Impact of Climate Change on Naval Operations in the Arctic

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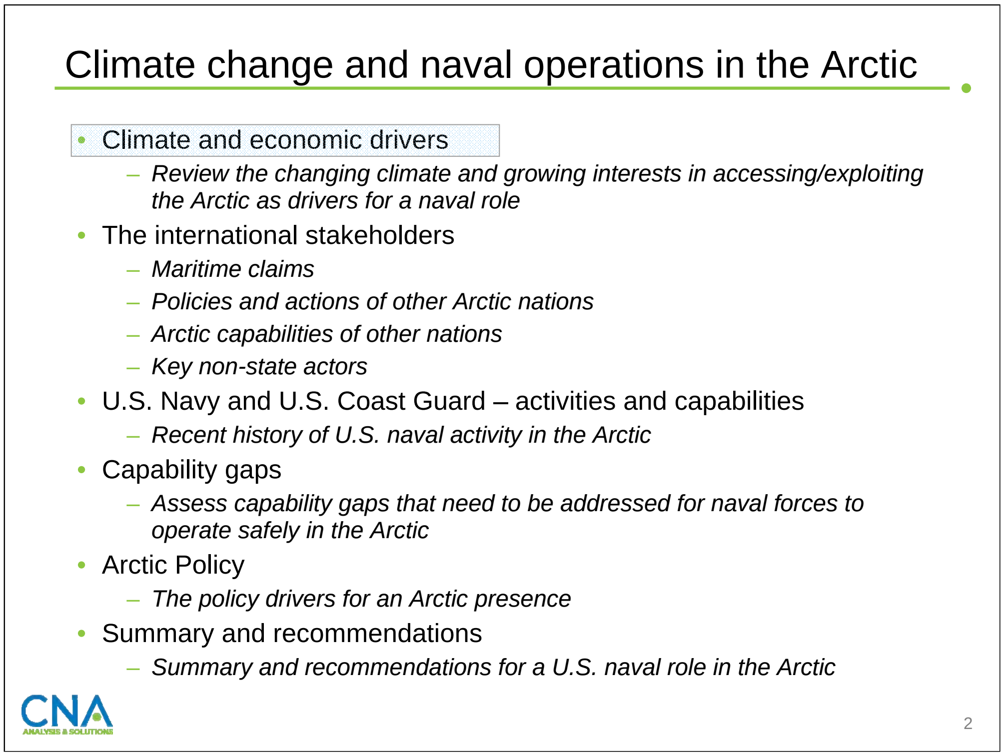
In August 2007, Russia demonstrated its intent to establish a robust presence in the Arctic by planting a flag on the seabed at the North Pole in seeming validation of its territorial claims under the United Nations Convention on the Law of the Sea (UNCLOS). Around the same time, satellite images revealed a substantial reduction in Arctic ice cover as compared to previous years. By late August 2007, the Northwest Passage was ice free for the first time since satellite record-keeping began in 1978. A year later, both the Northwest Passage and Northern Sea Route were simultaneously free of ice for the first time in recorded history.

Scientists now believe that a continued trend in climate change could lead to essentially ice-free summers in the Arctic Ocean within perhaps as few as 25 years. Based on recent observed changes, it is being speculated that the Arctic, long a quiet backwater, may become an area of strategic competition and a crossroads of economic activity. Impacts of climatic change may include easier access to oil and gas supplies, new fisheries in the Beaufort or Chukchi Sea, increased tourism and commercial activity, and increased traffic through the Barents Strait.

CNA was asked to review the changing situation in the Arctic and to assess the operational implications for the Navy of the potential increase in maritime activity. The study was requested by N812 to support the 2010 Quadrennial Defense Review (QDR).



Here is the outline of this briefing. We provide:

- An overview of the changing Arctic climate and the growing interest in accessing the Arctic
- An overview of what other Arctic nations are doing in regard to the Arctic
- A brief history of U.S. Coast Guard and Navy activities and their response to a changing Arctic
- An assessment of capability gaps in vessel structure, C2, and navigation that would need to be addressed if naval forces are assigned to operate in the Arctic
- An identification of naval roles and missions in the Arctic based on current strategic guidance, including the National Security Presidential Directive (NSPD)/Homeland Security Presidential Directive (HSPD) on Arctic policy
- Recommendations regarding a potential Navy role in the Arctic and opportunities to partner with the U.S. Coast Guard and Canada in areas of mutual interest.

We will introduce some the larger sections with an overview of findings drawn from the more detailed slides that follow. An appendix with selected ice nomenclature is provided on the final pages of this document.

Summary – climate and economic drivers

- The pace of Arctic opening is uncertain – but many expect largely ice-free summers between 2030 and 2060
  - *However, the Arctic will remain ice covered and hazardous in winter, and shipping seasons may be extended by little more than 2 months in 20 years*
- It is unlikely we'll see big increases in transits by cargo ships within 20 years
  - *Despite the potential distances saved – a limited shipping season, lack of facilities, schedule risks, ice hazards, and costs weigh against Arctic transits*
- However, some expansion of traffic related to resource extraction, local supply needs, and summer tourism does seem possible in the near future
  - *Waters above Alaska are already accessible by mid-August and into September*
  - *Interest in offshore oil and gas is heating up, and cruise traffic is growing*
- With the possibility of offshore drilling, cruise traffic, and fisheries eventually moving north – issues of SAR, ship safety, oil spills, enforcement, and maritime awareness are the drivers for an expanded presence
  - *These are issues that call for a Coast Guard presence*

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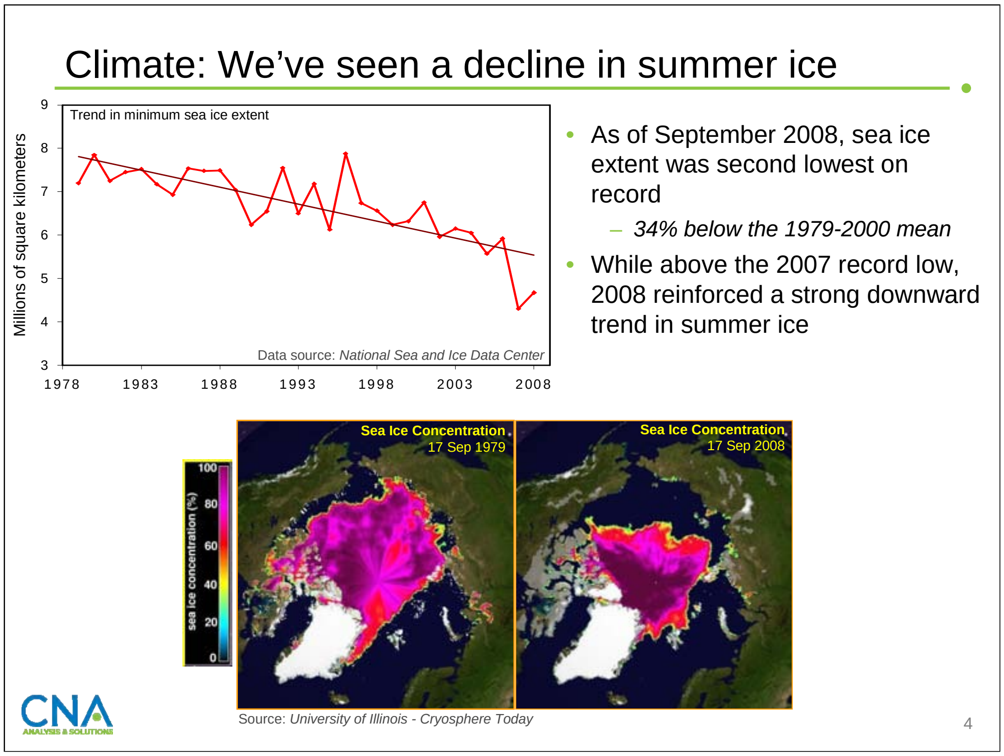
While the pace of the Arctic opening is uncertain, many scientists now expect summers to be largely free of ice by mid century. However, even with an ice-free summer, the Arctic will remain ice covered and hazardous for much of year. The commercial shipping season will be extended by little more than 2 to 3 months—to perhaps a 4-month season above Alaska.

To a degree, the likelihood of increases in maritime traffic in the Arctic Ocean by mid-century has been oversold. On one hand, with the limited shipping season, lack of support facilities, continuing ice hazards, and schedule uncertainties, it is unlikely we will see substantial increases in cargo transit across the Arctic within the next 20 years—despite the potential distance saved on intercontinental routes. On the other hand, there will almost certainly be some expansion in destination traffic related to local supply needs, resource extraction, and tourism in the near future. Indeed, the waters above Alaska are already accessible by mid-August into September and cruise traffic is growing.

Because of the possibility of increased offshore drilling, cruise ships, and fisheries eventually moving north, issues of ship safety, search and rescue (SAR), oil spills, fisheries enforcement, and maritime awareness become the immediate drivers for an expanded presence. These are issues that call primarily for a Coast Guard presence.



We are already seeing a decline in the extent of summer ice, with a decrease of 11.3 percent per decade in summer ice since 1979.

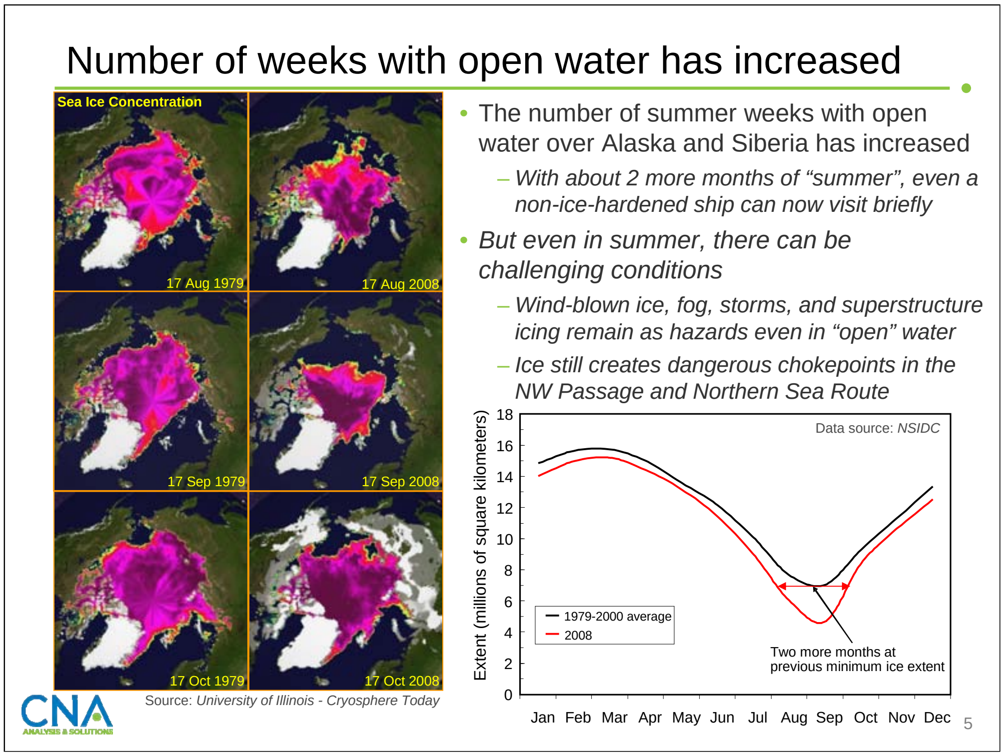
In September 2008, sea ice extent was the second lowest on record, making open-water transit of both the Northwest Passage and Northern Sea Route briefly possible for the first time in recorded history. While above the record-low minimum set in 2007, the 2008 season reinforced the strong negative trend in summertime sea ice extent.[1,2]

We have seen:

- 2007 minimum 39 percent below the 1979-2000 mean
- 2008 minimum 34 percent below the 1979-2000 mean
- 2005 as the third lowest extent on record.

The trend appears to coincide with a general increase in Arctic-wide, annually averaged surface air temperature, which began around 1970.

1. Images of sea ice are from the University of Illinois, Cryosphere Today web site *(http://igloo.atmos.uiuc.edu /cgi-bin/test/print.sh*).
2. Data on monthly sea ice extent are from the National Snow and Ice Data Center *(http://nsidc.org/data/ seaice_index/archives/index.html*).

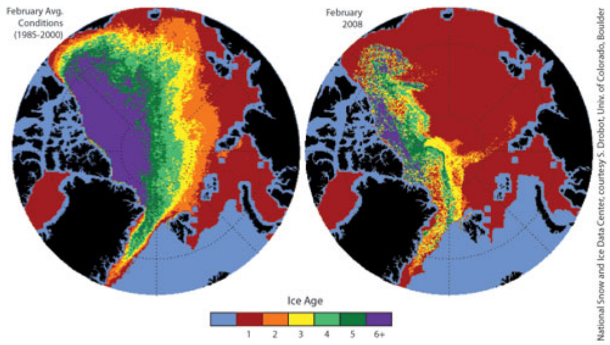


With the decline in summer ice extent, the number of weeks with navigable open water has increased, making the Arctic more accessible to maritime traffic.

Overall, we have seen an expansion of the summer season by about 2 months relative to what was typical in 1979 through 2000. The reduced areal extent of sea ice has made it possible even for ships that are not ice-hardened to briefly and cautiously visit the open waters above Alaska in September. (Open water means less than 10 percent ice cover.) Suitably strengthened ships could be present from mid-August into October and might even venture—slowly and carefully—into areas of ice with less than 60 percent cover.

Even in summer, however, a ship can face dangerous risks. There is the possibility of being trapped by wind-blown ice and the threat of superstructure icing. There may be rough seas, and fog often limits visibility. Furthermore, ice still creates dangerous chokepoints in the Northwest Passage and along the Northern Sea Route, making easy transit across the Arctic Ocean plausible now for at best a month.

Ice cover is thinning



- The ice is thinning
  - *The extent of perennial sea ice has declined from over 50% of winter ice cover in the mid-1980s to less than 30% in 2008*
  - *A larger area of the winter Arctic is now covered by first-year ice (neither as hard nor thick as older ice)*
  - *There's an estimated 34% decrease in annual mean ice thickness since 1980*
  - *However, even first-year ice can be more than a meter thick by February*
- As a result, volume of ice is declining faster than areal extent
  - *Ice volume may have set a record low in the summer of 2008*

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The ice cover is thinning. In the past, a large area of ice survived the summer melt. Now, more of the winter Arctic is covered by first-year ice. Ice that does survive more than a year (perennial ice) is usually both thicker and harder than first-year ice. While first-year ice might reach 1.5 meters in thickness, multiyear ice usually averages over 3 meters in thickness.

