers and ice-strengthened ships, and provision along the route of a network of radio- and meteorological stations. The radio stations set up in Arkhangelsk (1911), Yugorskiy Shar (1913), Vaygach Island and Marre-Sale (1914), and on Dikson Island (1915) allowed ships to receive meteorological and ice information, thereby contributing significantly to the study of the ice conditions and exploration of the north. Rusanov also proposed ice reconnaissance using a ship with a balloon, which became possible after 1920.

In general, during the pre-revolution period in Russia, significant progress was achieved in the study and exploration of the NSR; however, the problem of how to use it rationally and economically was not resolved.

1.4 THE SOVIET–RUSSIAN SYSTEM FOR SUPPORTING NAVIGATION

After the October Revolution, the Arctic Ocean was investigated on a large scale in a planned and purposeful way. A systematic study of the Russian Arctic using icebreakers and aircraft and a network of hydrometeorological and research stations under one centralized organization was made. With this aim, special research institutions dealing with the study of the Arctic seas and land were set up in 1920–1921 (Belov, 1959). Foremost among these were the Northern Research Commercial Expedition—later reorganized into the Arctic and Antarctic Research Institute (AARI)—and the Floating Marine Institute—later to become the State Oceanographic Institute.

Soon after the Russian Revolution, Roald Amundsen passed for the third time along the entire NSR. For this expedition, a ship with an even rounder hull than the Fram’s was built; this was called the Maud after the Norwegian queen. The ship began the voyage in summer of 1918 and in heavy close ice could only reach Cape Chelyuskin, where it stopped for wintering. From here, two expedition participants Knutsen and Tessem headed for Dikson on skis with dogs, but perished during the traverse. (In 1958, at the initiative of Soviet polar explorers, a monument was constructed at the place of Tessem’s death—see Belov, 1959.) The following summer, the Maud was only able to move eastward again on 12 September, and in 10 days, passing the mouth of the Kolyma, wintered again near the west coast of Ayon Island. The expedition reached Alaska only in the third year of navigation, where Amundsen left the ship and flew to Norway for a subsequent flight to the Pole by airplane (Borodachev and Shilnikov, 2002). Since the main expedition’s objective consisted in reaching the North Pole, the Maud began its drift in 1921, but advanced very slowly through to the next summer. Finally, in the following year the Maud was frozen in ice and began to drift in a general westward direction. An outline of her navigation and drift in the Chukchi and East Siberian Seas is presented in Figure 1.6.
Figure 1.6. The route of *Maud* (1922–25), her route under sail and engine (dashed line) and ice drift (solid line). The drift of *Fram*, *Jennette* and *Karluk* are indicated (dotted lines). From Sverdrup (1928).
The *Maud* voyage was quite successful from a scientific point of view. H.U. Sverdrup obtained valuable results on the water dynamics (Sverdrup, 1936a) and ice drift of the North Siberian Shelf (Sverdrup, 1936b), and F. Malmgren on sea ice properties (Malmgren, 1933).

During the post-revolution period the Soviet Union faced the problem of supplying bread to starving people in the northwest of the country. To resolve this, a “bread” expedition was organized in 1920 onboard the vessel *Ob’* that safely returned after the delivery of 11,000 tons of bread. The following year serious efforts were undertaken to establish a strong basis for Kara Sea operations. Later, during navigation in 1924, the export of Siberian timber began, which was economically beneficial due to a decrease in cargo and insurance rates (Arikainen, 1984). As a result, during the period 1920–1933, the annual volume of shipments increased more than six-fold and towards the end of this period timber exports comprised 82% of the entire cargo flow. From 1929, icebreakers regularly provided support for navigation, which increased in duration from 23–32 to 60–75 days (Arikainen, 1984).

Between 1923 and 1931, ten cruises were made from Vladivostok to deliver cargo to the northeast coast of the Arctic, and four of them ended with forced overwintering. These cruises were made without icebreaking support or airborne ice reconnaissance. Voyages between the Lena and Kolyma were also resumed.

