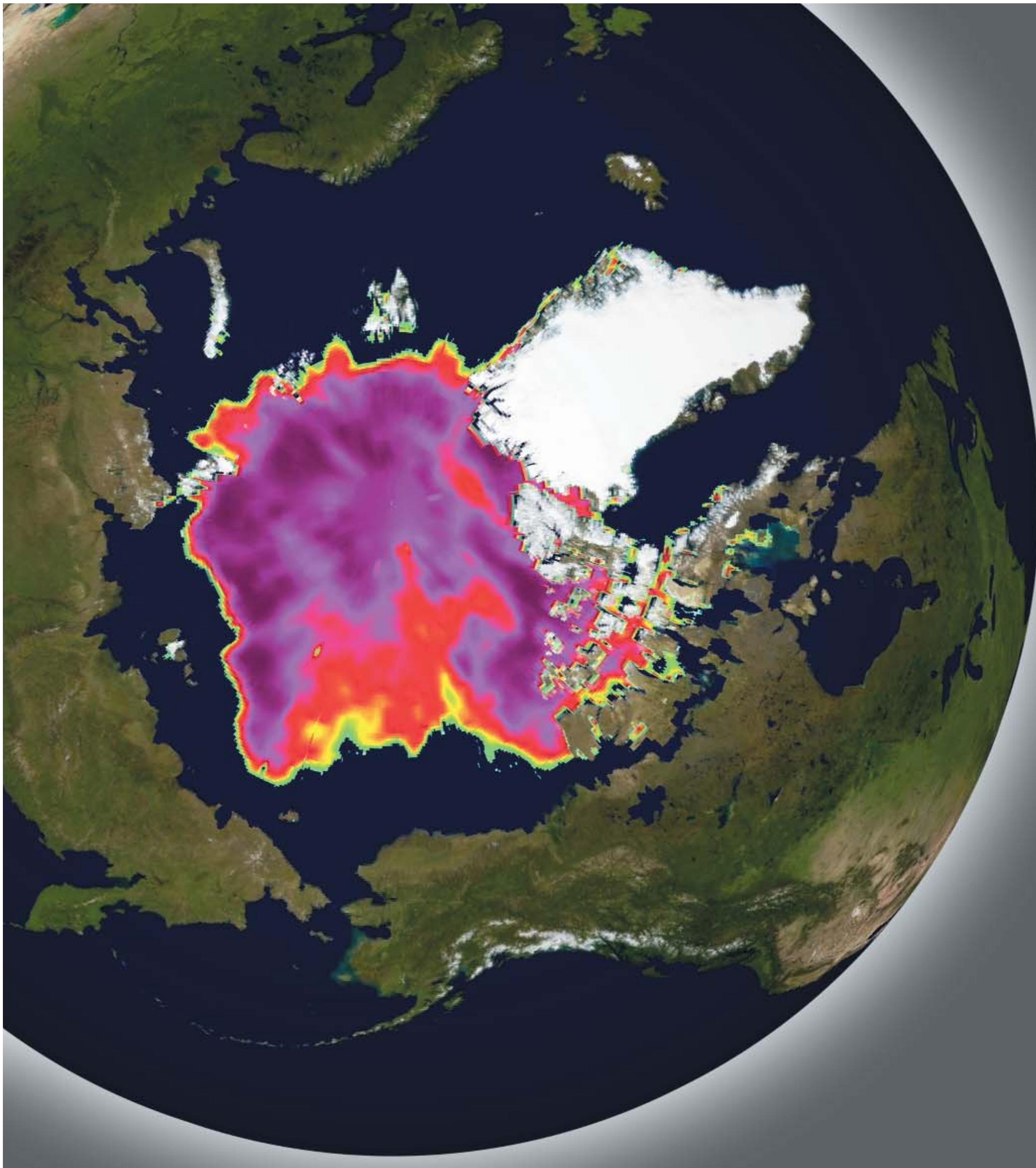
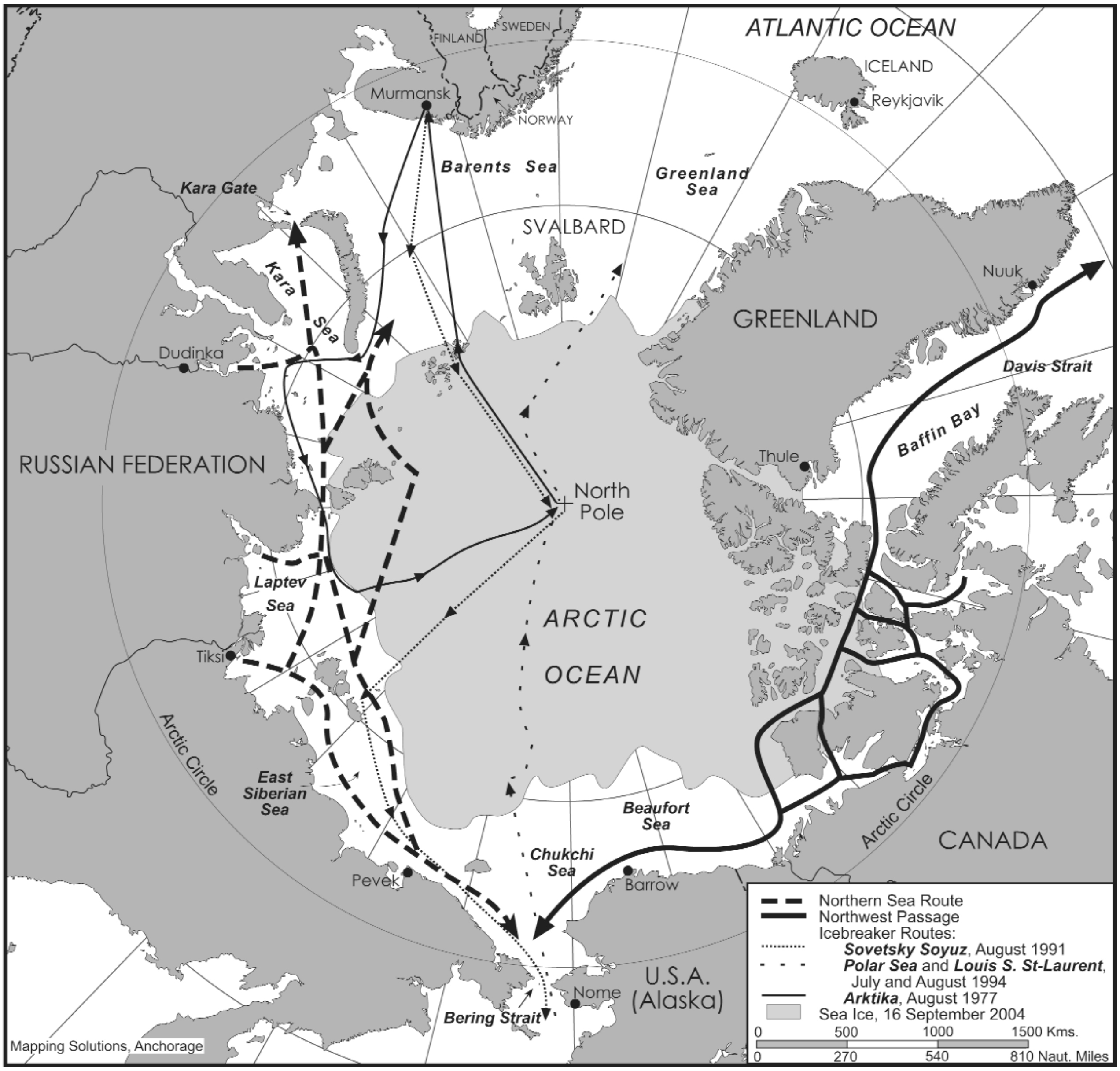


Arctic Marine Transport Workshop

28-30 September 2004

Institute of the North • U.S. Arctic Research Commission • International Arctic Science Committee

Arctic Ocean Marine Routes



This map is a general portrayal of the major Arctic marine routes shown from the perspective of Bering Strait looking northward. The official Northern Sea Route encompasses all routes across the Russian Arctic coastal seas from Kara Gate (at the southern tip of Novaya Zemlya) to Bering Strait. The Northwest Passage is the name given to the marine routes between the Atlantic and Pacific oceans along the northern coast of North America that span the straits and sounds of the Canadian Arctic Archipelago. Three historic polar voyages in the Central Arctic Ocean are indicated: the first surface shop voyage to the North Pole by the Soviet nuclear icebreaker *Arktika* in August 1977; the tourist voyage of the Soviet nuclear icebreaker *Sovetsky Soyuz* across the Arctic Ocean in August 1991; and, the historic scientific (Arctic) transect by the polar icebreakers *Polar Sea* (U.S.) and *Louis S. St-Laurent* (Canada) during July and August 1994. Shown is the ice edge for 16 September 2004 (near the minimum extent of Arctic sea ice for 2004) as determined by satellite passive microwave sensors. Noted are ice-free coastal seas along the entire Russian Arctic and a large, ice-free area that extends 300 nautical miles north of the Alaskan coast. The ice edge is also shown to have retreated to a position north of Svalbard.

The front cover shows the summer minimum extent of Arctic sea ice on 16 September 2002. This date represents the minimum coverage of Arctic sea ice in the historical or human observed record. The false colors represent sea ice concentrations as determined by satellite passive microwave sensors. Noted on this date are an ice-free area across the Russian Arctic coastal seas, an historic retreat of the ice edge in the Beaufort Sea, and an ice edge position north of Svalbard.

Arctic Marine Transport Workshop

Editors

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Ben Ellis, Institute of the North

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Overview of the Arctic Marine Transport Workshop

"The Arctic is now experiencing and is likely to experience some of the most rapid and severe climate change on Earth. Over the next 100 years, climate change is expected to contribute to major physical, ecological, social and economic changes, many of which have already begun."

- Arctic Climate Impact Assessment, November 2004

Amid growing interest and concern over the rapid climate changes occurring in the Arctic, experts in Arctic marine transport, international marine safety, as well as researchers of sea ice and climate change met at the Scott Polar Research Institute at Cambridge University to create a research agenda and identify critical issues related to the future of Arctic shipping.

Co-sponsored by the Arctic Council's Circumpolar Infrastructure Task Force, the U.S. Arctic Research Commission and the International Arctic Science Committee, the three-day workshop was comprised of six half-day sessions, each followed by a panel and participant discussion. The research agenda and critical issues in this workshop report were developed during the discussions and were made available to the participants for their review.

The international gathering included 54 experts from 11 countries (United States, Canada, Russia, Sweden, Iceland, Denmark, Norway, the United Kingdom, Finland, Germany and Japan) representing marine research institutions, transportation ministries, national ice centers, naval architects and shipbuilders, ship classification experts, international marine transport economists and social scientists.

The workshop, dedicated to the life-long work in the Arctic by Scott Polar Research Institute's Terence Armstrong, was the first critical step in addressing the multi-faceted issues of future Arctic marine transport, according to co-chairs Lawson Brigham, deputy director of the U.S. Arctic Research Commission and Ben Ellis, managing director of the Institute of the North. "We are hopeful this workshop is only a beginning of a series of meetings and conferences on this strategic Arctic marine issue," they told workshop participants.

In recent years, the extraordinary retreat of Arctic sea ice has focused renewed attention of the Arctic Ocean as a potential waterway for marine operations – both coastal or regional traffic, and the possibility of trans-Arctic navigation.

Institute of the North staff

Captain Vladimir Mikhailichenko, executive director for the Moscow-based Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, shares information on Northern Sea Rout traffic.

Also leading organizers to convene the world's experts on Arctic marine transport are several initiatives underway by the eight-member nations of the Arctic Council. The Council's Arctic Climate Impact Assessment, drawing on the expertise of nearly 300 scientists, will place an international spotlight on the increasing possibilities for marine access throughout the Arctic Ocean. Other Council initiatives underway with Arctic marine components include an Arctic Marine Strategic Plan - which calls for an Arctic Shipping Assessment and an Arctic Oil and Gas Assessment - which will include elements of Arctic marine transport and port operations.

Northern Sea Route

While the workshop considered the entire Arctic Ocean, a significant portion of the conclave focused on Russia's Northern Sea Route.

"In general, Arctic shipping began to develop in Russia at the beginning of the 19th century," Nikolay Babich, head of marine operations at Murmansk Shipping Company, told the gathering. "Beginning in 1920, there was commercial transit in the northern route, at only 500 horsepower."

First under Soviet rule and now the Russian Federation, strong emphasis continues to be placed on exploring and developing shipping through the Arctic Ocean. Therefore, it is not surprising that Russia had one of the largest delegations (along with the U.S. and Canada) at the workshop.

"Because of the Northern Sea Route, the Arctic is the leading economic region of Russia," noted Professor Alexander Granberg, head of the Council for Location of Productive Forces and Economic Cooperation and economic confidant to Russia's President Vladimir Putin. "The Arctic will develop more quickly than all of the rest of Russia."

Another indication of Russia's interest in expanding the activities in the Arctic Ocean is the creation of a new federal law dealing with the Northern Sea Route, according to Vladimir Mikhailichenko, former head of the Northern Sea Route Administration and currently the executive director of the Noncommercial Partnership of the Coordination of the Northern Sea Route Usages. The Partnership was created to improve the management structure along with increasing the effectiveness of the Northern Sea Route. "One concern (we) have is limiting marine risk," he noted.

Scientific information was presented on sea ice trends in the Russian Arctic by Sergey Pryamikov, head of the International Science Cooperation Department at the Arctic and Antarctic Research Institute, including ice data on the Greenland Sea, Barents Sea, Kara Sea, Laptev Sea, East-Siberian Sea, Chukchi Sea and Arctic overall.

Victor Medvedev, general director of the State Unitary Hydrographic Department, explained how the Russian government provides navigational and hydrographic support to shipping through the Northern Sea Route and is trying to cope with the loss of 300 navigational aids and more than 300 lighthouses. There is a need for key navigational charts for transit, he noted, as well as better communications between ship and shore concerning safe sailing conditions.

Using the Northern Sea Route as an export route to move oil and gas out of the Russian Arctic is a possibility but several issues must be addressed to attract potential investors, noted Kimmo Juurmaa, manager, Arctic Technology at Aker Finnyards, Finland's leading Arctic ship building company.

"To minimize these concerns," he said, "clarification is needed in technology, legal and administrative issues, and in environmental protection."

Hopefully, he noted, the European Community's Arctic Operational Platform project (ARCOP) will be able to address these issues. The three-year project focus is on oil and gas marine transit between Varandy, Russia and Rotterdam, the Netherlands.

Lawson Brigham

Russian nuclear ice breaker *Yamal* of Murmansk Shipping Company near the North Pole on 23 August 1994.

"The aims," said Juurmaa, ARCOP project coodinator, "is to understand the marine transportation problems of the Russian Arctic, as they apply to oil and gas and then create a permanent discussion forum between the European Union and Russia, as well as between industry and politicians so we can provide some common recommendations."

Arctic Marine Strategic Plan

Soffia Gudmondsottir, executive secretary of the Arctic Council's Protection of the Arctic Marine Environment working group, provided an overview of the council's Arctic Marine Strategic Plan.

"One of the aims of this plan," she said, "is to build on the internationally recognized need to manage human activities within the context of entire ecosystems, applying them to achieve the sustainable development of the Arctic marine enviroment."

Further discussion on the Northern Sea Route should also be based in the groundwork developed in the six-year International Northern Sea Route Program, experts noted.

"The purpose of the INSROP was to build up a scientifically based foundation of specialized and integrated knowledge encompassing all relevant aspects related to navigating the NSR, as to enable public authorities and private interests to make rational decisions based on scientific insights," explained Willy Østreng, scientific director and chairman of the Centre for Advanced Study/Ocean Future at the Norway Research Foundation. Østreng headed the secretariat and the joint research committee of INSROP from 1993-1999.

"Integrative concepts were developed, such as aggregated hot spots, issues-specific hot spots, cool spots, social-biodiversity, multi-value navigation, etc," Østreng noted in his abstract. "These concepts seem suitable to meet the ambition of the Arctic Marine Strategic Plan to base itself on an ecosystem-based management approach."

In developing the Northern Sea Route, there is a need to use more traditional knowledge of Native people of the Arctic, as well as the knowledge of non-Natives who are long-time residents of the Arctic region, emphasized Vladimir Etylin of the Russian Association of Indigenous People of the North.

Despite much of the discussion on the Northern Sea Route, workshop co-chair Brigham urged the body of experts to think about marine transport throughout the entire Arctic Ocean.

"During 1977 to 2004," he noted, "52 successful voyages have been made to the North Pole by the icebreakers of Russia (42), Sweden (4), Germany (2), United States (2), Canada (1), and Norway (1); remarkably eight surface ships reached the North Pole during the summer of 2004. Thirteen of the voyages were in support of scientific research and the remaining 39 were devoted to tourist voyages to the North Pole and across the Arctic Ocean."

Brigham pointed out that marine access in summer throughout the Arctic Ocean has been achieved by highly capable icebreakers, "however, little is known about the challenges of voyaging in other seasons except for the Sibir's expedition in May and June 1987."

Dick Voelker, chief of the division of advanced technology at the U.S. Department of Transportation's Maritime Administration, provided workshop participants an overview of the agency's Arctic Marine Transportation Program, which spanned 1979 to 1986. Fifteen voyages operating in ice-covered waters at both poles collected data to define ice conditions along the routes, measure ice loads on the ship and document ship performance during the transits.

The program found "year-round operation in the Bering Sea is not a problem, whereas in the Chukchi Sea ships must be designed for multi-year ice," Voelker told the gathering. "In the Beaufort Sea, there could be limited operations due to heavy multi-year ice, but if polar class ships were to operate, it would need a refuelling station."

Brigham noted, however, "the observed and projected retreat of multi-year ice from the Arctic coastal regions may very well change this situation."

Canadian Arctic

While not as rapidly as in the Russian Arctic, Canadian experts are witnessing a change as well.

"The amount of sea ice in the Canadian Arctic has been declining in recent decades in concert with the reductions observed in the Northern Hemisphere in general," said John Falkingham, chief of forecast operations at the Canadian Ice Service.

"There is mounting evidence that this reduction will continue, although there is great uncertainty over the rate at which ice will continue to diminish," he told the workshop. "Considering the predictions of global climate models, as well as, the observed rate of ice reduction, our estimate is that the Canadian Arctic will experience nearly ice free summer seasons starting as early as 2050, but probably not before 2100."

Falkingham noted that multi-year ice, particularly in low concentrations, will present the major hazard to shipping.

"Since the oldest and thickest ice in the Arctic Ocean is that which is driven against the western flank of the Canadian Archipelago," he said, "this will likely be the last multi-year ice to remain."

Marine operations in the Canadian Arctic will be regional in focus, said Bob Gorman, manager of environmental services, Enfotec, a Canadian-based marine service company.