The figure shows the February 2008 ice pack by age—as compared with the 1985-2000 average. Red areas correspond to first-year ice. As a percentage of total sea ice cover, perennial ice has declined from over 50 percent of cover in the 1980s to less than 30 percent in 2008.[1,2]

While the average thickness of the overall ice cover is intrinsically difficult to monitor, data from submarine-based observations suggest that average annual thickness of ice cover declined from 3.7 meters in 1980 to 2.5 meters in 2000, a decrease of over 1.2 meters.[3] Helicopter-borne and ice-based electromagnetic measurements indicate a reduction of sea ice thickness in the region of the North Pole by about 50 percent, from 2001 to 2007.[4] With the thinning, ice volume has declined faster than areal extent. As a result, the volume of ice is believed to have hit a record low in the summer of 2008.[5]

The thinning of Arctic ice suggests at least an increasing possibility of traffic by ice-hardened ships in the colder months, but even the first-year ice can be dangerous. It can be over a meter thick by the end of winter, and winds can create massive ridges and keels that are almost impassable.

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1. NASA. "Researchers Say Arctic Sea Ice Still at Risk Despite Cold Winter," Mar 18, 2008 *(http://www.nasa.gov/topics/earth/features/seaice_conditions_feature.html)*.

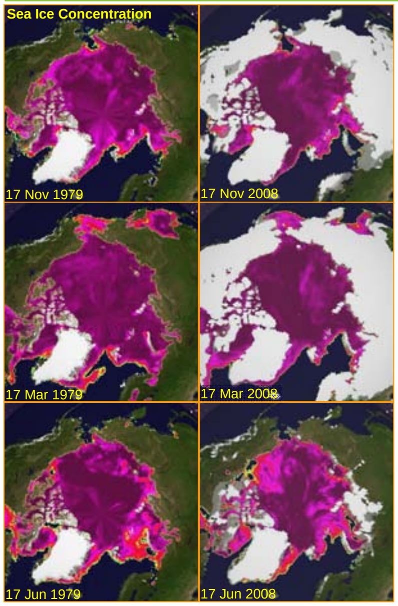
2. NOAA, Arctic Report Card 2008 *(http://www.arctic.noaa.gov/reportcard/seaice.html)*.

3. D. Rothrock, D. Percival, and M. Wensnahan, 2008. "The Decline in Arctic Sea-Ice Thickness: Separating the Spatial, Annual, and Interannual Variability in a Quarter Century of Submarine Data." *J. Geophys. Res*., 113.

4. C. Haas, 2004. "Late-Summer Sea Ice Thickness Variability in the Arctic Transpolar Drift 1991–2001 Derived From Ground-Based Electromagnetic Sounding." *Geophys. Res. Lett.*, 31.

5. NSIDC. "Arctic Sea Ice Down to Second-Lowest Extent; Likely Record-Low Volume" *(http://nsidc.org/news/press/20081002_seaice_pressrelease.html)*.

But the Arctic still remains challenging in winter



Source: *University of Illinois - Cryosphere Today*

- There has been only a modest downward trend in the extent of winter ice
  - *The 2008 maximum ice extent was only 3.4% below the 1979-2000 mean*
  - *The Arctic above North America is still almost completely ice covered from November through June*
- Winter conditions remain dangerous for shipping – with long nights, extreme cold, and heavy ice

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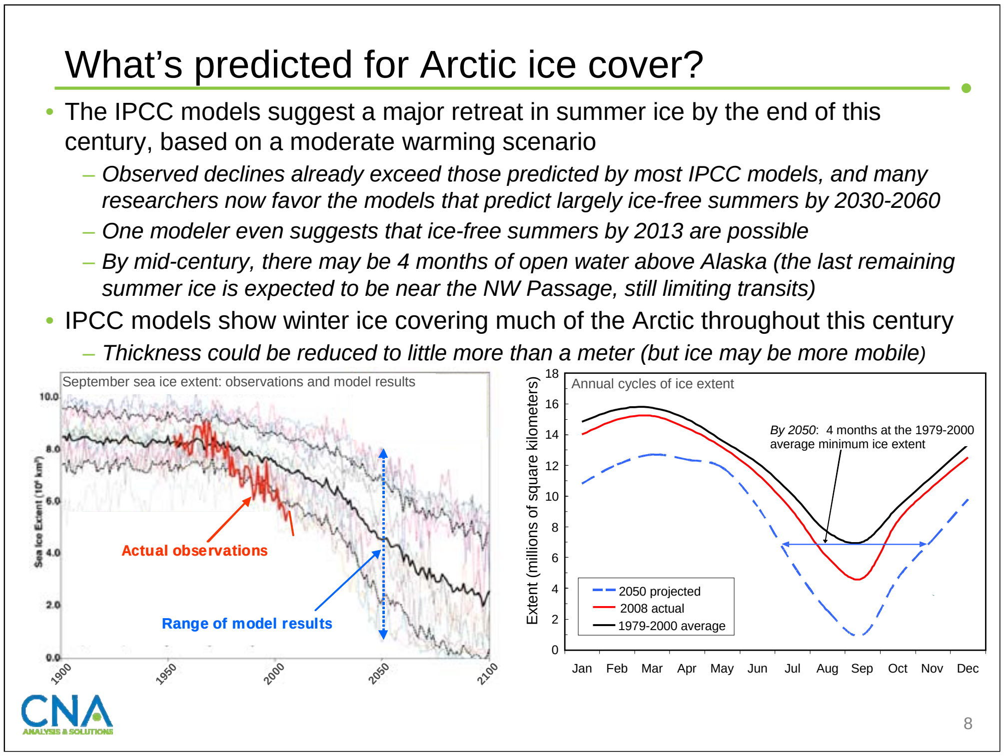
Despite the decline in summer ice, the Arctic remains ice covered and inaccessible to commercial shipping most of the year. There is still winter to deal with.

In contrast to the steep decline in summer ice, there has been only a modest decline in winter ice extent. The 2008 maximum ice extent was just 3.4 percent below the average for 1979 through 2000. Above North America, the Arctic is still almost completely ice covered from November through June.

The winter conditions remain challenging for commercial shipping, with long nights, extreme cold, and ice more than a meter thick covering the waters above North America. An extensive belt of fast ice limits access to the coast. The winter Arctic is accessible only to heavy icebreakers—and they find little reason to be there at this time of year.



There is considerable uncertainty in projections of future ice cover. The important message is that all but a few models predict enormous sea-ice retreat within a century, and many respected models predict nearly ice-free summers by mid-century, with retreat likely to be punctuated by rapid events.

The Intergovernmental Panel on Climate Change (IPCC) is the intergovernmental scientific body tasked with evaluating the risk of climate change. The 2007 IPCC report suggests a major retreat in the Arctic ice within 100 years (based on moderate increases in CO2 and temperatures).[1] Observed declines in ice cover already exceed those predicted by most IPCC models, and many researchers now favor the subset models that predicted a more rapid decline. Researchers have screened the models used by IPCC to remove those that did poorly in simulating past observations.[2,3,4] Model runs from the remaining set depict ice-free summers between 2040 to 2060. Some scientists think it likely that summers will be ice free even earlier—with many predicting 2030.[5] Others suggest even earlier dates, with modelers from the Naval Postgraduate School predicting ice-free summers by 2013.[6]

We show a projected annual cycle of ice cover. (These projections are based on a simple linear extrapolation of current monthly trends; they correspond well to the more aggressive IPCC model results for March and September.) Overall, the projections suggest about 4 months of ice-free water above Alaska by 2050 and about 2.5 months with no more ice than was observed during the 2008 minimum ice extent—during which time open transit of both the Northwest Passage and Northern Sea Route was briefly possible. The last remaining summer ice is expected to be along the Canadian archipelago, and that may tend to hinder transit of Northwest Passage for many years to come.

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1. IPCC, 2007. *Climate Change 2007 - The Physical Science Basis*, Cambridge University Press.

2. M. Wang et al., 2007. "Intrinsic Versus Forced Variability in Coupled Climate Model Simulations Over the Arctic During the Twentieth Century," *Journal of Climate*, 20.

3. M. Holland, et al., 2006. "Future Abrupt Reductions in the Summer Arctic Sea Ice," *Geophys. Res. Let*, 12.

4. J. Stroeve, et al., 2007. "Arctic Sea Ice Decline: Faster Than Forecast," *Geophy Res. Let.*, 34.

5. NSIDC, "Arctic Sea Ice Shatters All Previous Record Lows," 1 Oct 2007 *(http://nsidc.org/news/press /2007_seaiceminimum/20071001_ pressrelease.pdf).*

6. J. Whelan et al., 2007. "Understanding Recent Variability in the Arctic Sea Ice Thickness and Volume -Synthesis of Model Results and Observations," *American Geophysical Union Meetings*, Dec 2007.

Shipping: NW Passage will remain challenging

- There is a false sense of optimism regarding future ease of shipping in the NWP
  - *This is a remote area with little infrastructure and many risks.*
  - *The direct route though McClure Strait is always ice-choked. It may remain so, as multiyear ice drifts in from above.*
  - *The southern route by Victoria Strait has shallow drafts (10 meters) that limit ship size. It can also be choked with windblown ice.*

- Regular commercial transits of the NWP from Asia to Europe seem unlikely
  - *Short seasons, unpredictable hazards, schedule uncertainties, limited infrastructure, insurance, cost of ice hardening, and likely compromises in ship size and speed*
  - *The Northern Sea Route (NSR) from Asia to Europe is shorter (London-Tokyo is 8,000 miles by NSR; 9,950 by NWP; 13,000 by Suez Canal).*
  - *A pure polar route may ultimately be the most appealing.*
- Modest growth in destination shipping related to local supply needs, tourism, and resource extraction seems more likely

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Predictions of an ice-free Arctic summer by the middle of this century have led to a false sense of optimism regarding the ease of shipping in the Canadian Arctic. Even during periods of minimum ice cover, McClure Strait is usually heavily choked with old ice, making access to this desirable deepwater northern route almost impossible. The more frequently used Southern route can have windblown ice into August. A report by Canadian Ice Service researchers suggests that the future melting may actually allow increased amounts of older ice to drift into the Northwest Passage (NWP), continuing the development of chokepoints and creating significant hazards to navigation.[1] Also a concern is that the more accessible Southern route is among the most difficult to navigate in the Arctic, with numerous islands, reefs, and shoals. With drafts of just 10 meters, it is too shallow for large ships.[2]

One of the greatest challenges facing the Northwest Passage is its remoteness. The Canadian Arctic communities are small villages, offering virtually no infrastructure to support vessel traffic.[3,4] Only two anchorages are capable of berthing large vessels (Little Cornwallis Island and Nanisivik). There are virtually no repair facilities and no guarantee of adequate rescue response. Any needs for fuel and provisions would have to be met before entry into the Arctic. Navigation requires care. While the primary routes are fairly well covered, there are sporadic soundings in most areas, and chart positions can be off by hundreds of feet.

Overall, the practicality of using the NWP for intercontinental transit seems doubtful. Not the least of the issues is that a route over Russia offers greater distance savings for Asia-to-Europe traffic.

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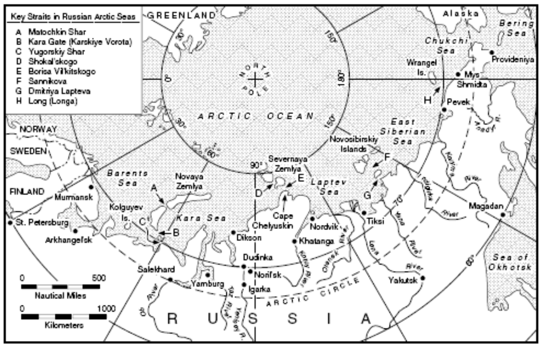
1. K. Wilson et al. 2004. “Shipping in the Canadian Arctic: Other Possible Climate Change Scenarios,” Canadian Ice Service.
2. D. Pharand and L. Legault. *International Straits of the World, The Northwest Passage: Arctic Straits*, Martinue Nijhoff Publishers, 1984.
3. Martec Polar. “Ice Navigation in the Northwest Passage,” presented at Ocean Innovation 2005, Quebec.
4. E. Stewart et al. “Sea Ice in Canada’s Arctic: Implications for Cruise Tourism,” *Arctic*, Vol. 60, No. 4, Dec 2007.

The Northern Sea Route may also be challenging



Source: US Army Corps of Engineers, CRREL, *Northern Sea Route and Icebreaking Technology*

- NSR transits are now rare due to ice, shallow drafts, uncertainties, fees
  - *Severnaya Zemlya passages have challenging ice. Narrow icebreaker channels limit ship size.*
  - *Novosibirskiy Islands passages have shallow drafts (6.7 and 12.5 meters).*
  - *Infrastructure and icebreaker support degraded since Soviet era. Many ports now support only shallow draft vessels.*
  - *Mandatory fees – pilot and icebreaker*
  - *Peak traffic was in late 1980s*
  - *Only one cargo transit since 1997*
- Although NSR seems more likely to be used than NWP, transit by commercial traffic is expected to be limited for many years
  - *NSR does offer distance savings over the NWP route and better infrastructure*
  - *However, the short season, schedule uncertainties, continuing ice hazards, limited services, high operational costs, and lack of transparency in fees will continue to limit use*
  - *Wildcards are the continued development of double-acting ships and the possibility of eventual passage to the north of the island straits*

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The Northern Sea Route (NSR) includes the maritime routes from the Kara Sea to the Bering Strait. The Soviet Union devoted significant resources to developing its northern frontier. Seaports, icebreakers, navigation aids, communications, and piloting expertise were developed. Since the end of the Soviet era, subsidies and investments have declined and traffic in eastern sections of the route has declined dramatically. Peak traffic was in the late 1980s. Still, although infrastructure on the NSR has degraded, it remains better than is found in the North American Arctic. [1,2,3]

This route presents considerable challenges due to sea ice and limited draft. Prevailing winds and currents can create ice massifs near island passages. An icebreaker escort is usually required in the Vil'kitskiy, Dmitry Laptev, Sannikov, and Shokalskiy Straits. Shallow depths and narrow icebreaker channels in key locations effectively limit the size of ships on the route. The Sannikova and Dmitrya Lapteva Straits are 13 and 7 meters deep, respectively. A route to the north of these island straits has no such depth limitations but is not reliably navigable due to ice.[2,3]

Due to draft limitations and channel widths, ships using the NSR may have less than 25 percent of the cargo capacity of ships using the conventional Suez Canal route—making the economics doubtful.[4,5] Mandatory fees for icebreaker support (whether necessary or provided) further discourage traffic. In fact, there have been no ordinary commercial transits of the NSR by foreign cargo ships since the passage was opened to world traffic in 1991 and only one full transit by a Russian ship since 1997.