The Kara trade exchange expeditions of 1921–1931 made a significant contribution not only to the economy of the country but also to the formation of a scientific-technical support system for shipping in the ice. First, the Hydrographic Service initiated support for voyages. Second, the weather services necessary for shipping were established: in Murmansk (1921) and in Novyy Port (1923). Third, Russian scientist N.V. Roze developed the first forecast of the ice state in the Kara Sea. Later on, polar researchers B. Multanovsky and V. Vize laid the foundation of ice and meteorological forecasts in the Barents and Kara Seas using a series of systematic ice observations. Daily weather and ice bulletins began: initially only from data of meteorological stations, and from 1926 from data of ice reconnaissance. Since 1926, groups of hydrometeorologists were based onboard the lead icebreakers to observe ice conditions and relay information to captains. The Russian pilot Ya.I. Nagurskiy made the first ice reconnaissance airplane flights as early as 1914 (Borodachev and Shilnikov, 2002). In 1924, the *Ju-20* (a Junkers aircraft) was allocated to the Hydrographic Administration. B.G. Chukhnovskiy made flights that supported the icebreaker *Lenin* and provided hydrographers with sea ice information. From 1929, airborne ice reconnaissance became an integral part of marine transport operations and studies in the Arctic (Belov, 1970). These innovations were dictated by the needs of shipping in the ice and carried the first components of scientific-operational support system for shipping along the NSR.

In June 1928, instead of the NSR Committee (a decision-making authority), a powerful economic organization was set up to develop industry, transport and trade. This was the North Siberian state joint stock company of industry and trade Komseveroput that stepped up activity in the development of the northern *Ob’–Yenisey* area. Usage of the river fleet was improved and the number of cargo vessels was increased to include large-tonnage seagoing vessels. Mining, commercial fishery and hunting were
developed. Finally the port of Igarka and the Igarka Wood-processing Center were created. However, the means of ship navigation in the Kara Sea did not change significantly.

From 1929 a network of polar stations began to be created. Ten stations were constructed and remained in operation until 1933. General geographical studies were also developed. In 1930 an expedition onboard the icebreaker Georghi Sedov headed by O.Yu. Schmidt surveyed the northern Kara Sea. This expedition discovered Vize, Isachenko and Voronina Islands as well as the Sedov Archipelago. In August the expedition landed four winterers—G.A. Ushakov, N.N. Urvantsev, V.V. Khodov and S.P. Zhuravlev—on Domashniy Island with the aim of exploring the Severnaya Zemlya Archipelago. In October 1930, during the first exploration by sledge, the Oktyabr’skoy Revolyutsii and Pioneer Islands were discovered. In 1932–1934, different expeditions to the Kara Sea discovered several new islands: Izvestiy Ts.I.K., Arkticheskogo Instituta, Kirova and Ushakov. Later, based on the results of the expedition onboard the G. Sedov, the chart of the northern Kara Sea was published (Vize, 1939).

In the early 1930s the Kara trade exchange expeditions reached the limit of their development while the ships of Kola voyages struggled to cope with the delivery of goods for the Kolyma–Indigirka territory. The question of organizing voyages of merchant ships from the west to Tiksi and Kolyma and from the east to Tiksi was now on the agenda. In 1930, cargo ships used for the first time the route around Cape Zhelaniya. In 1932, specialists from the Arctic Research Institute (ARI) planned a through-voyage along the NSR that was successfully realized onboard the Sibiryakov in one navigation season. Professor O.Yu. Schmidt and Captain V.I. Voronin were its leaders. Similar to many voyages before, this cruise was made without ice reconnaissance. Although the voyage of the Sibiryakov dispelled to a certain degree the doubts about suitability of the NSR as a transportation thoroughfare, it became however even more evident that sea operations under the complicated Arctic conditions using low-speed, weak icebreakers and an unreliable cargo fleet could never be completely successful. This was subsequently demonstrated by the voyage of the propeller-driven Chelyuskin, which was unsuited for ice navigation and sank as a result of strong ice pressure in February in the Chukchi Sea.