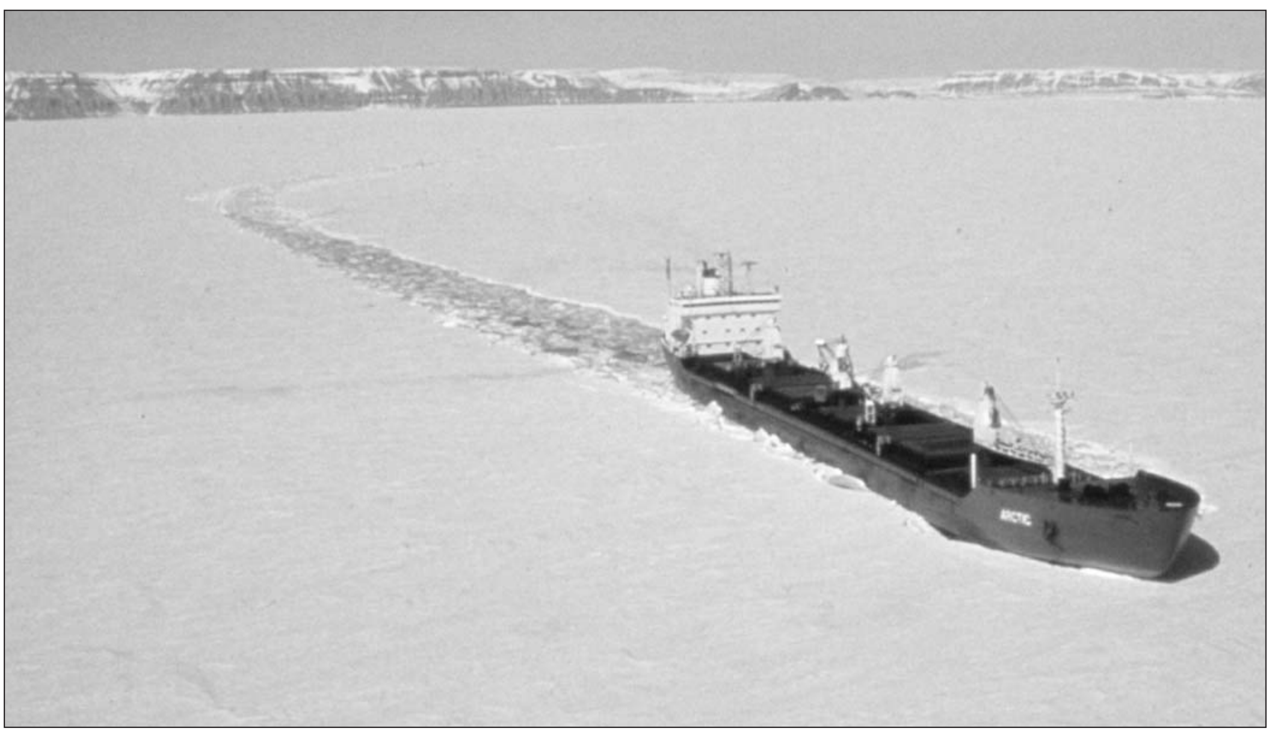
"It should be noted," Gorman told the gathering, "that the marine industry is focused on the Arctic as a destination and not a short-cut between the Atlantic and the Pacific either now or within the next 10 to 20 years."

Gorman said oil and gas activity is restricted to the on-shore Mackenzie Delta at the moment with plans by the Aboriginal Pipeline Group to build a gas pipeline to the delta during the next 10 years. "Once the pipeline is in place offshore oil and gas activity in the Canadian Beaufort Sea will likely pick-up once again," he projected.

"The marine industry, like most industries, is very myopic when it comes to long-term planning," Gorman noted. "We are able to take a vessel from concept design to sailing in three years. The concept that Arctic ice conditions may be more favorable for marine operations in 20 or 30 years has no commercial significance today."

Canada's Victor Santos-Pedro, director for marine safety for Transport Canada, emphasized the need for comprehensive safety and environmental protection measures based on the precautionary approach and best practices, harmonized international guidelines that apply to ships operating in Arctic ice-covered waters and an integrated approach that supplements basic requirements for the ship design, construction, crew qualifications, equipment and operations of the seven new Polar Classes of the International Maritime Organization's (IMO) 'Arctic Shipping Guidelines.'

"The harmonization of standards is the fundamental pillar," he said. "An integrated approach based on best practices and precaution can produce comprehensive



Canadian Coast Guard

Canadian ice breaking carrier M/V *Arctic* (owned by Fednav Limited) in the Northwest Passage.

"In 2002, September (sea) ice extent was 15 percent below average conditions. This represents an area roughly twice the size of Texas. From comparisons with records prior to the satellite era, this was probably the least amount of sea ice that had covered the Arctic over the past 50 years."

- National Snow and Ice Data Center, October 4, 2004

safety and environmental protection measures that also address economy of effort and cost, and efficiency."

Richard Hayward, a structural engineer with Germanischer Lloyd based in Hamburg, German, provided the workshop with an overview of the new International Association of Classification Societies' Unified requirements for Polar Ships, as well as what he envisaged concerning future developments.

"The most important issues," he said, "are the definitions of loads based on additional ship-ice interaction scenarios especially that of a ship caught under pressure; enhanced integration of limit state design concepts and more explicit definitions of risk levels. The question of whether ship propulsion power is a matter of safety and/or performance needs also to be addressed," he noted in his abstract.

Keld Hansen, head of the ice charting group at the Greenland Ice Service/Danish Meteorological Institute told the gathering that currently there is less ice than normal around Greenland with a retreat of multi-year ice in the northeast section, while the western waters are experiencing shorter winter ice season and the south is seeing larger year-to-year variations with slightly lighter than normal ice.

"It is very hard to predict," he said, "because of the amount of variations."

On an anecdotal note, Hansen pointed out that in February 2004 a Danish ice strengthened cargo vessel was able to sail to the harbors in Disko Bay, which is normally impossible without icebreaker assistance.

Icelandic Interest

While Iceland is not in ice-covered waters, Thor Jakobsson, project manager meteorology and sea ice at the Icelandic Meteorological Office pointed out to the group his country's interest is in creating a staging port to link cargo being shipped on non ice-strengthened ships to ice-strengthened ships.

"Decreasing ice cover in the Arctic Ocean during the last decades should support the idea of Iceland becoming an important entrepôt for the Northern Sea Route," he noted.

Ragnar Baldursson, counselor in Iceland's Department of Natural Resources and Environment Affairs, pointed out that the Suez and Panama canals "have insufficient capacity for future needs. Trade volume between the North Atlantic and East Asia - east of Hong Kong - amounts to around six million TEU (20-foot equivalent container unit) annually.

"World trade has increased at the rate of 6% annually since 1950, doubling every 12 years," he told the gathering. "If this trend continues the trade volume between the North Atlantic and the Pacific could amount to almost 50 million TEU by 2050."

Looking at a different aspect of Arctic marine shipping, Rob Huebert, associate professor, University of Calgary, warned the group of social aspects of an ice-reduced Arctic.

"The first and perhaps most complicated issues revolves around the issues of sovereignty," he said. "Canada and Russia have both claimed the Arctic waterways passing through their Arctic region as internal waters. While both states are committed to promoting international shipping through these waters, they do not accept the Northwest Passage or the Northern Sea Route as international straits. The United States and the European Union on the other hand have taken the position that these are international waters."

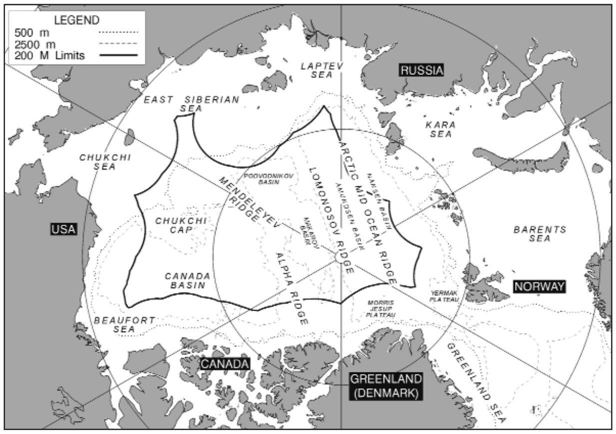
Numerous problems must be addressed, he said.

"The first is over control. If these waters are internal, then the coastal state retains control over shipping in these waters. On the other hand, if they are not, then the rules and standards governing international shipping are to be determined by the competent international organizations.

"The second main problem is the political sensitivity that surrounds theses disputes. A challenge to the position of any of these states carries ramifications that go beyond the Arctic. This greatly increases the challenges in resolving the differences that will arise as shipping increases," he noted.

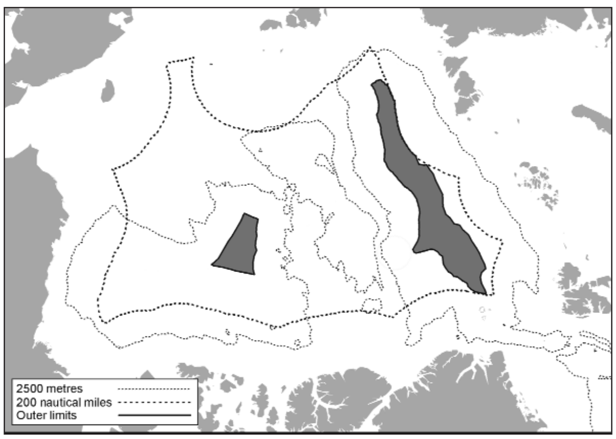
Security issues are another set of concerns facing an expanded international Arctic shipping regime.

"Any increase in shipping in the region will require an increase in the monitoring and enforcement of domestic and international laws governing smuggling, environmental standards and ship safety," Huebert said. "Given the isolated nature of the Arctic waters such requirements are challenging. Further complicating these issues is the new need to protect against international terrorism. An increase in shipping will mean that terrorists could use this traffic as a means of entry to either North America or Russia."



Ron Macnab

Map showing the coastal Arctic states, their joint Exclusive Economic Zones (EEZs), and the natural prolongations of their land territories.



Ron Macnab

A hypothetical map of the Arctic Ocean showing the combined continental shelves of the five Arctic coastal states after resolution of the extensions of their EEZs under Article 76 of the UN Convention of the Law of the Sea. Only two small 'donut holes' remain that would be considered international waters. This plausible future has key implications for Arctic shipping. (EEZs), and the natural prolongations of their land territories.

"From Alaska to the snowy peaks of the Andes, the world is heating up right now, and fast. Globally, the temperature is up 1 degree F (.5 degree C) over the past century, but some of the coldest, most remote spots have warmed much more. The results aren't pretty. Ice is melting, rivers are running dry and coasts are eroding, threatening communities."

- National Geographic Magazine, September 2004

Other significant issues

Another issue to consider is how Arctic marine shipping may fit into a future of changing geographical boundaries, as well as a changing climate, with resulting sea ice retreat.

"The juridical map of the Arctic Ocean will likely change substantially over the next decade or so," pointed out Ron Macnab, retired Canadian marine geophysicist, "as the five surrounding coastal states (Canada, Denmark, Norway, Russia, and the United States) seek to extend significant sovereign rights beyond their usual 200 nautical mile limits.

"Under the provisions of Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS), these extensions of sovereignty will be exercised in several ways: jurisdiction over the living and non-living resources of the seabed and subsoil; control over the emplacement and use of submarine cables and pipelines, artificial islands, installations, and structures; regulation of drilling; control and prevention of marine pollution; and regulation of marine scientific research," he told the gathering.

The gathering also considered existing and potential international cooperation, which can support development and expansion of the Arctic marine transport in local and global commerce.

"How feasible is the Northern Sea Route?" was the question posed by Mead Treadwell, Senior Fellow at the Institute of the North and commissioner on the U.S. Arctic Research Commission. Treadwell explored two scenarios for traffic growth: incremental investment approach and the large scale, major investment approach.

Under the former, traffic would grow slowly from its current base relying primarily on imports and exports from the region with little major impact on world commerce, Treadwell suggested. Under the major investment approach, those promoting the use of the Northern Sea Route would pursue a major share of the world shipping market.

"To compete against the Suez and Panama Canal routes, as well as the Trans-Siberian and North American rail land bridges," Treadwell contended "distance saving via the NSR must deliver reliable savings in time."

He suggested one estimate of three million tons per year could reduce unit costs to the point the route would be competitive against other shipping routes.

"Such a scenario would entail large-scale investments in escort vessels, aids to navigation, ports with an eye to minimize costs of exchanging cargo with regular vessels and larger cargo goals," Treadwell told the conference. The group acknowledged that significant economic research is required to underpin the future use of Arctic routes.

Japan's Norio Yamamoto, executive vice president of the Global Infrastructure Fund Research Foundation, noted his organization believes the development in Russia of oil and gas fields may make the Northern Sea Route feasible. But he added, "we will have to study more the international framework, new business models, technological challenges, incentives to ship owners and the potential of the market for further Arctic marine transportation development."

Held at the historic Scott Polar Research Institute at Cambridge University, the three-day workshop produced a plethora of information. While each area of discussion produced suggested topics for scientific research and questions on policy issues incorporated in this report, six crosscutting conclusions seemed to emerge as the editors synthesized this report.

Summary Conclusions

RESEARCH AGENDA

The workshop participants produced a list of significant issues and an inter-disciplinary research agenda for Arctic marine transport. The agenda specifically calls for a wide range of important economic analyses including trade cost-benefit analyses for regional (destination) as well as trans-Arctic shipping. Risk assessments and environmental impact assessments are critical components of any future research agenda. Also considered as key research topics are studies related to UN Law of the Sea Treaty impacts on Arctic navigation, the impacts on indigenous Arctic communities, core issues of conflict (boundaries, governance, international security, etc.), and Arctic climate change impacts on future marine access. Comprehensive studies related to marine safety and Arctic marine environmental protections are essential and the workshop results confirm these topics as core research requirements.

SEA ICE

Presentations at the workshop confirmed that the Arctic sea ice cover is undergoing an unprecedented transformation - sea ice thinning, a reduction in extent, and a reduction in the area of multi-year ice in the Central Arctic Ocean. These changes are documented in the Arctic Climate Impact Assessment, which also provides sea ice projections for the 21st century. These simulations show increasing ice-free areas in the Arctic coastal seas and suggest plausible increases in marine access throughout the Arctic Ocean. However, the participants also noted the observed records indicate the extreme, inter-annual variability of sea ice in select Arctic regions such as the Canadian Archipelago. The magnitude of variability creates difficult challenges for Arctic marine transport planning and adequate risk assessment. Representatives of six national ice centers were present (Canada, Denmark, Finland, Iceland, Russia and USA) and received key feedback regarding the future needs of national authorities as well as industry for enhanced sea ice information.

COMMUNICATIONS/INFORMATION

Workshop participants underscored the need for better communications and information in all sectors of Arctic marine transport. There is a great need to update Arctic marine charts and aids to navigation, as well as enhancing airborne ice information with satellite coverage. Research is needed to look at the unique needs of satellite communications in the Arctic followed by an action plan. A comprehensive study is needed of potential communications technologies for ships sailing in the Arctic. Once information is gathered, rapid transmission of data and environmental information needs to be communicated to Arctic ships.

RELIABILITY/SECURITY

Workshop participants underlined two key factors needed to expand and develop the use of the Arctic Ocean as a shipping corridor: route reliability and security. Whether it is the transportation of oil and gas cargo to regions south of 60 degrees or tourists bound for the North Pole, shipping schedules must be reliable. While year-round schedules are preferred, shippers will only use seasonal sailings if they can be assured their product will arrive on time. An increase in Arctic shipping will also require an increase in the monitoring and enforcement of national and international laws governing ship security. If the projection of continued thinning sea ice is realized in the central Arctic Ocean, an increase in the number and variety of vessels deployed in the region will increase, compounding the issue of security.

ECONOMICS

Workshop participants were divided over the economic drivers that could fuel expanded use of Arctic marine transport. If expansion is on an incremental level, regional traffic is expected to grow slowly with little to no impact on global commerce. Regional oil and gas development fits this scenario. A decision by world shippers that the Arctic Ocean provides an alternate to the Suez and Panama canals, would require large scale global investments of escort vessels, aids to navigation and staging ports to transfer cargo between ice-strengthened and non ice strengthened ships. It was noted that the Canadian commercial marine transport industry is not focused on the Arctic as an alternative to the Panama Canal either now or within the next 10 to 20 years.

TIMING OF ARCTIC MARINE TRANSPORT DEVELOPMENT

Discussion during the Cambridge Workshop and a post-workshop survey indicate that a majority of the experts believe the initial Arctic region to have an expanded Arctic marine system will be western Siberia (it is recognized there has been year-round transport to Dudinka on the Northern Sea Route since the late 1970s). The westward marine transport of oil and gas from the Kara and the Barents Seas is viewed as a plausible future, with a potential to be fully functional by 2015. The current retreat of Arctic sea ice presents a succession of plausible futures for the Northern Sea Route, Northwest Passage, and Central Arctic Ocean. It is probable that during the next several decades the coastal seas for the Russian Arctic will experience longer ice-free seasons; greater access and longer navigation seasons may also be experienced in Hudson Bay (to Churchill) and to the Red Dog Mine off Alaska's northwest coast. A wildcard will be the diminishing amount of multi-year ice in the Central Arctic Ocean; one ACIA climate model projects an ice-free Arctic Ocean in summer by mid-century, an extraordinary future with implications for ice navigation and Arctic ship construction standards. The potential development and role of trans-shipment ports in the European Arctic, Iceland, and Alaska is another option in need of comprehensive analyses and scenario-building.

Preliminary Survey of Workshop Participants

Prior to convening the Arctic Marine Transport Workshop in Cambridge, England, participants were asked to provide the organizers with key issues they believed significant to the future of Arctic Marine Transport. Half of the group responded to the survey and a list of 47 key issues were assembled and divided into five broad themes: Emerging Routes (Timetable and Factors); Infrastructure Needs; International Relations; Environmental Concerns; and Arctic Shipping Rules. No attribution for the individual issues was identified and no order of importance was determined. The resulting compilation represents a valuable pre-workshop understanding of the major issues facing Arctic Marine Transport from a small 'group of experts.' Most of these issues were discussed during the workshop and many reappear in the resulting issues and research agendas that were developed during sessions 1 through 5.

Theme: A Emerging Routes ~ Timetable and Factors

- Regional (annual seasonal) Arctic Marine Transport or trans-Arctic shipping ~ Which will dominate?
- Which will be commercially viable first: Northwest Passage or Northern Sea Route?
- Role of oil & gas industry in Arctic Marine Transport (timing and competition from pipelines)
- Impediments to Arctic Marine Transport: technology, economics and international politics?
- Levels of risk for potential operators
- Need for alternative & secure routes between Europe/North America and East Asia
- Independent icebreaking carriers vs. icebreaker assisted convoys
- Relationship of 'land bridges' to the Arctic routes
- Demonstration voyages – what was learned regarding economic competitiveness
- Timing for coastal shipping lanes when ice free
- Tight shipping schedules for passenger & cargo ships: Arctic system development to minimize delays and ensure safety

Theme: B Infrastructure Needs

- Trans-shipment/staging ports for Alaska, Iceland, and/or Norway?
- Better ice navigation training: international (IMO) vs. national certification
- Incentives for ship owners/charters to make better use of ice information
- Compilation of database of Arctic environmental conditions
- Continuity/delivery of high resolution satellite data for operations
- Increasing importance (+ costs) for ice centers
- International databank of Arctic shipping accidents (for risk/insurance)
- Aviation services (ice reconnaissance/search and rescue/emergency) – financing, role
- Maintenance of knowledge base of experts who understand Arctic & Antarctic issues and can relate them to maritime world
- Emergency preparedness in the Arctic Ocean
- State of the art of ice navigation – more research required for improvement in tactics of ice navigation

Theme: C International Relations

- Need for international regime governing security of Arctic shipping (monitoring/enforcement of laws for smuggling, environmental standards, ship safety)
- Increased conflict ahead – competing Arctic marine uses with greater access
- Resolution of existing Arctic disputes – international mechanisms required
- International polar marine safety campaign – owner awareness
- International agreement on legal status of the Northwest Passage and the Northern Sea Route
- Determination of the legality of 'sea ice'
- Which non-Arctic nations with maritime fleets are interested in Arctic Marine Transport: Japan, Germany, China, Korea, others?
- Mobilize Arctic parlimentarians for continuous, long-term involvement in Arctic affairs
- Scope & enforcement of national jurisdiction over international shipping in the Arctic

Theme: D Environment

- How much old ice (multiyear ice) remains as the retreat continues
- Is the sea ice retreat real, imagined, or shorter-term phenomena?
- The inter-annual variability of ice coverage in some regions like the Northwest Passage is high (What level is acceptable to industry?)
- Responding to and combating oil spills
- Impact on marine life, particularly marine mammals (sound routes)
- What are the impacts to indigenous and coastal Arctic communities?
- Circumpolar Arctic sea ice database for the past century required
- How can successful Arctic navigation be correlated with known climatic /sea ice fluctuations?

Theme: E Arctic Shipping Rules

- Ship hull and machinery construction rules – further harmonization?
- Requirements for ice navigator and crew Arctic training
- Adoption of current International Association of Classification Societies polar ship rules for hull & machinery
- Ice navigation systems – future regulation
- Mandatory International Maritime Organization (IMO) guidelines
- What type of sailing allowed in different national waters-limitations, oversight and icebreaker assistance?
- Future ship standards to evolve – future of no water & fuel discharge (polar ship becomes a 'sealed container')
- Requirements for special rules for 'special cargos' (nuclear reprocessed fuels)

Session Issues & Research Agendas

One very important task of the Cambridge workshop was to generate a research agenda for Arctic Marine Transport and identify significant issues that relate to change in marine access in the Arctic Ocean. Five topical sessions (as chosen by the international organizing committee) were held:

1) Historical Considerations;
2) Arctic Climate and Sea Ice Considerations;
3) Development and Shipping Economics;
4) Technological Considerations; and,
5) International Cooperation and Marine Environmental Safety.