Of interest is the continued development of double-acting ships—large ships with bows designed for normal speeds and with sterns capable of breaking through ice. But, even such ships would find the full route difficult to use for more than 6 months a year. Since intercontinental shipping depends on economies of scale and predictable schedules, it is doubtful that Arctic routes will meet the needs within the near future. The possibility of open passage to the north of the island straits might eventually change that equation.

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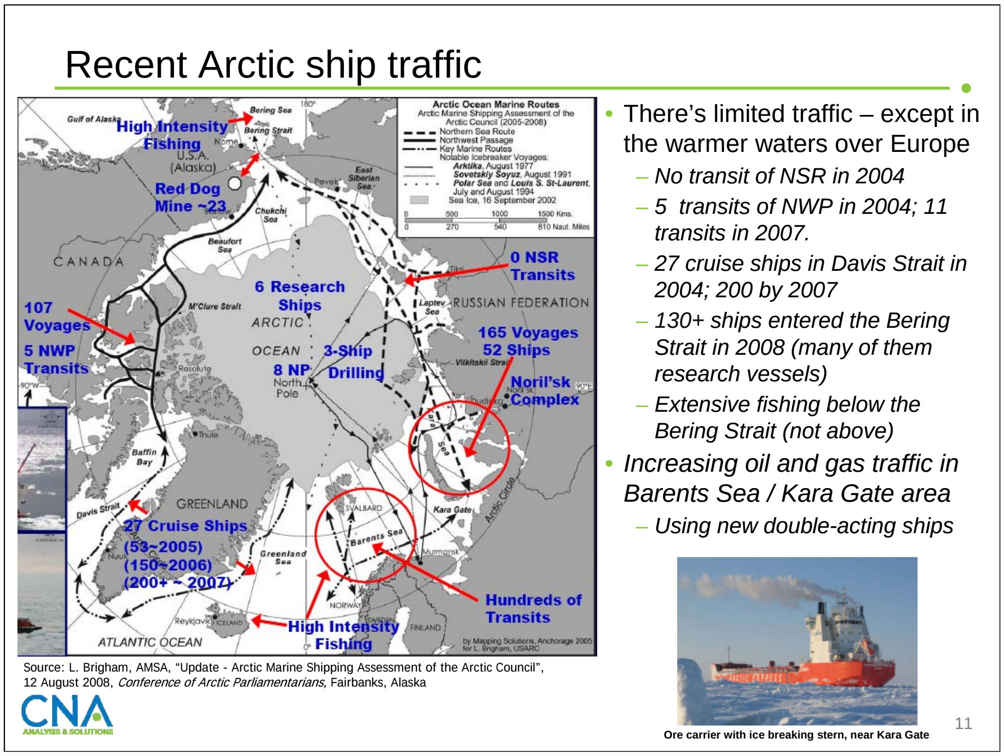
1. Institute of the North and U.S. Arctic Reseach Commission (2004), *Arctic Marine Transport Workshop.*

2. C. Ragner. “The Northern Sea Route” *(http://www.fni.no/doc&pdf/clr-norden-nsr-en.pdf).*

3. N. Mulherin et al. (1996) *The Northern Sea Route. Its Development and Evolving State of Operations in the 1990s*, U.S. Army Corps of Engineers CRREL Report 96-3.

4. INSROP. *The Northern Sea Route User Conference*, Nov 1999, Oslo *(http://www.fni.no/insrop/execsum.htm).*

5. INSROP. *International Northern Sea Route Programme*, “INSROP Overview” *(http://www.fni.no/insrop/).*



In November 2004, the Arctic Council—an intergovernmental forum founded to address sustainable development and environmental protection in the Arctic—requested an assessment of current and projected future Arctic shipping. The Arctic Marine Shipping Assessment (AMSA) was established to conduct that analysis.

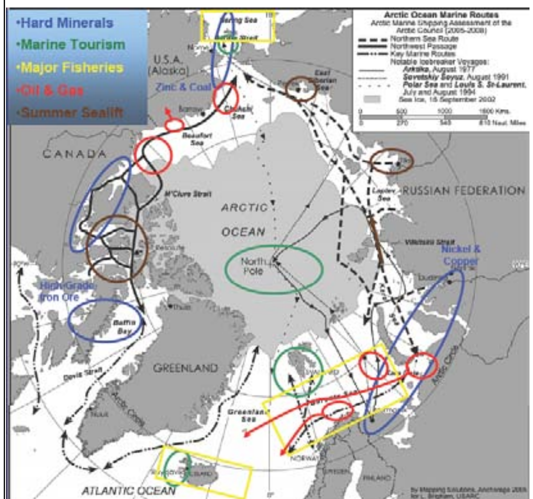
Presented here is a snapshot of Arctic traffic created by AMSA.[1] Since data on Arctic shipping activity are not made available in any systematic manner, these are estimates based on surveys and other informal sources. The conclusions follow:

- Most shipping occurs outside the areas with extended winter ice cover.
- There is minimal trans-Arctic traffic; most shipping is destinational.
- Approximately 60 percent of vessel activity is composed of fishing vessels.
- Arctic tourism and cruise traffic is increasing.

Most of the governmental presence in the ice-covered Arctic is related to scientific research, including bathymetry surveys.

1. L. Brigham, AMSA. "Update - Arctic Marine Shipping Assessment of the Arctic Council," *Conference of Arctic Parliamentarians*, 12 Aug 2008, Fairbanks, Alaska.

Potential drivers of growth in commercial traffic



Source: L. Brigham, AMSA, "Update - Arctic Marine Shipping Assessment of the Arctic Council", 12 August 2008, *Conference of Arctic Parliamentarians,* Fairbanks, Alaska

- Oil and gas, tourism, and mineral extraction are expected to be primary drivers for increased Arctic traffic
  - *2008 USGS appraisal estimates 22% of undiscovered oil and gas is in the Arctic (84% offshore, most Russian and U.S.)*
  - *But offshore activity above Alaska is currently restricted by law suits*
- Eventual expansion of commercial fisheries above Alaska is under study
  - *It's currently not allowed. Possibility of illegal fishing is already a concern*
- Little likelihood of substantial growth in cargo transit across the Arctic
  - *But local supply traffic may increase as the waters open*
- Search and rescue, fisheries enforcement, and oil spills seem to be the primary concerns raised by the potential growth in traffic
  - *USCG mission for foreseeable future*

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This figure (from AMSA presentations) shows some of the potential drivers for growth in commercial traffic in the Arctic.[1] It is most likely that increases in traffic will come from destinational traffic related to offshore drilling, mining, tourism, local supply, and fisheries that may eventually move north.

A 2008 U.S. Geological Survey (USGS) Arctic resource appraisal estimates that 22 percent of the world's undiscovered, recoverable oil and gas is in the Arctic. Both Canada and the United States have recently awarded leases for offshore exploration.

In 2007, a European cruise ship showed up unexpectedly in Barrow, Alaska. That event was followed 2 months later by the sinking of a cruise ship in Antarctica, raising Coast Guard concerns over what might happen if such an accident were to occur above Alaska.

Commercial fishing is not currently allowed above the Bering Strait. Fisheries may be established once an assessment of sustainable yield is completed. The possibility of illegal fishing is a concern.

The potential traffic raises serious issues as to our preparedness to deal with search and rescue, oil spills, and law enforcement. These are U.S. Coast Guard missions for the foreseeable future. There may be opportunities to harmonize safety and environmental planning between Arctic nations.

1. L. Brigham, AMSA. "Update - Arctic Marine Shipping Assessment of the Arctic Council," *Conference of Arctic Parliamentarians,* 12 Aug 2008, Fairbanks, Alaska.

Climate change and naval operations in the Arctic

- Climate and economic drivers
  - *Review the changing climate and growing interests in accessing/exploiting the Arctic as drivers for a naval role*
- The international stakeholders
  - *UNCLOS and maritime claims*
  - *Policies and actions of other Arctic nations*
  - *Arctic capabilities of other nations*
  - *Key non-state actors*
- U.S. Navy and U.S. Coast Guard – activities and capabilities
  - *Recent history of U.S. naval activity in the Arctic*
- Capability gaps
  - *Assess capability gaps that need to be addressed for naval forces to operate safely in the Arctic*
- New Arctic Policy
  - *Policy drivers for an Arctic presence*
- Summary and recommendations
  - *Summary and recommendations for a U.S. naval role in the Arctic*

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Summary – international stakeholders

- Arctic countries are beginning to assert maritime claims and sovereignty
  - *Interest in offshore resources is driving efforts to establish claims to the extended continental shelf under UNCLOS*
  - *Canada plans new sovereignty patrols and Arctic bases*
  - *Russia has expanded its air patrols*
- There are tensions and concerns
  - *A few disagreements over EEZ boundaries; more may arise over extended claims*
  - *Somewhat provocative Russian activities – many involving Norway*
  - *Canada's assertion that Northwest Passage is not an international strait*
- Overall, the likelihood of actions that seriously disturb stability seems low
  - *Arctic nations met at a 2008 summit aimed at easing tensions over territorial claims*
  - *Russia has significant commercial opportunities and much to lose from uncertainty*
  - *There is no obvious current threat to our Arctic borders*

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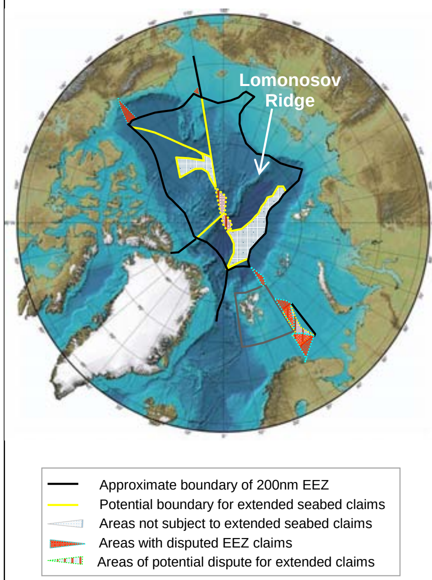
Driven by changing climate, oil and gas resources, and concerns over increased shipping traffic, nations are beginning to assert their maritime claims and sovereignty in the Arctic.

While this had led to some international tensions and concerns, overall it seems that the likelihood of actions that seriously disturb international stability is low. There is, for now, no obvious new threat to our Arctic borders.

UNCLOS and maritime claims



- Potential UNCLOS claims to continental shelf (beyond EEZ) could cover almost entire Arctic
  - *Claims are potentially overlapping*
  - *Lomonosov Ridge is a source of contention*
- Disputed EEZ boundaries
  - *Canada and U.S. disagree on their boundary*
  - *Russian and Norway disagree on EEZ and have a further dispute over Svalbard fisheries*
  - *Russia/U.S. agreement – not formally settled*
- Internal waters / international straits
  - *Canada claims NWP as internal waters*
  - *Russia claims many NSR passages as internal*
  - *U.S. views these as international straits*
- Territorial boundaries
  - *Canada and Denmark dispute over Hans Island*
- Ilulissat summit (2008) was aimed at easing tensions over Arctic territorial claims
  - *Declaration promises orderly settlement of overlapping claims according to Law of the Sea*
  - *Potential for conflict seems exaggerated*

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The 1982 United Nations Convention on the Law of the Sea (UNCLOS) sets out the legal classification for maritime zones. A coastal state has the right to resources (including fisheries and hydrocarbons) in the waters and seabed of an Exclusive Economic Zone (EEZ) extending 200 nm from the coastal baseline. In addition, a state may claim jurisdiction over the seabed resources of its continental shelf. These extended claims can reach to the outer limits of the continental shelf (except, no further than the more distant of (a) 350 nm from the coastal baseline, or (b) 100 nm out from the 2,500-meter water depth). UNCLOS Article 76 establishes the geological characteristics that define the edge of the continental shelf. A country has 10 years after it ratifies UNCLOS to submit its continental shelf claims for scientific review by a UN established commission. Disputes are to be resolved either by the parties involved or, if that fails, through binding arbitration or adjudication.[1,2]

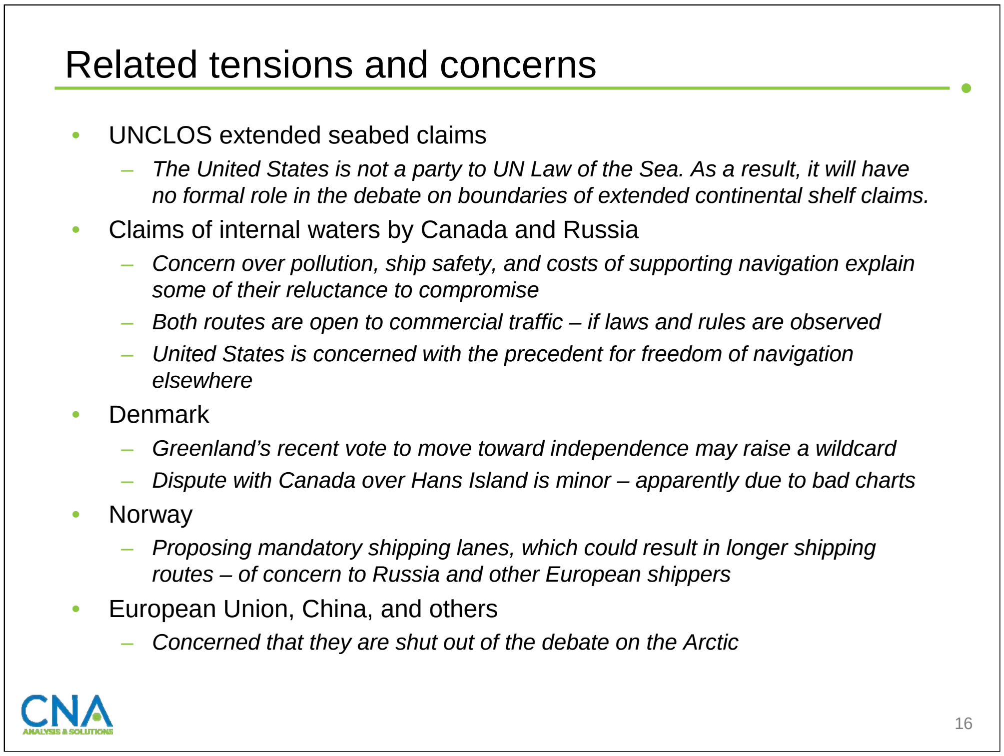
Continental shelf claims beyond the EEZ

Driven by interest in hydrocarbon resources, the Arctic nations (United States, Canada, Denmark [via Greenland], Norway, and Russia) are mapping the ocean floor to determine their potential claims to the continental shelf. The possibility of overlapping claims exists. Many arguments are likely to revolve around the Lomonosov Ridge, an underwater ridge across the Arctic Ocean.

