Marine Nuclear Power: 1939 – 2018

Part 6: Arctic Operations

Peter Lobner
February 2019

Foreword

In 2015, I compiled the first edition of this resource document to support a presentation I made in August 2015 to The Lyncean Group of San Diego (www.lynceans.org) commemorating the 60th anniversary of the world's first "underway on nuclear power" by *USS Nautilus* on 17 January 1955. That presentation to the Lyncean Group, *"60 years of Marine Nuclear Power: 1955 – 2015,"* was my attempt to tell a complex story, starting from the early origins of the US Navy's interest in marine nuclear propulsion in 1939, resetting the clock on 17 January 1955 with *USS Nautilus*' historic first voyage, and then tracing the development and exploitation of marine nuclear power over the next 60 years in a remarkable variety of military and civilian vessels created by eight nations.

In July 2018, I finished a complete update of the resource document and changed the title to, *"Marine Nuclear Power: 1939 – 2018."* What you have here is *Part 6: Arctic Operations*. The other parts are:

- *Part 1: Introduction*
- *Part 2A: United States - Submarines*
- *Part 2B: United States - Surface Ships*
- *Part 3A: Russia - Submarines*
- *Part 3B: Russia - Surface Ships & Non-propulsion Marine Nuclear Applications*
- *Part 4: Europe & Canada*
- *Part 5: China, India, Japan and Other Nations*

Foreword

This resource document was compiled from unclassified, open sources in the public domain. I acknowledge the great amount of work done by others who have published material in print or posted information on the internet pertaining to international marine nuclear propulsion programs, naval and civilian nuclear powered vessels, naval weapons systems, and other marine nuclear applications. My resource document contains a great deal of graphics from many sources. Throughout the document, I have identified all of the sources for these graphics.

If you have any comments or wish to identify errors in this document, please send me an e-mail to: PL31416@cox.net.

I hope you find this informative, useful, and different from any other single document on this subject.

Best regards,

Peter Lobner
July 2018

Updates:
Revision 1 update of Part 6 was posted in February 2019.

Marine Nuclear Power: 1939 – 2018
Part 6: Arctic Operations

Table of Contents

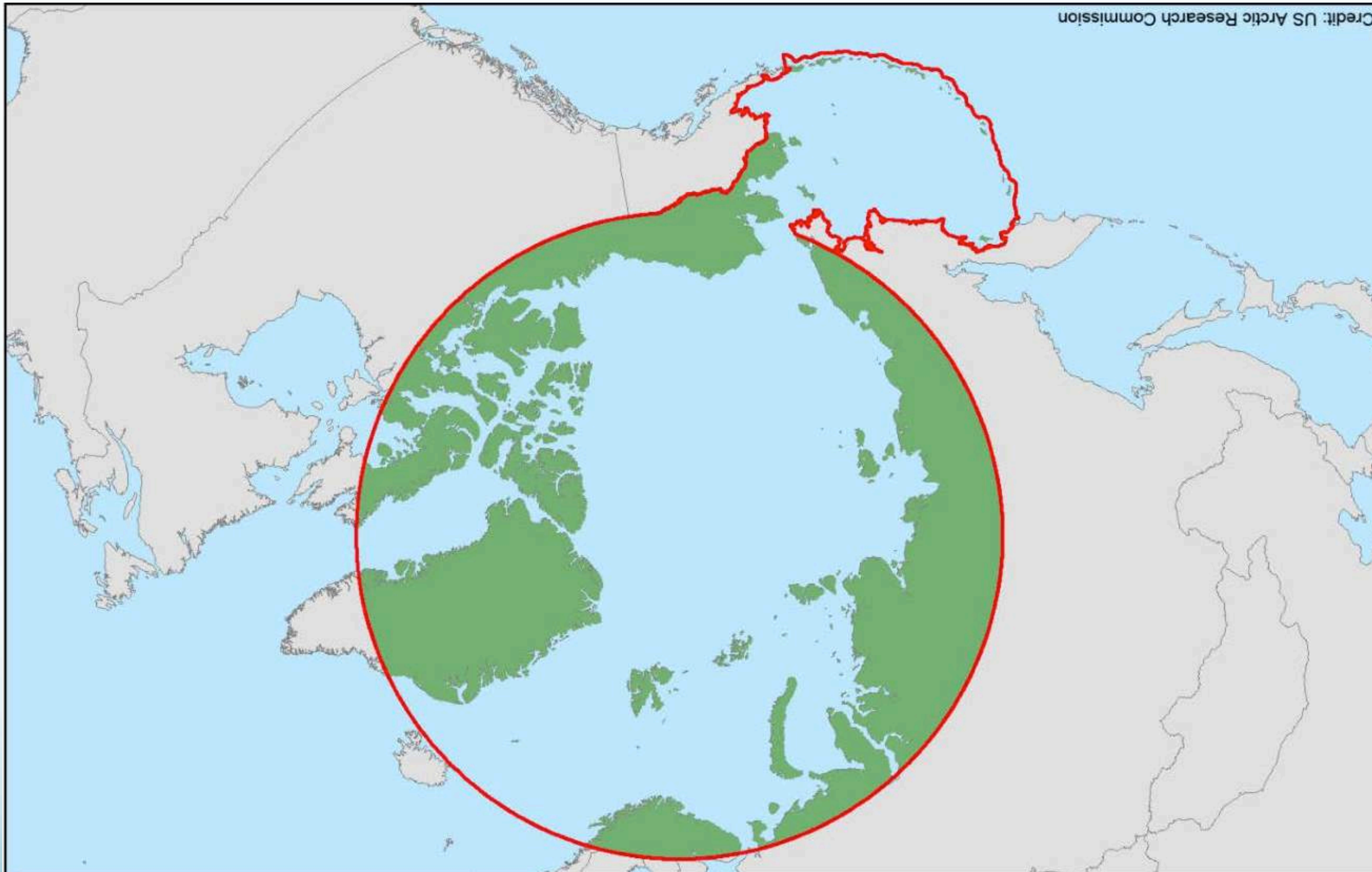
Rational for marine nuclear power in the Arctic

- Vessel propulsion was the first Arctic application of marine nuclear power.
  - Nuclear vessels can have very powerful propulsion plants, which can expand the mission capabilities of the vessel.
  - Nuclear vessel operations are not restricted by a need to refuel, except at very long intervals (years).
  - Nuclear submarine operations are independent of the need for replenishing air for crew or engines. Long-duration under-ice operations are practical.
  - Long-duration surface and underwater missions can be conducted without support, which is particularly important given the limited infrastructure available in most Arctic regions.
- Non-propulsion applications of marine nuclear power include delivery of electric power and/or process heat to towns and facilities in remote Arctic coastal regions and to off-shore facilities and systems sited on above-water platforms or on the seabed.
  - A large power source is needed to support remote towns and development and operation of large-scale industrial and military facilities and systems.
    - Electric power as well as process heat for district heating, desalination and other industrial uses
  - Marine nuclear power provides a means to minimize the amount of on-shore development needed before power delivery can start from a transportable power plant.
  - Marine nuclear power provides a means to meet high power demands in the hostile marine environments of Arctic off-shore platforms and the Arctic seabed.

Orientation to the Arctic region

Arctic boundary

As defined by the US Arctic Research and Policy Act



US Arctic Research Commission map, rotated 180 degrees, based on the US Arctic Research and Policy Act of 1984 (Amended 1990). Source: https://www.arctic.gov/maps.html

Arctic boundary
As defined by the Arctic Council

On 11 May 2017, the eight member states of the Arctic Council approved a legally binding agreement entitled, "*Agreement on Enhancing International Arctic Scientific Cooperation*," which is intended to ease the movement of scientists, scientific equipment and data sharing across the North. This agreement entered force on 23 May 2018.

AGREEMENT ON ENHANCING INTERNATIONAL ARCTIC SCIENTIFIC COOPERATION

ANNEX 1:
Identified Geographic Areas

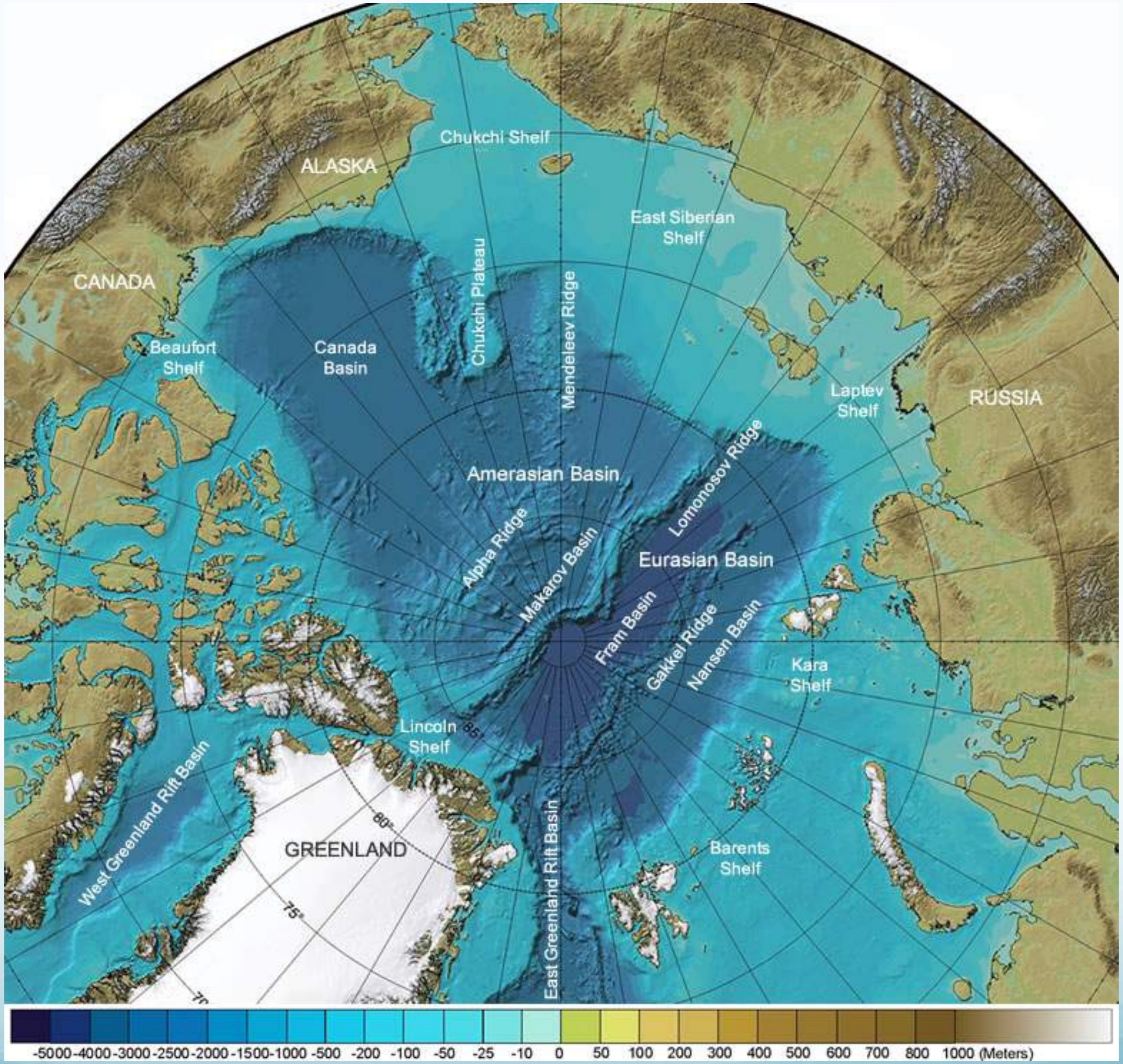
This map shows the approximate extent of the Identified Geographic Areas described in Annex 1 of the Agreement on Enhancing International Arctic Scientific Cooperation. It is intended for illustrative purposes only.