Three activities took place within each topical session: four to six presentations were made; the session chair provided a commentary following the presentations; and a panel of experts provided insight on the topic. At the completion of panel discussions, the floor was opened to all participants to provide further input on the topic. A simultaneous recording of major points (edited as 'bullets') was conducted during the panel and open floor discussions.

The tables of issues and research agendas that follow are derived directly from the five session discussions. Points were edited for clarity and brevity and each discussion point was identified as an 'issue' or 'research agenda' item. The workshop results represent a valuable record for use by the Arctic Council (and its working groups), the International Arctic Science Committee, U.S. Arctic Research Commission, and other research bodies, in planning future policy and research strategies.

Session: 1 Historical Perspectives

28 September 2004

Issues

- Requirement for comprehensive regional climate databases to facilitate Arctic Marine Transport
- Sea ice information must be 'uniform,' coordinated, and fully shared
- Results of Arctic Marine Transport demonstration projects conducted during the past 50 years must be open to the Arctic community
- Rich history and deep knowledge of the Northern Sea Route must be fully shared to build confidence
- Impacts of icebreaking operations on the Arctic environment and communities
- Economic and operational influences of Russia's Arctic oil and gas development on the Northern Sea Route
- Communication improvements for rapid transmission of data and environmental information to Arctic ships
- Detailed listing and protection of Arctic historical sites for tourism development

Research Agenda

- Relationship of Arctic indigenous peoples to Arctic Marine Transport
- Evaluation and adaptation of future airborne and satellite imagery for enhanced ice navigation
- Comprehensive review of changes in marine technology (during past century) and how these may influence future Arctic Marine Transport
- Analyses of the relationships of marine reserves and protected areas to Arctic shipping and historic waterways
- Global economic analyses to better understand the regional role of Arctic sustainable development
- Creation of a Geographic Information System (GIS) of historical Arctic voyages based on time periods and prevailing environmental conditions

Session: 2 Arctic Climate and Sea Ice Considerations

28 September 2004

Issues

- Contribution of observing systems to the International Polar Year 2007-08
- Provide monitoring and data requirements to the Global Earth Observation system (GEO) and EU/European Space Agency Global Monitoring for Environment and Safety (GMES) program
- Increase support for the International Arctic Buoy Program
- Enhance international agreements regarding sharing information and data dissemination
- Increase support for the Study of Environmental Arctic Change (SEARCH)
- Recognize that radar (synthetic aperture radar/SAR) information may become more difficult to share, rather than easier
- Request to space agencies for 90 degree orbiting or polar satellites, so the high-Arctic 'hole' disappears from many data sets
- Recognize that impacts of climate change are already making it possible for policy disputes to develop
- Learn how to incorporate indigenous knowledge in environmental assessments
- Develop programs to 'rescue' archived data and human memories that would enhance understanding of Arctic science, policy, history, etc.
- Develop agreements to release historical data not yet available to the scientific community
- Ensure the continuation of readily available SAR data for sea ice analyses
- Increase the number of users and support for the national ice centers
- Increase communication among Arctic scientists, polar ship designers, and shipping company representatives
- Improve the communication of sea ice data to ships and ensure that data are 'translated' as appropriate for different stakeholders
- Ensure that data is available in useful parameters, scales, etc. (e.g., macro- vs. micro-scale analysis; analysis of interactions between ship hulls and ice)

Research Agenda

- Research on changing frequency and distribution of icebergs
- Regional sea ice studies in the Bering Strait region
- Improved monitoring to better understand sea ice variability
- Expanded studies to understand sea ice thickness and extent changes, and the physical/chemical nature of sea ice
- Expanded research on fresh water flows into the Arctic Ocean
- Improved understanding of rapid climate change and 'phase shifts'
- Improved understanding of Arctic oscillations and cycles (particularly 50-year cycles) and how they influence sea ice variability
- Enhanced studies to improve understanding of the relationships between thermohaline circulation in the world ocean and the Arctic system
- Studies on regional predictions and impacts of global climate change
- Improve the resolution of Global Climate Models (GCMs) to resolve the complex geographies of the Canadian Arctic Archipelago and Russian Arctic coastal region

Session: 3 Development and Shipping Economics

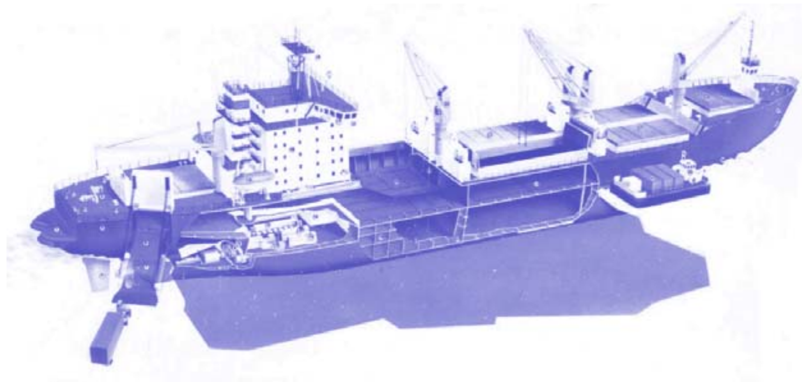
29 September 2004

Issues

- Development of regional Arctic and trans-Arctic shipping business plans
- What are the economic guarantees for Arctic Marine Transportation?
- Future Arctic Marine Transport meetings must include international institutions and financial experts within and outside the global maritime shipping community
- Location and placement of trans-shipment ports within Arctic Marine Transport
- Require more feedback on Arctic ship damage and accidents for adequate risk assessments
- Collaborative international financing for ice-strengthened cargo ships
- Role of China and other Pacific nations in the demand for Arctic shipping
- Promotion of the Northern Sea Route (NSR) by Russia; marketing the NSR to the international shipping community, national authorities, and regional Arctic bodies
- Closer cooperation and better communication between Russia and the international shipping community (key objective - overcome false perceptions)
- Creation of a comprehensive catalogue of national and international rules, regulations, and laws related to Arctic Marine Transport - all little known to the international maritime community - overcome perceived obstacles to Arctic Marine Transport
- Potential for World Trade Organization and International Monetary Fund (as well as other international financial institutions) for investment in Arctic Marine Transport
- Understanding the perceptions of risk in the political world vs. risks to the Arctic shipping community
- Focus of the research community on seasonal, short-term Arctic sea ice forecasts vs. longer-term forecasts and projections

Research Agenda

- International trade cost-benefit analyses for Arctic routes and destinations
- Analyses of national and international security mechanisms and institutions to protect the Arctic Ocean as a commercial shipping route;
  comparative security analyses of the Panama Canal, Suez Canal, and trans-Arctic routes
- Analyses of sovereignty and other international legal issues involving Arctic coastline and exclusive economic zones: obstacles and opportunities?
- Synthesis of all Arctic research projects influencing Arctic Marine Transport
- Research on risk assessment for ice damage in Arctic Marine Transport systems
- Examination of economic needs and demands for trans-Arctic shipping
- Comparative economic analyses of Arctic routes vs. Suez - Panama Canal routes
- Calculations of total volume of trade vs. GDP growth regionally and internationally: How do the numbers relate to Arctic Marine Transport?
- Economic benchmarks for trans-Arctic year-round shipping
- Economic analyses of large trans-shipment ports for Arctic Marine Transport
- Comparison of legal and political issues with environmental and technical issues
- Study of trans-Arctic shipping impediments vs. seasonal coastal shipping
- Study of types of sea ice forecasts vs. shipping company needs
- Risk assessments and environmental impact assessments for Arctic Marine Transport
- Study of the trend of increasing ship size (on global routes) in relationship to future Arctic Marine Transport
- Analysis of trends in global trans-shipping and its implications for Arctic Marine Transport
- Comprehensive analysis of all Arctic shipping damage in all regions; creation of an accident data/statistical analysis base for the international shipping community



Session: 4 Technological Considerations

29 September 2004

Issues

- All future Arctic icebreaking and ice-capable ships will be environmentally safe
- Arctic ship designs and marine system developments will be influenced by geopolitical issues
- New national legislation and international regulations/agreements on nuclear icebreaker safety
- Regulating Arctic ships for performance vs. regulating for safety
- Impacts of changing regulations for ship stack emissions
- Continuing Arctic Council support for technological and operational projects involving Arctic Marine Transport
- Sufficiency of current emission rules for regions of the Arctic
- Requirements for updated Arctic charts and aids to navigation in all coastal regions of the Arctic Ocean
- Lack of harmonized requirements for propulsion power of ice class ships (requirements for minimal power); possible review by IMO and IACS
- Many proven technologies for Arctic ships (CPP systems, nuclear power)

Research Agenda

- Cost-effectiveness of different icebreaking propulsion systems and auxiliary systems
- Analyses of impacts of regional snow cover and ice ridges on Arctic Marine Transport
- Relationships of propulsion power to icebreaker class and the need for requirements for power specification (for safety)
- Create a design process for pollution control mechanisms on board Arctic ships
- Development of operational guidelines/design considerations for exhaust emission and ballast water exchange
- Comparison of North American vs. European emission controls on ships; comparison of rules and regulations in both regions
- Updates on navigation systems for new ships; installation and training issues of new navigation technologies
- Satellite vs. airborne ice information systems
- Technological considerations of diesel ships vs. nuclear ships
- Economic and environmental cost-benefit analysis of nuclear-powered icebreakers (vs. other ships)
- Comprehensive study of potential communication technologies for Arctic Marine Transport ships; complete survey of communication
  coverage for all Arctic regions
- Research on novel propulsion and auxiliary systems (example: use of ballast water for engine cooling water) for Arctic ships

Session: 5 International Cooperation and Marine Environmental Safety

30 September 2004

Issues

- Have comprehensive safety and environmental protection measures based on the precautionary approach and best practices
- Develop a model training course for ice navigation
- Use an integrated approach to Arctic Marine Transport that addresses issues of economics, the environment, and human concerns
- Develop an international Arctic shipping regime - incremental approach, and build on existing agreements; develop new international initiatives
- Integrate Arctic Marine Transport research projects as part of the International Polar Year 2007-08 activities
- Differentiate clearly the Northern Sea Route, the Northwest Passage, and trans-Arctic routes
- Harmonize international guidelines that apply to SOLAS (Safety of Life at Sea) standard ships operating in defined Arctic ice-covered waters
- Understand that Arctic Marine Transport faces the prospect of major international disputes
- Develop a communications network to effectively pass reliable information into the hands of the proper individuals

Research Agenda

- Research transfer/trans-shipment ports on each end of the Northern Sea Route to minimize use of ice strengthened vessels and icebreakers
- Determine how reductions in marine shipping risk from climate change and improved aids to navigation can reduce the costs of insurance for Arctic Marine Transport
- Determine the range of impacts the UNCLOS (Law of the Sea) has on Arctic Marine Transport; types of vessel operations that could be impacted are: cargo/passenger carriers; exploration ships; support and replenishment ships; fishing vessels; mapping and scientific research vessels; and, surveillance, enforcement, and search & rescue ships
- Increase understanding of how thinning ice in the Arctic could improve transits and regional access and potentially make it easier to reach natural resources.
- Study the core issues of conflict: international status of waters, delimitation of continental shelf, maritime boundaries, land boundaries, climate change, Arctic indigenous residents, international security, resource development, and political governance
- Study key international issues - resource security, international terrorism, and new security threats - in the context of Arctic shipping
- Analyze issues related to secure and safe Arctic Marine Transport: requirement for better navigational charts, coordination of Arctic shipping, transmissions about safety sailing conditions to ships
- Take the next steps in building global infrastructure to include a new business model, technological challenges, incentives to ship owners and assessment of the market potential

Final Issues: Session 6

The final exercise of the workshop was a roundtable discussion by all participants held on 30 September 2004. Unlike the previous five sessions with presentations and panel discussions, Session 6 was a facilitated open forum, where participants were asked to briefly summarize a key issue resulting from the workshop and their experience. Individuals were randomly selected by the facilitators for their statements and no priority was assigned to the topic or issue. As before, the summary issues are not attributed to any individual or nationality. The summary issues listed below are diverse; however, nearly one third related to sea ice and climate, and 205 comments focused on economics and development of Arctic Marine Transport. The keywords for each major issue are in bold type.

Session: 6 Participant Roundtable Discussion & Key Summary Issues

30 September 2004

- **Certainty and predictability** of regulations, passage making, passage fees, infrastructure availability, and ship construction requirements
- Need for comprehensive analysis of **historical climatological data** for the entire Arctic
- Continuing the **Arctic Climate Impact Assessment** (ACIA) processes
- Concept development for **trans-shipment ports** on the ends of Arctic routes
- Formulate **insurance and risk factors** for the Northern Sea Route and other routes
- Assessment of **future levels of Arctic cargo shipping** for strategic planning purposes
- Study **ice characteristics** (and ship design parameters) from the perspective of navigation factors such as drift, physical condition of the ice, ice dynamics, leads, etc.
- Development of more robust **sea ice forecasting** methods
- Development of **improved communications** in areas north of INMARSAT coverage for search and rescue/emergency operations
- Research on the most appropriate systems for **Arctic shipping** (convoys, independent icebreaking carriers, strategically-located icebreakers)
- Full range of **marine transportation economic studies**, which will uncover various issues that Arctic shippers need to know
- Recognition of the **need for profit** in Arctic Marine Transport
- Note there will be large seasonal, annual, and year-to-year variations in sea ice and other physical parameters creating **challenges for future planning**
- Stress the **Arctic as a destination**, as well as a trans-ocean waterway
- Gain commitments from national governments to back and assist in the creation of **trans-shipment** ports around the Arctic Ocean
- Seek **harmonization of rules** governing scientific research in the Arctic
- **Concept of 'global climate change'** rather than 'global warming' should be used; change may bring completely new and currently unforeseen living conditions and needs
- **Future Arctic Marine Transport workshops** might meet aboard an icebreaker with invitations extended to the worldwide media
- Formulate plans for the **protection of Arctic historic sites** as tourism and other access increases

>

Participant Roundtable Discussion & Key Summary Issues continued

- Full examination, identification, and mitigation of **conflicts** affecting Arctic Marine Transport
- Recognition that **marine environmental protection** is a paramount issue with future Arctic Marine Transport
- Come to terms with a **cooperative security agreement** for the Arctic
- Further improve **standardization** of construction rules, navigation, navigator and crew training
- Research and implement **improved sea ice information and communication services**
- Advance studies necessary to develop best practices to **minimize/prevent Arctic Marine Transport accidents**
- **Advanced satellite remotely-sensed images** (SAR and future data) should be more available and translatable for ship-board use
- **Ice services** and products of different countries should be pooled to provide navigational support
- Must have the Arctic national authorities, the Arctic Council, and international scientific bodies, to discuss and understand the **complex range of issues** involving Arctic Marine Transport

Appendixes

Appendix A: Workshop Agenda

Arctic Marine Transport Workshop
Scott Polar Research Institute
28-30 September 2004

Tuesday, 28 September 2004

- Introduction (Brigham)
- Welcome to Scott Polar (Dowdeswell)
- Institute of the North and Aims of CITF (Parker and Ellis)
- Pre-Workshop Issues from the Participants (Brigham)

Session 1: Historical Perspectives
Chair: Barr

- Northwest Passage Voyages (Headland)
- Northern Sea Route System: History and Current Operation (Babich)
- Central Arctic Ocean and Trans-Arctic Voyages (Brigham)
- Marine Trafficability Studies in the Alaskan Arctic (Voelker)
- Panel Discussion/Research Agenda
  - Commentary: Barr
  - Panel Members: Backman, Mikhailichenko and Parker

Session 2: Arctic Climate and Sea Ice Considerations
Chair: Brigham

- Arctic Sea Ice Extent and Multiyear Sea Ice Changes (Sandven)
- Arctic Sea Ice Thickness Changes (Wadhams)
- Sea Ice Trends in the Russian Arctic (Pryamikov)
- Sea Ice Trends in the Canadian Arctic Archipelago (Falkingham)
- Sea Ice Trends Around Greenland (Hansen)
- Sea Ice in Icelandic Waters (Jakobsson)
- Panel Discussion/Research Agenda
  - Commentary: Brigham
  - Panel Members: Brass, Seina, Van Woert and Gorman

Arctic Marine Transport Reception honoring Dr. Terence Armstrong

5:30 p.m., Scott Polar Research Institute Museum

Wednesday, 29 September 2004

Session 3: Development and Shipping Economics
Chair: Parker

- International Northern Sea Route Program: Lessons Learned (Østreng)
- ARCOP: Western Siberian Oil and Gas Marine Transport (Juurmaa)
- The NSR and Development of the Russian Arctic (Granberg)
- Future of Canadian Arctic Shipping (Gorman)
- Russian Indigenous People and the NSR (Etylin)
- Panel Discussion/Research Agenda
  - Commentary: Parker
  - Panel Members: Smith, Paterson, Baldursson, Rasti, Doyle

Wednesday, 29 September 2004 continued

Session 4: Technological Considerations
Chairs: Santos-Pedro and Peresypkin

- Ship Design Considerations for the Russian Arctic (Peresypkin)
- Future Icebreaking Cargo Ship Designs (Juurmaa)
- Future Icebreaker Designs (Rupp)
- Update of Arctic Shipping Rules (Hayward)
- Remote Sensing/Observing Systems: ICEMON and Northern View (Seina and Randell)
- Panel Discussion/Research Agenda
  - Commentary: Santos-Pedro and Peresypkin
  - Panel Members: Backman, Jaan, Voelker and Monko

Arctic Marine Transport Banquet

- 7:00 p.m., Sidney Sussex College, Keynote Speaker, Captain Anders Backman
- Topic: International Arctic Ocean Drilling Program 2004 Expedition in the Central Arctic Ocean

Thursday, 30 September 2004

Session 5: International Cooperation and Marine Environmental Safety
Chair: Treadwell

- Noncommercial Partnership and the NSR (Mikhailichenko)
- Development and Future of the Arctic Guidelines (Santos-Pedro)
- Implications for Delimiting the Arctic Continental Shelf (Macnab)
- International Arctic Marine Safety Cooperation and Issues (Huebert)
- Hydrographic Considerations for the NSR (Medvedev)
- Polar Sea Route as a Global Infrastructure Project (Yamamoto)
- Panel Discussion/Research Agenda
  - Commentary: Treadwell
  - Panel Members: Sidock, McClellan, Hayward and Pryamikov

Session 6: The Future of Arctic Marine Transport
Chairs: Brigham and Ellis

- Arctic Climate Impact Assessment (Brigham)
- The Arctic Council's Arctic Marine Strategic Plan (Gudmundsottir)
- Future Arctic Development: A Global Vision (Governor Hickel)
- Roundtable Discussion: Future Research and Key Issues (All Participants)
- Adjourn (Brigham and Ellis)

Appendix B: Workshop Participants

- **Nikolai Babich,** Murmansk Shipping Company, Russia
- **Anders Backman,** Master Mariner, Sweden
- **Ragnar Baldursson,** Ministry for Foreign Affairs, Iceland
- **William Barr,** Arctic Institute of North America, Canada
- **Tony Bilkinghurst,** Scott Polar Research Institute, Cambridge University, UK
- **Philip Bottomley,** BP Shipping Limited, UK
- **Garry Brass,** US Arctic Research Commission, USA
- **Lawson Brigham** (Co-chair), US Arctic Research Commission, USA*
- **Julian Dowdeswell,** Director, Scott Polar Research Institute, Cambridge University, UK
- **John Doyle,** 64th Parallel International, USA
- **Ben Ellis** (Co-chair), Institute of the North, USA *
- **Vladimir Etylin,** Russian Association of Indigenous People of the North, Russia
- **John Falkingham,** Canadian Ice Service, Canada
- **Robert Gorman,** Enfotech Technical Services, Canada
- **Alexander Granberg,** Council for Study of Productive Forces and Economic Cooperation, Russia
- **Soffia Gudmundsottir,** Secretariat, Protection of the Arctic Marine Environment, Iceland
- **Keld Q. Hansen,** Danish Meteorological Institute, Demark
- **Richard Hayward,** Germanischer Lloyd AG, Germany
- **Bob Headland,** Scott Polar Research Institute, Cambridge University, UK
- **Walter Hickel,** Institute of the North, USA
- **Keith Hill,** Scott Polar Research Institute, Cambridge University, UK
- **Rob Huebert,** University of Calgary, Canada
- **Roy Jaan,** Swedish Marine Administration, Sweden
- **Thor Jakobsson,** Marine Meteorology and Sea Ice, Iceland
- **Kimmo Juurmaa,** Aker Finnyards, Inc., Finland
- **Ron Macnab,** Geological Survey of Canada, Canada
- **Daniel McClellan,** US Coast Guard, USA
- **Victor Medvedev,** State Unitary Hydrographic Department, Russia
- **Vladimir Mikhailichenko,** Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, Russia *
- **Nikolay Monko,** Federal Agency for Marine and River Transport, Ministry of Transport, Russia
- **Willy Østreng,** Norway Academy of Science and Letters, Norway
- **Walter Parker,** Circumpolar Infrastructure Task Force, USA *
- **Tom Paterson,** Fednav Limited, Canada
- **Vladimir Pavlenko,** International Arctic Science Committee, Russia
- **Vsevolov Peresypkin,** Central Marine Research and Design Institute, Russia
- **Sergei Pryamikov,** Arctic and Antarctic Research Institute, Russia
- **Charles Randell,** C-Core Memorial University, Canada
- **Lai Chan Rasti,** European Bank for Reconstruction & Development Transport Team, UK
- **Karl-Heinz Rupp,** Hamburg Ship Model Basin, Germany
- **Stein Sandven,** Nansen Environmental and Remote Sensing Center, Norway
- **Victor Santos-Pedro,** Transport Canada, Canada *
- **Steven Sawhill,** Scott Polar Research Institute, Cambridge University, UK
- **Ari Seina,** Finnish Institute of Marine Research, Finland
- **Gary Sidock,** Canadian Coast Guard, Canada
- **Andrew Smith,** Lloyds Register of Shipping, UK
- **Matthew Stubbs,** Columbia University, USA
- **Mead Treadwell,** US Arctic Research Commission, USA *
- **Michael Van Woert,** US National Ice Center, USA
- **Richard Voelker,** US Maritime Administration, USA
- **Peter Wadhams,** Cambridge University, UK
- **Norio Yamamoto,** Global Infrastructure Fund Research Foundation, Japan

Staff

- **Matthew Moon,** Institute of the North, USA
- **Hillary Pesanti,** Institute of the North, USA
- **Malcolm Roberts,** Institute of the North, USA
- **Shirley Sawtell,** Scott Polar Research Institute Library, Cambridge University, UK
- **Amanda Saxton,** US Arctic Research Commission, USA
- **Isabella Warren,** Scott Polar Research Institute Library, Cambridge University, UK

* = Members of the International Organizing Committee

Note: Professor Kaj Riska of Helsinki Technical University was also a member of the international organizing committee, but was unable to attend the workshop.