Russia submitted the first Arctic extended shelf claim in December 2001. It claimed a vast area of the sea floor, including the North Pole, based on a belief that the Lomonosov Ridge is an extension of its continental shelf. Russia has been asked to provide more data to prove this connection. A revised claim is to be resubmitted in 2009. The planting of a Russian flag on the seabed at the North Pole in 2007 was an act of no legal relevance, but served to emphasize Russia's expansive claim.

Canada and Denmark are now working together to determine if the Lomonosov Ridge is an extension of the North American continent. Such a finding might allow them to make claims to the North Pole, overlapping the Russian claim. Canada is due to submit its claim in 2013. Denmark's claim is due in 2014. Despite the potential for overlapping claims, the media description of the process as an adversarial scramble is exaggerated. The Ilulissat summit in 2008 addressed the process, and each of the Arctic nations has agreed to settle overlapping claims according to the Law of the Sea.[3]

(Continued on next page)



The United States is not a party to UNCLOS and, as a result, can neither formally assert any rights to the extended seabed resources nor play a formal role in evaluating or resolving claims. However, the United States is preparing scientific data for a possible future claim.

<u>Other disputes and concerns</u>

Norway and Russia: the Barents Sea. A 1976 EEZ agreement between Norway and Russia did not deal with a large area referred to as the "Grey Zone" between Norway and the Russian islands. The two countries each manage access to this area until final agreement can be reached.[2] The 1920 Paris Treaty gave Norway limited sovereignty over Svalbard (formerly Spitsbergen). Norway has established a 200-mile EEZ and enforces fisheries protection there—against Russia's protests.

Russia and the United States: the Beaufort Sea. In 1990, the Soviet Union and United States signed an agreement on their borders in the Bering Sea, Arctic Ocean, and northern Pacific. The U.S. Senate ratified the agreement in 1991. Russia has agreed to abide by the agreement on a provisional basis, but its parliament has not yet ratified it. The possibility of oil and gas in the small Beaufort Sea parcel may complicate final resolution.

Canada and the United States: the Beaufort Sea. An 1825 Convention between Great Britain and Russia set the border between Alaska and Canada along the 141st meridian. The United States rejects this as the maritime border in favor of one based on equidistance from the two land masses.

Canada and the Northwest Passage. Canada considers the waters of the Northwest Passage to be internal waters. Accordingly, they claim control over access and the right to impose regulations on ship traffic. Concerns over their ability to control pollution and ship safety explain some of Canada's reluctance to compromise. The United States perceives the waters as international straits, with full freedom of navigation.

Canada and Denmark: Hans Island. This is a minor dispute over a small, unpopulated island that is claimed by both Canada and Denmark.

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1. Senate, Parliament of Canada. *The Coast Guard in Canada's Arctic,* Jun 2008 (*www.parl.gc.ca/39/2/parlbus/commbus/senate/com-e/fish-e/rep-e/rep04jun08-e.pdf*).

2. International Boundaries Research Unit, Durham University. *Maritime Jurisdictionand Boundaries in the Arctic Region,* Dec 2008 (*http://www.dur.ac.uk/resources/ibru/arctic.pdf*).

3. Arctic Council, *The Ilulissat Declaration*. May 2008 (*http://arctic-council.org/filearchive/Ilulissat-declaration.pdf)*

Russian activities and capabilities

- UNCLOS maritime claims
  - 2007 flag-planting episode under the North Pole emphasized the expansive nature of their seabed claims
- Military patrols and maneuvers
  - 2007 – Russia announces renewed long-range bomber patrols in Arctic
    - *April 2006 – a bomber flew undetected through U.S. airspace*
    - *Bombers carry out test cruise missile launches*
  - 2008 – Russia announces regular naval patrols in the Arctic
    - *Surface presence is in western Russia – near the home of its Northern Fleet*
    - *Increased naval presence near Svalbard appears to be related to dispute over fisheries*
  - 2008 – Russian missile sub sails underwater from the Barents to the Pacific
    - *Announced as reaffirming the fleet's ability to conduct strategic missions in the Arctic*
  - Naval maneuvers and air sorties among Norway's oil and gas platforms
  - Mock bombing run on Norway's northern command center
- Capabilities
  - The world's most capable icebreaker fleet with 7 active nuclear icebreakers and 5 diesel electric Arctic icebreakers – 12 in total. Many are aging (only one < 17 yrs).
  - A significant investment has occurred in ice-capable ships to support the oil and gas industry – with several of the new tankers having double-acting hulls

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Recent years have seen an increase in Russian assertiveness and capacity to operate in the Arctic as revenues from oil and gas have allowed Russia to begin to rebuild its military and resume some of the patrols that were common during the cold war.

In 2001, Russia submitted a claim for 460,000 square miles of the Arctic seabed, including the North Pole. In 2007, Russia sent an icebreaker and research submarines to the North Pole, planting a flag on ocean floor. The episode was played up in the press as an attempt by the Russians to assert a claim to North Pole.

Shortly after the flag-planting incident, Russia announced that it would resume regular long-range bomber patrols over the Arctic. A year later, it announced that naval patrols would begin in the Arctic waters. Norway, in particular, has seen a substantial increase in Russian maneuvers and patrols. Although provocative, the actions have not risen to the level of a serious threat to stability. Indeed, Russia would seem to have much to gain from a stable Arctic and continuing commercial development.

Russia's primary interest is in the economic development of the Arctic. Russia has been investing in the Murmansk area to develop offshore and onshore hydrocarbon resources. It is purchasing new ice-strengthened and double-bowed tankers that can operate efficiently in both open and ice covered water. These are being used to shuttle oil from Siberia to Murmansk, where it is reloaded on to larger tankers. Russia's interest in opening up the Northern Sea Route is evidenced by its 6-year involvement with Japan and Norway on the International Northern Sea Route Programme (INSROP), an effort to assess and encourage commercial viability of the NSR.

Russian Arctic icebreakers

	Power (MW)	Current age	Termination year
Nuclear			
Sibir	49	33	2018
Rossiya	49	24	2016
Sovetskiy Soyuz	49	20	2017
Yamal	49	17	2018
50 Let Pobedy	49	2	
Taimyr	32.5	20	2012
Vaigach	32.5	19	2013
Diesel-Electric			
Admiral Makarov	26.5	34	2015
Krasin	26.5	33	2017
Kapitan Nikolaev	16	31	2017
Kapitan Dranitisyn	16	29	2019
Kapitan Khlebnikov	16	28	2017

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Russia has the world's most capable icebreaker fleet, with 7 active nuclear icebreakers and 5 other large nonnuclear polar and coastal icebreakers (12 heavy icebreakers in working condition). The icebreakers serve in primarily commercial roles. Many are aging (Russia's newest nuclear icebreaker was launched in 2007—after sitting unfinished since a planned 1993 launch), and the fleet is stretched thin with the long Arctic coastline and high operating costs. New icebreakers are under consideration for construction over the next decade.

The Canadian military presence in the Arctic lapsed with the end of the cold war. Arctic surveillance flights with the aging Aurora patrol aircraft have declined dramatically, to now at most one or two a year. In 2004, Canadian Navy ships entered Arctic waters (near the NWP) for the first time in 15 years. Its modest icebreakers are aging; only two are capable of extended operations (maybe five months) in the Arctic. The CCGS *Louis S. St-Laurent* is able to break through 4 feet of ice without stopping. The CCGS *Terry Fox* is able to break 3 feet of ice.

As part of the *Canada First Defence Strategy*, Canada has announced a number of initiatives that will help increase presence in the Arctic region. These include:[1]

- The acquisition of six to eight Arctic Offshore Patrol Ships to patrol Arctic approaches and provide a Canadian Navy presence in the high-Arctic.
- The establishment of a deepwater docking and refueling facility in Nanisivik.
- The expansion of the size and capabilities of the Canadian Rangers (a local volunteer force) to provide a stronger and more effective military presence in the North.
- The establishment of an Arctic Training Centre in Resolute to provide Canadian Forces (CF) with the training and skills necessary to operate effectively in the North.
- The enhancement of the CF's ability to conduct surveillance in the North through the modernization and replacement of the Aurora patrol aircraft, the use of unmanned aerial vehicle technology, and the Radarsat satellite program.[2]

In addition, the Canadian Navy now holds regular exercises (Operation Nanook) dealing with simulated oil spills and maritime safety incidents in the Arctic waters.

Radarsat 2 was launched Dec 2007 in a sun-synchronous polar orbit. Its synthetic aperture radar payload offers ship detection and ice monitoring capabilities that contribute to Arctic domain awareness (the U.S. receives images). The Radarsat Constellation Mission, planned for 2014, will include three new satellites and will add Automatic Identification System (AIS) reception to the ship recognition capabilities. A potential new mission called PCW would provide robust polar communications capability and near-real time meteorological information.

1. *Canada First Defence Strategy – Canadian Forces' Contribution to Sovereignty and Security in the North*, May 2008. (*http://www.forces.gc.ca/site/news-nouvelles/view-news-afficher-nouvelles-eng.asp?id=2645*).

2. P. Butler. *Project Polar Epsilon: Joint Space-Based Wide Area Surveillance and Support Capability*, Directorate of Space Development, National Defence Headquarters (*www.isprs.org/publications/related/ISRSE/html/papers/1000.pdf*)

Denmark and Norway

- Denmark has made substantial investments in Greenland’s sovereignty
  - *A year-round naval presence performing sovereignty patrols, fisheries enforcement, surveillance, and search and rescue*
    - Thetis class – four ice-strengthened frigates patrol eastern Greenland. They handle over 2.5 ft of ice. Designed to minimize ice formation on their superstructure.
    - Knud Rasmussen class – two new Arctic offshore patrol vessels handle almost 2.5 ft of ice
    - No icebreakers - foreign icebreakers assist them in doing bathymetry for UNCLOS claims
  - *Aerial surveillance of the EEZ*
  - *Claims to the continental shelf above Greenland to be submitted in 2014*
- Norway
  - *K/V Svalbard – capable of handling 3 ft of ice – patrols near the Svalbard Islands*
  - *A new ground-based Automatic ID System (AIS); an AIS satellite is coming soon*

Thetis – sonar is operated from under the deck

Knud Rasmussen – Arctic Patrol Vessel near Greenland

K/V Svalbard operates north of Norway

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Denmark has made substantial investments in Greenland’s sovereignty, with a year-round presence performing sovereignty patrols, fisheries enforcement, surveillance, and search and rescue. It operates ice-strengthened patrol boats and conducts aerial surveillance:

- *Thetis class* – four ice-strengthened frigates currently patrol eastern Greenland. They handle over 2.5 feet of ice.
- *Knud Rasmussen class* – two new Arctic offshore patrol vessels now patrol western Greenland. They can handle almost 2.5 feet of ice
- Aerial surveillance is conducted with Bombardier CL-604 aircraft.

Denmark is preparing to submit Greenland’s claims to the continental shelf in 2014. It is conducting bathymetry surveys with the assistance of Swedish and Russian icebreakers and in cooperation with Canada. It is possible that these claims will extend to the North Pole.

The Norwegian and Danish patrol vessels are considered the best current models for a purpose-built Arctic patrol ship. They are well designed to minimize ice formation on their superstructure and deck equipment. The Canadians are expected to adapt from these designs.

Norway has recently issued a “High North Strategy” that emphasizes cooperation, environmental protection, sustainable development, and projecting sovereignty in the northern waters.[1]

1. Norwegian Ministry of Foreign Affairs. *The Norwegian Government’s High North Strategy*, Dec 2006 (http://*www.regjeringen.no/upload/UD/Vedlegg/strategien.pdf*).

Non-Arctic nations

- China has scientific and commercial interests in the Arctic
  - *The Chinese Arctic and Antarctic Administration (CAA) organizes research*
    - *Xue Long (Snow Dragon) – capable of handling over 1 meter of first-year ice has undertaken recent Arctic voyages*
    - *A scientific research station was been established on the Svalbard Islands*
  - *China, along with Japan and Korea, stands to gain economically from shorter shipping routes to Europe*
- The European Union has expressed its interest in Arctic maritime safety and pollution – and concern over its limited role in the Arctic debate

Xue Long provides some icebreaking capabilities to the Chinese

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Other nations have scientific and commercial interests in the Arctic. For example, China has conducted research in the polar regions. The *Xue Long*, a research vessel with icebreaking capabilities, has been deployed to both the Arctic and Antarctic in recent years. The Chinese have also established a research station on Svalbard (the eighth country to do so), where scientists conduct research on oceanography, meteorology, space physics, geology, and biology.

Japan funded a 6-year effort in the late 1990s to investigate the economic potential of the Northern Sea Route.[1] While that study led to no obvious changes in shipping or to the management of the Northern Sea Route, their interest in Arctic oil and gas remains. Korea is heavily involved in building some of the new double-acting, icebreaking tankers used in the Murmansk area oil fields of Russia.

The European Union has expressed its interest in Arctic maritime safety and pollution and the development of Arctic shipping routes. It also expresses its concern with the lack of effective governance of the Arctic and over the limited role that non-Arctic nations have in the Arctic debate.[2]

1. INSROP Organization. (*http://www.fni.no/insrop/INSROPINSROP_organization.html*)

2. European Parliament. *The European Union and the Arctic Region*. Nov 2008 (*http://ec.europa.eu/maritimeaffairs/arctic_overview_en.html*).

Arctic Council: The Arctic Council is an intergovernmental organization established in 1996 to address sustainable development and environmental protection of the Arctic. It has also served as an informal forum for broader discussion.