Approximate Extent of Identified Geographic Areas
62°N
Arctic Circle

Continental shelf areas are not depicted.
U.S. Department of State, OES/OPA, 10/2017

Source: https://www.arcus.org/witness-the-arctic/2017/2/article/27780

Arctic bathymetric features



Source: https://geology.com/articles/arctic-ocean-features/

Arctic oil & gas resources

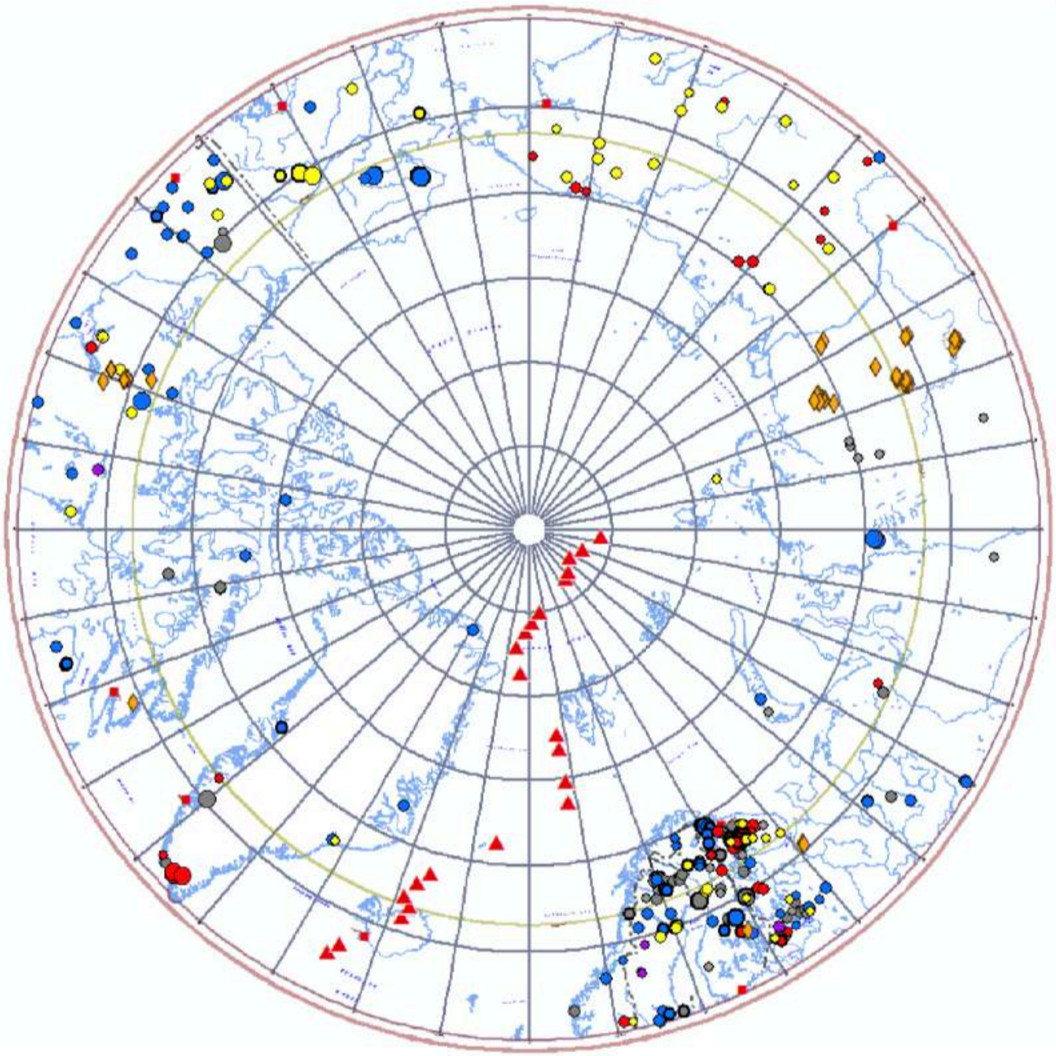
Source: US Energy Information Agency, 2012

Barents Sea oil reserves

The Norwegian Atlantic Committee Report 4-2006

Source: http://www.atlanterhavskomiteen.no/

Arctic mineral resources



DEPOSITS REGISTERED

- STATUS 30.06.15

Circles -

(Grey): Ferrous metals (Cr, Fe, Mn, Ti, V)

(Blue): Base metals (Al, Co, Cu, Ni, Pb, Zn)

(Yellow): Gold, silver

(Red): Special metals (incl. Mo, Nb, REE, Sb, Sc, W)

Diamonds (orange): diamond deposits

Triangles (red): hydrothermal fields (main source: InterRidge)

Deposit numbers (metal/diamond):

Alaska:	12/-
Canada:	38/6
Greenland:	13/-
Norway:	9/-
Sweden:	33/-
Finland:	23/1
Russia:	162/62 (including placers)

Source: Geological Survey of Norway, 2015;
http://fem.lappi.fi/c/document_library/get_file?folderId=2807764&name=DLFE-28482.pdf

Northern Sea Route

The New York Times

September 11, 2009

A Shortcut Across The Top of the World

The Northeast Passage, across the Arctic Ocean, provides a shorter alternative for cargo vessels travelling between Europe and Asia than using the Suez Canal. It is shorter than the Panama Canal route for some voyages between the North American west coast and Europe.

LENGTH OF A VOYAGE TO ROTTERDAM FROM:

YOKOHAMA, JAPAN
12,894 miles via Suez Canal,
8,452 miles via Northeast Passage

SHANGHAI, CHINA
12,107 miles via Suez Canal,
9,297 miles via Northeast Passage

VANCOUVER, CANADA
10,262 miles via Panama Canal,
8,038 miles via Northeast Passage

Source: The Russian Ministry of Transport

THE NEW YORK TIMES

SIGN IN TO RECOMMEND

Source: The Russian Ministry of Transport via The New York Times

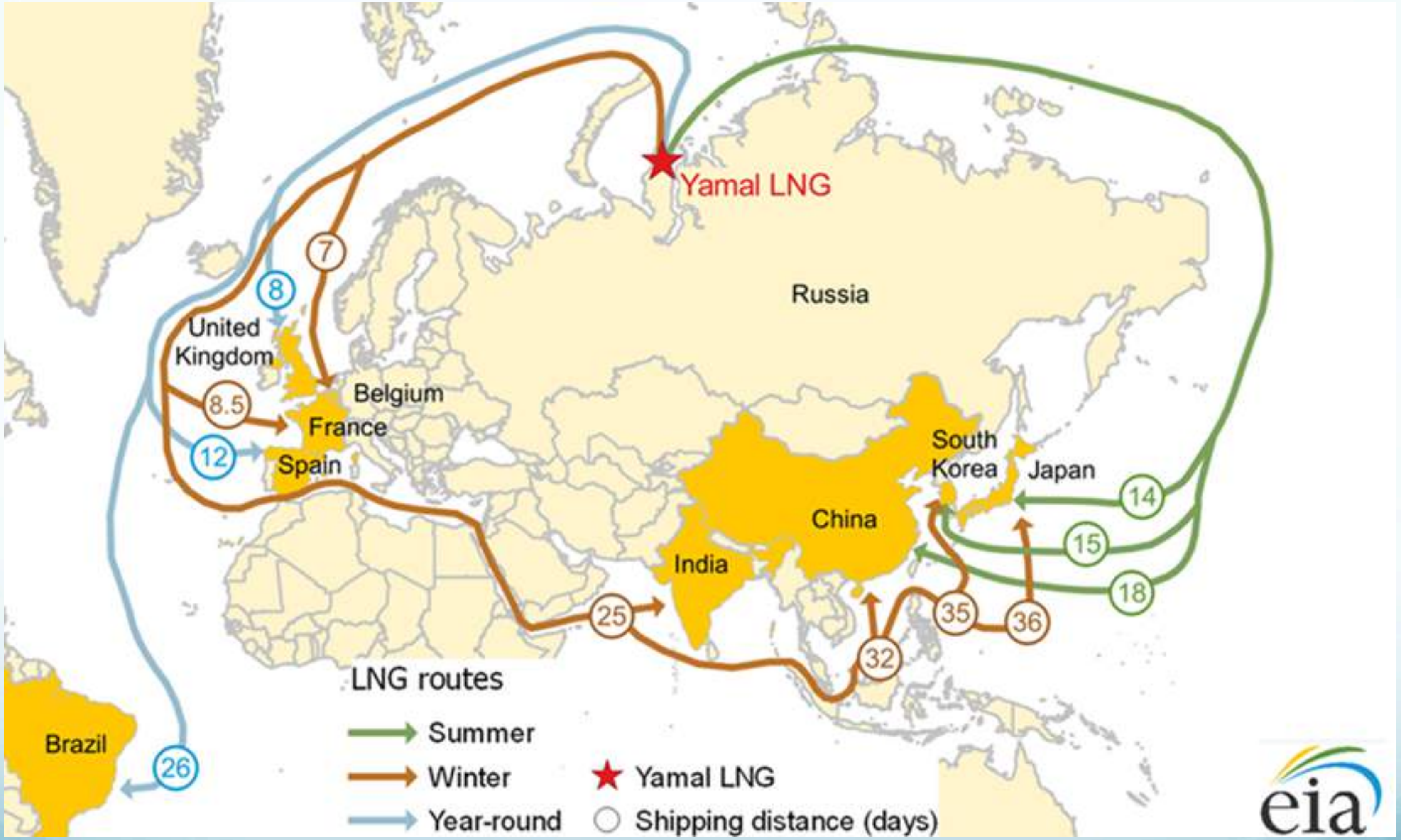
Northern Sea Route

- Northern Sea Route, also known as Northeast Passage, is a water route along the northern coast of Russia, between the Atlantic and Pacific oceans.
- First traversed by Nils A. E. Nordenskjold of Sweden in 1878-79.
- Regular use of this route was first established in the 1930s by the USSR.
- This route enables shipping to support Russian cities and industrial infrastructure along the north coast and cuts the distance between Russian Atlantic and Pacific ports in half, relative to routes through the Suez Canal.
- A fleet of Russian icebreakers, aided by aerial reconnaissance and by radio weather stations, keeps the entire Northern Sea Route navigable from June to October, and the route from Murmansk to Dudinka open all year.