Appendix C: Abstracts of Presentations

Icebreakers and Ice Type Vessels Operation Experience at Northern Sea Route

Nikolai Babich, Murmansk Shipping Company, Russia
Session 1: Historical Perspectives

The Northern Sea Route embraces the full water-areas of Arctic seas (Kara Sea, Laptev Sea, East Siberian Sea, western part of Chukchi Sea) as well as part of the Arctic Ocean water area exclusively inside the Russian Federation economic zone. The main tool of Northern Sea Route exploration is the icebreaker fleet. At present, the total power of the operative icebreaker fleet of Russia (14 icebreakers) constitutes approximately 600,000 horsepower, where eight icebreakers with approximately 400,000 horsepower are working in the Northern Sea Route.

Regular commercial navigation in Arctic seas during the limited summer period started in 1920. In the following years, the navigation time was prolonged due to icebreaker fleet power increase. After the icebreakers of "Arktika" type were put into operation in 1978, year-round navigation was guaranteed in the western part of Northern Sea Route. At the same time, new routes of navigation were explored, including those passing along the northern borders of Arctic seas as well as high latitude and pole-close routes.

In the last 50 years of active cargo operations at the Northern Sea Route, the Arctic sea transportation system was established, which includes icebreaker, navigational-hydrographic, hydrometeorological (science-operative) navigation service. A sufficient base of categorized data including general and regional weather conditions and ice process was accumulated, basic technical requirements for construction and equipment of icebreakers and ice type vessels were defined and the basic laws of transportation depending on seasonal changes of ice condition at directions of Arctic transportation were found. This provides the opportunity to design reliable transportation-technological schemes of promising cargo transportation including the requirements for technical conditions, equipment of vessels and next generation icebreakers. ■

Central Arctic Ocean: North Pole and Trans-Arctic Voyages 1977 – 2004

Lawson Brigham, U.S. Arctic Research Commission, USA
Session 1: Historical Perspectives

One of the extraordinary polar achievements at the end of the twentieth century was the operation of icebreakers at the Geographic North Pole and throughout the Central Arctic Ocean. During 1977 – 2004, 52 successful voyages have been made to the North Pole by the icebreakers of Russia (42), Sweden (4), Germany (2), USA (2), Canada (1) and Norway (1); eight surface ships reached the North Pole during the summer of 2004. Thirteen of the voyages were in support of scientific research and the remaining 39 were devoted to tourist voyages to the North Pole and across the Arctic Ocean. The Soviet nuclear icebreaker *Arkitka*, during a celebrated voyage, was the first surface ship to attain the Pole on 17 August 1977. The only voyage of the 52 not to be conducted in summer was that of the Soviet nuclear icebreaker *Sibir*, which supported scientific operations 8 May to 19 June 1987 (reaching the Pole 25 May 1987). *Sibir* navigated in near-maximum thickness of Arctic sea ice while removing the personnel from North Pole Drift Station 27 and establishing a new drift station (number 29) in the northern Laptev Sea. This Arctic voyage should be considered the most demanding icebreaker operation to date. During the decade of the 1990s, five remarkable trans-Arctic voyages were accomplished: a transit across the Central Arctic with tourists by the Soviet nuclear icebreaker *Sovetskiy Soyuz* in August 1991; transits by the *Louis S. St-Laurent* (Canada) and the *Polar Sea* (USA) during July and August 1994 from the Bering Strait to the North Pole and to Svalbard; and two crossings by the nuclear icebreaker *Yamal* (Russia) with tourists in 1996. The Arctic Ocean Section 1994 Expedition (conducted by the *Louis S. St-Laurent* and *Polar Sea*) was the first scientific transect of the Arctic Ocean conducted by surface ships. The expedition made extensive use of real-time satellite imagery (received aboard the *Polar Sea*) for strategic navigation and scientific planning. During the late summer of 2004, a small 'armada' consisting of the nuclear icebreaker *Sovetskiy Soyuz*, the icebreaker *Oden* (Sweden) and the icebreaker *Vidar Viking* outfitted for drilling, conducted a historic scientific drilling voyage in the remote reaches of the Arctic Ocean.

A review of these pioneering voyages indicates that marine access in summer throughout the Arctic Ocean has been achieved by highly capable icebreakers. However, little is known about the challenges of voyaging in other seasons except *Sibir's* expedition in May and June 1987. The nuclear icebreakers of Murmansk Shipping Company have clearly pioneered independent operations in the Central Arctic Ocean, while conventionally powered icebreakers have operated in tandem during high-latitude voyages. A compilation and analyses of ship performance and environmental data from each of these Arctic voyages would make a significant contribution to understanding the future operation of ships in the Central Arctic Ocean. ■

Russian Indigenous People and the Northern Sea Route

Vladimir Etylin, Russian Association of Indigenous People of the North, Russia
Session 3: Development and Shipping Economics

This report dealt with social issues in developing the Northern Sea Route. The view of using more traditional knowledge of Native people of the Arctic and the knowledge of non-Native people who are long-time residents of the Arctic region of Russia was put forth concerning the environment, the ocean, ice, shelter and traditional food and clothing in Arctic conditions.

The two basic issues focused on were:

1. A global approach to Arctic issues "Arctic Civilization;" and
2. Key concerns of the Native people of Chukotka should the Northern Sea Route be developed. ■

Sea Ice in the Canadian Arctic

John Falkingham, Canadian Ice Service, Canada
Session 2: Arctic Climate and Sea Ice Considerations

The amount of sea ice in the Canadian Arctic has been declining in recent decades in concert with the reductions observed in the Northern Hemisphere in general. There is mounting evidence that this reduction will continue, although there is great uncertainty over the rate at which ice will continue to diminish. Considering the predictions of Global Climate Models as well as the observed rate of ice reduction, it is estimated that the Canadian Arctic will experience nearly ice-free summer seasons starting as early as 2050 but probably not before 2100. The inter-annual variability in ice conditions will continue to be extreme. It is quite likely that the latter half of this century will still experience occasional summers with ice conditions as severe as those witnessed in the 1980s. Multi-year ice, particularly in low concentrations, will present the major hazard to shipping. Small multi-year ice floes in high sea states are a significant threat as are multi-year floes hidden in a matrix of relatively weak annual ice. Since the oldest and thickest ice in the Arctic Ocean is that which is driven against the western flank of the Canadian Archipelago, this will likely be the last multi-year ice to remain. As long as this remains a source of multi-year ice in the Arctic Ocean, it will continue to drift through the Canadian Archipelago. Based on observations of changes to the ice in the Arctic Ocean itself, together with the expected patterns of ice movement, it is conjectured that the Arctic Ocean itself may become open to trans-polar shipping routes before the Northwest Passage. ■

Sea Ice Trends in the Russian Arctic

Ivan Ye. Frolov, Sergey V. Frolov, Vasily M. Smolyanitsky, Sergey M. Pryamikov
Arctic & Antarctic Research Institute of Roshydromet

Linear trend coefficients A_{xy} ($Y=aX+b$) were assessed for the total concentration (ice index at a point) for the Eurasian Arctic Seas for the whole period of ice charting (1933-2003) and separately for the last period of Arctic warming from 1946. Results show that during the summer time (August) it is possible to speak with 95% significance level on the existence of a negative trend (decrease of ice) only for the Greenland, Barents, Kara, Chukchi Seas and for the Eurasian Arctic as a whole, while for the Laptev and Eastern-Siberian Seas, a positive trend (increase of ice) with 95% significance level is not exclusive.

Analysis of A_{xy} spatial distribution, assessed for the period from 1946 until 1992 (end of conduction of air reconnaissance in the Russian Arctic) shows predominance of A_{xy}, positive (increase of ice) values during the winter period >

(April) for the area of Eurasian Seas, excluding the Barents Sea and a partial area of Greenland Sea, where negative values are observed.

Due to significant variability of sea ice total concentration, greater spatial variability of A_{xy} is also observed. For the northwest Barents Sea, southwest Kara Sea, practically all area of Laptev Sea, western part of the Eastern-Siberian Sea and southwest of the Chukchi Sea, negative values of A_{xy} are observed. Simultaneously, for the northeast Barents Sea, northeast Kara Sea, and eastern part of the Eastern-Siberian Sea, prominent areas with positive values of A_{xy} are noted.

Several regions should be noted for a change of A_{xy} sign from winter (April) to summer (August) seasons. These are northeast Barents Sea (-/+), southwest Kara Sea (+/-), Laptev Sea (+/-), western part of the Eastern-Siberian Sea (+/-), and the southwestern part of the Chukchi Sea (+/-). It is obvious that such changing linear trends make it possible to propose the existence of several natural phenomena affecting the sea ice cover in different regions during the same season. ■

Future of Canadian Arctic Shipping

Bob Gorman, Enfotec Technical Services & Tom Paterson, Fednav Limited, Canada
Session 3: Development and Shipping Economics

This presentation focuses on the future of shipping into the Canadian Arctic. The discussion includes outlooks on various sectors that are served by marine transportation including community sealift operations, the resource industry (mining and oil/gas), as well as tourism.

Northern Canadian native communities have the fastest rate of population growth in Canada and one of the fastest in the world increasing at a rate of 16% per decade so the demand on the northern sealift will continue to grow into the future. The boost in sealift requirements will increase with the expected increase in mineral, oil and gas exploration in the north over the coming decades.

Resources-based marine operations have suffered a decline in the Canadian Arctic with the closures of the Polaris and Nanisivik mines in 2002. This is the first time in many decades that there are no operating mines in the Nunavut Territory. However, there is a high level of exploration for diamonds and gold in the north and several new diamond and gold mines will open over the coming decade. If base-metal prices remain robust, the development of base-metal mines in the Coronation Gulf region associated with the Bathurst Road-Port project is expected. In the sub-Arctic nickel is the commodity of choice with the Raglan Mine in Northern Quebec in full operation since 1997 and the Voisey's Bay Mine set to go into full production in late 2005.

Oil and gas activity is restricted to the on-shore Mackenzie Delta at this time. Plans are in place by the Aboriginal Pipeline Group to build a gas pipeline to the delta over the next 10 years. Once the pipeline is in place offshore oil and gas activity in the Canadian Beaufort Sea will likely increase once again.

There was a spike in adventure tourism cruises into the Canadian Arctic over the past 10 years but this has receded recently as the initial "wave" of tourists has past. There may be a slight increase in this sector in the future but it will likely operate at a low level for many years to come.

Overall, it is important to note that marine operations in the Northwest Passage will be focused on destinations within the Canadian Arctic. The commercial marine transportation industry is not focused on the passage as a shortcut over the Panama Canal either now or within the next 10 to 20 years. ■

The Northern Sea Route and Development of the Russian Arctic

Alexander Granberg, Council for Study of Productive Forces and Economic Cooperation, Russia
Session 3: Development and Shipping Economics

In the 20th century, the Northern Sea Route has played a leading role in natural resources development and social development of the Russian Arctic regions, formation of large complexes on manufacture of carbohydrates, nonferrous metals, diamonds, wood and the world's largest northern cities. The maximum volume of transportation on the Northern Sea Route was achieved in 1987 (6.6 million tonnes).

Political and economic transformations in the USSR and Russia in the 1990s, had painful effects on social and economic positions of the Russian Arctic regions (fall in manufacturing, investments and incomes, and significant emigration). Transportation on the Northern Sea Route was reduced significantly.

Renewal of economic growth since 1999 has captured all Russian Arctic regions. Due to export of raw material and metals, a number of the Arctic regions (Yamalo-Nenetsky and Nenetsky autonomous regions, Murmansk area) became financial donors to Russian and world economics. In the report economic dynamics of seven regions adjoining the

Northern Sea Route are analyzed. The volume of sea transportation on the Northern Sea Route is gradually increasing.

The forecast of sea transportation on the Northern Sea Route for 2015 is developed in two variants: pessimistic 7.8 million tonnes, optimistic – 11.4 million tonnes. For maintenance of such growth of transportation, modernization of ice-breaking and transport fleet and reconstruction of all Arctic ports and infrastructure is planned. ■

The Arctic Marine Strategic Plan

Soffia Gudmondsottir, Protection of Arctic Marine Environment (PAME)
Session 6: The Future of Marine Arctic Transport

The Arctic marine environment is of great importance to the states of the Arctic region and the world as a whole. It holds some of the most important seas for commercial fisheries in the world, has unique socio-cultural aspects, economic potential and plays an integral role in climatic processes.

Abundant natural resources, increasing economic activity and significant changes due to climatic processes are resulting in increased use, opportunities and threats to the Arctic marine and coastal environments. Increased activities will lead to increased human presence in the high Arctic. Responding to this the Arctic Council Ministers recognized that:

"...existing and emerging activities in the Arctic warrant a more coordinated and integrated strategic approach to address the challenges of the Arctic coastal and marine environment and agree to develop a strategic plan for protection of the Arctic marine environment under leadership by PAME." (Arctic Council Ministerial Declaration, Inari, Finland, 2002)

The Arctic Marine Strategic Plan (AMSP) has been developed over the last two years under the leadership of the Protection of the Arctic Marine Environment Working Group with Canada and Iceland as the lead countries. The final version will be presented to the Arctic Council Ministerial meeting to be held in Reykjavik, Iceland, 24 November 2004 for approval.

The purpose of the AMSP is to guide Arctic Council activities related to the protection of the Arctic seas. One of the aims of this plan is to build on the internationally recognized need to manage human activities within the context of entire ecosystems, applying them to achieve the sustainable development of the Arctic marine environment. ■

Variability in the Sea Ice Cover near Greenland - Recent Observations

Keld Q. Hansen, Denmark Meteorological Institute, Denmark
Session 2: Arctic Climate and Sea Ice Considerations

Operational sea ice mapping for navigational use is an excellent opportunity to get details on sea ice conditions and variability in a key area in Greenland. This presentation briefly describes the operational Denmark Meteorological Institute activities near the Greenland shores. Observations through the last 2-3 years have generally shown ice conditions lighter than normal, especially in Northeast Greenland where the multi-year ice has retreated dramatically in three consecutive summers from 2002 (record low) to 2004. The West Greenland ice seasons since 2002 have also been characterized by being short and light. In February 2004 a Danish (ice-strengthened) cargo vessel was able to go to the harbors in Disko Bay, normally impossible without icebreaker assistance. To the south ice conditions in recent years were more diffuse, from an extremely light and short ice sea season in 2003 to a longer than normal ice season in 2004. These events are discussed in relation to the record for the years 1946-2004 for the South Greenland Waters. A new feature observed here was several giant tabular iceberg or ice islands of Northeast Greenland origin after the remarkable breakup of semi-permanent fast ice in 2002 and 2003 near latitude 78.00-79.30N. ■

The New IACS Unified Requirements for Polar Ships

Richard Hayward, Germanischer Lloyd AG, Germany
Session 4: Technological Considerations

The new IACS Unified Requirements for Polar Ships, along with international guidelines, answer the call of IMO and national administrations for a proactive, comprehensive and unified approach to the safeguarding of life, property and the environment in polar waters. The IACS Unified Requirements for Polar Ships are a set of construction standards for the >

hull and machinery of vessels navigating polar ice-covered waters. The purpose of these requirements is to enable polar class ships to withstand the effects of global and local ice loads, as well as temperatures, characteristic of their polar class.

Despite the obvious difficulties in unifying various requirements based on decades of contrary experiences and design philosophies, the IACS Unified Requirements for Polar Ships constitute a state-of-the-art set of construction requirements. In the structural standards, for instance, ice loads are defined on the basis of ice collision mechanics with due regard to ice failure mechanisms and observed pressure-area relationships between load levels and contact area. Structural response criteria are defined in terms of plastic limit states, including interactions between shear and bending, thereby providing much clearer pictures of ship safety levels than the elastic response criteria normally used.

Concerning future development of the IACS Unified Requirements for Polar Ships, the most important issues are the definition of loads based on additional ship-ice interaction scenarios (especially that of a ship caught under pressure), enhanced integration of limit state design concepts and more explicit definitions of risk levels. The question of whether ship propulsion power is a matter of safety and/or performance also needs to be addressed. ■

Northwest Passage Voyages

Bob Headland, Scott Polar Research Institute, Cambridge University, United Kingdom
Session 1: Historical Perspectives

A historical summary of exploration and transits of the Northwest Passage is presented noting that the first transit was made in 1853 (led by Samuel Cresswell) although this was by sledge across the sea-ice in the central portion. The centenary of the first transit aboard one vessel (Gjøa, commanded by Ronald Amundsen) was described. A chronological list of all transits to the 2004 summer was produced for analysis by route, nationality, and other factors.

Vessels have used seven routes through the passage. There have been a total of 99 transits to date, 27 of which have carried passengers. Of these, 62 were eastbound and 37 westbound, almost half of them (45) used the southern route. Only one vessel has made a complete transit through McClure Strait and the northern route, the most ice-infested, but deepest, way. This is the course used by submarines but these records are incomplete. The majority of vessels wore the Canadian flag (38), followed by Russia (18 - mainly with tourists aboard), United States and Bahamas (11 each, the latter being tourist vessels). Eleven flags were represented by only one vessel each.

Comparisons between the Northwest Passage, Northern Sea Route, and other ways between the North Sea and the Sea of Japan were made involving distance, navigational problems, and territories traversed. While distances of both the Arctic routes are similar between the North Sea and the Sea of Japan, navigation is much easier in the Northern Sea Route. Should reduction of Arctic ice cover develop further, the relative ease of both may be expected to persist, thus the Northern Sea Route will remain the more effective passage.