International Maritime Organization: The International Maritime Organization regulates the safety and environmental performance of shipping. It has issued voluntary guidelines for ships operating in Arctic waters.[1] Many have expressed interest in stronger, binding regulations for navigation in ice-covered waters.

Indigenous groups/Inuit Circumpolar Council: The Inuit Circumpolar Council is an international nongovernmental organization that represents the interests of approximately 150,000 Inuit and Yupik people of the United States, Canada, Greenland, and Russia. They are one of six Arctic indigenous groups to have the status of participants on the Arctic Council. The indigenous communities will be the most directly affected by development and marine activity. In Alaska, they have sought to limit ship noise and activities that would interfere with subsistence hunting. A coalition of indigenous and environmental organizations recently sued successfully to halt exploratory offshore drilling by Shell Oil.[2]

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1. IMO. *Guidelines for Ships Operating in Arctic Ice-Covered Waters.* Dec 2002 *(http://www.imo.org/includes/blastDataOnly.asp/data_id%3D6629/1056-MEPC-Circ399.pdf*).

2. Pacific Environment. *Shell Oil's Arctic Offshore Drilling Plan Illegal, Says 9th Circuit Court of Appeals,* Nov 2008 (*http://www.pacificenvironment.org/article.php?id=2896*).

Climate change and naval operations in the Arctic

- Climate and economic drivers
  - *Review the changing climate and growing interests in accessing/exploiting the Arctic as drivers for a naval role*
- The international stakeholders
  - *Maritime claims*
  - *Policies and actions of other Arctic nations*
  - *Arctic capabilities of other nations*
  - *Key non-state actors*
- U.S. Navy and U.S. Coast Guard – activities and capabilities
  - *Recent history of U.S. naval activity in the Arctic*
- Capability gaps
  - *Assess capability gaps that need to be addressed for naval forces to operate safely in the Arctic*
- New Arctic Policy
  - *Policy drivers for an Arctic presence*
- Summary and recommendations
  - *Summary and recommendations for a U.S. naval role in the Arctic*

CNA ANALYSIS & SOLUTIONS

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United States – selected history of Arctic activity

- Mid-1940s – post-World War II
  - *With Soviet-American relations deteriorating, it was feared the Arctic might become a battleground, and there were preparations for polar operations.*
- The 1950s – DEW Line era
  - *Concern over Soviet bombers led the United States and Canada to build a system of Arctic radar stations, with a massive maritime supply effort*
  - *In 1958, USS* Nautilus *completes the first submerged transit across the North Pole*
- Late 1970s and 1980s
  - *In a period of cold war tensions, the United States again begins to explore their capabilities for operating surface combatants in Arctic conditions*
- Post-cold-war era – mid-1990s to today
  - *Limited surface presence in true Arctic conditions*
  - *Cooperative exercises, science, supply missions*
  - *USCG begins to expand its Arctic presence*

USNS Lawrence H. Gianella, Navy owned sealift tanker

USS Normandy (CG-60), June 2007

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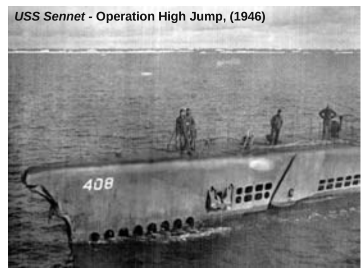
In the next few slides, we will discuss some of the recent history of U.S. naval activity in the Arctic. There have been occasional periods of interest, but no sustained capability, for operating surface vessels in ice-covered Arctic waters. The stories highlight some of the operational challenges.

The Navy currently has no ice-hardened surface combatant ships. The Navy does own four ice hardened sealift tankers used by MSC to supply Thule and Antarctica.

Post-World War II – Mid-1940s

- Operation Frostbite (March 1946)
  - *USS* Midway *went to the Davis Strait to test the capabilities and limitation of carriers under severe weather. It was found feasible to operate carriers in the sub-Arctic, but the recommendation to planners was to "resist pressures to get up into the ice."*
- Operation Nanook (July–August 1946)
  - *A mission to establish weather stations in Canadian Arctic and Greenland. A Navy icebreaker, seaplane tender, and three other ships also conducted tests of air and surface operations near the ice pack.*
- Operation High Jump (August 1946 to February 1947)
  - *An expedition to explore the feasibility of establishing Antarctic bases – but also viewed as way to train men in handling ships and aircraft in polar climates*
  - *Thirteen Navy ships, over 4,000 men, and a large fleet of aircraft participated: 3 ships badly damaged; 3 dead in a seaplane crash caused by impaired visibility.*

USS Midway - Operation Frostbite (1946)



USS Sennet - Operation High Jump, (1946)

CNA ANALYSIS & SOLUTIONS

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Operation Frostbite. By 1946, Soviet-American relations were deteriorating. With the realization that the Arctic region might become a strategic battleground, it was felt to be in America's best interest to prepare personnel, ships, and equipment as quickly as possible to operate in the polar regions. A handful of ships accompanied USS *Midway* to the Davis Strait to test the capabilities and limitations of aircraft carriers under severe cold and heavy weather conditions. Testing helicopters for the first time in SAR missions and refueling in adverse weather conditions were among the highlights of the operation. While it was concluded that cold weather operations with aircraft carriers in subarctic regions were feasible, Vice Admiral Sherman also concluded that the carriers were better used elsewhere and recommended that planners "resist pressure to get up into the ice." [1,2,3]

Operation Nanook. The mission was to establish weather observation and reporting stations in the Canadian Arctic and Greenland. One icebreaker, a seaplane tender, and three other Navy ships conducted exercises and tests of air and surface operations in the general vicinity of the southern limit of the ice pack in the Baffin Bay and Thule area. This project began the Navy concerted effort to expose men and equipment to polar conditions.[1,2]

Operation High Jump. This was an expedition to the Antarctic made up of 13 navy ships, 4,000 personnel, and a large fleet of airplanes. Although the main purposes of this expedition were related to exploring the feasibility of establishing Antarctic bases, the expedition was also viewed as an excellent way to train men in handling warships and aircraft in polar climates. The operation proved challenging. Eleven vessels were trapped in ice at one point. USS *Yancey* (AKA-93) had its ¾-inch steel plate severely dented and punctured by windblown ice. USS *Merrick* (AKA-97) received extensive rudder damage. USS *Sennet* (SS-408) had to be towed out of ice and suffered significant damage to its bow. Three men died in a seaplane crash caused by ice and impaired visibility.[1,2]

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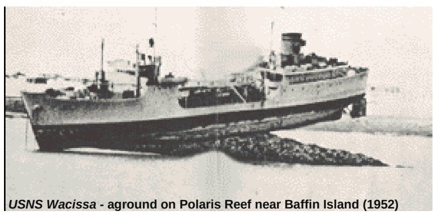
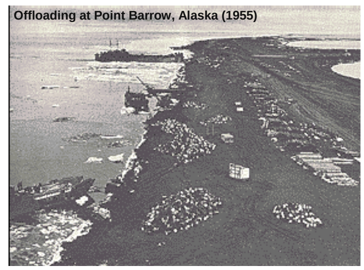
1. Operation Highjump (*http://www.south-pole.com/p0000151.htm*).
2. L. Rose. *Explorer: The Life of Richard E. Byrd*, University of Missouri Press, 2008.
3. M. Palmer. *Origins of the Maritime Strategy: The Development of American Naval Strategy, 1945-1955*, U.S. Naval Institute Press, 1990.

The DEW Line era – 1950s

- Operation SUNAC (1951-1952)
  - *Over 50 ships of the Military Sea Transportation Service (MSTS, now MSC) supported construction of radar outposts and enlargement of Thule Air Force Base*
- Operation Sealift for Security (1955-1957)
  - *Navy and MSTS assisted in construction of the Distant Early Warning (DEW) Line*
  - *A fleet of 118 ships delivered over 1 million tons of cargo, despite some of the worst ice conditions ever recorded. After numerous hull punctures and broken propellers, ships were hardened and modified propellers added.*
  - *In 1957, Coast Guard vessels transited and charted NW Passage as an escape route*
- The late 1950s mark the beginning of the nuclear submarine era in the Arctic
  - *USS* Nautilus *completes the first submerged transit of the North Pole in 1958*



USNS Wacissa - aground on Polaris Reef near Baffin Island (1952)



Offloading at Point Barrow, Alaska (1955)

CNA ANALYSIS & SOLUTIONS

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Operation SUNAC . Ships of the Military Sea Transportation Service (MSTS) entered the Davis Straits for two seasons (1951-1952) to construct radar outposts and enlarge the Air Force base at Thule. Accompanied by icebreakers, 37 ships (mostly chartered) transported equipment. USNS *Sappa Creek* struck an iceberg and suffered severe damage. USNS *Wacissa* ran aground in Baffin Bay.[1]

Operation Sealift for Security. From 1955 to 1957, the Navy and MSTS assisted in construction of the Distant Early Warning (DEW) Line along the rim of the Arctic. The DEW Line represented a tremendous logistical feat. Before 1955, no large steam-driven, steel ship had navigated the waters east of Point Barrow. The fleet was divided into two task forces. From the west, 27 cargo ships, 2 tankers, and 20 smaller support craft, led by 3 icebreakers, sailed around Point Barrow to deliver supplies. In the east, 31 cargo ships, 10 tankers, 4 passenger ships, 14 support vessels, and 7 icebreakers delivered supplies. The 3-year effort encountered some of the worst ice condition recorded in the Arctic but succeeded in delivering more than a million tons of cargo and building supplies. The operations did prove hazardous to many ships. There were numerous hull punctures and broken propeller blades. To prevent further damage, many ships underwent hardening. This included doubling the keel of LSTs for landings on frozen beaches. In addition, a modified propeller was installed to prevent damage when striking loose ice floes. Other ships received steel sheathing on their waterline.[1,2]

MSTS also started constructing ships specifically designed to operate in polar regions. The first was a cargo ship dock, USNS *Point Barrow* (T-AKD 1). This resembled a Navy LSD with an icebreaker bow, a thickened ice belt, and fiberglass hull insulation to protect crew and equipment from cold. The second class included two tankers. USNS *Alatna* and *Chattahoochee* featured Arctic hardening but also included a secondary pilothouse on the foremast and several booms for use in case the ships became trapped in ice. The last class included the *Mirfak, Mizar,* and *Eltanin,* which were cargo versions of *Alatna,* with many of the same features.

In 1957, the Coast Guard was given the mission of finding an escape route for ships that might be trapped by polar ice above Alaska, as had nearly occurred in 1955 and 1956. In response, Canadian icebreakers and ice-hardened Coast Guard cutters transited and charted the Northwest Passage. These were the first American vessels to ever transit the Northwest Passage.[3]

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1. "To Boldly Go Where No Fleet Had Gone Before-MSTS in the Arctic", (*www.usmm.org/msts/arctic.html*)
2. MSTS Arctic Operations in the 1950s (video), *www.militaryvideo.com*
3. Across the World: The U.S. Coast Guard's 1957 Northwest Passage Expedition, *www.uscg.mil/History/articles/ Northwest_Passage1957.pdf*

Late 1970s and 1980s

- Replenishment exercises (1977-1983)
  - *Investigations of cold-weather underway replenishment (UNREP) conducted in the Bering Sea led to modification of winches for better operation in the cold.*
- Arctic SHAREM
  - SHAREM 55 *(Mar-Apr 1984): The first ASW exercise in the marginal ice zone (MIZ), conducted north of Iceland*
  - SHAREM 62 *(Nov 1985): An exercise north of Newfoundland to determine best means of providing ASW protection to carriers operating in Norwegian fjords*
  - *Difficult getting away from ice with a towed array; helicopter operations were hampered by frequent fog; replenishment hampered by cold and bulky clothing*
- Navy experiments in Arctic ship design
  - *Air cushion vehicles for the Arctic*
  - *An attachable ice-transit bow for an LSD and FFG*

CNA ANALYSIS & SOLUTIONS

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Arctic SHAREM 55. *(Spring 1984).* This was the first antisubmarine (ASW) exercise in the marginal ice zone (MIZ). The primary goal was to investigate sonar performance near ice. The destroyer USS *Spruance* joined three frigates to operate in the MIZ, east of Greenland and north of Iceland, to determine how well towed arrays performed in detecting submarines under the ice. They were accompanied by a Navy icebreaker. P-3 maritime patrol aircraft operated in support of the task group from the Naval Air Station at Keflavik. An attack submarine was on station under the ice.[1,2]

They found the marginal ice zone a dangerous place. Ice drifts were often accompanied by "sea smoke"—fogs caused by condensation as cold air moves across warmer water. If a wind shift was detected while the towed array was in the water, an immediate course change away from the ice was required. It took nearly a half-hour, using small rudder increments, to head toward open water and recover the tail. Helicopter operations were hampered by weather and lack of deicing equipment.

To prepare for Arctic operations, the ships were able to rebalance their heating and ventilation systems to maintain reasonably comfortable interior temperatures. Still, boiler technicians and machinist's mates in normally hot spaces worked in foul weather jackets. The crew had a routine to break off the topside ice. Topside crews had immersion suits and could attach themselves to the lifelines while chipping away ice. The seawater injection temperature was 22 °F and sea chests and intakes in the main spaces were ice covered. The ships used special lubricants that wouldn't solidify in the cold for all topside rotating machinery. The light icing during SHAREM 55 provided an opportunity to evaluate anti-icing coatings that had been applied to selected areas of the superstructure, but there were no opportunities to observe the effects of heavy icing on ship stability.