Northern Sea Route

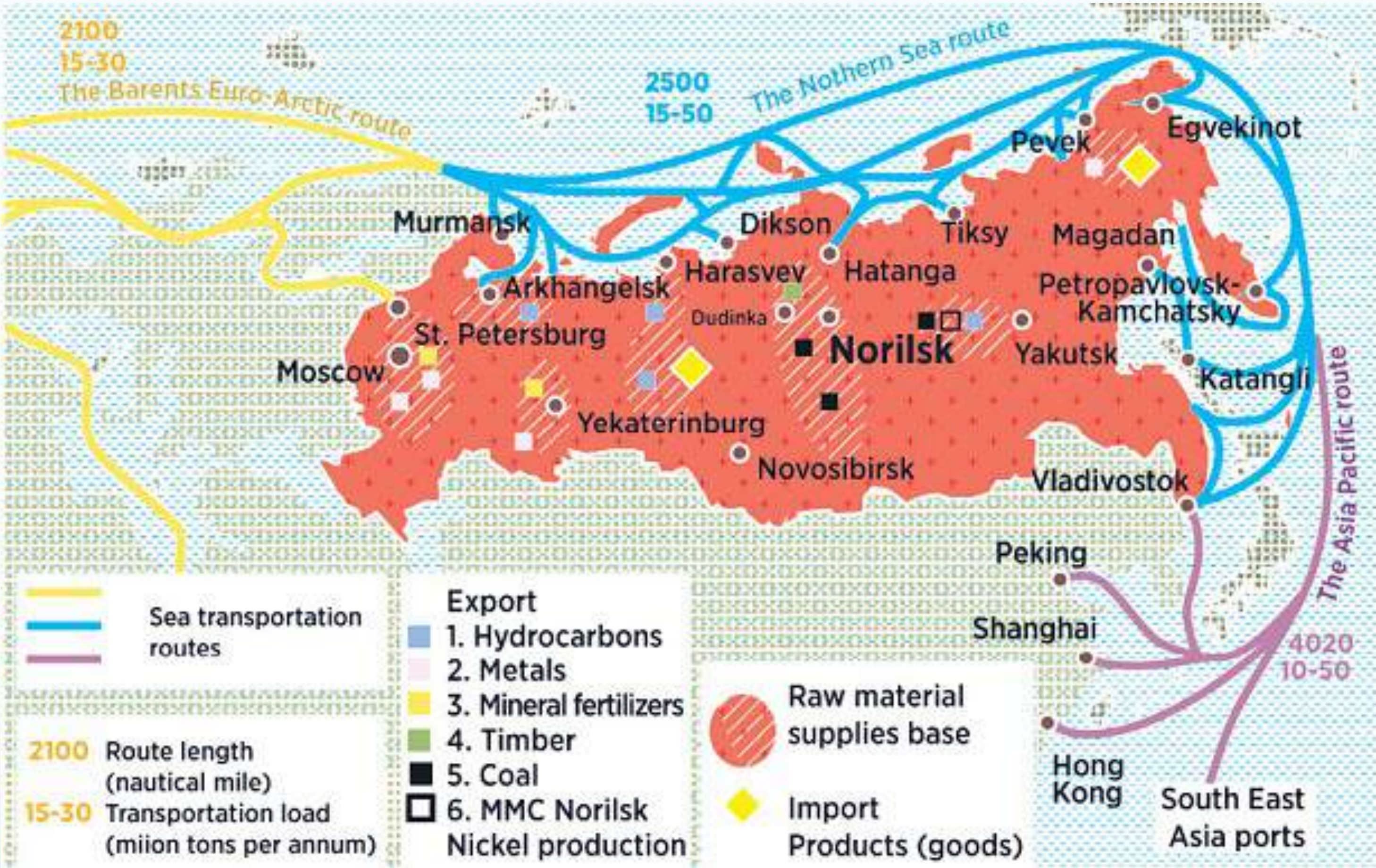
- Russia maintains 16 deep water ports along the Northern Sea Route (NSR).
- Between 2011 and 2016, 18 to 71 vessels per year made full transits of the NSR. Many more vessels were serving ports along the NSR.
- Economic development of the Russian Arctic coast is focused on extraction of oil, gas, coal, and mineral resources.
- In February 2017, Russian representatives at the Arctic-2017 conference in Moscow provided the following details on cargo traffic along the NSR:
  - In 2015, deliveries NSR ports accounted for 73% of total traffic. The primary cargo delivered was for construction of the Yamal liquefied natural gas (LNG) terminal.
    - When completed, Yamal LNG is expected to produce 16.5 million tons of LNG and 1.5 million tons of gas condensates per year, all to be shipped out via the NSR.
  - In 2016, deliveries to NSR ports accounted for only 43% of total traffic, reflecting the growth in export traffic along the NSR.
    - Traffic on the NSR exceeded 7 million tons with 19 complete transits of the NSR.
  - NSR traffic is projected to reach 75 million metric tons by 2025.
- In November 2018, it was reported that NSR shipping traffic exceeded 15 million tons of cargo during the first eleven months of the year. Traffic growth primarily came from the export of LNG, crude oil, and coal.
  - The Danish-registered ship *Venta Maersk* was the first of a new class of large (42,000 tons) ice-breaking cargo ships to transit the NSR from Europe to customers in Asia.

Northern Sea Route utilization



Source: US Energy Information Administration (EIA), Natural gas Weekly Update, 20 December 2017

Northern Sea Route utilization



Diesel-electric icebreaking ships owned by Norilsk Nickel operate regularly between Murmansk for the mouth of the Yenisei, Siberia's biggest river. After five to seven days of breaking through thick ice, these ships reach the port of Dudinka, bringing supplies to the Norilsk mining region, which has large deposits of nickel, copper and precious metals.

Source: Russia Beyond, 2012; https://www.rbth.com/

Northwest Passage

Source: http://www.britannica.com/place/Northwest-Passage-trade-route

Northwest Passage

- The Northwest Passage is a sea route connecting the northern Atlantic to the northern Pacific via sea lanes in the Arctic Ocean, some of which are claimed by Canada as "internal waters". The US position is that the Northwest Passage is an international strait open to shipping, and does not require permission from Canada for transit.
  - The first recorded transit of the Northwest Passage was made in 1903 – 06 by the Norwegian polar explorer Roland Amundsen in the ship *Gjoa*.
  - The Canadian Coast Guard was formed on January 26, 1962 as a subsidiary of the Department of Transport (DOT).
    - Among its many missions, the CCG is responsible for icebreaking and Arctic sovereignty protection.
    - CCG icebreakers are not responsible for maintaining a commercial shipping lane through the Northwest Passage.
  - In August 1969, the heavily modified oil tanker *SS Manhattan* became the first commercial vessel to navigate the Northwest Passage from the Atlantic to Prudhoe Bay, where oil was discovered in 1968.
  - In 1985, the US Coast Guard icebreaker *Polar Star* transited the Northwest Passage after notifying the Canadian government of the voyage, but without seeking formal authorization from the Canadian government for the voyage.

Northwest Passage

- In 1986 the Canadian government officially claimed the Northwest Passage as Canadian internal waters through the application of straight baselines.
  - This Canadian sovereignty claim has not been accepted by the US, the European Union and other nations, which believe the Passage is an international strait.
- In 2009, Canada re-named this waterway the "Canadian Northwest Passage."
- The Canadian government reported that 350 marine voyages traversed the Canadian Arctic in 2013. Only 20 of these voyages were complete transits of the Northwest Passage.
- In September 2016, the *Crystal Serenity* made the first west-east transit of the Northwest Passage by a passenger cruise liner. It was accompanied for part of its journey by the icebreaking escort vessel *RRS (Royal Research Ship) Ernest Shackleton*.
- Scott Polar Research Institute reported that there were there were 32 complete transits of the Northwest Passage in 2017, the greatest annual number of transits to date.

Northwest Passage

- Canada has only one deep water port in the high Arctic, and that is a private mining port.
  - In contrast, Russia has 16 deep water ports along its Northern Sea Route.
- Despite plans by previous Canadian governments to establish as many as seven deep water ports in the Nunavut Territory, which makes up most of the Canadian Arctic Archipelago, little has been accomplished.
  - The lack of infrastructure along the Northwest Passage complicates Canada's efforts to exercise sovereignty over that part of the Arctic and promote economic development.
  - In 2016, the Canadian federal government committed $64 million and the Nunavut government committed an additional $21 million for a new port at Iqaluit, the capital of the Nunavut Territory, located near the eastern entrance to the Northwest Passage.
    - Port design will have to cope with 13 meter (42.6 foot) tides and large ice flows.
    - The new port is expected to be complete in 2020.
- While Russia and China are spending billions to develop the Northern Sea Route infrastructure and commercial traffic, similar investments are not being made by Canada along the Northwest Passage.