On 17 December 1932, the Main Administration of the Northern Sea Route (MANSR) was organized and entrusted with the objective “to finally lay the sea route from the White Sea to Bering Strait, equip this route, maintain it in a good state and ensure safety of navigation along this route” (Belov, 1959). The MANSR was in addition given control over the icebreaking and transport fleets, polar aviation, polar stations, a hydro-base,\(^5\) industrial facilities and the ARI (Frolov, 2002).

In 1932–1933 the Special North-East Polar Expedition of Narkomvod onboard eight ships with the icebreaker Fedor Litke at the head delivered cargo from Vladivostok to Dal’stroy. Provision of ice reconnaissance support was given by aircraft, used for the first time in the east (R-5, pilot A.M. Berdnik; Savoya-62, pilot Ye.M. Koshelev). Although the ships could not be completely unloaded and

\(^5\) Russian hydro-meteorological station, providing meteorological and oceanographic data.
had to overwinter in Chausnaya Bay, this expedition signalled a new period in ice
voyages from Vladivostok to Kolyma, one that differed in the organization and
methods of routing compared with previous voyages.

Thus, by the time of creation of the MANSR, composite parts of the scientific–
technical system for providing services to ice shipping in the Arctic had already been
tested. Under common leadership and financing, a combination was made of: ice-
breakers and the cargo fleet, ports, hydrographic and scientific support, aviation and
communication. All composite parts of the system influenced the success of sea
operations. The MANSR began practical development of the polar route in 1933.
In summer of 1934, the icebreaker *Fedor Litke* made the first transit voyage from east
to west in one season. The same year, routing of cargo ships from the west to the
mouth of the Lena and between the Lena and the Kolyma was performed.

In 1935, under the MANSR, sea operations began to be conducted according to a
common plan of cargo operations, necessary as a result of intense industrial con-
struction in the Arctic. For most of the regions of the north coast of Siberia, cargo
ships were the only means of transport (Belov, 1969). As a consequence, Kara, Lena
and Kolyma cruises were included from that year in the general plan of Arctic
navigations. All icebreakers were distributed throughout the separate segments of
the NSR for escorting ships along the entire route. This allowed successful traverses of
the *Vainsotetti* and *Iskra* from Leningrad to Vladivostok and of *Stalingrad* and *Anadyr*
in the reverse direction. In the same year the marine fleet transported through the NSR
246,800 tons of cargo and the river fleet 124,100 tons.

During the subsequent two years, the volume of cargo shipping increased. However,
there was a catastrophe during the navigation season of 1937, when several
ships including three of the four escorting icebreakers had to overwinter at the end of
the season in different parts of the Arctic. In January 1938, as a result of intense ice
pressure, the propeller-driven *Rabochiy* sank. The icebreaker *Sedov* had a seriously
damaged rudder and could not exit from the ice and drifted across the central Arctic
for 812 days. One of the causes of these failures was weak aviation support. Another,
according to the government, was “poor organization of the work of the MANSR,
complacency and conceit” (*Soviet Arctic*, 1938). From 1939, the Arctic Institute was
heavily involved in shipping support in the Arctic.

For the first time since the *Maud*, a foreign ship was permitted to sail along the
NSR in 1940, when, before the USSR entered World War II, the German Navy’s
*Kometa* passed along this route (Belov, 1969). It was escorted through the ice in the
Laptev Sea by the icebreakers *Lenin* and *Stalin*, and to the east of Sannikov Strait by
the icebreakers *Malygin* and *Kaganovich*. Beyond Pevek, the ship continued navigation
without icebreaking support. For 23 days, 2,200 nautical miles were passed, 720
of them through the ice (Ruthe, 1943). After the *Kometa*, no foreign ship voyages were
made along the NSR for more than half a century—until 1991, when a French ship
*L’Astrolabe* sailed successfully through it.