SHAREM 62. *(Fall 1985)*. This exercise was just north of Newfoundland. The primary interest was in determining the best means of providing ASW protection to carriers operating in the Norwegian fjords. The location was chosen to approximate the fjords. The exercise also was intended to obtain information on ship icing and operational problems in a cold, wet environment. Unfortunately, the weather was warmer than hoped for and there were no icing encounters.[2]

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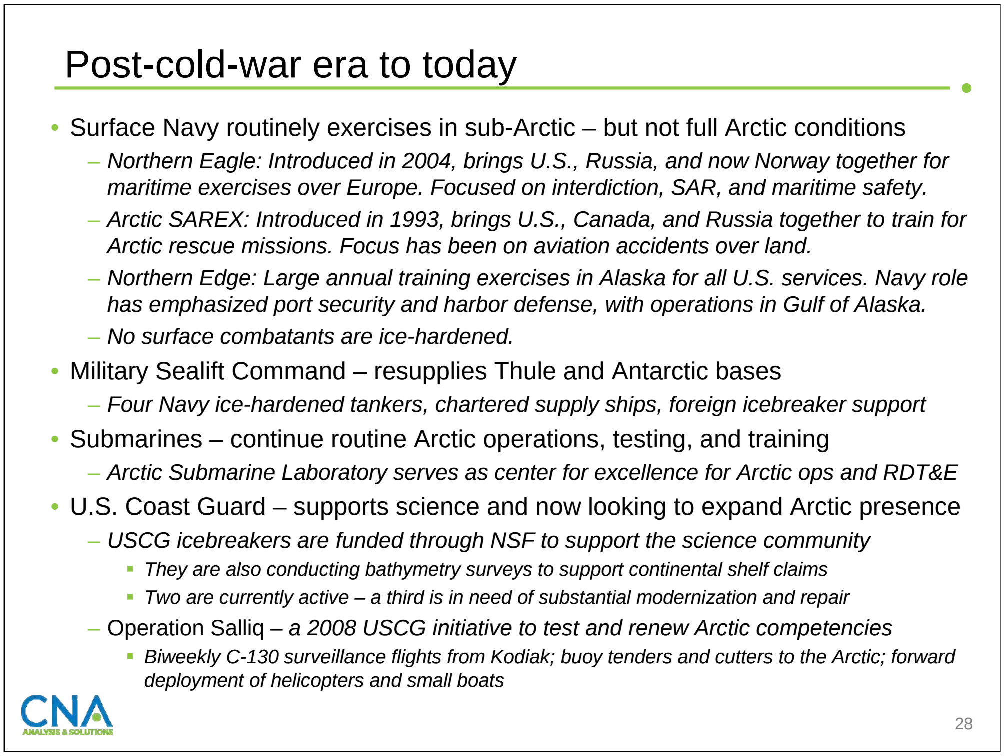
1. "Arctic Gives Surface Warriors Chilly Reception," *Surface Warfare Magazine,* Winter 2008.
2. DON. *Proceedings of 1985 US Navy Symposium on Arctic/Cold Weather Operations of Surface Ships*, Dec 1985.
3. *Thyssen-Waas Ice Transit Bow Seakeeping Study,* David Taylor Research Center, Bethesda, MD, Sep 1991.



Exercises

Northern Eagle. Introduced in 2004, this annual exercise focuses on maritime interdiction operations, search and rescue, and tactical interoperability to improve maritime safety and security. Northern Eagle 2008 was held in the Norwegian and Barents Seas. It marked the third time the Russian Federation has hosted the exercise, and the first time Norway was invited to participate.

Arctic SAREX. Introduced in 1993, these are search and rescue exercises that bring U.S., Canadian, and Russian troops together to train for rescue missions. These three countries are developing a cooperative agreement to assist each other during emergencies, such as an airliner crash in the Arctic. The exercise location rotates between countries. Exercises have focused on land incidents.

Northern Edge. This is the largest military training exercise in Alaska, with thousands of U.S. military participants. The joint exercises are intended to help prepare forces to respond to crises in the Asian-Pacific region by practicing operations and procedures. Naval exercises have emphasized port security and harbor defense, with operations primarily in the Gulf of Alaska.

U.S. Coast Guard. The U.S. Coast Guard (USCG) has been active over last year in preparing itself for an expanded Arctic presence. Operation Salliq was an initiative to test and renew Arctic competencies. The USCG initiated biweekly C-130 surveillance flights from Kodiak, the deployment of buoy tenders and cutters to the Arctic, and forward deployment of helicopters and small boats. The following were among the challenges and lessons learned:[1]

- Summer storms dropped August temperatures to the 20s, with zero visibility and snow
- Unpredictable sea ice, beach erosion, and sea state rendered small boats ineffective
- Icing conditions, distances, and scarcity of aviation fuel limited helicopter effectiveness
- Lack of communications limited operating ranges
- Consultation with local people was invaluable in avoiding potential conflicts.

U.S. Navy. The news of USS *Normandy's* (CG-60) recent visit into ice above Iceland emphasizes how rare such an event has become for the Navy. It also points to the critical importance of timely and accurate ice forecasts.[2] Routing information received by the Normandy made no mention of ice.

1. 17th CG District. "Operation Salliq 2008: The Coast Guard Arctic Initiative," *Alaska Bear*, Winter 2008.
2. "Encountering Ice," *Surface Warfare Magazine*, Winter 2008.

Climate change and naval operations in the Arctic

- Climate and economic drivers
  - *Review the changing climate and growing interests in accessing/exploiting the Arctic as drivers for a naval role*
- The international stakeholders
  - *Maritime claims*
  - *Policies and actions of other Arctic nations*
  - *Arctic capabilities of other nations*
  - *Key non-state actors*
- U.S. Navy and U.S. Coast Guard – activities and capabilities
  - *Recent history of U.S. naval activity in the Arctic*
- Capability gaps
  - *Assess capability gaps – ship structure, general operations, navigation, communication, Arctic domain awareness – that may need to be addressed*
- New Arctic Policy
  - *Policy drivers for an Arctic presence*
- Summary and recommendations
  - *Summary and recommendations for a U.S. naval role in the Arctic*

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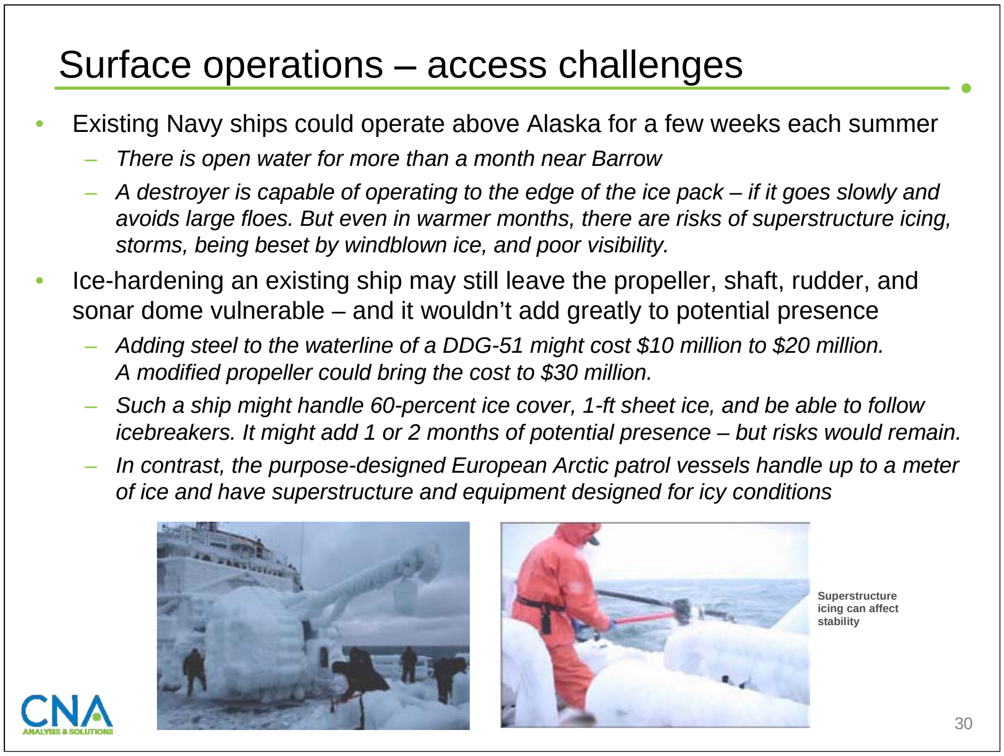

Some of the key challenges to operations in the Arctic include:[1]

- Ship structure and equipment issues
- Replenishment and logistics
- Personnel comfort and safety
- Ice avoidance and weather information
- Marine mammals and indigenous rights
- Navigation
- Communications.

While the Navy currently has no ice-hardened combatant ships, many existing ships could operate above Alaska for a few weeks each summer. A destroyer, for example, is capable of operating to the edge of the ice—if it goes slowly and avoids large floes. However, such a ship could not operate in the channel of ice following an icebreaker without extensive modification to the hull and propulsion systems. Even in open waters, there would be risks from wind-blown ice, poor visibility, and superstructure icing.

Ice-hardening an existing destroyer (adding ¾ inch of steel to the waterline) might cost $10 million to $20 million. Replacing the vulnerable propellers with stronger steel might bring the cost up to $30 million. Such a ship could handle perhaps 60 percent ice cover and 1 foot of sheet ice, and would now be able to follow icebreakers. The ship would also be noisier and less efficient to operate. These changes still would not add greatly to presence—adding perhaps 2 months of potential presence without icebreaker support. The ship would remain vulnerable to ice damage to its propellers, rudder, sonar, and propulsion train. Extra heating and insulation would have to be provided for extended operations. Icing and cold would be likely to disrupt the function of deck equipment. It would be preferable to have purposefully designed ships. The European Arctic patrol vessels, for example, can handle a meter of ice, and they have equipment built specifically for operations in icy conditions.

1. The surface operation discussion draws on (a) ATP 17(C), *Naval Arctic Manual*; (b) COMSCINST 3121.9A, *MSC Standard Operating Manual*, Ch. 2, Sect. 10, "Cold Weather Operations"; (c) USCG, *Arctic West-East Summer, 2005, USCGC Healy Cruise Report;* (d) DON, *Proceedings of 1985 US Navy Symposium on Arctic/Cold Weather Operations of Surface Ships*, Dec 1985; and (e) conversations with Donald Nalchajian of NAVSEA's Future Concepts and Surface Ship Design Group.

Surface operations – structural & logistical challenges

- Ship structural and equipment issues
  - *Hull, propeller, shaft, rudder, and sonar dome are vulnerable to damage.*
  - *Superstructure icing can affect stability, block intakes, interfere with antennas, limit visibility, and disrupt the function of and access to deck equipment.*
  - *Low-temperature lubricants are required. Pipes, tanks, and fuels are at risk of freezing. Air and water intakes must be kept clear. Hydraulic oils may require heaters. Batteries weaken. Gaskets and seals deteriorate. More insulation may be needed to prevent condensation in electronics and to provide crew comfort.*
- Replenishment and logistics
  - *Lack of deepwater ports and facilities above the Aleutians is a major problem.*
  - *Even accessing the shore in small boats can be problematic due to shore-fast ice.*
  - *Helicopters may be grounded – because fog forms over open waters near ice.*
  - *Weather and bulky clothing make UNREP demanding.*
  - *Limited availability of ice capable supply ships*
  - *Pollution concerns*

ATP 17C-*Naval Arctic Manual* serves as the Navy manual on cold weather operations. It is an excellent guide to prepare ships and crews for Arctic operations.

Even accessing the shore can be problematic due to shore-fast ice

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Structural and Equipment Issues

Turbine propulsion systems are far from ideal for operations in ice since the shaft and propellers spin at high RPM even at low ship speed. That leaves the shaft and reduction gears subject to damage if propeller blades jam. The rudder is also very vulnerable to ice, particularly when backing down. Icebergs and ice floes may also pose a risk to the sonar dome, particularly in stormy seas. However, during slow speed operations it is unlikely that ice floes would be pushed under the bow.

Superstructure icing can affect stability, block intakes, interfere with antennas, and disrupt the function and access to deck equipment. Deck equipment and superstructure on existing ships are not well designed for icing conditions or extreme cold. Low-temperature lubricants are required. Hydraulic oils may require heaters. It is essential that air and water intakes be kept clear of ice.

Insulation and extra heating would have to be provided for long-duration Arctic operations. They would help prevent freezing, limit condensation in electronics, and provide greater crew comfort.

Replenishment and Logistics

The lack of deepwater ports and facilities above the Aleutians is a major problem. The coastal waters of the Northern Slope of Alaska are shallow and subject to sedimentation and scouring by ice. Accessing the coast and maintaining facilities are made difficult by shore ice. Nome, south of the Bering Strait, offers perhaps the best northern port facilities, with 20-foot depths at the dock and 40 feet of water within a mile of shore. However, this harbor is iced over from mid-November to May. The shore ice may extend a mile into the sound, with 20-foot pressure ridges at the margin of the ice sheet.

Accessing shore in small boats can be problematic due to fast ice. Helicopters may be grounded due to the fogs that often form over the open water near ice. Replenishment operations are further complicated by cold weather and bulky cold weather gear. There is limited availability of fuel and provisions and no nearby repair facilities; you are constrained by what you bring with you, or fly in.

Surface operations – other challenges

- Personnel comfort, safety, and performance
  - *Safety implication of wind chill, low visibility, icy deck, extended darkness in winter*
  - *Crews must be well trained in ice removal and hazards of cold weather activity*
- Weapon systems
  - *Issues with lubrication, condensation, icing, hydraulics, gaskets*
  - *Mine detection near ice and handling of towed arrays are particularly challenging*
  - *Crews are not trained to handle weapons in Arctic conditions*
- Ice avoidance information and weather predictions
  - *Critical to mission success*
- Marine mammals and indigenous rights
  - *Possible interference with two subsistence whaling seasons needs consideration*
  - *Noise and pollution, in general, are of great local concern because of risk to food*
  - *Even the noise of icebreaking has been raised as a marine mammal concern*

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Personnel Comfort and Safety

Safety and performance will be affected by wind chill, low visibility, icy decks, and extended darkness in winter. Crews must be well trained in ice removal, ice watches, and in the hazards of cold weather activity. Lack of robust communication connectivity may also impact quality of life.