References to some personal observations were included following several voyages through the Northwest Passage and Northern Sea Route. ■

International Politics and Arctic Shipping

Rob Huebert, University of Calgary, Canada
Session 5: International Cooperation & Marine Environmental Safety

A scientific consensus is now developing that the polar regions are experiencing a substantial warming process. As such, considerable debate is emerging as to the impact that this will have on human activity in the region. Of particular note are the questions regarding the prospects of increased shipping in Arctic waters. While some preliminary observations on the expected nature of this increase may be made, many questions remain unanswered. Perhaps the most confounding issues pertain to the future actions taken by the Arctic coastal states.

The first and perhaps most complicated issue revolves around issues of sovereignty. Canada and Russia have both claimed the Arctic waterways passing through their Arctic region as internal waters. While both states are committed to promoting international shipping through these waters, they do not accept the Northwest Passage or the Northern Sea Route as international straits. The United States and the European Union, on the other hand, have taken the position that these are international waters. This disagreement creates numerous problems. The first is over control. If these waters are internal, then the relative coastal state retains control over shipping in these waters. On the other hand, if they are not, then the rules and standards governing international shipping are to be determined by the competent international organizations. The second main problem is the political sensitivity that surrounds theses disputes. A challenge to the position of any of these states carries ramifications that go beyond the Arctic. This greatly increases the challenges in resolving the differences that will arise as shipping increases. How then can these differences be managed as shipping increases?

The second major set of concerns facing a developing international arctic shipping regime pertains to security. Any increase in shipping in the region will require an increase in the monitoring and enforcement of domestic and international laws governing smuggling, environmental standards, ship safety and so forth. Given the isolated nature of the Arctic waters such requirements are challenging. Further complicating these issues is the new need to protect against international terrorism. Currently there seems little likelihood that international terrorists would specifically target the north; however, an increase in the number of Arctic ships can never be ruled out as future targets. Furthermore, an increase in shipping will mean that terrorists could use this traffic as a means of entry to either North America or Russia. How then is security to be protected in this region? What are the steps that can be taken individually and collaboratively?

Thus, it is clear that there is a need to carefully consider the international challenges that face the emerging international shipping regime in the Arctic. How can these important questions be answered so that any increased Arctic shipping can be managed in a fair and safe manner? These questions will be the main focus of this presentation. ■

The Northern Sea Route - Interest in Iceland

Thor Jakobsson, Marine Meteorology and Sea Ice, Iceland
Session 2: Arctic Climate and Sea Ice Considerations

The name Iceland stems from the surprising sight of sea ice during one of the first Scandinavian exploration voyages to this newly found country in the ninth century, A.D. Sea ice at Iceland originates mainly from the East Greenland current and has been very variable through the ages. It has quite often caused trouble of different kinds, hazards for shipping along the coasts of Iceland and sometimes closed harbors in the north.

Despite this hazard Icelanders have learned how to avoid the sea ice, or, if needed, traverse carefully along the marginal sea ice zone. In recent decades they have ventured further North into subarctic conditions for fishing and transport activities. It is, therefore, no wonder that the idea of looking for possibilities still further north, even across the Arctic Ocean, is gradually catching on in Iceland.

The suggestion of considering the possible role of Iceland in connection with the so-called Northern Sea Route is no longer a futuristic idea and has in recent months been investigated again from a practical point of view. The idea, however, still needs a thorough study where links to recent projects on the Northern Sea Route itself, along the coasts of Russia, have to be considered. The International Sea Route Program (Phase I 1993-1995 and Phase II 1995-1999) resulted in a great number of papers on different aspects of the idea of future route across the Arctic Ocean.

On October 8, 1987, a conference was held in Iceland on the Northern Sea Route and the possibility of Icelandic harbors being linked to the route. In particular, the idea of Iceland providing a location for an entrepôt at the North Atlantic end of the Northern Sea Route was discussed. With the participation of the American Embassy as well as the rather hesitant Soviet Embassy in Iceland, the timing of the meeting turned out to be fortunate. News was received just before the meeting of an encouraging speech given on October 1, 1987, in Murmansk by Mr. Mikhail Gorbachev on Arctic matters. In his speech Mr. Gorbachev announced the possibility of opening the Northern Sea Route to foreign ships.

During the more than 15 years since this meeting, the idea has been kept alive by architect Gestur Ólafsson, Ambassador Ólafur Egilsson and the writer of this brief account. The possible role of Iceland has been emphasized, with its advantageous location in the middle of the northern part of the North Atlantic Ocean providing a gateway to the Arctic Ocean. The necessity of economic and technical feasibility studies has been pointed at, as well as the consideration of natural circumstances in relation to this opportunity, in particular, concerning weather, sea ice and oceanographic conditions along the sea route.

Lately, encouraging interest in this topic has been created, not the least due to the support given by Björn Gunnarsson at the University of Iceland. During this period of interest, some progress has been made, marked by meetings at the Ministry of Foreign Affairs and a report by Nigel Chattey, containing a pre-feasibility assessment and a proposal for a demonstration project including suggestions for possible participation of the United States and Canada.

It should further be mentioned that a study is being undertaken on the idea of establishing an entrepôt harbor at Isafjordur in northwest Iceland. Previously, the harbors at Reykjavik and Reydarfjordur in East Iceland had been suggested.

The main conclusion of the research made during the International Northern Sea Route Program is that in spite of climatic, technological and political restraints, an increase in international commercial shipping along the Northern Sea Route is feasible – in economic, technological and environmental terms.

Decreasing ice cover in the Arctic Ocean during the last decades should support the idea of Iceland becoming an important entrepôt for the Northern Sea Route, the shortest shipping route between the two world oceans, the Atlantic Ocean and the Pacific Ocean. ■

ARCOP - Oil and Gas Transportation from the Western Arctic Russia

Kimmo Juurmaa, Kvaerner Masa-Yards, Inc. (now Aker Finnyards, Inc.), Finland
Session 3: Development and Shipping Economics

ARCOP comes from the words Arctic Operational Platform. It is a research and development project for the Northern Sea Route. ARCOP is co-funded by the Directorate-General Energy and Transport under the 5th European Community Framework Program for Research and Technological Development.

The work within is carried out by leading experts from European Union (EU), Russia and Norway. There are 21 participating organizations and the overall budget is 5.2 million euros. The funding from EU is 3.2 million euros with the rest coming from participating organizations. The scope of work is coordinated by Kvaerner Masa-Yards, Inc. (now Aker Finnyards, Inc.) in Finland.

Oil and gas development in Arctic Russia suffers from the lack of export routes. Several alternatives have been studied and suggested. Marine transportation using the Northern Sea Route is a vital alternative, but several issues raise concerns among the potential investors. Investing in an oil field without knowing the terms and the cost of the transportation of the produced oil is not possible. To minimize these concerns, clarification is needed in several areas: technology, legal and administrative issues and environmental protection.

ARCOP aims to create an understanding about marine transportation problems of Russian Arctic oil and gas, and answer questions that potential investors may have on a general level. Making information available, ARCOP will generate permanent discussion forums between the EU and Russia and between industry and politicians. It is sometimes easier to discuss certain challenges based on realistic scenarios with direct commercial interest. Using this strategy, it is possible to develop common recommendations. ■

Chapter B Future Arctic Cargo Vessels

Kimmo Juurmaa, Kvaerner Masa-Yards, Inc. (now Aker Finnyards, Inc.), Finland
Session 4: Technological Considerations

When designing vessels for Arctic areas, certain principles are normally followed. The first deals with the safety of human life, the environment and material property. Basically this is simple, but it becomes complicated when one starts to analyse the different accident scenarios and tries to set the requirements for the strength, maneuverability and stability of the vessel in different situations. Damage statistics is an efficient way to approach this problem, but unfortunately there is only a limited amount of data available from accident statistics in the Arctic areas. Some detailed analyses of individual sailings reveal that the current rules for vessel construction need further development. Rules should not be based on single measurements but rather on long term experience and statistics.

The second principle is economics. This is more complicated since the economics of transportation has several levels. Towing by an icebreaker may be feasible for a single vessel, but the overall transportation cost may be high. Also, if the whole sea area and the transportation needs of the industry in that region are considered, the towing of each vessel through the ice may be less economically feasible.

A typical feature for the ice cover in all Arctic sea is the seasonal variation (fully open water conditions to 100 % ice coverage). In most cases the transportation is not to the ice edge, but the route includes also an open water leg even during the hardest winter months. This means that the economics of the transportation is not only dependent on the icebreaking performance of the vessel, but also the open water characteristics. Thus, an efficient cargo vessel has to be optimised for both ice and open water, which may result in compromises that are not really efficient in any condition.

Several different hull forms have been proposed throughout the history for icebreaking purposes; almost all have been developed to break uniform level ice. In practise the vessels operating in ice have to cope with a mixture of different type of ice conditions, including ice ridges which most probably will stop the ship. One solution presented a century ago was that of the Russian Admiral Makarov. He suggested that the propellers and the propeller stream should be utilised to help the vessel to move through the ice ridges. This idea was adopted to the sub-arctic icebreakers and they were equipped with propellers also in the bow. The largest and most advanced icebreaker in the Baltic used to be built with this principle. The reason to have propellers at both ends of the vessel was that the stern was fitted with rudders for steering and the bow was used to break passage though the ridges. It was only when developing the azimuth thrusters with electric drive, the so called Azipod propulsion, when the full advantage of this principle could be utilised. It was possible to put all the power at one end of the vessel and still have full steering capability. The first vessels built with this principle were tested in the most difficult ice conditions. The test results showed that power savings up to 50% could be gained. The ice model testing showed the tremendous difference in penetrating the ridges: when running ahead, the vessel must do continuous ramming to get through the ridge; when running astern, the vessel was able to maintain continuous speed with no need to ram.

Encouraged by these results, a 106,000 tdw vessel was built with the principle called Double Acting Tanker (DAT). The vessel has a bow shape optimised for open water conditions. The stern of the vessel is designed for ice breaking and with the help of a 16 MW Azipod propulsion unit, the vessel was able to transit all ice conditions in the Baltic. During ice trials in winter 2003 the vessel was tested in ice ridges 15 m deep. The vessel had no problems getting through these ice features.

The use of new technology may open up new possibilities for the Arctic navigation. Based on the long term extensive research and development work the first vessel using the DAT principle is now under construction for the Northern Sea Route conditions. This 14,500 tdw container carrier is planned to operate on the western region of the Northern Sea Route with minimum assistance from icebreakers. The vessel will be completed in 2006 and if the vessel works in practise as planned, we may see a completely new scheme of Arctic navigation for the future. ■

Arctic Marine Transport and the Juridical Continental Shelf: The Conflicting Impacts of Thinning Ice and UNCLOS Article 76

Ron Macnab, Geological Survey of Canada (Retired), Canada
Session 5: International Cooperation and Marine Environmental Safety

The juridical map of the Arctic Ocean will likely change substantially over the next decade or so, as the five surrounding coastal states (Canada, Denmark, Norway, Russia and the USA) seek to extend significant sovereign rights beyond their usual 200 nautical mile limits. Under the provisions of Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS), these extensions of sovereignty will be exercised in several ways: jurisdiction over the living and non-living resources of the seabed and subsoil; control over the emplacement and use of submarine cables and pipelines, artificial islands, installations and structures; regulation of drilling; control and prevention of marine pollution; and regulation of marine scientific research.

Most, if not all, of the activities that will be affected by the new sovereign rights involve the use of vessels, be they deployed as operating platforms or as carriers of cargo and passengers. With the prospect of thinning ice cover in the central Arctic Ocean, we can expect to see an increase in the number and variety of vessels deployed throughout the region for these purposes. Conversely, where ship operations are currently subject to relatively few legal hindrances in the high seas beyond 200 nautical miles, eventually they will have to comply with new coastal state regulations within extended continental shelves that could almost totally encompass the central Arctic Ocean.

This presentation will describe how thinning ice could make the central Arctic Ocean amenable to expanded vessel operations, while Article 76 of UNCLOS will simultaneously transform a large portion of the Arctic high seas into a zone where new coastal state jurisdiction could curtail some of these same operations. ■

Navigational and Hydrographic Support of Shipping on the Waterways of the Northern Sea Route

Victor Medvedev, State Unitary Hydrographic Department, Russia
Session 5: International Cooperation & Marine Environmental Safety

The navigational and hydrographic support of shipping on the waterways of the Northern Sea Route is entrusted in Russia to the federal body of executive power in the field of transport – Ministry of Transport. The Federal State Unitary Hydrographic Department of the Ministry of Transport of the Russian Federation is directly responsible for Navigation and Hydrographic Support since its establishment in 1933.

Areas to be covered: Hydrographic Survey of Russian Arctic seas and inland waterways suitable for sea navigation in view of publishing navigational charts and manuals; maintenance of navigational aids; pilotage and composition of the Arctic pilot service; measures on the prevention of pollution from ships in Arctic seas; and ways to improve the Northern Sea Route Navigation and Hydrographic Support. ■

Noncommercial Partnership of the Coordination of the Northern Sea Route Usages

Vladimir Mikhailichenko, Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, Russia
Session 5: International Cooperation & Marine Environmental Safety

The presentation gives a historical outline of the Partnership foundation. It identifies its main goals and objectives, highlighting the most important: the development of federal law of the Russian Federation concerning the Northern Sea Route. The presentation will also dwell upon the structure of the Partnership and briefly characterize some of its member organizations. Information on how legal bodies can become Partnership members will be shared. Statistical information in the form of tables about the Northern Sea Route will be included also on the following:

- Annual traffic on the Northern Sea Route 1933 – 2003 (thousand tonnes)
- Main characteristics of Arctic shipping during the period of 1985 – 2003 (total amount of cargo, number of ships and number of voyages)
- Cargo turnover of Arctic ports (thousand tonnes) – name of ports, the year in maximum as compared with 2003
- Annual transit traffic along Northern Sea Route 1991 – 1997 and main types of cargo
- Preliminary assessment of marine Arctic cargo shipment for the period up 2015 as estimated by Russian research institutes. ■

The International Northern Sea Route Program (INSROP): Lessons Learned

Willy Østreng, Norway Research Foundation, Norway
Session 3: Development and Shipping Economics

Among all the lessons learned from this comprehensive research program on the Northern Sea Route, only a sketchy depiction of the outcome and premises of the research will be addressed and assessed in light of the guiding principles laid down in the 3rd Draft of the Arctic Marine Strategic Plan of 7 June 2004. The purpose of the INSROP was to build up a scientifically based foundation of specialized and integrated knowledge encompassing all relevant aspects related to navigating the Northern Sea Route, so as to enable public authorities and private interests to make rational decisions based on scientific insight. To this end, INSROP was organized as a five-year multidisciplinary and multinational research program split into four sub-programs:

I. Natural conditions and Ice navigation
II. Environmental factors and Challenges
III. Trade and Commercial Shipping
IV. Political, Legal, Cultural and Military-strategic factors.

The program was designed around two countervailing variables: obstacles to increasing utilization and factors that promote increasing utilization. These variables were subsequently broken down into two parameters: natural and societal. The approach was to link the natural and societal and parameters so as to better understand the complexity, distribution, variability, interactional pattern and value composition of the navigational challenges facing the Northern Sea Route. To integrate the disciplinary findings of the four sub-programs, integrative concepts were developed, such as: aggregated hot spots, issue-specific hot spot, cool spots, socio-biodiversity, multi-value navigation etc. These concepts seem suitable to meet the ambition of the Arctic Marine Strategic Plan to base itself on an ecosystem-based management approach. ■

Ship Design Considerations for the Russian Arctic

Vsevolod Peresypkin, Central Marine Research and Design Institute, Russia
Session 4: Technological Considerations

Information is provided on the Russian Arctic fleet constructed during the last decades of the last century. Consideration is given to the icebreaking cargo ships of highest ice class, capable of ensuring all-the-year-round navigation in the Arctic. The paper sets out the performance characteristics and ice performance of nuclear-powered and diesel- driven liner and auxiliary icebreakers providing escorting of transport vessels through the Northern Sea Route seaways. The peculiarities of various design solutions for securing ice performance of ships are discussed. ■

Northern View

Charles Randell, Northern View, Canada
Session 4: Technological Considerations

In February 2003, the European Space Agency (ESA) awarded C-CORE of Newfoundland, Canada a contract to initiate Northern View as a Global Monitoring for Environment and Security (GMES) program. Stage 1 of the program is for 20 months with the goal of defining the public sector need for northern monitoring and information that exploits the many benefits of earth observation satellites. Earth observation is a near ideal tool in the northern context, readily providing information on the large inaccessible regions. This information supports monitoring and analysis of issues relating to the environment (e.g. climate change, pollution, biodiversity), security (e.g. human activity monitoring, disaster management, search and rescue), and sustainable development (e.g. resource exploration, site remediation, bio-productivity monitoring). It is ideally suited to provide either high or low-resolution ice information over many thousands of square kilometers in real time. The Northern View team has over 30 participants from six countries.

It is the long-term objective of the Northern View to become a sustainable, "one-stop-shop" for information required by government and other public agencies, shipping interests, indigenous peoples, and other northern stakeholders. In the short-term the goal is to provide northern information based at least in part on satellite surveillance. These information services currently include ship and iceberg detection, high-resolution ice type, concentration and thickness charts, glacier monitoring, and various other northern monitoring activities.

The program has continued to grow and is considered so successful that the plan for Stage 2 is to merge a compatible GMES program, ICEMON, with Northern View. The new proposed program is Polar View. Stage 2 will be for three years. Further information can be found at www.northernview.org. ■

Icebreakers Today and Trends for the Future

Karl-Heinz Rupp, Hamburg Ship Model Basin, Germany
Session 4: Technological Considerations

Developments over the past few decades concerning hull form and propulsion concepts for icebreakers are reviewed. The operating of icebreakers today for guiding other vessels and in particular for guiding much larger vessels in the future will present a challenge for icebreakers and for icebreaking tactics.

The increased use of icebreakers for a variety of new tasks will affect their design and will result in a larger work scope for these vessels in the future. Examples for such extended applications of icebreakers are for instance platform supply, standby with emergency rescue duties for offshore platforms, oil recovery and research. ■

Arctic Sea Ice Extent and Multiyear Sea Ice Changes

Stein Sandven and O. M. Johannessen, Nansen Environmental and Remote Sensing Center, Norway
Session 2: Arctic Climate and Sea Ice Considerations

The Arctic sea ice is predicted to change severely in the 21st century as a consequence of the global warming. Many human activities will be affected by a reduced ice cover such as ship transport, tourism, offshore operations, fisheries and living conditions for indigenous people in the north. Observing the Arctic sea ice area and extent has been done successfully for the last 2-3 decades using passive microwave satellite data. These data have shown a decrease of the total ice area of 3 – 4 % per decade. For multiyear ice, the reduction is more significant, about 7 – 8 % reduction per decade. Surface air temperature data, extending back to the beginning of the 20th century, shows that there was a significant warmer period in the 1920s – 1940s, followed by a colder period in 1950s – 1960s. Decadal variability's in the sea ice cover can only be detected in longer time series, but sea ice extent data for the whole century are more irregular and scattered and, therefore, less accurate than the passive microwave satellite data. Since observational data on Arctic sea ice is far from sufficient to estimate variability and trends of the ice volume, it is necessary to use coupled ice–ocean models to simulate sea ice variables on seasonal, decadal and century time scale. These models need to be validated against available data sets such as ice area from passive microwave data, ice thickness and ice motion from drifting buoys and satellite data. >

Prediction of the Arctic sea ice during this century has been done by several climate models such as the Bergen Climate Model, the ECHAM model and the Hadley Center's climate model. The model results indicate that the ice area in the summer will decrease significantly, while the winter sea ice will decrease less. The models also show that the ice thickness will be reduced during this century, but the rate of the reducing varies between the models. Several ice thickness data sets show more or less reduction of the ice thickness over the last few decades. The most dramatic changes indicated a 40 % reduction in thickness over the last four decades.