The development of the NSR during the pre-war period was related to the
production needs of the Arctic region and all aspects of Arctic shipping—icebreakers,
iclass ships, ports, navigation-hydrographic, scientific and aviation support, and
also the communication facilities. In these years, the flow of cargo constantly
increased and the mean duration of the navigable period between 1935 and 1940 increased, compared with 1925–1930, from 45 to 107 days in the western Arctic and from 30 to 79 days in the eastern Arctic. Before the war, 4.3 million tons of cargo were transported through the NSR.

The Arctic did not escape the Great Patriotic War (WWII)\(^6\) of 1941–1945—particularly so in its western region, where German submarines and the battleship Admiral Scheer operated. The major part of cargo turnover, which decreased in 1942 to 144,000 tons and then again began to increase, was reoriented to the eastern segment of the route. During the war years, most of the goods and food supplies were transported along the NSR to plants in the north and to people in Yakutia, Chukotka, Kamchatka and Magadan (Belov, 1969).

How did the various components of the system for servicing the Northern Sea Route develop? Well, before the war, the icebreaking fleet still comprised old icebreakers of the type Yermak, Krasin and Lenin with engines that gave 10,000 horsepower, and the icebreaker Litke. In 1944–1945 the icebreakers Severnyy Veter and Severnyy Polyus, received by lend-lease from the USA, were operating in the NSR. From 1936, ice class timber ships of the Arktika type and cargo ships of the Volga type supplemented the transport fleet. In 1938, the icebreakers S. Dezhnev and Levanovsky were introduced into operation and ships of the type Anadyr’, Igarka and tankers Nenets and Yukagir were built. The Hydrographic Administration, which possessed many vessels and icebreakers, was involved in hydrographic work and the production of charts. Since 1936, measurements of sea depth were implemented from the ice during winter.

The scientific support of navigation along the NSR was based on observations from polar stations, ice reconnaissance, ice patrol and ARI expeditions. During ice reconnaissance flights the functions of onboard observers were gradually transferred from polar aviation navigators to specialists from the ARI, resulting in the creation of standardized symbolism for ice charts and expansion of the reconnaissance methods with winter reconnaissance beginning in 1939. Ice reconnaissance was subdivided into strategic reconnaissance, including flights every 10 days, and operational–tactical reconnaissance using aircraft to escort ships across complicated segments. Hydro-aviation began to be replaced by land aviation and special airfields were constructed for its use in the vicinity of large ports (Borodachev and Shilnikov, 2002). New instrumentation was developed and was incorporated in ice reconnaissance: from 1945 aerial photography, from 1952 radar stations Kobalt and PSBN-M, from 1964 side-looking radar stations, the first one was Igla and then Toros onboard AN-24 aircraft. The flights using Toros equipment began on 13 August 1968. From 1973, IR radiometers and a radar video-pulse meter to measure ice thickness were used for ice reconnaissance. In 1978 the Nit’ system entered operation, which was installed in an airplane where the ice information was sent down to the icebreaker (Borodachev and Shilnikov, 2002). From the early 1980s, the Nit’ system was used onboard IL-18D aircraft, later called IL-24N. In 1991 a multi-frequency side-looking radar station was tested. These remote-sensing methods are described in Chapter 3.

\(^6\) Soviet term for the latter years of World War 2.
Scientists from the ARI began to make long-range ice forecasts, based on the studies of the ice regime of the seas. From the 1940s, development of meteorological forecasts began on the basis of a synoptic circulation method.

In the post-war years (until 1960), the system operated faultlessly and successfully despite using obsolete icebreakers, which could not escort ships in heavy ice. In these years, research–operational groups—a necessary link for scientific shipping support in ice—began to actively influence managerial decision making of sea operations. It is not by chance that the increase of cargo shipments through the NSR from the 1940s to 1960 corresponded to the increase in the number of ice reconnaissance flights and short-term ice forecasts. From 1954 at Dikson, Tiksi and Pevek, scientific research observatories started their operations and were actively included in scientific–operational activity.