Weapon Systems

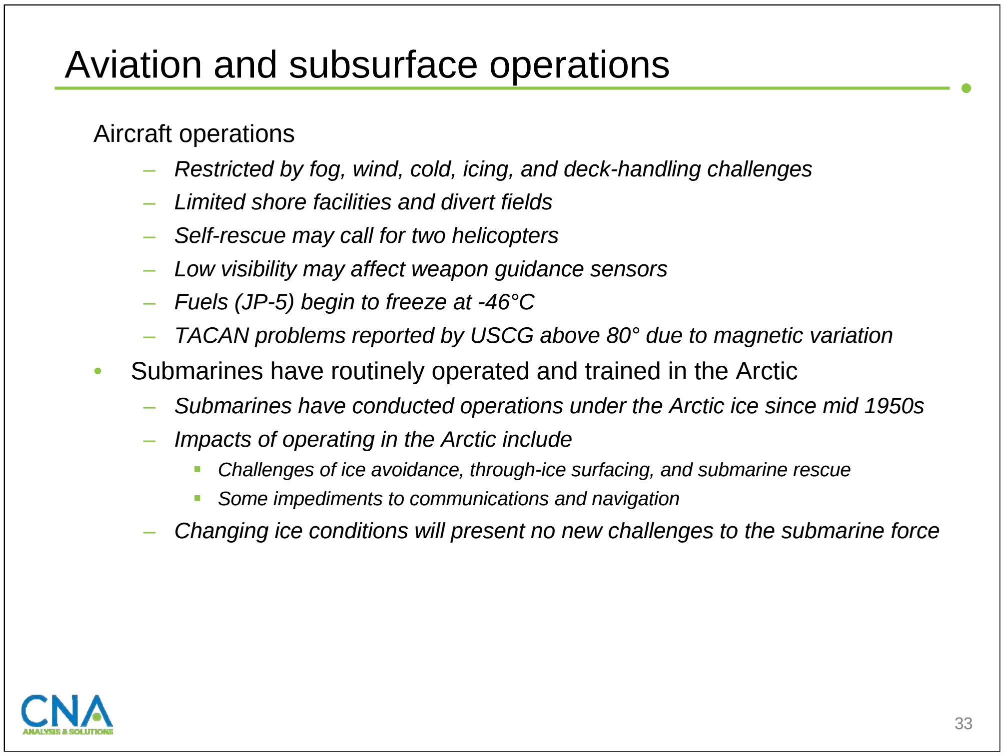
Weapon systems face the same issues with lubrication, condensation, and icing as other deck equipment. Overall, the potential problems that may occur with weapons and sensors in extreme cold, poor visibility, and high latitudes are certainly unpracticed. The operation of towed arrays near ice is challenging, as are mine detection activities.

Ice Avoidance Information and Weather Predictions

This information is critical to safety and mission success. Our ability to provide detailed tactical information, at short notice, for safe routing through icy waters is limited due to lack of communications bandwidth and surveillance capabilities. Crew training in ice avoidance is also limited.

Marine Mammals and Indigenous Rights

Interference with two subsistence whaling seasons should be avoided to the extent possible. The spring hunt at Barrow typically occurs in May, with the deterioration of winter pack ice. The fall hunt typically occurs in mid September, with the migration of bowhead whales. It is unknown how climate change may change these migratory patterns.



Aircraft operations are subject to issues with weather, icing, and lack of facilities. The possibility of fuels gelling becomes a concern for aircraft stored in unheated locations and with extended surveillance flights. Jet fuels (JP-5) can begin to gel at -46 °C. At very high latitudes, the Coast Guard icebreaker *Healy* found problems with the headings reported by their tactical air navigation (TACAN) systems.

The submarine community routinely operates in the Arctic. They have done so since the mid 1950s. The Arctic Submarine Laboratory, formally established in 1969, is unique in the Navy for its expertise in the procedures and equipment needed to enable submarine forces to operate safely and effectively in the Arctic Ocean. Submarine operations under the ice do present unique challenges, including ice avoidance, through-ice surfacing, and submarine rescue. However, the submarine community does not anticipate any new problems to result from changing ice conditions.[1]

1. Information provided by CDR Dave Soldow, OPNAV N87, Submarine Warfare Division.

Navigation issues

- GPS is fully operational at the poles
  - *Ideally GPS is used in combination with a ring laser gyro navigation system*
- Compasses can be problematic near the poles
  - *Magnetic compasses are subject to severe disturbance*
  - *Mechanical gyro-compass errors can begin to grow above 70°*
    - *Although modern systems have "high latitude" modes that offers reliability to 86° and they shift to "directional gyro" mode to give simple course headings above 86°*
  - *Ring laser gyro systems in conjunction with GPS present no substantial problems*
- Charts in Arctic areas are often not to modern standards
  - *Can be particularly unreliable near shore in areas subject to sediment and ice scour*
  - *Many are based on sporadic single-track soundings; positional accuracy may not be reliable; digital coverage above 84° is lacking*
  - *Still, most primary routes are sufficiently well covered to enable safe navigation if diligence is taken – with an echo sounder operated continuously*
- Ice detection radar/sonar is essential
  - *Experienced pilots used to reading ice and radar returns from ice are invaluable*
  - *Growlers (small dense cores from iceberg) pose a serious problem for detection*
  - *Ice is best detected from aircraft or satellites*
  - *Fog and storms add to the danger of navigation near ice*
- Electronic and visual aids to navigation are sparse

GPS is fully operational at the poles

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The GPS (Global Positioning System (GPS) is fully operational at the poles. Horizontal positional accuracy at the North Pole is similar to that for the east coast of the United States.[1,2] There is occasional scintillation due to ionospheric effects; however, military GPS receivers are dual frequency, with the two frequencies allowing a receiver to compensate for ionospheric error. Ring laser gyro systems linked to GPS have largely resolved the shipboard navigational problems that were expected in polar regions.[3]

Ice detection and tactical information on the location of ice fields is critical to safe navigation. Experienced pilots used to reading radar returns from ice are invaluable. These skills are lacking. Electronic and visual aids to navigation are sparse and have a short life with the ice conditions.

Navigation charts in Arctic areas are not up to modern standards. Many are based on sporadic single-track soundings, and positional accuracy may not be reliable. Reported depths can be particularly unreliable in areas subject to shoaling and ice scour:

- The National Geospatial-Intelligence Agency (NGA) has no Digital Nautical Chart (DNC) coverage north of 84 degrees. Available NGA charts for the Arctic region are mostly old and small scale. Bathymetry is often from foreign sources and supplemented with random tracks and icebreaker data. Modern surveys are needed to improve the accuracy and currency of these charts in order to support naval operations in the Arctic.
- National Oceanic and Atmospheric Administration (NOAA) charts are similarly outdated, with many of the NOAA surveys north of the Bering Strait done in late 1940s or 1950s. These charts are based on single beam data and visual navigation. Canadian charts suffer many of the same shortcomings. Their focus has been on the Northwest Passage, and a large amount of the Canadian Arctic is still unsurveyed. Russia has a series of Electronic Navigation Charts (ENCs) covering the Northern Sea Route, but these charts are not readily available.
- Despite the overall shortcomings, many of the primary routes are considered sufficiently well covered to enable safe navigation by commercial vessels in ice-free waters, as long as diligence is taken and an echo sounder is continuously operated.

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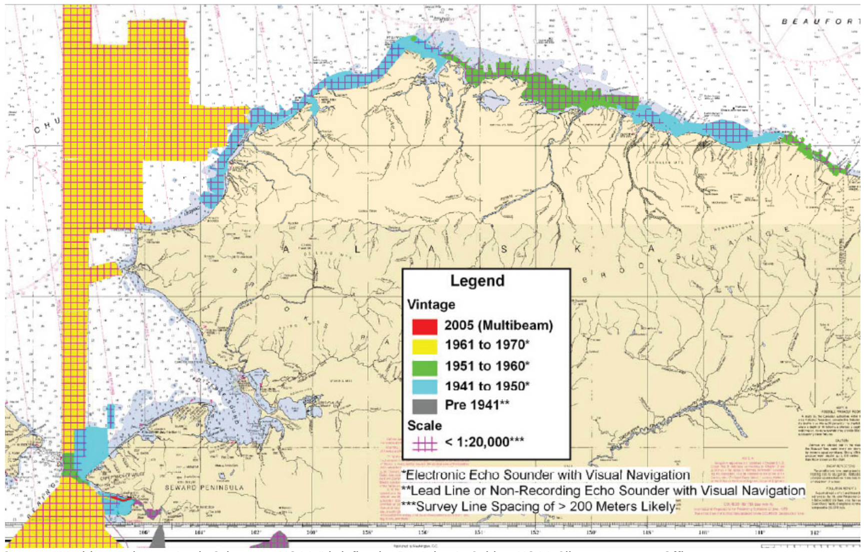
1. Horizontal and vertical errors average 1.5 and 2.4 meters, respectively (Cdr A. Lomax, Naval Observatory).
2. USAF, GPS Operations Center Performance Reports (gps.afspc.af.mil/gpsoc/performance_reports.aspx).
3. R. McEwan, H. Thomas, D. Weber, F Psota. "Performance of an AUV Navigation System at Arctic Latitudes," *IEEE Journal of Oceanic Engineering, Vol 30, Issue 2*, April 2005.

Vintage of NOAA hydrography – North Slope (Jun 08)



Source: "Maritime-Relevant Arctic Science at NOAA," briefing by Dr. John A. Calder, NOAA Climate Program Office

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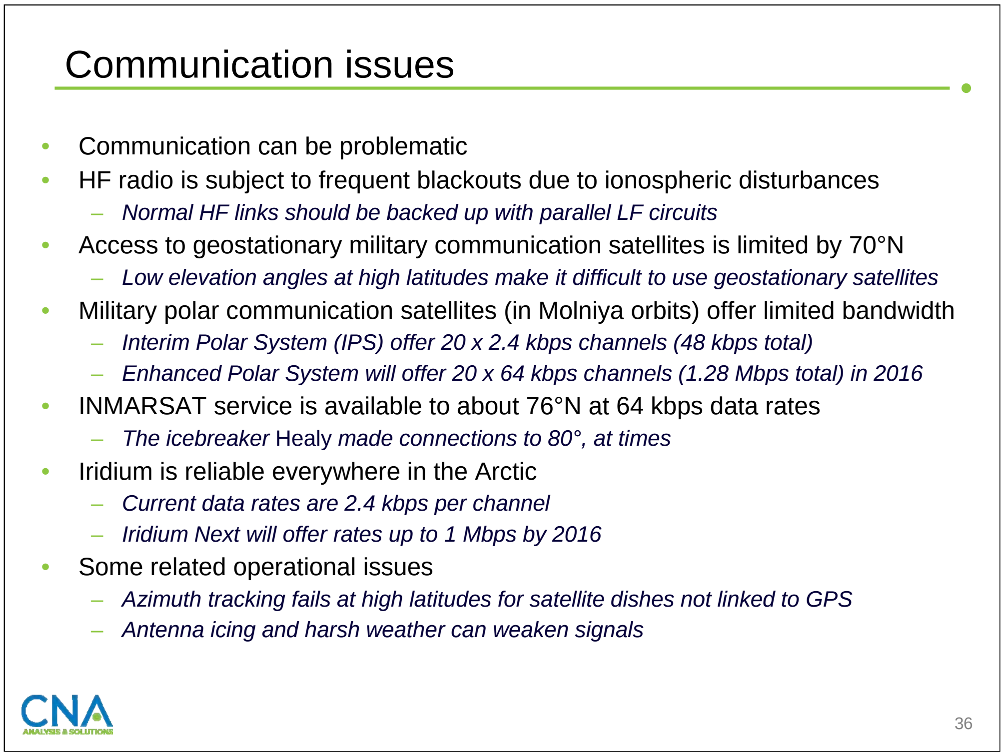
This figure shows the vintage of NOAA charts for northern Alaska. Many of the charts in coastal areas are based on soundings from the 1940s or 1950s, with single-beam soundings, visual navigation, small scale, and survey line spacing of greater than 200 meters.



Arctic communications are problematic.

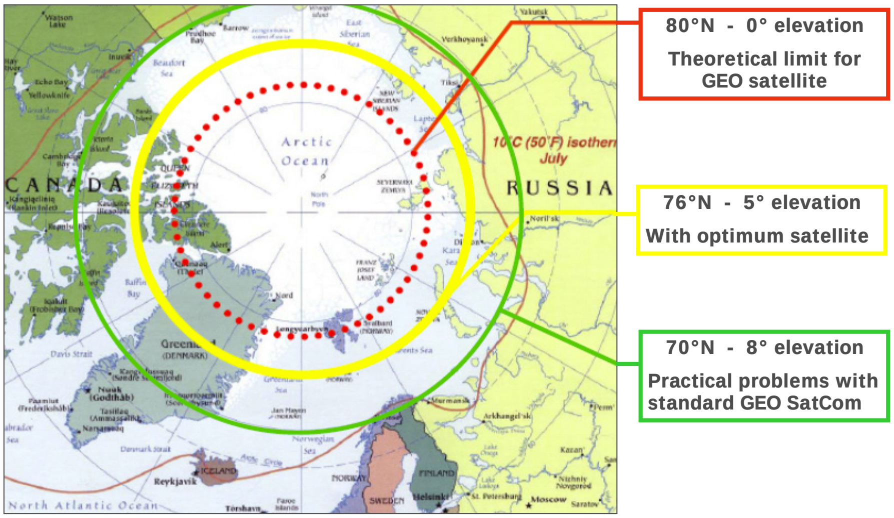
- Long distance communication with high-frequency radio is unreliable due to ionospheric background noise at Arctic latitudes. The icebreaker USCGC *Healy* has found that transmission and receipt of message traffic can be disrupted for days on end.
- Access to the standard geostationary military communications satellites becomes unreliable above 70°N.
- The two current U.S. military polar communications satellites (in Molniya orbits) offer limited bandwidth.

The Interim Polar System (IPS) provides 24 hour military communications coverage at latitudes above 65°N, but the bandwidth available is minimal.[1,2] The IPS payloads (hosted on two classified platforms in highly elliptical orbits) provide 20 channels with 2.4kbps per channel. The system is currently used only by submarines. By 2016, the IPS satellites are expected to be replaced by the Enhanced Polar System (EPS). The new satellites will each offer 1.28Mbps of capacity (20 channels each supporting 64kbps) to users in the polar region. These channels can be bound together, if not in use by others. While adequate for individual ships, these satellites will not support the normal practices of a large number of users.

Commercial satellites may eventually provide a reasonable alternative for satisfying unprotected communications requirements in the Arctic. The Iridium system is currently the only commercial system that is reliable at very high latitudes. Iridium data rates are now only 2.4 kbps. However, the planned upgrade to Iridium Next promises a significant increase in bandwidth by 2016. While Iridium Next hasn't been completely specified yet, it is expected to offer internet protocol data channels of up to 1.0Mbps.

1. NAVSEA Warfare Centers, Newport. *The Navy & the Enhanced Polar System (EPS)*, briefing, Jul 2008.
2. Discussions and briefing slides provided by Richard Michaux, OPNAV N6F1.