Operational monitoring of sea ice by satellites is an important part of the monitoring systems presently under implementation in the context of the Global Monitoring for Environment and Security (GMES) where a number of institutions from many countries are involved. One GMES project with a focus on sea ice is ICEMON, which is one of the ESA service consolidation actions in 2003 – 2004 (http://www.icemon.org). ICEMON is preparing for the implementation of a coherent network of monitoring services for the high latitudes, including sea ice, meteorological, oceanographic services (met-ocean services). ICEMON will serve operational users such as ships, offshore operators and others who need near real time information as well as climate users who need longer time series of measurements for monitoring and modeling of seasonal, interannual and decadal variability of sea ice and other met-ocean parameters. ■

Arctic Shipping Rules: the Climate is…. a-Changin'

Victor Santos-Pedro, Transport Canada, Canada
Session 5: International Cooperation & Marine Environmental Safety

It is always challenging to choose the timing for rule development. Often it is imposed by circumstances of accidents or industrial activity, and rarely the result of continuous renewal. The most recent Arctic shipping rules, originally know as the Polar Code, were sparked by a fortuitous coincidence of negative reactions to positive initiatives that eventually attracted attention and expertise from around the world. And now is the right time for implementation, before all of the ice melts.

The chronology of events is straightforward, the why and how it happened is more complex. Talking about the principles underlying each of the resultant products, the status of completion, and what is ahead may be best. The harmonization of standards is the fundamental pillar. An integrated approach based on best practices and precaution can produce comprehensive safety and environmental protection measures that also address economy, of effort and cost, and efficiency. How effective the rules are depends entirely on monitoring.

The IMO Guidelines for Ships Operating in Arctic Ice-covered Waters and the IACS Polar Ship Rules Unified Requirements for machinery and hull were introduced, as well as its respective components – construction, equipment, operations, including the Ice Navigator endorsement concept and the education of operators. Most importantly, the climate of acceptance for international rules predominates and leads to clear and understandable outcomes in terms of safety and environmental protection. ■

ICEMON

Ari Seina, Finnish Institute of Marine Research, Finland
Session 4: Technological Considerations

ICEMON (SAR ice monitoring for climate research, environmental management, resource exploitation and marine operation safety in Polar Regions) is a project under Stage 1 Service Consolidation Actions of the Earthwatch GMES services Element (GSE). Coordinated by the Nansen Environmental Remote Sensing Center (Norway), ICEMON has 18 partners from 16 countries, and links to EuroClim and IRIS projects.

Objectives of ICEMON, in the short term, is to demonstrate SAR ice monitoring in key areas of the Arctic Ocean and surrounding seas, delivering high-resolution products. This represents that a significant improvement of the quality of ice information in intermediate term sea ice products will gradually be integrated with meteorological and oceanographical products, including monitoring, hindcast and forecast products. EO products based on SAR and scatterometer data will be expanded to include ice thickness from CryoSat. The EO-based sea ice products will be used in modeling and data assimilation for improved forecasting services. A long-term objective of ICEMON is to deliver operational monitoring and forecasting services of met-ice-ocean conditions at high latitudes. It is envisaged that an integrated service network will be implemented offering atmospheric, sea ice and oceanographical information products.

For the next stage of GSE (2005-2008) there is a plan to merge ICEMON and Northern View projects into a single Polar View project, in which services should be fully operational in 2008. ■

Marine Trafficability Studies in the Alaskan Arctic

Richard Voelker, US Maritime Administration, USA
Session 1: Historical Perspectives

During the period 1979 to 1986, the U.S. Maritime Administration was the lead agency for a multiyear Arctic Marine Transportation Program. The primary objectives of the program were to: (1) assess the feasibility of year-round commercial marine operations in ice-covered waters of Alaska; (2) define the environmental conditions along potential Arctic marine routes; and, (3) improve icebreaking ship design criteria. These objectives were met as a result of the 15 voyages aboard the U.S. Coast Guard POLAR Class icebreakers in the Arctic and Antarctic. This paper describes the U.S. Arctic national policy at the time as well as the many participating government agencies, industrial organizations, and academic institutions in the program. Major achievements are highlighted, including a series of conclusions, which identify the most critical technology and skills needed in the future. Environmental, operational, and technical data from these voyages are contained in 58 technical reports that are available to the public. ■

Arctic Sea Ice Thickness Changes

Peter Wadhams, University of Cambridge, United Kingdom
Session 2: Arctic Climate and Sea Ice considerations

Major changes have occurred in Arctic Ocean ice and water structure over the pat two decades. The summer ice thickness over much of the Arctic Basin has declined by some 40% since the 1970s amounting to a reduction in mean thickness of 1-1.3 m with an accompanying reduction of some 73% in the frequency of deep pressure ridges. The pressure ridge reduction in particular indicates a radical change in ice dynamics, presumably associated with a change in phase of the Arctic Oscillation (AO). There is some evidence that the thinning slowed during the 1990s and it has been suggested that rarely visited parts of the Arctic such as the offshore region north of Greenland and the Canadian Archipelago may not share the general thinning. Satellite data has, however, shown a reduction in the area of perennial (multi-year) ice throughout the Arctic, while there has been a steady decline in the total area of Arctic ice since 1979, with some evidence of a recent acceleration.

The ice thinning has been accompanied by a warming of the Atlantic layer in the Arctic Ocean, a retreat of the cold halocline layer due to re-routing of Siberian river outflows and Bering Strait inflows, and a change in the pattern of atmospheric pressure over the Arctic and thus of ice dynamics. Atlantic layer warming and cold halocline retreat have been postulated as a direct cause of ice thinning via increased ocean heat flux. The change in pressure field and hence of ice and upper ocean circulation has been assigned to a change of phase of the AO, with the possibility suggested that global warming induces a persistent AO of a particular phase. Such a change inevitably alters the distribution of ice thickness and dynamics, and hence the ice flux through Fram Strait, particularly by affecting the trajectory of ice drift around the Arctic and hence the age and deformation history of ice reaching Fram Strait. Changes in the AO also affect the salinity of the upper water column through changes in freshwater storage by sea ice.

The ice and fresh water variability in the Fram Strait exit route couple in turn to Greenland Sea processes via the fresh melt water which spreads over the Greenland Sea in summer, capping long-lived convective features and creating a reserve of buoyancy which must be overcome the following winter before convection can recommence. In addition, that part of the Arctic outflow which continues through Denmark Strait is then able to influence convection in the Labrador Sea. Thus, the outflow of fresh water is in a position to affect two important high-latitude components of the Atlantic thermohaline circulation.

Another important implication of Arctic sea ice thinning was pointed out by Walter Munk in the form of a mismatch which it introduces into global estimates of sea level rise. Twentieth Century sea level rise has been estimated at 1.5-2 mm/yr with a steric component of 0.5 mm/yr. A global salinity census suggests a freshening rate equivalent to the addition of 650 km^3 of fresh water to the ocean per year. If this came from terrestrial runoff it would indeed yield the required 1-1.5 mm eustatic rise. Yet, the Arctic thinning rate alone adds some 600 km^3/yr without altering sea level. The implications are that sea level is rising at only the steric rate, and that run-off from the retreat of subpolar glaciers must be balanced by extraction of water elsewhere, e.g. from growth of the Antarctic ice sheet. These are serious consequences. >

A further paper refines these estimates and allows a small amount of land run-off but it is clear that, from the sea level point of view alone, a major effort needs to be made to reduce the uncertainties in our knowledge of sea ice thinning rates.

New observations of Arctic ice thickness, made during 2003-4, reflect a transition towards new types of measurement technique. There is still an emphasis on direct measurements from sonic techniques, but increasingly these are seen as validation methods for satellite methods which offer the attraction of synoptic coverage of the Arctic Ocean. The main need in ice mapping is to develop a satellite-based remote sensing technique which will enable ice thickness to be mapped synoptically. When combined with ice velocities which can already be mapped from satellites, it will then be possible to map ice fluxes throughout the Arctic Basin. I anticipate that a combination of existing sensor data (passive and active microwave) interpreted in new ways, and new sensors such as radar and laser altimeters, will provide a way forward towards this goal.

It is also vital that direct sonic measurements, from submarines, AUVs and moored sonar, be continued, as well as buoy measurements, so that any new satellite method can be subject to appropriate validation. ■

Polar Sea Route as a Global Infrastructure Project

Norio Yamamoto, Global Infrastructure Fund Research Foundation, Japan
Session 6: The Future of Arctic Marine Transport

In 1986 in Anchorage, Alaska, Governor Walter Hickel hosted the 1st Int'l Conference on the Global Infrastructure including the following the Arctic subjects:
- Bridge or tunnel over/under the Bering Strait
- Shipping the natural gas resources from the Arctic Sea area
- Road across and around the North Pole by making use of highly sophisticated freezing, sub-zero technology

The Global Infrastructure Fund Research Foundation Japan has been promoting global scale infrastructures for sustainable development, growth and peace since the middle of 1970s, making use of "peace dividend" and "conversion" of military technology for civil use in the form of massive "resource transfer" to the developing parts of the world. Multinational and global scale infrastructure projects totaling $10 Billion for sustainable growth in the following areas:
- Environmental improvement and preservation
- Transportation
- Energy and Natural Resources
- Habitat

Under the transportation category, GIF Japan is promoting projects such as the new Silk Road and the Northern Sea Route. GIF Japan expects Arctic maritime transportation will make the development of natural gas feasible in its use of nuclear-submarine type tankers. Recently, Russian organizations proposed transportation of heavy machinery manufactured in a naval shipyard facing the Arctic Sea through the Bering Strait to a project site of the ITER nuclear fusion machine, which is expected to be built in Japan. ■

Appendix D: Shipping Data for the Northern Sea Route

I. Annual Traffic on the Northern Sea Route 1933 - 2003 (thousand tonnes)

Year	Traffic	Year	Traffic
1933	130	1969	2621
1934	134	1970	2980
1935	176	1971	3032
1936	201	1972	3279
1937	187	1973	3599
1938	194	1974	3969
1939	237	1975	4075
1940	350	1976	4349
1941	(WWII) 165	1977	4553
1942	(WWII) 177	1978	4789
1943	(WWII) 289	1979	4792
1944	(WWII) 376	1980	4952
1945	(WWII) 444	1981	5005
1946	412	1982	5110
1947	316	1983	5445
1948	318	1984	5835
1949	362	1985	6181
1950	380	1986	6455
1951	434	1987	6579 (max)
1952	389	1988	6295
1953	506	1989	5823
1954	612	1990	5510
1955	677	1991	4804
1956	723	1992	3909
1957	787	1993	3016
1958	821	1994	2300
1959	888	1995	2362
1960	963	1996	1642
1961	1013	1997	1945
1962	1164	1998	1458
1963	1264	1999	1580
1964	1399	2000	1587
1965	1455	2001	1800
1966	1778	2002	1600
1967	1934	2003	1700
1968	2179		

Source: Vladimir Mikhailichenko, Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, Russia

II. Main Characteristics of Arctic Shipping During the Period 1985-2003

Year	Total Amount of Cargo	# Vessels	# Voyages
1985	6181	296	1115
1986	6455	312	1224
1987	6579	331	1306
1988	6295	296	1016
1989	5823	273	928
1990	5510	252	886
1991	4804	243	811
1992	3909	206	606
1993	3016	117	463
1994	2300	153	315
1995	2362	134	309
1996	1642	75	234
1997	1945	70	220
1998	1458	51	152
1999	1580	49	155
2000	1587	52	169
2001	1800	60	194
2002	1600	47	170
2003	1700	47	160

During the time of the most intensive navigation, certain vessels conducted up to five voyages within one navigation period.

Source: Vladimir Mikhailichenko, Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, Russia

III. Cargo Turnover of Arctic Ports (thousand tonnes)

Name of Port	Year of Maximum	Total/only Oil Products	2003 Total/only Oil Products
Amderma	1986	156/65	0.2/0.1
Dikson	1986	49/7	Approx. 3.0/0
Dudinka	1987	2583/102	1074/0
Igarka	1988	751/	54/
Khatanga	1987	271/63	113/10
Tiksi	1987	1044/200	38/28
Zeleniy Mys	1986	540/244	6/6
Pevek	1987	839/119	134/49
Mys Schmidta	1987	155/25	31/16

The Arctic ports, situated along the NSR have a certain potential for cargo handling.
Today however, the situation has drastically changed with a dramatic decrease in cargo amounts.

Source: Vladimir Mikhailichenko, Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, Russia

IV. Annual Transit Traffic: Along the Northern Sea Route (1991 - 1997)

	1991	1992	1993	1994	1995	1996	1997
# of Vessels	15	12	22	7	8	3	2
Traffic (1000 tonnes)	210	186	226	10	120	38	30

Main types of cargo from Europe to the Far East: Chemicals (potash salts; fertilizers; potassium chloride); rolled metal; and timber (Finland, Sweden-Japan)

Main types of cargo from the Far East to Europe: Processed agricultural goods (rice, soy beans, cake from China and Thailand); magnesite; and spar.

Source: Vladimir Mikhailichenko, Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, Russia

V. Preliminary assessment of marine Arctic cargo shipment for the period up to 2015 as estimated by Russian research institutes (thousand tonnes)

	Report Period	Preliminary Assessment					
		Variant I			Variant II		
	2003	2005	2010	2015	2005	2010	2015
Total along the NSR	1700	2340	4890	7810	3575	8620	11380
• only oil products	465	710	2515	4640	795	4635	5890

Variant I - pessimistic scenario / Variant II - optimistic scenario

Source: Vladimir Mikhailichenko, Noncommercial Partnership of the Coordination of the Northern Sea Route Usages, Russia

Appendix E: Marine Traffic in the Canadian Arctic

June – November 2004

Canadian Government Vessels	8	
Commercial Traffic		
Canadian Vessel Voyages	62	
Foreign Vessel Voyages	18	(14 to Churchill)
Foreign Cruise Ships	7	
Foreign Research Vessels	2	
Foreign Pleasure Craft	5	
	Total = 94	
Northwest Passage Transits		
Canadian Coast Guard	2	
Canadian Commercial Vessels	0	
Foreign Cargo Vessels	0	
Foreign Cruise Ships	1	
Foreign Pleasure Craft	2	
	Total = 5	
∑	**Total Voyages = 107**	

Note: Listing prepared from responses to the Canadian Coast Guard voluntary reporting system.

Source: Canadian Coast Guard

Appendix F: Transits of the Northwest Passage

Seven routes have been used for transits of the Northwest Passage between the Atlantic Ocean (Labrador Sea) and Pacific Ocean (Bering Sea) or in the opposite direction. Several minor variations have also been used (for example through Pond Inlet and Navy Board Inlet, Jones Sound, etc). These routes are:

Route 1: Labrador Sea, Davis Strait, Lancaster Sound, Barrow Strait, Viscount Melville Sound, McClure Strait, Beaufort Sea, Chukchi Sea, Bering Strait, Bering Sea.

The shortest and deepest, but most difficult way owing to the severe ice of McClure Strait; the route could be used by submarines because of its depth.

Route 2: Labrador Sea, Davis Strait, Lancaster Sound, Barrow Strait, Viscount Melville Sound, Prince of Wales Strait, Amundsen Gulf, Beaufort Sea, Chukchi Sea, Bering Strait, Bering Sea.

An easier variant of route 1 which may avoid severe ice in McClure Strait; suitable for deep draft vessels.

Route 3: Labrador Sea, Davis Strait, Lancaster Sound, Barrow Strait, Peel Sound, Franklin Strait, Victoria Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea, Chukchi Sea, Bering Strait, Bering Sea.

This is route used by most vessels of draft less than 10 m.

Route 4: Labrador Sea, Davis Strait, Lancaster Sound, Barrow Strait, Peel Sound, Rae Strait, Simpson Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea, Chukchi Sea, Bering Strait, Bering Sea.

A variant of route 3 for small vessels if ice from McClintock Channel has blocked Victoria Strait; Simpson Strait is only 6.4 m deep and has difficult currents.

Route 5: Labrador Sea, Davis Strait, Lancaster Sound, Prince Regent Inlet, Bellot Strait, Franklin Strait, Victoria Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea, Chukchi Sea, Bering Strait, Bering Sea.

This route is dependent on ice conditions in Bellot Strait which has difficult currents; mainly used by eastbound vessels.

Route 6: Labrador Sea, Davis Strait, Lancaster Sound, Prince Regent Inlet, Bellot Strait, Rae Strait, Simpson Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea, Chukchi Sea, Bering Strait, Bering Sea.

A variant of route 5 for small vessels if ice from McClintock Channel has blocked Victoria Strait, Simpson Strait is only 6.4 m deep, difficult currents run in Bellot and Simpson Straits.

Route 7: Labrador Sea, Hudson Strait, Foxe Basin, Fury and Hecla Strait, Bellot Strait, Franklin Strait, Victoria Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea, Chukchi Sea, Bering Strait, Bering Sea.

A difficult route owing to severe ice usually at the west of Fury and Hecla Strait and the currents of Bellot Strait. Transits of the Northwest Passage (continued)

Until the 2004-05, winter 99 complete transits of the Northwest Passage (Atlantic to Pacific waters or vice versa) have been made. Including these are 175 partial transits recorded through waters of the Canadian Arctic Archipelago. An analysis of these routes shows:

Complete transits of the Northwest Passage

Route 1	west	1	east	0	total	1
Route 2	west	7	east	3	total	10
Route 3	west	16	east	29	total	45
Route 4	west	6	east	5	total	11
Route 5	west	4	east	10	total	14
Route 6	west	3	east	10	total	13
Route 7	west	0	east	2	total	2
All Routes	west	37	east	62	total	99

Partial transits through the Canadian Arctic Archipelagos

Route 1	west	2	east	1	total	3
Route 2	west	10	east	6	total	16
Route 3	west	50	east	58	total	108
Route 4	west	6	east	6	total	12
Route 5	west	5	east	12	total	17
Route 6	west	3	east	10	total	13
Route 7	west	1	east	2	total	3
All Routes	west	77	east	98	total	175

Source: Robert Headland,
Scott Polar Research Institute, United Kingdom

Transits of the Northwest Passage

The following 99 voyages, by 67 vessels, carrying 17 different flags, have made complete transits of the Northwest Passage to September 2004. These transits proceed to or from the Atlantic Ocean (Labrador Sea) in or out of the eastern approaches of the Canadian Arctic archipelago (Lancaster Sound or Foxe Basin), then the western approaches (McClure Strait or Amundsen Gulf), across the Beaufort Sea and Chukchi Sea of the Arctic Ocean, from or to the Pacific Ocean (Bering Sea). The seven routes which have been used are indicated, with any significant variations listed. Some voyages are discontinuous because the complement left the vessel during a winter. Details of submarine transits are not included because only two of them (USS Seadragon in 1960 and USS Skate in 1962) have been reported and they do not navigate through ice.

The sources for these data include a compilation by Thomas Pullen and Charles Swithinbank published in 1991 (Cambridge: *Polar Record*, 27 [163]; 365-367), subsequent information from Brian McDonald (Canadian Coast Guard) who maintained and expanded the compilation (completing it for a Centenary Edition in 2003), details provided by Captains Patrick Toomey (CCG) and Lawson Brigham (USCG), some personal observations acquired during voyages aboard *Kapitan Khlebnikov* and *Kapitan Dranitsyn*, and many published works.