In 1955, the first ice tank was set up at the ARI. As a result of studies, the basic theory of modeling ship motion in ice was developed and the methodology for calculating ice loads exerted on ships’ hulls was developed and substantiated theoretically and experimentally. The methodology developed in these years was widely applied in practice. From 1961 a new direction in sea ice research was developed: study of the conditions of ship navigation in ice. This contributed to improvement in the ice navigation tactics of isolated ships and ships in convoy. The influence on navigation conditions of such indicators as composition of the convoy of ships, order of sailing in a convoy and motion speed dependence on conditions of visibility, ice concentration, thickness, stage of melting, hummock and ridge concentration and the degree of ice pressure were investigated. The performance of ships (without and under the escort of icebreakers) in ice was determined, as were the optimal dates for transport in the Arctic.

Studies of the nature of Polar regions expanded. In 1937 the first drifting research North Pole 1 (NP-1) station was set up, and from spring of 1954 one or, simultaneously, two NP stations drifted in the ice of the Arctic Basin (Frolov et al., 2005). Their personnel and payload were usually delivered by aircraft of the High-Latitude Airborne Expedition Sever. The Sever Expedition carried out exploration using aircraft. After landing aircraft on the ice at points marked in advance, hydrological stations were set up, ice and meteorological observations were carried out and a number of other objectives connected with the support of ship navigation along the NSR were addressed (Konstantinov and Grachev, 2000). These expeditions discovered the underwater ridges Lomonosov and Mendeleyev. Data from these expeditions were widely used in the development of the Atlas of the Arctic Ocean (Gorshkov, 1980) and the Atlas of the Arctic (Treshnikov, 1985), and also in operational work for ship navigation support. These data were important in the preparation of long-range meteorological and ice forecasts. Physical–statistical and numerical methods based on hydrodynamic and thermodynamic models of ice process change and ice cover evolution were developed. The scientific basis for a tracing and prognostic automated system was created for the purpose of monitoring the Arctic Ocean and acquisition of information on its actual state (Frolov, 1995). All studies of the Arctic Research Institute were primarily aimed at providing support for shipping in ice along the NSR.
Significant work on navigational development of the NSR was performed by the Hydrographic Enterprise. First, hydro-bases were set up at different points along the Arctic coast. Ice class ships of the type Meridian constantly supplemented the hydrographic fleet. For depth measurements, new radio navigation systems were introduced. Radio beacons and the radio-navigation systems RSVT-1S were also introduced.

In 1964 there were changes in the structure of NSR management. The MANSR was reorganized and became the Administration of the NSR (ANSR) under the Ministry of Marine Fleet with responsibility for surveillance. The next year AARI was transferred from the Ministry of Marine Fleet to the Hydrometeorological Service (Frolov, 2002).

From the early 1960s, the icebreaking and transport fleet developed. The diesel-electric icebreakers Moskva, Leningrad (1961), Kiev (1965), Murmansk (1968) and Vladivostok (1969), whose engines gave about 20,000 horsepower, became operational. Slightly later, the Yermak, Admiral Makarov and Krasin with more than 30,000 horsepower appeared. For work in shallow depths, the icebreakers Kapitan Sorokin, Kapitan Nikolayev, Kapitan Dranitsyn and Kapitan Khlebnikov were built. All these icebreakers had helicopters for ice reconnaissance. In 1960 the first nuclear icebreaker Lenin, with a capacity of 44,000 horsepower, began operation along the route. The transport fleet of UL and ULA⁷ classes was rapidly supplemented. At the start of the 1970s, a new generation of nuclear icebreakers became operational: Arktika, Sibir’, Rossiya, Sovetsky Soyuz and Yamal. The nuclear icebreakers Taymyr and Vaygach, with drafts of 9 m, were specially built for navigation support on the Yenisey.

The appearance of these icebreakers drastically changed the tactics of ice navigation and significantly extended navigation duration. From 1970, navigation to Dudinka was made almost on a year-round basis, and was only interrupted by flood periods and spring ice drift. From 1976, winter voyages of ships to the Yamal Peninsula began, whose cargo was unloaded on fast ice and subsequently transported onshore.