Geostationary earth orbit (GEO) satellites



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Access to geostationary communications satellites is frequently a problem north of 70°N. The area above 70°N includes almost all of the Arctic Ocean.

Arctic domain awareness

- Virtually no surface presence above the Bering Strait
- USCG air patrols limited to once every 2 weeks in summer
- Orbcomm satellites will pick up AIS signals
  - *USCG has contracted with Orbcomm to collect AIS data: 6 of 30 Orbcomm satellites currently have AIS capability. Their coverage will extend only up about 74°N .*
- Canada has the most sensor capabilities
  - *Radarsat-2 (2007 launch) has ship detection capability with synthetic aperture radar*
  - *Proposed Radarsat Constellation Mission satellites will add AIS capabilities in 2014*
  - *Surveillance aircraft utilize side-looking radar, AIS receivers, and infrared camera*
  - *Tested UAVs in 2004 – but found them limited by communication bandwidth*

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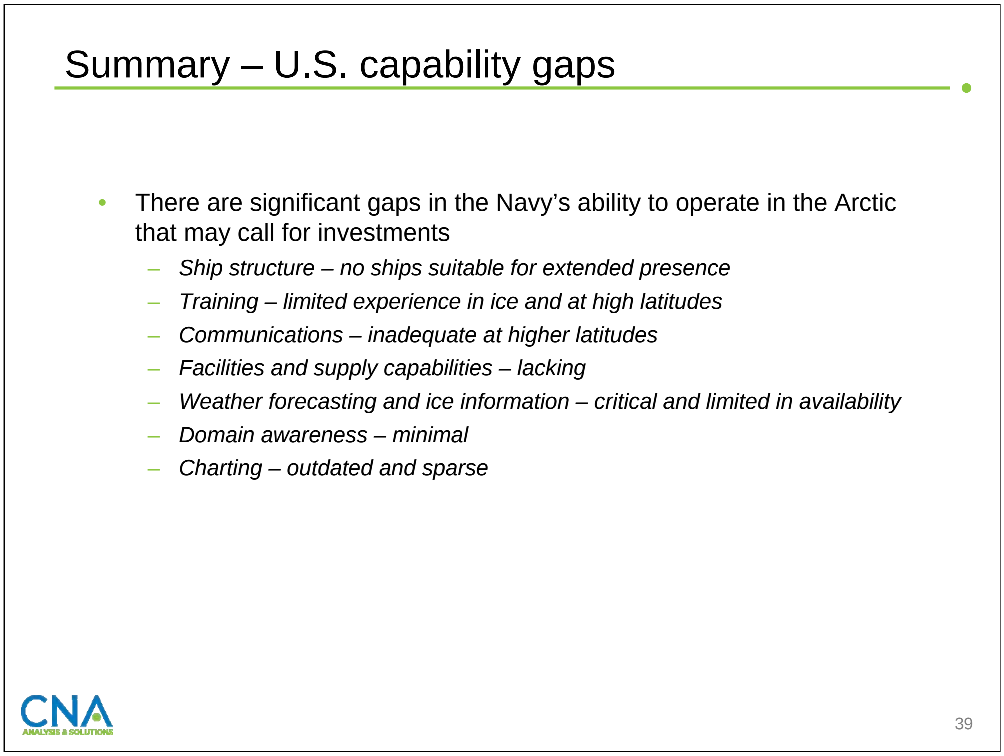
Arctic domain awareness is limited. There is virtually no U.S. surface presence above the Bering Strait. Coast Guard air patrol flights are limited to one every 2 weeks in summer.

Orbcomm owns six satellites that are able to pick up Automatic Identification System (AIS) signals from ships. The Coast Guard has contracted with them to receive some of this information. Eventually, the entire Orbcomm system is expected to be AIS enabled. However, the footprint covered by the current constellation does not extend much above 74°N.

Canada offers some of the best capabilities. Its Radarsat-2 system has proven ship detection capability with its synthetic aperture radar. The future Radarsat Constellation Mission satellites will add to coverage and introduce AIS capabilities by 2014. Canada’s surveillance aircraft are aging, but a modernization program is expected to add to Arctic awareness.

In 2004, Canada experimented with unmanned aerial vehicle (UAV) flights for Arctic surveillance. At the time, they were found to be limited by communication bandwidth at higher latitudes. There were also some issues with icing.



In summary, there are significant gaps in the Navy's ability to operate in the Arctic that may call for investments:

- Ship structure – no ships suitable for extended Arctic presence
- Training – limited experience in ice and at high latitudes
- Communications – inadequate at higher latitudes for normal operating practices of carrier strike group or surface action group
- Facilities and supply capabilities – lacking
- Weather and ice forecasting – inadequate
- Domain awareness – minimal
- Charting – outdated and sparse.

Climate change and naval operations in the Arctic

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New Arctic Policy

- A new directive NSPD-66/HSPD-25 establishes the policy of the United States with respect to the Arctic region. An example:
  - The United States must safeguard its broad and fundamental national security interests in the Arctic region. These interests include:
    - *Missile defense and early warning*
    - *Deployment of sea and air systems for strategic sealift*
    - *Strategic deterrence*
    - *Maritime presence and maritime security operations*
    - *Freedom of navigation and overflight consistent with international law*
- Although the directive does highlight security needs, it is equally (at least) focused on cooperative relations and sustainable development
- The strategic interests presented align with established naval policy

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NSPD-66/HSPD-25 was signed 9 January 2009. This directive establishes the policy of the United States with respect to the Arctic region and directs related implementation actions. This document supersedes the directive (PDD-26/NSC-66) issued in 1994 with respect to Arctic policy.

Although the new directive mentions national security and homeland security needs first in all areas, most of the implementation actions relate to international relations, the economy, and protection of environment and natural resources. As such, the directive is likely to have a greater impact on the Department of State than on the Departments of Defense or Homeland Security.

The strategic interests laid out in the new Arctic Policy are well aligned with established Navy policy presented in the *Cooperative Strategy for 21st Century Seapower*.[1]

1. *Cooperative Strategy for 21st Century Seapower*, Oct 2007 (http://www.navy.mil/maritime/MaritimeStrategy.pdf).

Implementation of Arctic Policy

- The Secretaries of Defense and Homeland Security shall …
  - *Develop greater capabilities and capacity to protect U.S. borders in the Arctic*
  - *Increase Arctic maritime domain awareness in order to protect commerce, infrastructure, and key resources*
  - *Preserve the global mobility of U.S. military and civilian vessels and aircraft throughout the Arctic*
  - *Project a sovereign U.S. maritime presence in the Arctic*
  - *Encourage the peaceful resolution of disputes in the Arctic region*
  - *Develop measures, in cooperation with other nations, to address issues likely to arise from expected increases in shipping*
  - *Establish a risk-based capability to address hazards in the Arctic, including necessary icebreaking capabilities and cooperative plans for search and rescue*
  - *Develop Arctic waterways management regimes*
  - *Evaluate the feasibility of using access through the Arctic for strategic sealift*
- Bottom line – same missions in a new region
  - *Funding for any increased scope must compete against existing priorities*
  - *Though tasked to defend borders, there is no clear current threat to the borders*
  - *Ensuring safety and stability of commerce seems to be main reason for a presence*

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The bottom line is that no new naval missions are specified; clearly, however, there is a call for an increased scope of naval operations in an ice-free Arctic. Projecting sovereignty, ensuring access, and stabilizing the global commons are the main reasons for increased presence in the Arctic. Despite tasking to defend U.S. borders, there is no clear and current threat to those borders. All five Arctic nations have pledged to resolve territorial claims through existing multilateral mechanisms.

A single paragraph touches on the need for additional resources to achieve the implementation directives. It simply states, “The heads of executive departments and agencies with responsibilities relating to the Arctic region shall work to identify future budget, administrative, personnel, or legislative proposal requirements to implement the elements of this directive.” For DoD, this means that that programs intended to meet NSPD-66 requirements will compete with all the other requirements.

Climate change and naval operations in the Arctic

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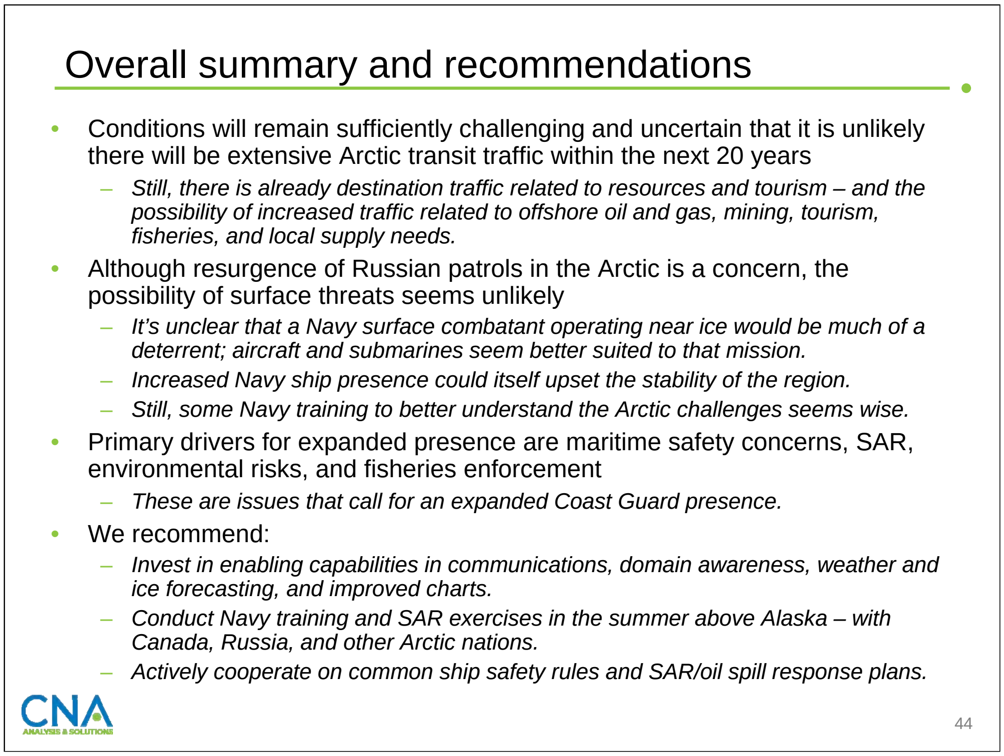

Our conclusions follow.

While conditions will remain sufficiently challenging such that substantial increases in Arctic transits are unlikely within the next 20 years, there are likely to be increases in destinational traffic related to resource extraction, local supply need, and cruise ships. With offshore drilling, fisheries migrating north, and cruise traffic, issues of maritime safety, SAR, environmental risks, and fisheries enforcement become the primary drivers for an expanded presence. These are primarily Coast Guard issues.

Although the resurgence of Russian patrols in the Arctic is a concern, the possibility of surface threats seems unlikely. In any case, it's unclear that Navy surface combatants operating near the ice would be much of a deterrent. Aircraft and submarines—supported by satellite surveillance and ground systems—seem better suited to the missions. An ongoing Navy presence with surface combatants could itself upset the stability of the region. (New multi-mission ships to support bathymetry and salvage missions in the ice might be appropriate). Still, some training to better understand the challenges and prepare for an eventual Arctic presence seems wise.

We recommend the following:

- Invest in enabling capabilities in communications, domain awareness, weather and ice forecasting, and improved charts.
- Conduct Navy training and SAR exercises in the summer above Alaska—with Canada, Russia, and other Arctic nations.
- Actively cooperate on common ship safety rules and SAR/oil spill response plans.

Appendix: Selected ice nomenclature

Selected ice nomenclature

- ***Bergy bit***: A large piece of floating glacier ice, generally showing less than 5 meters above sea level but more than 1 meter and normally 100-300 square meters in area.
- ***Beset***: Situation of a vessel surrounded by ice and unable to move
- ***Concentration***: The ratio expressed in tenths describing the amount of the sea surface covered by ice as a fraction of the whole area being considered.
- ***Fast ice***: Sea ice that forms and remains fast along the coast, where it is attached to the shore, to an ice wall, or between shoals.
- ***First-year ice***: Sea ice of not more that one winter's growth, developing from young ice; thickness 30 centimeters to 2 meters.
- ***Floe***: Any relatively flat, isolated piece of sea ice 20 meters or more across.
- ***Growler***: A piece of ice smaller than a bergy bit less and floating less than 1 meter above the sea surface. Growlers are difficult to distinguish when surrounded by sea ice or in high sea state.
- ***Iceberg***: A massive piece of ice of greatly varying shape, more than 5 meters above sea level, which has broken away from a glacier, and which may be afloat or aground.
- ***Ice cover***: The ratio of an area of ice of any concentration to the total area of sea surface within some large geographic locale.
- ***Ice edge***: The demarcation at any given time between the open sea and sea ice of any kind.
- ***Ice field***: Area of floating ice consisting of any size of floes, which is greater than 10 km across.
- ***Ice free***: No ice present. If ice of any kind is present, this term should not be used.
- ***Ice keel***: From the point of view of the submariner, a downward projection from the underside of the ice canopy; the counterpart of a ridge. Keels may extend 50 meter below sea level.

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Selected ice nomenclature (cont.)

- ***Ice massif***: A variable accumulation of close or very close ice covering hundreds of square kilometers which is found in the same region every summer.
- ***Ice shelf***: A floating ice sheet of considerable thickness showing 2 to 50 meters or more above sea level, attached to the coast.
- ***Lead***: Any fracture or passageway through sea ice that is navigable by surface vessels.
- ***Multiyear ice***: Old ice up to 3 m or more thick that has survived at least two summers of melt.
- ***Old ice***: Sea ice which has survived at least one summer's melt; typical thickness up to 3 meters or more.
- ***Open water***: A large area of freely navigable water in which sea ice is present in concentrations less than one-tenth. No ice of land origin is present.
- ***Drift ice/pack ice***: Term used in a wide sense to include any area of sea ice, other than fast ice, no matter what form it takes or how it is disposed. When concentrations are high, *drift ice* may be replaced by the term *pack ice*.
- ***Polynya***: Any nonlinear shaped opening enclosed by ice.
- ***Ridge***: A line or wall of broken ice forced up by pressure.The submerged volume of broken ice under a ridge, forced downwards by pressure, is termed an ice keel.
- ***Sea ice***: Any form of ice found at sea that has originated from the freezing of sea water.
- ***Young ice***: Ice in the transition to first-year ice, 10-30 centimeters in thickness.

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