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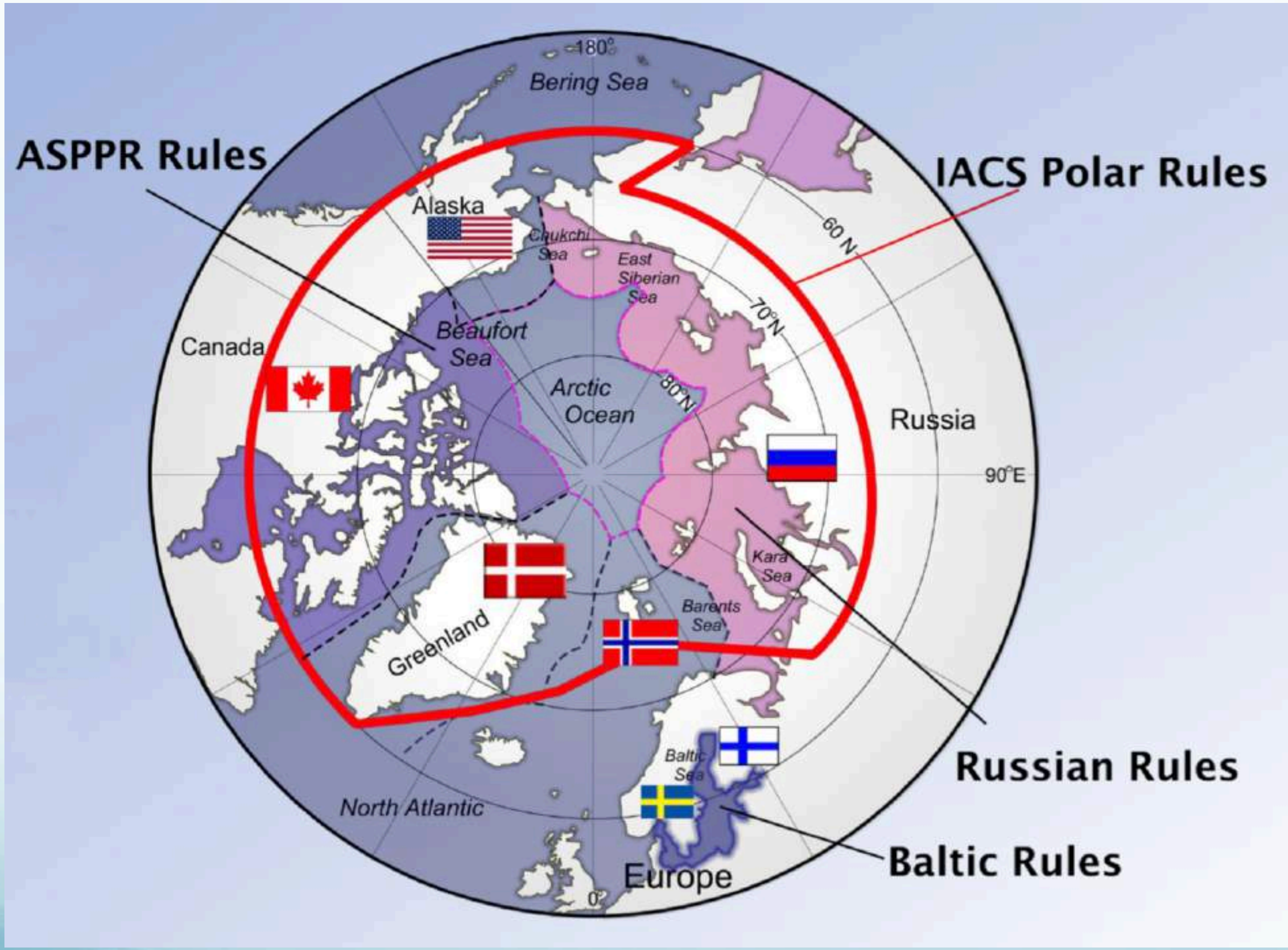
Arctic-class vessel classification and design requirements



Source: C. Daley, “Ice Class Rules Description and Comparison,” Memorial University St. John’s, Canada, April 2014

Uniform rules are not yet in place across the Arctic region.

ASPPR = Canada’s Arctic Shipping Pollution Prevention Regulations

IACS = International Association of Classification Societies requirements

Arctic-class vessel classification and design requirements

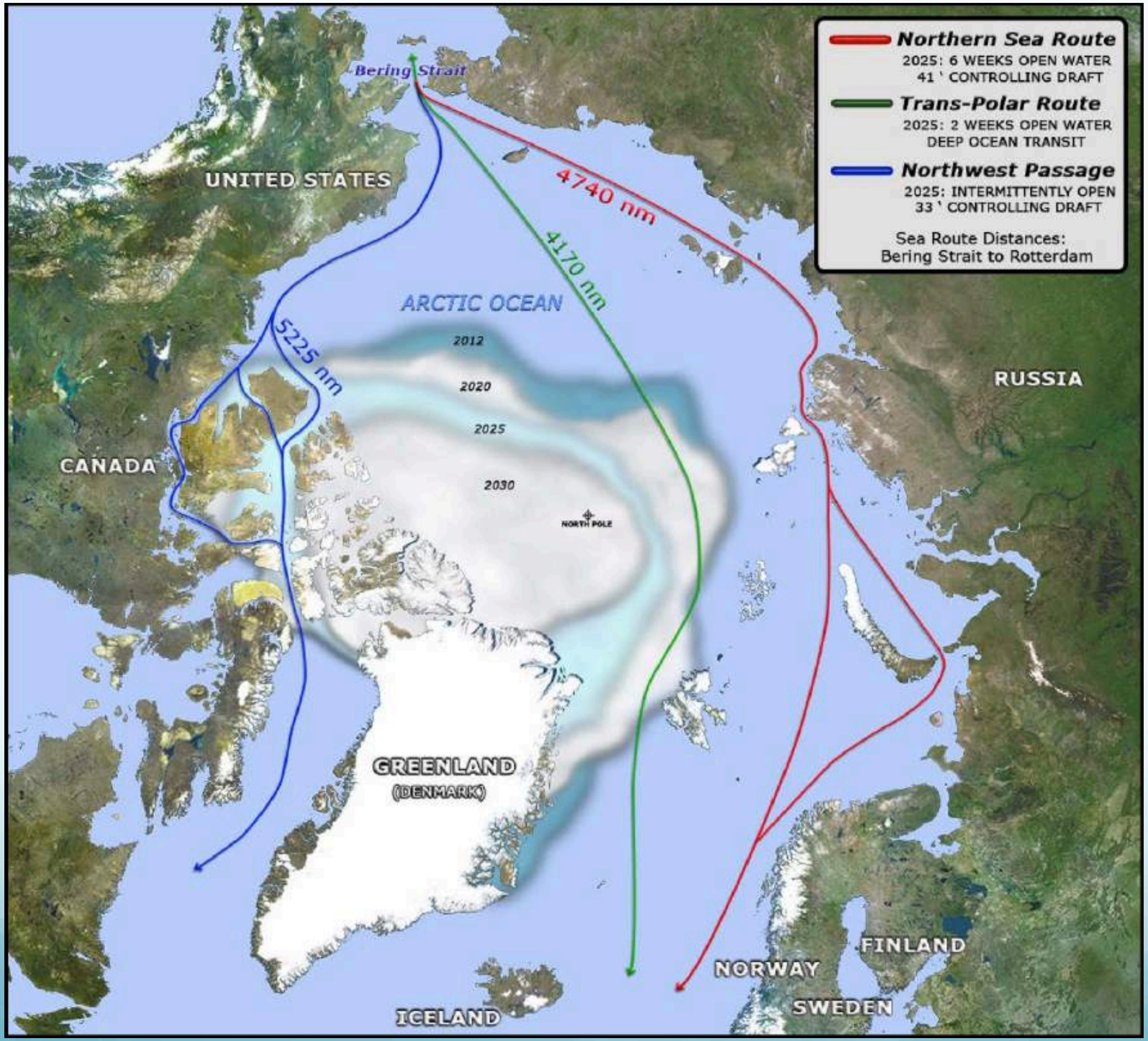
- For more information on Arctic vessel classification and design requirements, refer to:
  - C. Daley, *"Ice Class Rules Description and Comparison,"* Memorial University St. John's, Canada, April 2014
    - https://www.engr.mun.ca/~cdaley/8074/Ice%20Class%20Rules_CD.pdf
  - *"Requirements Pertaining to Polar Class,"* International Association of Classification Societies (IACS), IACS Req. 2016
    - www.iacs.org.uk/download/1803
  - *"Arctic Shipping Pollution Prevention Regulations"* (ASPPR), Government of Canada
    - https://www.tc.gc.ca/eng/marinesafety/debs-arctic-acts-regulations-asppr-421.htm

Extent of Arctic ice pack

Comparison of 30-year sea ice minimum average with the 2012 historical minimum, inside the red line.

Source: US Navy
Arctic Roadmap 2014 - 2030

Anticipated future Arctic transit routes



Routes superimposed over US Navy consensus assessment of sea ice extent minima.