During the post-war period, the volume of cargo transportation along the NSR increased (Table 1.2). However, as a result of the economic reforms after the collapse of the Soviet Union, much production in the north was stopped and cargo turnover along the NSR began to decrease, and from 1996 it comprised approximately 1.5–2.0 million tons. In 2000 the export of oil from Ob’ Bay, Varandey and Kolguyev to Europe began. Gas is exported from northwest Siberia to Rotterdam in accordance with an agreement between the European Union and Russia, coordinated by the Finnish company Fortum Oil and Gas. From 1 July 1991 the NSR was officially declared open for foreign ships.

Voyages along the NSR are carried out along coastal, marine, high-latitude and near-pole routes (Figure 1.7). Coastal routes are the most traditional. The main areas for sea transportation are: the Barents Sea (Murmansk port), Dikson (Dikson port), Cape Chelyuskin (Chelyuskin port), Tiksi (Tiksi port), Kolyma River (Kolyma

⁷ Classes of merchant vessels operating in the Arctic according to the category of the strength of the hull.
Table 1.2. Marine cargo transportation along the NSR. From V.Ya. Plaksiy (pers. commun).

<table>
<thead>
<tr>
<th>Year</th>
<th>Cargo flow (1,000 tons)</th>
<th>Year</th>
<th>Cargo flow (1,000 tons)</th>
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<th>Cargo flow (1,000 tons)</th>
<th>Year</th>
<th>Cargo flow (1,000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>441.1</td>
<td>1980</td>
<td>4,983.7</td>
<td>1987</td>
<td>6,578.8</td>
<td>1994</td>
<td>2,300.1</td>
</tr>
<tr>
<td>1950</td>
<td>500.0</td>
<td>1981</td>
<td>5,004.8</td>
<td>1988</td>
<td>6,295.2</td>
<td>1995</td>
<td>2,361.3</td>
</tr>
<tr>
<td>1955</td>
<td>632.0</td>
<td>1982</td>
<td>5,109.5</td>
<td>1989</td>
<td>5,823.0</td>
<td>1996</td>
<td>1,642.0</td>
</tr>
<tr>
<td>1960</td>
<td>962.5</td>
<td>1983</td>
<td>5,443.9</td>
<td>1990</td>
<td>5,510.5</td>
<td>1997</td>
<td>1,945.0</td>
</tr>
<tr>
<td>1965</td>
<td>1,455.1</td>
<td>1984</td>
<td>5,834.7</td>
<td>1991</td>
<td>4,804.0</td>
<td>1998</td>
<td>1,458.4</td>
</tr>
<tr>
<td>1970</td>
<td>2,947.7</td>
<td>1985</td>
<td>6,181.3</td>
<td>1992</td>
<td>3,909.2</td>
<td>1999</td>
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</tr>
<tr>
<td>1975</td>
<td>4,065.0</td>
<td>1986</td>
<td>6,454.7</td>
<td>1993</td>
<td>3,015.7</td>
<td>2000</td>
<td>1,587.0</td>
</tr>
</tbody>
</table>

port), Pevek (Pevek port), Cape Schmidt (Cape Schmidt port) and Bering Strait. Routes through the the main Siberian rivers and estuaries have been charted: to Cape Kamennyy in Ob’ Bay, to the port of Igarka on the Yenisey and to the port of Cape Zelenyy on the Kolyma. Marine routes include the route from Cape Zhelaniya (northern tip of Novaya Zemlya) to Dikson and from the New Siberian Islands to the port of Pevek. The high-latitudinal route, shorter for crossings, passes to the north of Cape Zhelaniya, Cape Arkticheskii (northern tip of Severnaya Zemlya) and the New Siberian Islands. The fourth route, which is 700 miles shorter than the coastal

Figure 1.7. Map of the Northern Sea Route with the main transit routes (see also color section). From Mulherin (1996).
route, passes the large circle across the geographical North Pole (Mulherin, 1996). For planning the routes of ships in ice, the most important factor appears to be optimal use of zones with the easiest ice conditions, regardless of whether they are encountered on coastal or high-latitudinal routes.