	Year	Vessel	Registry	Master	Route
1	1903-06	*Gjøa* (21 m auxiliary sloop)	Norway	Roald E. G. Amundsen	West 4
			Wintered twice in Gjøa Haven and once off King Point		
2	1940-42	*St Roch*[1] (29.7 m RCMP aux. schooner)	Canada[1]	Henry Asbjørn Larsen[1]	East 6
			Wintered at Walker Bay and Pasley Bay, traversed Pond Inlet		
3	1944	*St Roch*[2] (RCMP auxiliary schooner)	Canada[2]	Henry Asbjørn Larsen[2]	West 2
			Return voyage, first transit in one season, traversed Pond Inlet		
4	1954	HMCS *Labrador* (icebreaker)	Canada[3]	Owen Connor S. Robertson	West 2
			First continuous circumnavigation of North America		
5	1957	USCGC *Storis* (icebreaker)	United States[1]	Harold L. Wood	East 6
6	1957	USCGC *Bramble* (buoy tender)	United States[2]	H. H. Carter	East 6
7	1957	USCGC *Spar* (buoy tender)	United States[3]	C. V. Crewing	East 6
			USCGC *Storis* escorted convoy with *Bramble* and *Spar*		
8	1967	CCGS *John A. McDonald*	Canada[4]	Paul M. Fournier	West 3
			Dispatched to assist USCGC *Northwind* beset 900 km N off Point Barrow with damaged propeller, circumnavigated North America		
9	1969	USCGC *Staten Island* (icebreaker)	United States[4]	Eugene F. Walsh	East 3
			Escorted oil tanker *Manhattan* on return voyage from Point Barrow		
10	1970	CSS *Baffin* (research icebreaker)	Canada[5]	P. Brick	East 2
11	1970	CSS *Hudson*[1] (research icebreaker)	Canada[6]	David W. Butler	East 2
			First circumnavigation of the Americas		
12	1975	*Pandora II* (hydrographic research vessel)	Canada[7]	R. Dickinson	East 7
13	1975	*Theta* (research vessel)	Canada[8]	K. Maro	East 7
			Traveled in company		
14	1975	CSS *Skidgate* (buoy tender)	Canada[9]	Peter Kallis	East 6

	Year	Vessel	Registry	Master	Route
15	1976	CCGS *J. E. Bernier*[1] (icebreaker)	Canada[10]	Paul Pelland	East 3
16	1977	*Williwaw* (13 m sloop)	Netherlands	Willy de Roos	West 4
			Single-handed after Gjøa Haven, continued to circumnavigate the Americas		
17	1978	CCGS *Pierre Radisson* (icebreaker)	Canada[11]	Patrick M. R. Toomey	East 2
18	1976-79	*J. E. Bernier II* (10 m ketch)	Canada[12]	Réal Bouvier	West 4
			Wintered in Holsteinburg, Resolute, and Tuktoyaktuk		
19	1979	*Canmar Kigoriak* (icebreaker)	Canada[13]	C. Cunningham	West 2
20	1979	CCGS *Louis S. St Laurent* (icebreaker)	Canada[14]	George Burdock	West 2
			Circumnavigated North America		
21	1980	CCGS *J. E. Bernier*[2] (icebreaker)	Canada[15]	E. Chasse	East 4
22	1980	*Pandora II* (hydrographic survey vessel)	Canada[16]	R. A. Jones	East 4
23	1981	CSS *Hudson*[2] (research icebreaker)	Canada[17]	F. Mauger	East 3
24	1979-82	*Mermaid* (15 sloop)	Japan	Kenichi Horie	West 6
			First single-handed transit, wintered in Resolute and Tuktoyaktuk		
25	1983	*Arctic Shiko* (tug)	Canada[18]	S. Dool	East 3
26	1983	*Polar Circle* (research vessel)	Canada[19]	J. A. Strand	East 4
27	1983-88	*Belvedere* (18 m yacht)	United States[5]	John Bockstoce	East 6
			Reached Tuktoyaktuk 1983, conducted whaling research to 1987, completed transit in 1988, traversed Pond Inlet		
28	1983-90	*Ikaluk*[1] (icebreaker)	Canada[20]	R. Cormier[1]	East 3
			Reached Beaufort Sea in 1983, where worked to 1990 when completed transit		
29	1984	*Lindblad Explorer*[1] (ice strengthened ship)	Sweden	Hasse Nilsson	West 4
			First passenger[1] transit		
30	1982-85	*Vagabond II1* (23·1 m yacht)	France[1]	W. Jacobsen[1]	West 6
			Wintered in Arctic Bay, Gjøa Haven, and Tuktoyaktut, eastbound voyage made in 1986-88		
31	1985	USCGC *Polar Sea*[1] (icebreaker)	United States[6]	John T. Howell	West 2
			Accompanied by CCGS *John A. McDonald* for part of voyage		
32	1985	*World Discoverer* (ice-strengthened ship)	Singapore	Heinz Aye1	East 4
			Carried passengers[2], traversed Pond Inlet		
33	1976-88	*Canmar Explorer II* (drilling ship)	Canada[21]	Ronald Colby	West 3
			Reached Beaufort Sea for oil drilling program from 1976 until completed transit		
34	1986-88	*Vagabond II*[2] (23.1 m yacht)	France[2]	W. Jacobsen[2]	East 6
			Wintered twice in Gjøa Haven, westbound voyage made in 1982-85		
35	1986-89	*Mabel E. Holland* (12.8 m lifeboat)	Britain[1]	David Scott Cowper	West 6
			Single-handed voyage, discontinuous transit, wintered at Fort Ross twice, and at Inuvik		
36	1988	CCGS *Henry A. Larsen* (icebreaker)	Canada[22]	Stephen Gomes	East 3
37	1988	*Society Explorer*[2] (ice-strengthened ship)	Bahamas[1]	Heinz Aye[2]	East 3
			Carried passengers[3], traversed Pond Inlet [formerly *Lindblad Explorer*]		
38	1988	CCGS *Martha L. Black* (icebreaker)	Canada[23]	Robert Mellis	East 3

	Year	Vessel	Registry	Master	Route
39	1988	USCGC *Polar Star*[1] (icebreaker)	United States[7]	Paul A. Taylor	East 3
			Accompanied by CCGS *Sir John Franklin* to Demarcation Point		
40	1988-89	*Northanger* (15 m ketch)	Britain[2]	Richard Thomas	West 4
			Wintered in Inuvik		
41	1989	USCGC *Polar Star*[2] (icebreaker)	United States[8]	Robert Hammond	West 3
			Accompanied by CCGS *Sir John Franklin* to Demarcation Point		
42	1990	USCGC *Polar Sea*[2] (icebreaker)	United States[9]	Joseph J. McCleland	West 3
			Accompanied by CCGS *Pierre Radisson* to Demarcation Point		
43	1990	*Terry Fox* (icebreaker)	Canada[24]	P. Kimmerley	East 3
44	1991	*Canmar Tugger* (tug)	Canada[25]	L. Lorengeek	East 3
45	1992	*Frontier Spirit*[1] (ice-strengthened ship)	Bahamas[2]	Heinz Aye[3]	West 3
			Carried passengers[4], traversed Pond Inlet		
46	1992	*Ikaluk*[1] (icebreaker)	Canada[26]	R. Cormier[2]	West 3
47	1992	*Kapitan Khlebnikov*[1] (icebreaker)	Russia1	Piotr Golikov[1]	East 3
			Carried passengers[5]		
48	1993	*Kapitan Khlebnikov*[2] (icebreaker)	Russia[2]	Piotr Golikov[2]	East 3
			Carried passengers[6]		
49	1993	*Frontier Spirit*[2] (ice-strengthened ship)	Bahamas[3]	Heinz Aye[4]	West 3
			Carried passengers[7]		
50	1993	*Dagmar Aaen*[1] (27 m yacht)	Germany	Arved Fuchs	West 5
51	1994	*Kapitan Khlebnikov*[3] (icebreaker)	Russia[3]	Piotr Golikov[3]	East 3
52	1994	*Kapitan Khlebnikov*[4] (icebreaker)	Russia[4]	Piotr Golikov[4]	West 2
			Return voyage, carried passengers[8 & 9]		
53	1994	*Hanseatic*[1] (ice-strengthened ship)	Bahamas[4]	Hartwig van Harling[1]	West 3
			Carried passengers[10]		
54	1994	*Itasca* (converted tug)	Britain[3]	Allan Jouning	East 4
55	1995	*Kapitan Khlebnikov*[5] (icebreaker)	Russia[5]	Viktor Vasiliev[1]	East 5
			Carried passengers[11]		
56	1995	CCGS *Arctic Ivik*[1] (icebreaker)	Canada[27]	Norman Thomas	East 5
57	1995	CCGS *Arctic Ivik*[2] (icebreaker)	Canada[28]	Robert Mellis	West 5
			Return voyage to and from Kap York		
58	1995	*Canmar Ikaluk*[2] (icebreaker) [formerly Ikaluk]	Canada[29]	D. Connolly	East 3
59	1995	*Dove III* (8.2 m yacht)	Canada[30]	Winston Bushnell	East 3
			The smallest vessel to have completed the transit		
60	1995	*Canmar Miscaroo* (icebreaker)	Canada[31]	D. W. Harris	East 3
61	1995	*Hrvatska Cigra* [Croatian Tern] (19.8 m yacht)	Croatia	Mladan Sutej	West 5
62	1996	*Kapitan Dranitsyn*[1] (icebreaker)	Russia[6]	Oleg Agafonov	East 5
			Carried passengers[12]		

	Year	Vessel	Registry	Master	Route
63	1996	CCGS *Sir Wilfrid Laurier* (icebreaker)	Canada[32] Escorted by CCGS *Louis S. St Laurent* for part of voyage, traversed Pond Inlet	Norman Thomas	East 5
64	1996	*Hanseatic*[2] (ice-strengthened ship)	Bahamas[5] Carried passengers[13] until grounded in Simpson Strait, escorted by CCGS *Henry A. Larsen* to Victoria Strait, traversed Pond Inlet	Hartwig van Harling[2]	West 3
65	1996	*Canmar Supplier II* (cargo vessel)	Canada[33]	P. Dunderdale	East 3
66	1996	*Arctic Circle* (tug)	Canada[34]	J. McCormick	East 3
67	1997	*Hanseatic*[3] (ice-strengthened ship)	Bahamas[6] Carried passengers[14], escorted to Victoria Strait by CCGS *Henry A. Larsen*, traversed Pond Inlet	Heinz Aye[5]	West 3
68	1997	*Kapitan Khlebnikov*[6] (icebreaker)	Russia[7] Carried passengers[15]	Viktor Vasiliev[2]	East 3
69	1997	*Alex Gordon* (tug)	Canada[35] Escorted by CCGS *Sir Wilfred Laurier* to Franklin Strait and then CCGS *Pierre Radisson*	Paul Misata	East 5
70	1997	*Supplier* (tug)	Bahamas[7] Escorted by CCGS *Terry Fox* to Victoria Strait	Allan Guenter	East 5
71	1998	*Kapitan Khlebnikov*[7] (icebreaker)	Russia[8] Carried passengers[16]	Piotr Golikov[5]	East 3
72	1998	*Hanseatic*[3] (ice-strengthened ship)	Bahamas[8] Carried passengers[17], escorted to Victoria Strait by CCGS *Sir John Franklin*, traversed Pond Inlet	Heinz Aye[6]	East 3
73	1999	*Admiral Makarov* (icebreaker, dock in tow)	Russia[9]	Vadim Akholodenko	East 3
74	1999	*Irbis* (tug, dock in tow)	Russia[10] Travelled in convoy each towing a component of a steel floating dock, Korea to Carribean	Aleksandr Aleksenko	East 3
75	1999	*Kapitan Dranitsyn*[2] (icebreaker)	Russia[11] Carried passengers[18], circumnavigated the Arctic	Viktor Terekhov[1]	West 3
76	2000	USCGC *Healy*[1] (icebreaker)	United States[10]	Jeffery M. Garrett	West 3
77	2000	*Hanseatic*[4] (ice-strengthened ship)	Bahamas[9] Carried passengers[19], traversed Pond Inlet	Thilo Natke	West 3
78	2000	*Kapitan Dranitsyn*[3] (icebreaker)	Russia[12] Carried passengers[20], circumnavigated the Arctic	Viktor Terekhov[2]	West 3
79	2000	*Nadon [St Roch II]* (17.7 m RCMP catamaran)	Canada[36] Voyage to commemorate St Roch 1940-42 transit	Kenneth Burton	East 6
80	2000	*Simon Fraser* (icebreaker, formerly CCGS)	Canada[37] Escorted Nadon	Robert Mellis	East 6
81	2000	*Evohe* (25 m yacht)	New Zealand	Stephen Kafka	East 6
82	2001	*Kapitan Khlebnikov*[8] (icebreaker)	Russia[13]	Viktor Vasiliev[3]	East 3
83	2001	*Kapitan Khlebnikov*[9] (icebreaker)	Russia[14] Return voyage, carried passengers[21 & 22]	Viktor Vasiliev[4]	West 1
84	2001	*Turmoil* (46 m yacht)	Cayman Islands	Philip Walsh	West 4

	Year	Vessel	Registry	Master	Route
85	2001	*Northabout* (14.9m yacht)	Ireland (Eira)	Patick Barry	West 3
86	2001-02	*Le Nuage* (12.8 m yacht)	France[3]	Michèle Demai	East 3
			Complement of mother and daughter, wintered in Cambridge Bay		
87	2002	*Kapitan Khlebnikov*[10] (icebreaker)	Russia[15]	Piotr Golikov[6]	East 3
			Carried passengers[23]		
88	2002	*Sedna IV* (51 m yacht)	Canada[38]	Stéphan Guy	West 5
89	2002	*Apostol Andrey* (16.2 m yacht)	Russia[16]	Nikolay Litau	East 5
			Assisted by CCGS *Louis S. St Laurent* through Prince Regent Inlet, voyage previously made a transit of Northeast Passage		
90	2002	*Arctic Kalvik* (icebreaker tug)	Barbados	Sanjeev Kumar	East 3
91	2002	*Hanseatic*[6] (ice-strengthened ship)	Bahamas[10]	Thilo Natke	West 3
			Carried passengers[24], traversed Pond Inlet		
92	2003	*Kapitan Khlebnikov*[11] (icebreaker)	Russia[17]	Viktor Vasiliev[5]	East 5
93	2003	*Bremen*[3] (ice-strengthened ship)	Bahamas[11]	Daniel Fogner	West 3
			Carried passengers[25 & 26], *Bremen* [formerly *Frontier Spirit*] traversed Pond Inlet		
94	2003	*Norwegian Blue* (12.9 m yacht)	Britain[4]	Andrew Wood	East 5
95	2003	*Vagabond II*[3] (23.1 m yacht)	France[4]	Eric Brossier	East 5
			Both traversed Pond Inlet		
96	2003	*USCGC Healy*[2] (icebreaker)	United States[11]	Daniel Oliver	West 3
97	2003-04	*Polar Bound* (14.6 m motorboat)	Britain[5]	David Scott Cowper[2]	West 5
			Wintered in Cambridge Bay, assisted by CCGS *Louis S. St Laurent* for part of voyage, traversed Pond Inlet		
98	2003-04	*Dagmar Aaen*[2] (27 m yacht)	Germany[2]	Arved Fuchs[2]	West 5
			Wintered in Cambridge Bay, traversed Pond Inlet, previously made a transit of the Northeast Passage		
99	2004	*Kapitan Khlebnikov*[12] (icebreaker)	Russia[18]	Pavel Ankudinov	East 5
			Carried passengers[27]		

Prospects for completion after 2004

Year	Vessel	Registry	Master	Route
2003-0?	*Ocean Search* (12.5 m yacht)	France	Olivier Pitras	East
2003-0?	*Minke I* (12.8 m yacht)	Canada	Peter Brook	East
		Both vessels wintered in Cambridge Bay twice		
2003-0?	*Jotun Arctic* (13.4 m yacht)	Norway	Knut Espen Solberg	West
		Wintered in Godhavn and Arctic Bay, voyage to commemorate *Gjøa* 1903-06 transit		
2004-0?	*Fine Tolerance* (13.7 m yacht)	Australia	Philip Hogg	East
		Wintered in Cambridge Bay		

Source: Robert Headland, Scott Polar Research Institute, United Kingdom

Appendix G: Icebreakers that have Reached the North Pole

	Name	Master	Date arrived	Flag	Power
1	*Arktika*	Yuriy Kuchiyev	17 August 1977	Soviet Union[1]	Nuclear
2	*Sibir'*	Zigfrid Vibakh	25 May 1987	Soviet Union[2]	Nuclear
3	*Rossiya*	Anatoly Lamehov	8 August 1990	Soviet Union[3]	Nuclear
4	*Sovetskiy Soyuz*[1]	Anatoly Gorshkovskiy[1]	4 August 1991	Soviet Union[4]	Nuclear
5	*Oden*[1]	Anders Backman[1]	7 September 1991	Sweden[1]	Diesel
6	*Polarstern*[1]	Ernst-Peter Greve	7 September 1991	Germany[1]	Diesel
7	*Sovetskiy Soyuz*[2]	Anatoly Gorshkovskiy[2]	13 July 1992	Russia[5]	Nuclear
8	*Sovetskiy Soyuz*[3]	Anatoly Gorshkovskiy[3]	23 August 1992	Russia[6]	Nuclear
9	*Yamal*[1]	Andrey Smirnov[1]	21 July 1993	Russia[7]	Nuclear
10	*Yamal*[2]	Andrey Smirnov[2]	8 August 1993	Russia[8]	Nuclear
11	*Yamal*[3]	Andrey Smirnov[3]	30 August 1993	Russia[9]	Nuclear
12	*Yamal*[4]	Andrey Smirnov[4]	21 July 1994	Russia[10]	Nuclear
13	*Kapitan Dranitsyn*	Viktor Terekhov[5]	21 July 1994	Russia[11]	Diesel
14	*Yamal*[5]	Andrey Smirnov[6]	5 August 1994	Russia[12]	Nuclear
15	*Yamal*[6]	Andrey Smirnov[7]	21 August 1994	Russia[13]	Nuclear
16	*Louis S. St Laurent*	Philip Grandy	22 August 1994	Canada	Diesel
17	*Polar Sea*	Lawson Brigham	22 August 1994	United States[1]	Diesel/Gas Turbine
18	*Yamal*[7]	Andrey Smirnov[8]	12 July 1995	Russia[14]	Nuclear
19	*Yamal*[8]	Andrey Smirnov[9]	28 July 1995	Russia[15]	Nuclear
20	*Yamal*[9]	Andrey Smirnov[10]	12 July 1996	Russia[16]	Nuclear
21	*Yamal*[10]	Andrey Smirnov[11]	27 July 1996	Russia[17]	Nuclear
22	*Yamal*[11]	Andrey Smirnov[12]	14 August 1996	Russia[18]	Nuclear
23	*Oden*[2]	Anders Backman[2]	10 September 1996	Sweden[2]	Diesel
24	*Sovetskiy Soyuz*[4]	Stanislav Shmidt[1]	12 July 1997	Russia[19]	Nuclear
25	*Sovetskiy Soyuz*[5]	Stanislav Shmidt[2]	25 July 1997	Russia[20]	Nuclear
26	*Sovetskiy Soyuz*[6]	Yevgeniy Bannikov[1]	10 July 1998	Russia[21]	Nuclear
27	*Sovetskiy Soyuz*[7]	Yevgeniy Bannikov[2]	23 July 1998	Russia[22]	Nuclear
28	*Yamal*[12]	Stanislav Rumantsev[1]	25 July 1999	Russia[23]	Nuclear
29	*Yamal*[13]	Aleksandr Lembrik[1]	29 July 2000	Russia[24]	Nuclear
30	*Yamal1*[4]	Aleksandr Lembrik[2]	11 August 2000	Russia[25]	Nuclear
31	*Yamal*[15]	Aleksandr Lembrik[3]	12 July 2001	Russia[26]	Nuclear
32	*Yamal*[16]	Aleksandr Lembrik[4]	24 July 2001	Russia[27]	Nuclear
33	*Oden*[3]	Mats Johansen	31 July 2001	Sweden[3]	Diesel
34	*Yamal*[17]	Aleksandr Lembrik[5]	5 August 2001	Russia[28]	Nuclear
35	*Yamal*[18]	Aleksandr Lembrik[6]	23 August 2001	Russia[29]	Nuclear
36	*Healy*	David Vizneski	6 September 2001	United States[2]	Diesel
37	*Polarstern*[2]	Jurgen Keil	6 September 2001	Germany[2]	Diesel
38	*Yamal*[19]	Aleksandr Lembrik[7]	11 July 2002	Russia[30]	Nuclear
39	*Yamal*[20]	Aleksandr Lembrik[8]	21 July 2002	Russia[31]	Nuclear
40	*Yamal*[21]	Aleksandr Lembrik[9]	12 August 2002	Russia[32]	Nuclear
41	*Yamal*[22]	Aleksandr Lembrik[10]	25 August 2002	Russia[33]	Nuclear
42	*Yamal2*[3]	Stanislav Rumantsev[2]	25 July 2003	Russia[34]	Nuclear
43	*Yamal*[24]	Stanislav Rumantsev[3]	10 August 2003	Russia[35]	Nuclear
44	*Yamal*[25]	Stanislav Rumantsev[4]	24 August 2003	Russia[36]	Nuclear
45	*Yamal*[26]	Aleksandr Lembrik[11]	8 July 2004	Russia[37]	Nuclear
46	*Yamal*[27]	Aleksandr Lembrik[12]	21 July 2004	Russia[38]	Nuclear
47	*Yamal*[28]	Aleksandr Lembrik[13]	8 August 2004	Russia[39]	Nuclear
48	*Yamal*[29]	Aleksandr Lembrik[14]	28 August 2004	Russia[40]	Nuclear
49	*Sovetskiy Soyuz*[8]	Stanislav Shmidt[3]	7 September 2004	Russia[41]	Nuclear
50	*Oden*[4]	Tomas Årnellon	7 September 2004	Sweden[4]	Diesel
51	*Vidar Viking*	Jörgen Haave	7 September 2004	Norway	Diesel[11]
52	*Yamal*[30]	Aleksandr Lembrik[15]	11 September 2004	Russia[42]	Nuclear[41]

Source: Robert Headland, Scott Polar Research Institute, United Kingdom

Appendix H: Arctic Climate Impact Assessment

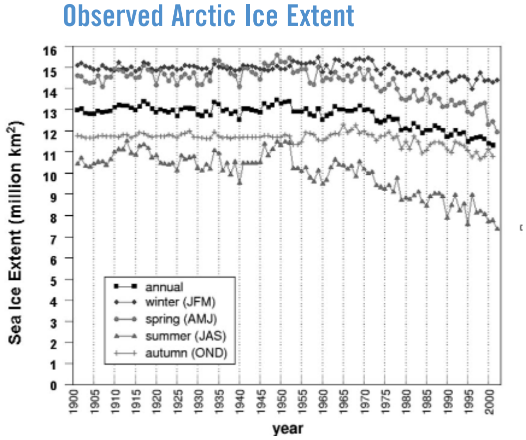
The Arctic Climate Impact Assessment (ACIA) released in November 2004 (following the Cambridge workshop) was called for by the Arctic Council and the International Arctic Science Committee. ACIA found that the Arctic is extremely vulnerable to observed and projected climate change and its impacts. The Arctic is now experiencing some of the most rapid and severe climate change on earth. During the 21st Century, climate change is expected to accelerate, contributing to major physical, ecological, social, and economic changes, many of which have already begun. Changes in Arctic climate will also affect the rest of the planet through increased global warming and rising sea levels.