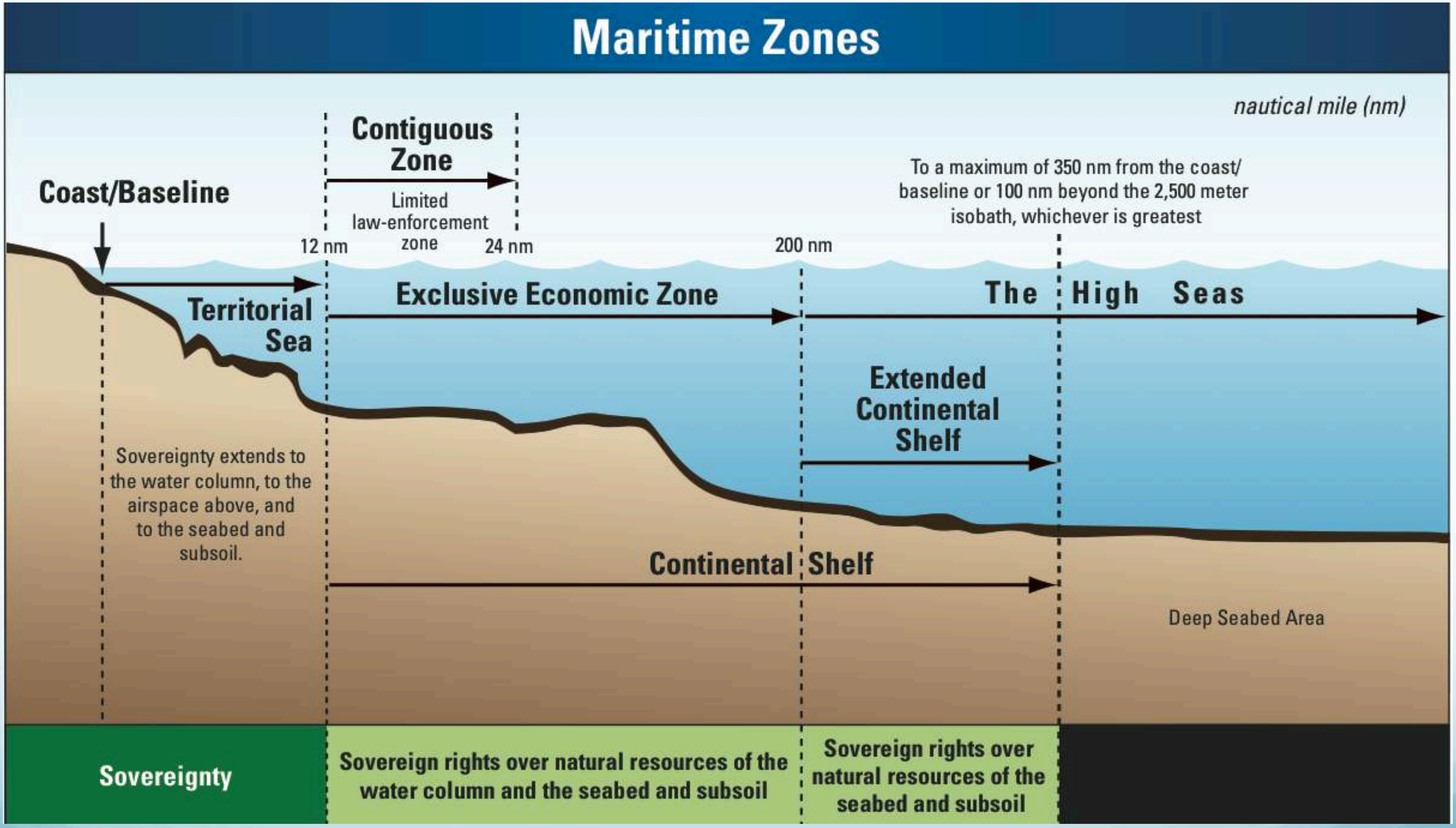
Source: US Navy
Arctic Roadmap 2014 - 2030

UN Convention on the Law of the Sea (UNCLOS)

Law of the Sea Treaty

- The UNCLOS establishes a comprehensive regime of law and order in the world's oceans and seas, establishing rules governing all uses of the oceans and their resources.
  - Opened for signature on 10 December 1982; entered into force on 16 November 1994.
    - The original Convention was modified by the 1994 Agreement on Implementation.
  - To date, 162 countries and the European Union have joined the Convention.
  - While the US participated in the negotiations that established UNCLOS and the subsequent Agreement on Implementation, Congress has not ratified the Convention.
    - In March 1983 President Ronald Reagan, through Proclamation No. 5030, claimed a 200-mile exclusive economic zone, consistent with UNCLOS.
    - In December 1988 President Reagan, through Proclamation No. 5928, extended U.S. territorial waters from three nautical miles to twelve nautical miles, consistent with UNCLOS.
  - Part IV of the Convention, dealing with the continental shelf, and Annex II, which established a Commission on the Limits of the Continental Shelf, define the basis for coastal nations to make extended continental shelf (ECS) claims.
- Arctic natural resource exploration has revealed large reserves of oil, gas, minerals and other valuable resources. This has motivated Arctic coastal nations to make ECS claims with the goal of expanding their exclusive access to Arctic resources on and beneath the seabed.

Maritime zones & sovereignty



Source: http://continentalshelf.gov/media/ECSposterDec2010.pdf

Arctic territorial claims

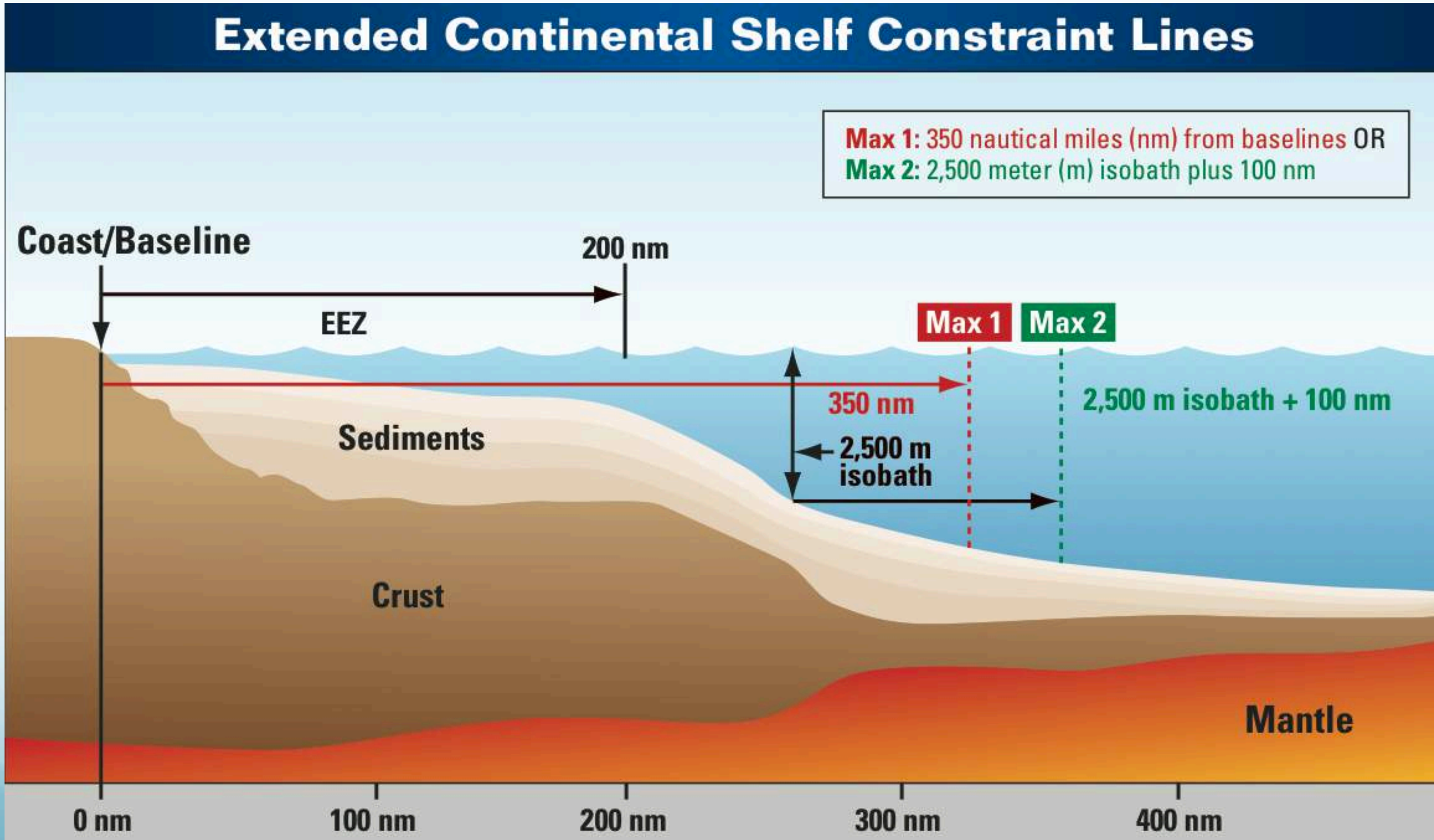
Source: Encyclopedia Britannica

The issue of Arctic territorial claims is much more complex than portrayed in this diagram, which serves mainly to identify the Arctic nations and the approximate extent of their respective claims.

For a comprehensive summary of Arctic territorial claims, see the January 2017 European Parliament briefing, "Arctic continental shelf claims - Mapping interests in the circumpolar North," which is available at the following link:

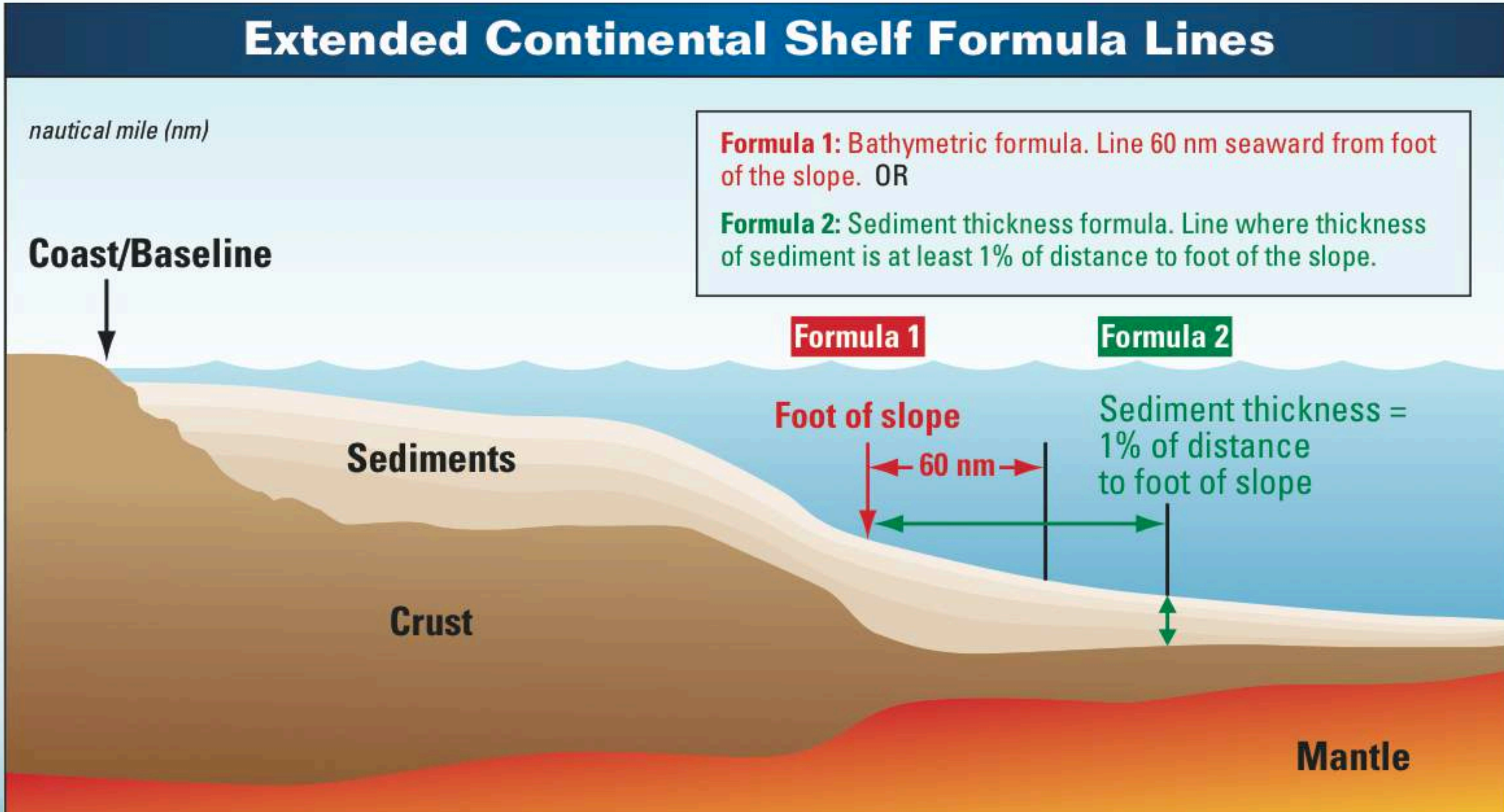
https://cor.europa.eu/en/engage/studies/Documents/EPRS_BRI(2017)595870_EN.pdf