ACIA documented that declining Arctic sea ice is a key climate change indicator. During the past five decades the observed extent of Arctic sea ice has declined in all seasons, with the most prominent retreat in summer. Each of the five Global Climate Models (GCMs) used in ACIA project a continuous decline in Arctic sea ice coverage throughout the 21st Century. One of the models projects an ice-free Arctic Ocean in summer by 2050, a future scenario of great significance for Arctic marine shipping since multi-year ice would essentially disappear in the Arctic Ocean (all the next winter's sea ice would be first-year). GCM projections to 2100 suggest that Arctic sea ice in summer will retreat further and further away from most Arctic coasts, potentially increasing marine access and extending the season of navigation in nearly all Arctic regional seas.

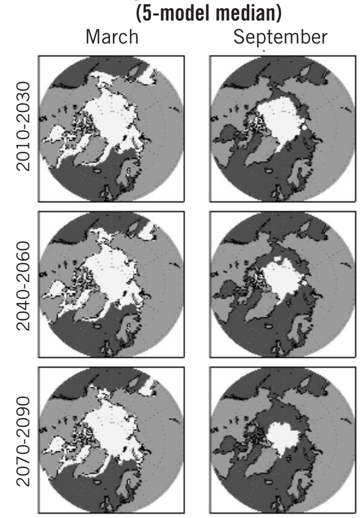
One limitation of the GCMs is that they are not useful at determining the state of sea ice in the Northwest Passage region. Their resolution is much too coarse to be applied to the narrow straits and sounds of the Canadian Arctic Archipelago. In ACIA the only reliable observed data comes from the Canadian Ice Service and this information, archived since the late 1960s, shows a mean negative trend of sea ice coverage in the Canadian Arctic Archipelago but very high inter-annual variability. The ACIA models, however, could be applied to the more open coastal seas of the Russian Arctic. ACIA sea ice projections for Russia's Northern Sea Route indicate an increasing length of the navigation season throughout the 21st century.

In summary, ACIA confirms that the observed retreat of Arctic sea ice is a real phenomenon. The GCM projections to 2100 show extensive open water areas in summer around the Arctic Basin. Thus, it is highly plausible there will be increasing regional marine access in all the Arctic coast seas. However, the projections show only a modest decrease in winter Arctic sea ice coverage; there will always be an ice-covered Arctic Ocean in winter although the ice may be thinner and may contain less multiyear ice. The very high, inter-annual variability of observed sea ice in the Northwest Passage and non-applicability of the GCMs to the region, prevent an adequate assessment of this complex region. Although the ACIA projections indicate an increasing length of the navigation season for the Northern Sea Route, detailed quantification of this changing marine access is testing the limitations of today's GCMs. There is a definite need for improved Arctic regional models to adequately assess future changes in sea ice and their considerable implications for the expanded marine uses of the Arctic Ocean. Go to www.acia.uaf.edu for more information.

Observed Arctic Ice Extent



Projected Ice Extent
(5-model median)



Appendix I: Arctic Council's Arctic Marine Strategic Plan

The Arctic Council's Arctic Marine Strategic Plan is designed to foster a healthy and productive Arctic Ocean and coasts that support environmental, economic and socio-cultural values for current and future generations.

The Strategic Plan addresses emerging issues, such as oil and gas and shipping activities, employing a risk assessment approach. It takes into account the special needs and requirements of indigenous communities while maintaining an objective of sustainable development of the Arctic marine environment.

The Plan aims to improve how the Arctic coastal and marine environment is managed, particularly given the accelerated changes occurring in the North due to climate change and increasing economic activity. The Plan reflects the four goals the Arctic Council has for the marine environment:

- Reduce and prevent pollution in the Arctic marine environment
- Conserve Arctic marine biodiversity and ecosystem functions
- Promote the health and prosperity of all Arctic inhabitants
- Advance sustainable Arctic marine resource use.

The Plan relies on the existing structures and mechanisms of the Arctic Council and other bodies for its implementation. Some examples of key strategic actions include:

- Conduct a comprehensive assessment of Arctic marine shipping at current and projected levels.
- Improve capabilities for responding to marine emergency situations, including those resulting from climate variability.
- Promote World Summit on Sustainable Development actions related to the marine and coastal environment, including the application of an ecosystem approach and establishment of marine protected areas, including representative networks.
- Identify elements that can serve as key environmental and socio-economic indications of the state of the Arctic marine ecosystems and thus guide effective decision-making.
- Foster partnerships among governments, indigenous peoples organizations, communities, industry, international bodies, NGOs and academia to advance the goals of this Plan, employing such mechanisms as partnership conferences and workshops.
- Promote oceans education through appropriate instructions and organizations such as the University of the Arctic; encouraging training related to best operating practices.
- Promote a marine and coastal component in the International Polar Year program.

The Arctic Marine Strategic Plan was approved by the Arctic ministers in November 2004.

Appendix J: A Vision for the Arctic

By the Honorable Walter J. Hickel, Former U.S. Secretary of Interior, Twice Governor, State of Alaska
30 September 2004, The Arctic Marine Transport Workshop

I would like to begin by thanking all of you for attending this historic gathering. And I would like to specifically thank my Russian friends. I believe this meeting at Scott Polar is the beginning of something great and new in the world. The day of the Arctic has come.

To many who live in the temperate climates "down there, looking up," the high latitudes are remote, hostile and as mysterious as the moon. We look foreign and strange. Most people avoid and even fear our part of the world. But those of us who live in the Arctic and sub-Arctic see the world differently. We don't look up. We don't look down. We look around. To us, the Arctic is home. The Arctic is heritage. The Arctic is our here-and-now and our hereafter. Many in generations past moved north to make a killing and leave. But a new generation is on the scene with a new vision. This new generation lives in and loves the North because we believe it can be a model for a better world.

In October 1988 the world watched helplessly as two Gray Whales off the northern coast of Alaska fought for survival. The ice pack had trapped them miles from freedom. Only a small hole in the ice, kept open by Eskimo whalers, allowed them to breathe. The whalers and the best engineers in Alaska worked for weeks, but they couldn't figure out how to save the whales. Then, an act of mercy took place --- an act that represented the true spirit of the North. A Russian icebreaker arrived, unannounced.

Without hesitation, it plowed a highway through the thick ice and freed the whales. No other nation had such technology . . . nor did some of us even know it existed. There was no fanfare from the Russians. The captain of the icebreaker held no press conference and attended no champagne receptions. He just freed the whales and sailed home. And the man responsible is here today! Captain Mikhailichenko. It was a symbol of things to come.

Those nations closest to the pole – and they are all represented here: Canada, Russia, Scandinavia, Iceland and the U.S. – have a unique opportunity. The development of the Arctic can become one more arena for international jealousy and conflict. Or it can become an example of how the nations of this globe are meant to live and work together.

This vision came into focus in 1991 just two years after the Ice Curtain melted that had divided the Russian Far East from Alaska. That year the governors of 14 regional governments met in Anchorage and launched the Northern Forum. We demonstrated the reality that remains today. We hold no animosities. We dare to communicate. We dare to make friends. We dare to learn from each other and help each other. We dare to think beyond the stereotypes that pit environment versus development and people versus nature.

Drawing on the wisdom of our past, we understand that the total environment stands on three legs – people, people's needs and nature. If we ignore even one leg, the system will lose its balance and crash. We cannot ignore or abuse nature. We cannot ignore or abuse people. As our indigenous ancestors learned long ago, in a cold, harsh environment, you have to care about others. You waste nothing. You share to survive. You care for the total. Every hunter's prize is a gift, not just for that hunter, but for his family and village.

Throughout the world, this sense of shared responsibility must be mobilized, as we address the needs of the environment and development. Pollution knows no borders. All rives eventually run into a common sea. All living things breathe the common air. We must share our concern and our knowledge. Fundamentally it is a collective world, but one in which we live so privately.

Without concern for other people, for their needs and wants, activities for strictly private gain become destructive, not only to others but eventually to oneself. In the Far North, we observe that nothing changes the environment as much as nature. Man is not always the culprit . . . as some would have us believe. We see it in our volcanoes, our earthquakes, and our rivers, most of which don't run blue. They run rich with the colors of a changing earth. In the North, we do not fear change.

We understand that when civilizations are not allowed to grow, the harvest is revolution. Without pointing fingers, it is obvious that the world is involved in such a struggle today.

What can people of goodwill do?

There is no simple answer. But we in the North are providing a counter-vision for the world. In St. Petersburg last year, President Olafur Grimsson of Iceland described that vision by calling it "The New North." And he isn't the only national leader to see the picture. On April 28 of this year, President Vladimir Putin traveled to the Russian Arctic and met with northern Russian leaders. At the end of that session, Putin gave a speech, so important that it should have gone 'round the world. He called for "improvement in the living standard of the millions of people" who live in the Far North. He spoke of the preservation of the cultures of our Native peoples . . . through the renewal of the economic and legal foundation of traditional forms of land ownership. What we in Alaska call "the commons" – the lands owned in common that are meant to benefit the total.

Today's northerners are determined to improve our quality of life. This we can do, because Nature blessed us with great natural riches. But there is no wealth without production. Someone has to catch a fish, dig a hole, cut a tree. But we of the North must and will insist that production is environmentally responsible.

And it must benefit the residents of our resource-rich lands . . . not just local Insiders, Outside interests, and international corporations. Yes, production is the key, and the key to production is infrastructure…infrastructure that moves people, their goods and their ideas.

Four years ago the Institute of the North, the host of this workshop, initiated the Circumpolar Infrastructure Task Force, an ambitious project that was later endorsed by both the Northern Forum and the Arctic Council. CITF teams are evaluating links throughout the Arctic for telecommunications, aviation, and marine transportation. They are studying where these links are needed and how to make them sustainable.

The Cold War forced northern transportation infrastructure to run North-South. Now is the time to think East-West.

In the realm of telecommunications, many Arctic communities are isolated, preventing bright young people from entering the global marketplace.

But we have a different vision.

Throughout the North, we see a "connected Arctic." We are studying how remote communities can join the flow of ideas that now encircle the world instantaneously. When it comes to air travel, east-west air routes have been slow in coming.

But we have a different vision.

Air connections are being studied, mapped and explored, along with improved air safety.

But perhaps the most exciting possibility has been the focus of this historic Workshop - - - maritime commerce. Most of the ships that carry global east-west cargo still sail south and funnel through the Panama and Suez Canals.

But we have a different vision.

The Northern Sea Route, as we have heard at this workshop, has been pioneered by the Russian people over the past 100 years. This project, alone, can change the world. I call it the water highway to the future. It will dramatically shorten shipping time from the U.K. and Western Europe to Tokyo and the U.S. West Coast. This pioneering venture, long imagined by visionaries of the past, will provide more benefits for the North than any other project . . . ever. It will do for the world what the Panama Canal did for the Atlantic and the Pacific. Think of the time and resources it will save. And the commerce it generates has the potential to improve the quality of life of those who live along the route. It will open a new frontier in Russia and help bring young people back to the North.

The main obstacle is economic competition. I have discovered over the years that large business interests are slow to change. In the early 1900s, West Coast shippers fought against the construction of the Panama Canal. They were accustomed to shipping around the southern tip of South America and wanted it to stay that way. Today there are interests that oppose the Northern Sea Route because they are accustomed to shipping through the Panama Canal. It's time to crack through that thinking with action . . . action as bold as that Russian icebreaker that saved the whales.

It's tragic irony that in many parts of the world there are millions of hungry and poor people living on rich land. That's why I often talk about the Northern Commons.

Alaska's great success began when we convinced our federal government to share the benefits of our commons with our people. When we achieve this goal throughout the Arctic and sub-Arctic, there will be no legitimate reason for poverty in the North. And, if we care for our common lands and resources properly, we will pioneer a way of life that far surpasses both unbridled capitalism and failed communism. As you know, to build a pioneering country, it takes more than studies and speeches. And it takes more than money. It takes belief.

To build a new world, you have to literally BUILD it. The source of the funding will come from our resources. Many of our regions are beginning to do just that. Excellent examples in Russia are the Sakha Republic and Khanty-Mansyisk. These two regions are what I call the "Owner State" in action. The benefits from the resources of these regions can be seen in the architecture of the cities and the spirit of the people.

I have written a book about this Owner State model. Next week in Moscow, Progress Publishing will release a Russian edition. It is my testament to the new frontier of our time. And I hope it helps the current generation of leaders and inspires Russia's scholars and thinkers. In Alaska, we've seen the benefits.

In just a few decades, the Alaska people have risen out of poverty. We have improved our communities. We have created a $27 billion Permanent Fund. And we have done it within a democratic system, a free enterprise economy, and as champions of the environment. And yet, unlike the rest of America, Alaska's development has been accomplished from "the commons." Regions with like problems should work together - - - not just nations with political ties. This is the way of the North.

As President Putin said in April, "the Russian north is our huge common wealth. It is our common property and will also serve our grandchildren and our great grandchildren."

In the U.S., Alaska is often called the "Last Frontier." Well, I disagree. Having just celebrated my 85th birthday, I have never believed more strongly than I do today that there will be frontiers as long as there are humans. Every child born is given new frontiers to explore. God's way to test us is to give us our own frontiers. The frontiers are in the heart and in the mind. Yes, the days of pioneering have just begun. That's a vision for the Arctic, and it lies within our grasp. There are those who always think about why great ideas won't work. And there are those who say "Let's make them happen."

I feel the "make it happen" spirit here. And that spirit can change the world. Thank you.

DEDICATED TO
DR. TERENCE E. ARMSTRONG
7 APRIL 1920 – 21 FEBRUARY 1996
FOR HIS CONTRIBUTIONS TO THE CIRCUMPOLAR ARCTIC
SPANNING FIVE DECADES

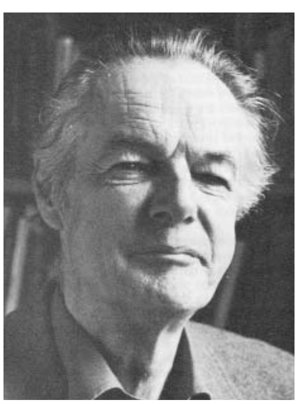
THE ARCTIC MARINE TRANSPORT WORKSHOP
SCOTT POLAR RESEARCH INSTITUTE
UNIVERSITY OF CAMBRIDGE
28 – 30 SEPTEMBER 2004

SPONSORED BY:

INSTITUTE OF THE NORTH, SECRETARIAT OF THE
CIRCUMPOLAR INFRASTRUCTURE TASK FORCE

UNITED STATES ARCTIC RESEARCH COMMISSION

INTERNATIONAL ARCTIC SCIENCE COMMITTEE



The Arctic Marine Transport Workshop of 2004 was held at Scott Polar Research Institute, Cambridge University, to honor the memory of Dr. Terence E. Armstrong (1920-1996), noted post World War II Arctic scholar. Terence Armstrong, admired and respected throughout the polar world, spent his academic career at Scott Polar and many of the workshop participants were his colleagues. Among his many areas of research, Arctic marine transport was perhaps closest to his heart. He wrote seminal works on the Northern Sea Route, sea ice, Russian Arctic development, and geography of the Circumpolar North. He established many 'bridges' with Soviet and Russian scholars during an era where interaction did not come easily, if at all. He assembled the Institute's extensive and unmatched Russian Arctic collection. Together with other northern scholars, Terence worked tirelessly to enhance the education of Arctic and sub-Arctic indigenous peoples. Throughout their lives, Terence and his wife, Iris, were generous hosts to legions of polar scholars who ventured to Cambridge. Terence would have enjoyed and would have been a touch astonished at the historic gathering of Arctic marine transport experts at Scott Polar in September 2004.

Guided by his legacy and celebrating his life's work, we presented this plaque to Scott Polar Research Institute in honor of Terence Armstrong, one of the leading Arctic scholars of the 20th Century. We remember him fondly and with great respect.

- Lawson Brigham, Co-chair

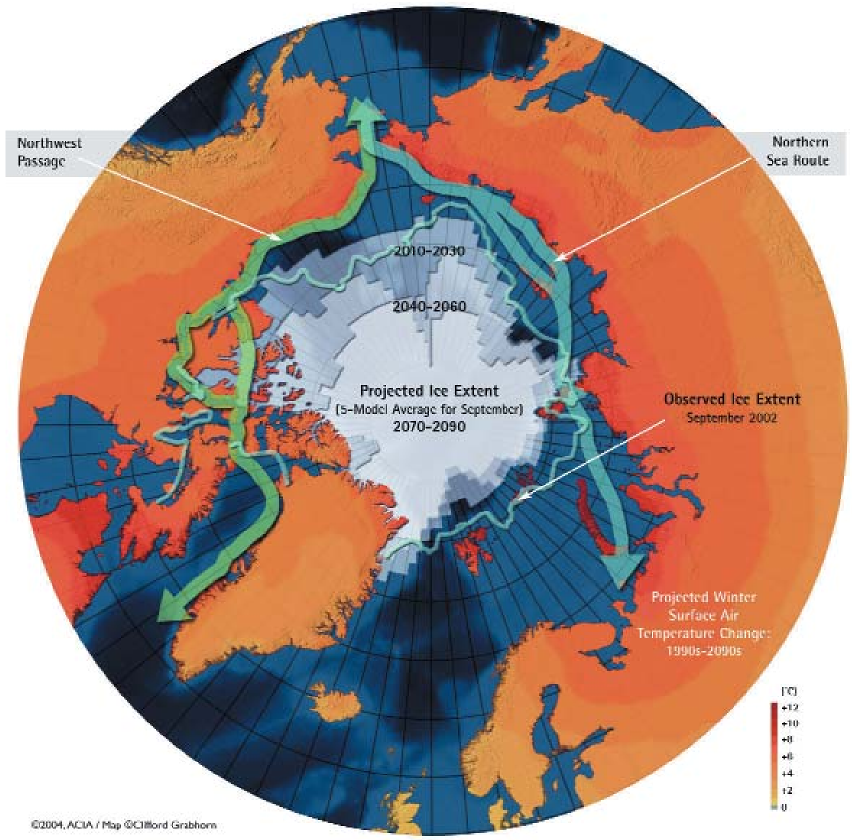
Arctic Marine Transport Workshop Participants

Held at Scott Polar Research Institute
Cambridge University
United Kingdom
28-30 September 2004

Arctic Climate Impact Assessment

Key Finding #6

"Reduced sea ice is very likely to increase marine transport and access to resources."



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