Basis for an extended continental shelf (ECS) claim



Source: http://continentalshelf.gov/media/ECSposterDec2010.pdf

Basis for an extended continental shelf (ECS) claim



Source: http://continentalshelf.gov/media/ECSposterDec2010.pdf

The Arctic Council

- The Arctic Council was formally established in 1996 by the *Ottawa Declaration* as the leading intergovernmental forum promoting cooperation, coordination and interaction among the Arctic States, Arctic indigenous communities and other Arctic inhabitants on common Arctic issues, in particular on issues of sustainable development and environmental protection.
- The Ottawa Declaration defined the eight nations with territorial claims in the Arctic as members of the Arctic Council:
  - Canada
  - Kingdom of Denmark (for Greenland & Faroe Islands)
  - Finland
  - Iceland
  - Norway
  - Russian Federation
  - Sweden
  - United States
- In addition, six organizations representing Arctic indigenous peoples have status as Permanent Participants. Observer status is open to non-Arctic states, along with inter-governmental, inter-parliamentary, global, regional and non-governmental organizations that the Council determines can contribute to its work.
  - Currently, 13 non-Arctic states have been approved as observers, including UK, China and France.
- The Arctic Council plays an important role in establishing standards for Arctic vessel operation and for Arctic pollution monitoring, which is managed by the Arctic Monitoring and Assessment Program (AMAP) working group.
- The Arctic Council also has a role in promoting cleanup of contaminated areas in the Arctic, including areas contaminated by radioactive waste and sunken nuclear-powered vessels.

Source: https://arctic-council.org/index.php/en/about-us

US Arctic Policy

US Arctic Policy

- US Arctic policy and its implementation are governed by a tier of plans, strategy and related documents. Key among them are the following:
  - **Executive Branch:**
    - National Security Presidential Directive 66 / Homeland Security Presidential Directive 25 (NSPD-66/HSPD-25), *Arctic Region Policy*, January 2009
    - *National Strategy for the Arctic Region* (NSAR), May 2013
    - *Implementation Plan for the NSAR*, January 2014
    - *Executive Order for Enhancing Coordination of Arctic Efforts*, January 2015
  - **Department of State (DoS):** *Report on Arctic Policy* by the DoS International Security Advisory Board (ISAB), September 2016
  - **Department of Defense (DoD):** *Report to Congress on Strategy to Protect United States National Security Interests in the Arctic Region*, December 2016
  - **US Navy:** *US Navy Arctic Roadmap 2014 - 2030*
  - **US Coast Guard (USCG):**
    - *USCG Arctic Strategy*, May 2013
    - *USCG Arctic Strategy Implementation Plan*, December 2015
  - **Department of Commerce:** National Oceanic and Atmospheric Administration (NOAA) *Arctic Action Plan*, April 2014
  - **Department of Interior:** US Geologic Survey (USGS) *Arctic Science Strategy 2015 – 2020*
  - **US Environmental Protection Agency (EPA):** EPA supports implementation of US Arctic policy as the US representative on two Arctic Council working groups.

US Arctic Policy

Presidential Directive NSPD-66/HSPD-25, *Arctic Region Policy*

- This Presidential Directive, issued in January 2009, states that US Arctic policy is based on the following six principal objectives:
  - Meet national security and homeland security needs relevant to the Arctic region
  - Protect the Arctic environment and conserve its biological resources
  - Ensure that natural resource management and economic development in the region are environmentally sustainable
  - Strengthen institutions for cooperation among the eight Arctic nations (the United States, Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, and Sweden)
  - Involve the Arctic's indigenous communities in decisions that affect them
  - Enhance scientific monitoring and research into local, regional, and global environmental issues
- This Presidential Directive provides implementation guidance on:
  - National security and homeland security interests in the Arctic
  - International governance
  - Extended continental shelf and boundary issues
  - Promoting international scientific cooperation
  - Maritime transportation in the Arctic region
  - Economic issues, including energy
  - Environmental protection and conservation of natural resources

US Arctic Policy

National Strategy for the Arctic Region (NSAR), May 2013

- "To meet the challenges and opportunities in the Arctic Region, and in furtherance of established Arctic Region Policy (this is a reference to NSPD-66/HSPD-25), we will pursue the following lines of effort and supporting objectives in a mutually reinforcing manner that incorporates the broad range of US current activities and interests in the Arctic region."
- Advance US security interests
  - Evolve Arctic infrastructure and strategic capabilities
  - Enhance Arctic domain awareness
  - Preserve Arctic region freedom of the seas
  - Provide for future US energy security
- Pursue responsible Arctic region stewardship
  - Protect the Arctic environment and conserve Arctic natural resources
  - Use integrated Arctic management to balance economic development, environmental protection and cultural values
  - Increase the understanding of the Arctic through scientific research and traditional knowledge
  - Chart the Arctic region
- Strengthen international cooperation
  - Pursue arrangements to promote Arctic state prosperity, protect the Arctic environment and enhance security
  - Work through the Arctic Council to advance US interests in the Arctic region
  - Accede to the Law of the Seas Convention
  - Cooperate with other interested parties

Implementing US Arctic Policy

Implementation Plan for the NSAR, January 2014

- The Executive Branch issued this Implementation Plan with the intent of providing the further guidance for each "line of effort" identified in the NSAR:
  - Outlined expected next steps
  - Defined means for measuring progress
  - Identified lead and supporting agencies
- Security-related objectives were assigned to the Department of Homeland Security.
- Oddly, the Department of Defense (DoD) was assigned lead responsibility for only one objective: "Develop a framework for observations and modeling to support forecasting and prediction of sea ice."
  - This objective seems to be part of the "core business" of the National Oceanic and Atmospheric Administration (NOAA) and is addressed in the NOAA *Arctic Action Plan.*

Implementing US Arctic Policy

Executive Order for Enhancing Coordination of Arctic Efforts, January 2015

- President Obama issued this Executive Order (EO) and established a White House Arctic Executive Steering Committee with broad membership to provide guidance to executive departments and agencies and enhance coordination of Federal Arctic policies across agencies and offices, and, where applicable, with State, local, and Alaska Native tribal governments and similar Alaska Native organizations, academic and research institutions, and the private and nonprofit sectors.
- At about the same time, Russia took a very different approach to implementing their Arctic policy with the formation of the Arctic Joint Strategic Command, which became operational on 1 December 2014, with a charter to employ military forces to protect Russian national interests in the Arctic.

Implementing US Arctic Policy

US Department of State (DoS) Arctic Policy

- DoS Arctic policy is consistent with NSPD-66/HSPD-25 and NSAR 2013.
- The role of promoting U.S. interests in the Arctic is managed by the DoS Office of Ocean and Polar Affairs
- The 2016 *"Report on Arctic Policy"* by the DoS International Security Advisory Board (ISAB), made six recommendations:
  - The US must continue to lead on Arctic safety, security and stewardship.
  - The US should promptly ratify the United Nations Convention on the Law of the Sea (UNCLOS).
  - The US should increase its presence and domain awareness in the Arctic.
  - The US needs to continue to strengthen its alliances and partnerships, including with Arctic Council nations, observers, and other partners.
  - The US should adopt policies and practices to deal with the Russian dimension of Arctic developments.
  - Transparency and confidence building measures should be strengthened to reduce the risk of miscalculation or accident.
    - Issues include interpretation in the Arctic of the Open Skies Treaty (1994), the Vienna Document (2011), the Incidents at Sea Agreement (INCSEA, 1972) and the Agreement on Prevention of Dangerous Military Activities (DMA Agreement, 1989), all which have been applied in other regions of the world for many years.

Implementing US Arctic Policy

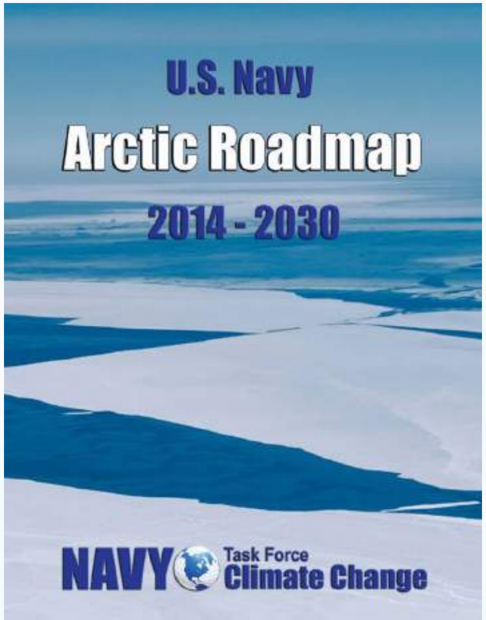
US Department of Defense (DoD) Arctic Strategy

- The current DoD Arctic policy document is the December 2016 *"Report to Congress on Strategy to Protect United States National Security Interests in the Arctic Region,"* which addresses the following:
  - Enhance the capability of US forces to defend the homeland & exercise sovereignty
    - DoD will depend on submarines, aircraft and Coast Guard vessels. The Navy does not have the capability to conduct "blue water" operations in the Arctic.
    - The Navy has no plans to develop ice-hardened military surface ships.
  - Strengthen deterrence at home and abroad
  - Strengthen alliances and partnerships
  - Preserve freedom of the seas in the Arctic
  - Engage public, private, and international partners to improve domain awareness in the Arctic
  - Evolve DoD Arctic infrastructure and capabilities consistent with changing conditions and needs
  - Provide support to civil authorities, as directed
  - Partner with other departments, agencies, and nations to support human and environmental security
  - Support international institutions promoting regional cooperation and the rule of law
- In the 2018 National Defense Authorization Act, Congress directed DoD to submit an updated report on US Arctic capabilities and resource gaps no later than 1 June 2019.

Implementing US Arctic Policy

US Navy Arctic Roadmap

- The Navy's "*Arctic Roadmap 2014 – 2030*" provides implementing guidance necessary to prepare the Navy to respond effectively to future Arctic region contingencies, delineates the Navy's leadership role, and articulates the Navy's support to achieve national priorities in the region.
- The Roadmap identifies four strategic objectives:
  - Ensuring sovereignty of the United States' Arctic region
  - Providing ready naval forces to respond to crises and contingencies
  - Preserving freedom of navigation
  - Promoting partnerships within the U.S. government and with its international allies and partners
- "Navy functions in the Arctic Region are not different from those in other maritime regions; however, the Arctic Region environment makes the execution of many of these functions much more challenging."
- "As opposed to combat-related missions, Navy forces are far more likely to be employed in the Arctic Region in support of Coast Guard search and rescue, disaster relief, law enforcement, and other civil emergency/civil support operation."



Source: US Navy

- "While the region is expected to remain a low threat security environment where nations resolve differences peacefully, the Navy will be prepared to resolve conflicts and ensure national interests are protected."
  - The presence of vast resource endowments and territorial disagreements "contributes to a possibility of localized episodes of friction in the Arctic Region, despite the peaceful intentions of the Arctic nations."
  - Note that the Navy currently is not prepared for "blue-water" Arctic operations with surface ships even though the region has become ice-free enough for open waterways in some areas and seasons.
- In 2018, the Navy started preparation of a new document, "*Arctic Strategic Outlook*," which is expected to replace the Arctic Roadmap in 2019.

Implementing US Arctic Policy

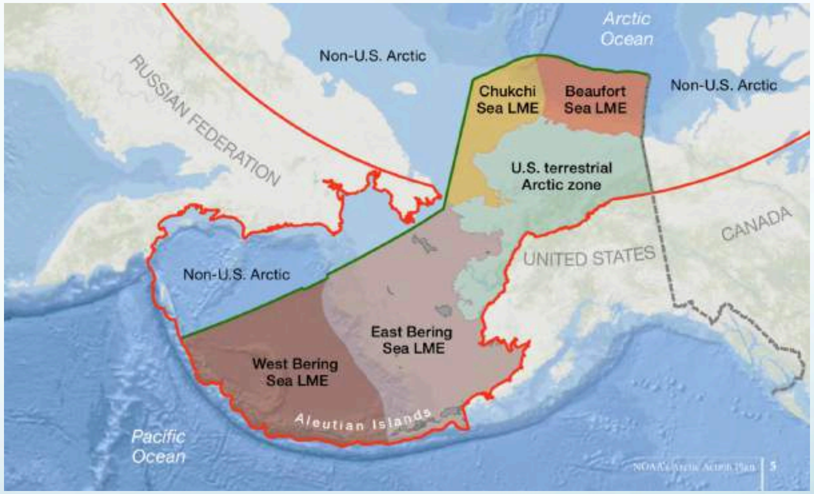
US Coast Guard (USCG) Arctic Strategy

- The *"USCG 2013 Arctic Strategy"* outlines three objectives in the Arctic for the USCG over the next 10 years (thru 2023):
  - Improving awareness of the Arctic domain, currently restricted due to limited surveillance, monitoring, and information system capabilities
    - Ensure effective coordination and information sharing
    - Enhance collection, fusion, and analysis of maritime Information and intelligence
    - Achieve effective presence
      - Note that the USCG currently has only a single, aging but operable heavy polar icebreaker (*Polar Star*, normally assigned to Antarctic duty) and one medium icebreaker (*Healey*). The first new heavy polar icebreaker is unlikely to be delivered to the USCG before 2030.
  - Modernizing governance to prepare for future (unspecified) missions throughout the Arctic
    - Inform domestic and international governance related to safety, security, and environmental standards
    - Safeguard the marine environment by establishing best practices that protect and promote environmental resilience
    - Preserve living marine resources increased foreign incursions into the US EEZZ in the Arctic Ocean
    - Protect U.S. sovereignty and sovereign rights, primarily relating to freedom of navigation and overflight
  - Broadening partnerships
    - Develop and promote the USCG as an expert resource for partners
    - Leverage domestic and international partnerships as "force multipliers" to secure the region against transnational threats, facilitate legitimate commerce, and protect the environment
    - Support a national approach for Arctic planning
- This strategy is implemented via the *"USCG Arctic Strategy Implementation Plan"*, December 2015.

Implementing US Arctic Policy

NOAA Arctic Action Plan

- National Oceanic and Atmospheric Administration (NOAA) implements US Arctic policy through its *Arctic Action Plan*, dated April 2014, via the following "lines of effort":
  - Advance US security interests
    - Issue Arctic weather and sea ice forecasts
    - Conduct sea ice research to better understand the drivers and associated impacts that cause ice to form and melt
  - Pursue responsible Arctic region stewardship
    - Issue an annual Arctic Report Card, issued since 2006
    - Conduct ecosystem and habitat research
    - Conduct hydrographic, coastal land and tidal surveys needed to improve charting in the Arctic; partner with survey-capable vessels such as the U.S. Coast Guard, US Navy, the academic fleet, and private industry.
    - Deliver scientific support to the U.S. Coast Guard for marine hazards
  - Strengthen international cooperation, for example:
    - Represent the US on one Arctic Council working group
    - Collaborate on sea ice mapping with the International Ice Charting Working Group, the North American Ice Service, the International Ice Patrol, and the U.S. National Ice Center



The marine areas in the U.S. Arctic comprise four discrete large marine ecosystems (LME).

Source: Esri Ocean Basemap, via NOAA's Arctic Action Plan

Implementing US Arctic Policy

US Geologic Survey (USGS) Arctic Science Strategy 2015 – 2020

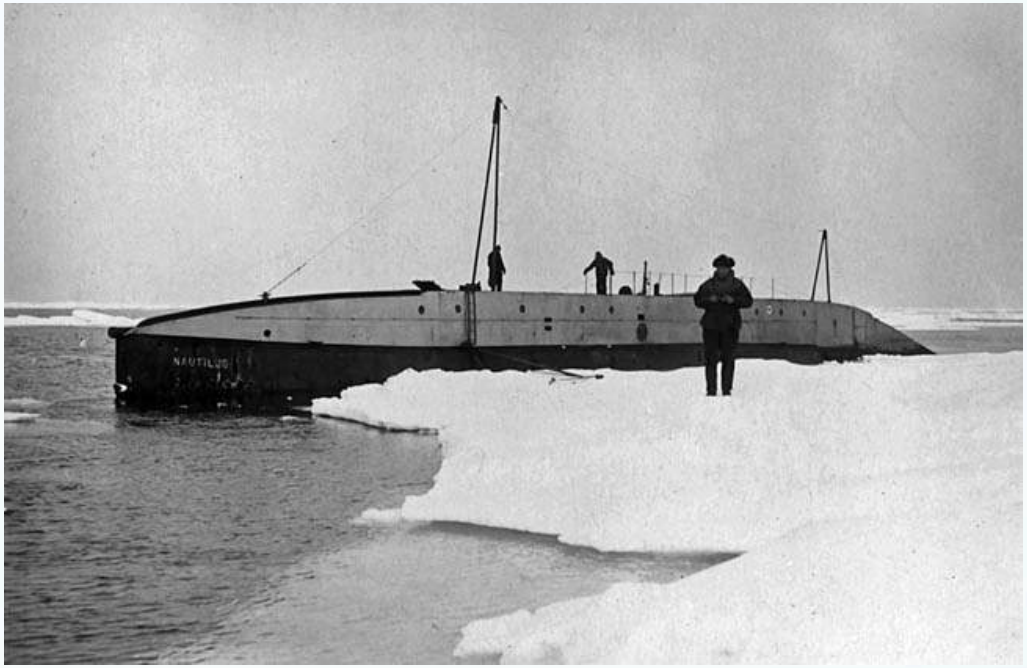
- USGS provides sound and relevant scientific information that supports the goals identified in the National Strategy for the Arctic Region (NSAR 2013).
- The "*USGS Arctic Science Strategy 2015 – 2020*" focuses USGS science efforts on the following goals and actions:
  - Improve scientific information for Arctic coastal communities and ecosystems
  - Advance an integrated, landscape-scale understanding of Arctic ecosystems and the potential for future change
  - Assess mineral and energy resources present in Arctic landscapes, and evaluate environmental implications of Arctic resource development
  - Determine effects of a changing Arctic on environmental health
  - Enhance the scientific understanding of the physical processes unique to the Arctic
  - Improve statewide geospatial data and mapping to meet the needs of safety, planning, research, and resource management partners

Dream of the Arctic submarine

The dream of the Arctic submarine

Source: http://rsgs.org

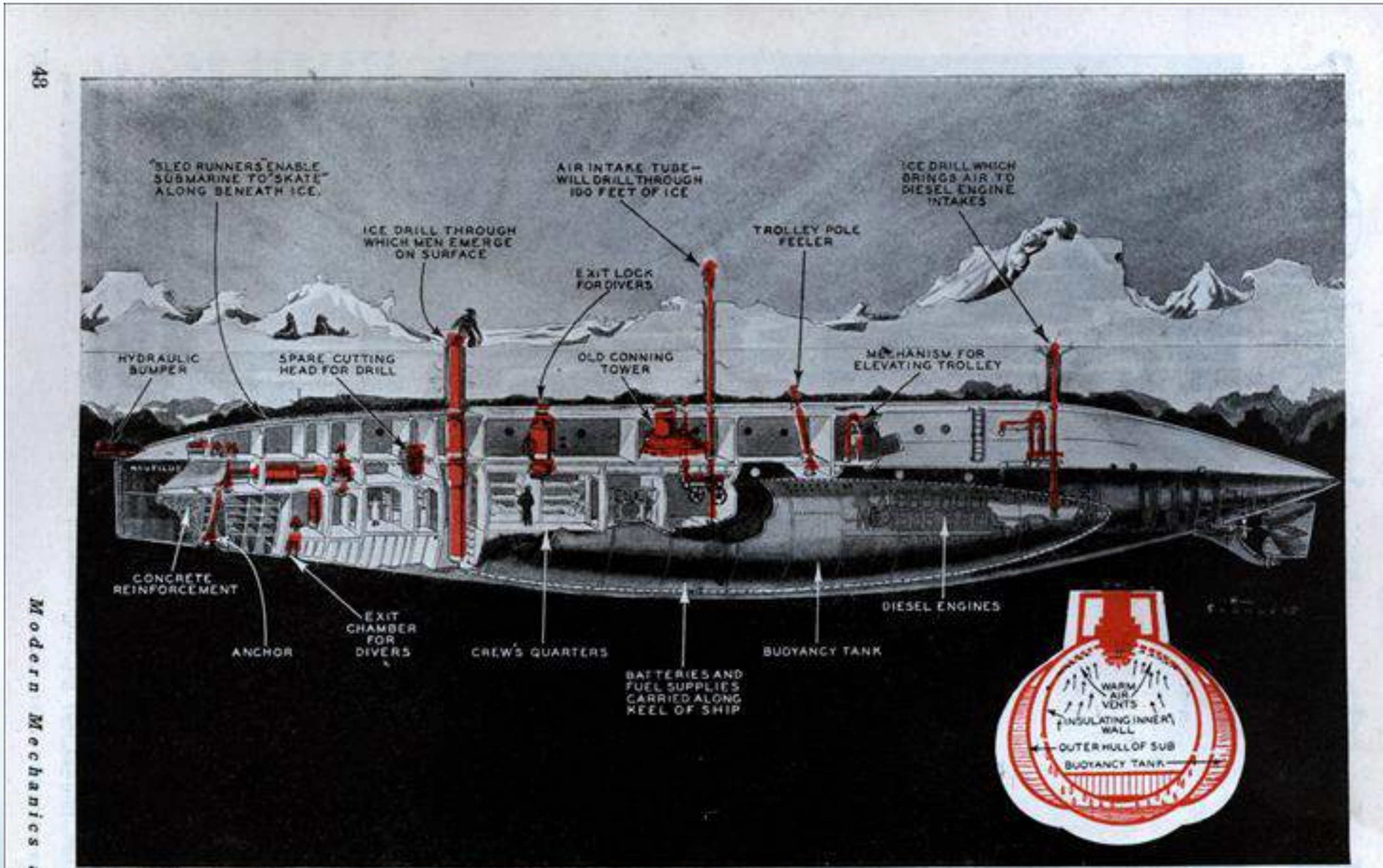
Sir Hubert Wilkins



Source: http://www.polarhistorie.no/personer/Wilkins,%20George%20Hubert

In 1931, Sir Hubert conducted an Arctic expedition in the research submarine *Nautilus* (former US sub O-12), intending to explore under the ice and reach the North Pole. *Nautilus* operated briefly under the ice, but could not sustain operations for long.

Sir Hubert Wilkins' *Nautilus*



Cross-section drawing of the Nautilus, showing disposition of special devices which will enable the sub to operate in ice-choked seas. In the lower right corner is a diagram showing the method of insulating the walls which keeps the interior of the huge submarine reasonably warm and dry at all times.

Length: 175 ft. (52.1 m)
Beam: 16.6 ft. (5.05 m)

Source: http://blog.modernmechanix.com/will-the-nautilus-freeze-under-the-north-pole/2/

Sir Hubert Wilkins' *Nautilus*

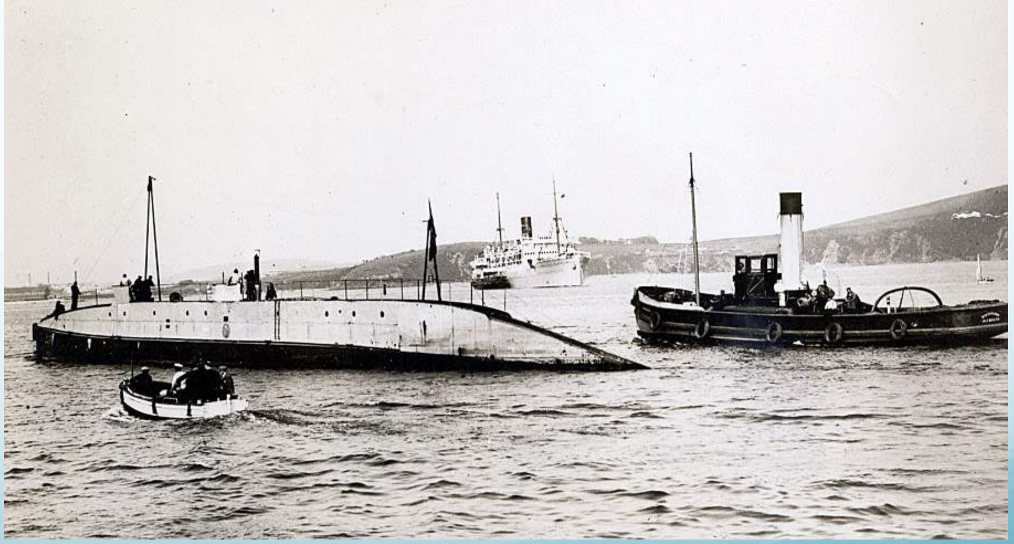
Source: http://www.delcampe.net/

Main external features included:

- The conning tower and periscope were modified to be retractable.
- Added wooden superstructure four feet wide and six feet high to house extra buoyancy chambers intended to prevent loss of stability when surfacing through the ice.
- Iron-shod "sledge runners" were installed in top of the superstructure to permit the sub to slide along the bottom of the icepack.

Other features included:

- A cushioning bowsprit 12 feet long to act as a bumper,
- An ice drill to provide access to the surface in case the submarine was unable to break through the ice,
- An emergency air intake system, and
- A diving chamber



Source: http://www.dvrbs.com/camden/camdennj-mathisshipyard.htm

US nuclear marine Arctic operations

USS Nautilus (SSN-571)

The 1st nuclear submarine Arctic under-ice missions

- Under the command of Capt. William R. Anderson, sailing from New London, CT on 19 Aug 1957, *Nautilus* conducted the first extended Arctic under-ice voyage (1,202 nm, 2,226 km) by a nuclear submarine.
  - *Nautilus* became lost due to failures of its navigational equipment and ultimately had to turn back.
  - At the time, *Nautilus* was equipped with relatively primitive navigational aids, namely, a gyrocompass and magnetic compass, both of which were ineffective at high latitudes.
- In response to navigational failures on its first attempt, a new navigation system was installed on *Nautilus*, an N6A-1 inertial guidance system, originally produced by North American Aviation for the Navaho supersonic intercontinental cruise missiles.
  - There were concerns about this system's capability on *Nautilus* as it was designed to support missiles traveling at fast speeds and for short periods of time, whereas a submarine moves slowly for weeks or months.

USS Nautilus (SSN-571)

The 1st nuclear submarine Arctic under-ice missions

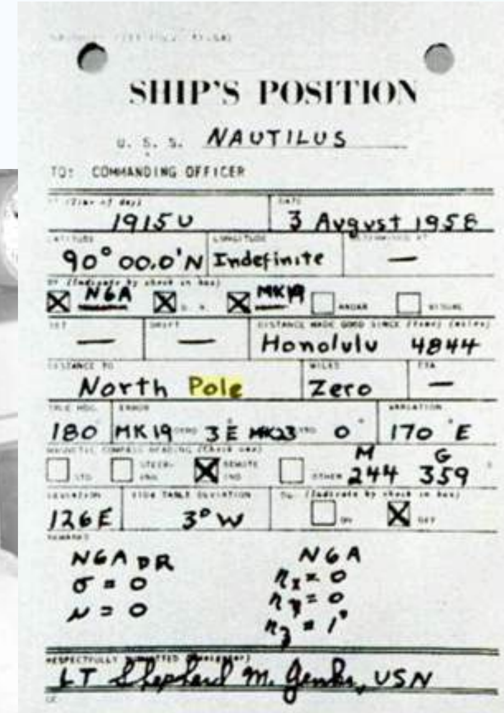
- Other modifications made to *Nautilus* included a hardened sail to help in penetrating the Arctic ice sheet and upward looking sonar and video systems developed by the Navy's Arctic Submarine Laboratory (ASL).
- 9 Jun 1958: Under the code name Operation Sunshine, *Nautilus* departed Seattle, WA for the polar ice pack, but was turned back by thick ice conditions blocking all paths through the shallow Chukchi Sea to the deep Arctic Ocean and the North Pole.
- After departing Pearl Harbor on 23 July 1958 on its second Operation Sunshine mission voyage, *Nautilus* encountered improved ice conditions near point Barrow, Alaska, allowing it to enter deep water and complete the voyage across the North Pole.
  - The *Nautilus'* 3 August 1958 position log at the North Pole reads, Latitude: "90° 00.0' N", representing the North Pole, and longitude "Indefinite" as the great circles representing the lines of longitude all converge at the Poles and thus longitude is undefined.

Nautilus 90° North

3 Aug 1958

Dr. Waldo Lyon & *Nautilus'* 2nd CO, Capt. William Anderson

Source: http://www.navy.mil/navydata/



SHIP'S POSITION

U. S. S. NAUTILUS

TO: COMMANDING OFFICER

1915U | 3 August 1958

90° 00.0'N | Indefinite | —

☒ N6A ☒ ☒ MK19 ☐ ☐

— | — | Honolulu 4844

North Pole | Zero | —

180 | MK19 3 E MK23 0 | 170 E

☐ ☐ ☒ ☐ M 244 G 359

126E | 3° W | ☐ ☒

N6A DR
σ = 0
ν = 0

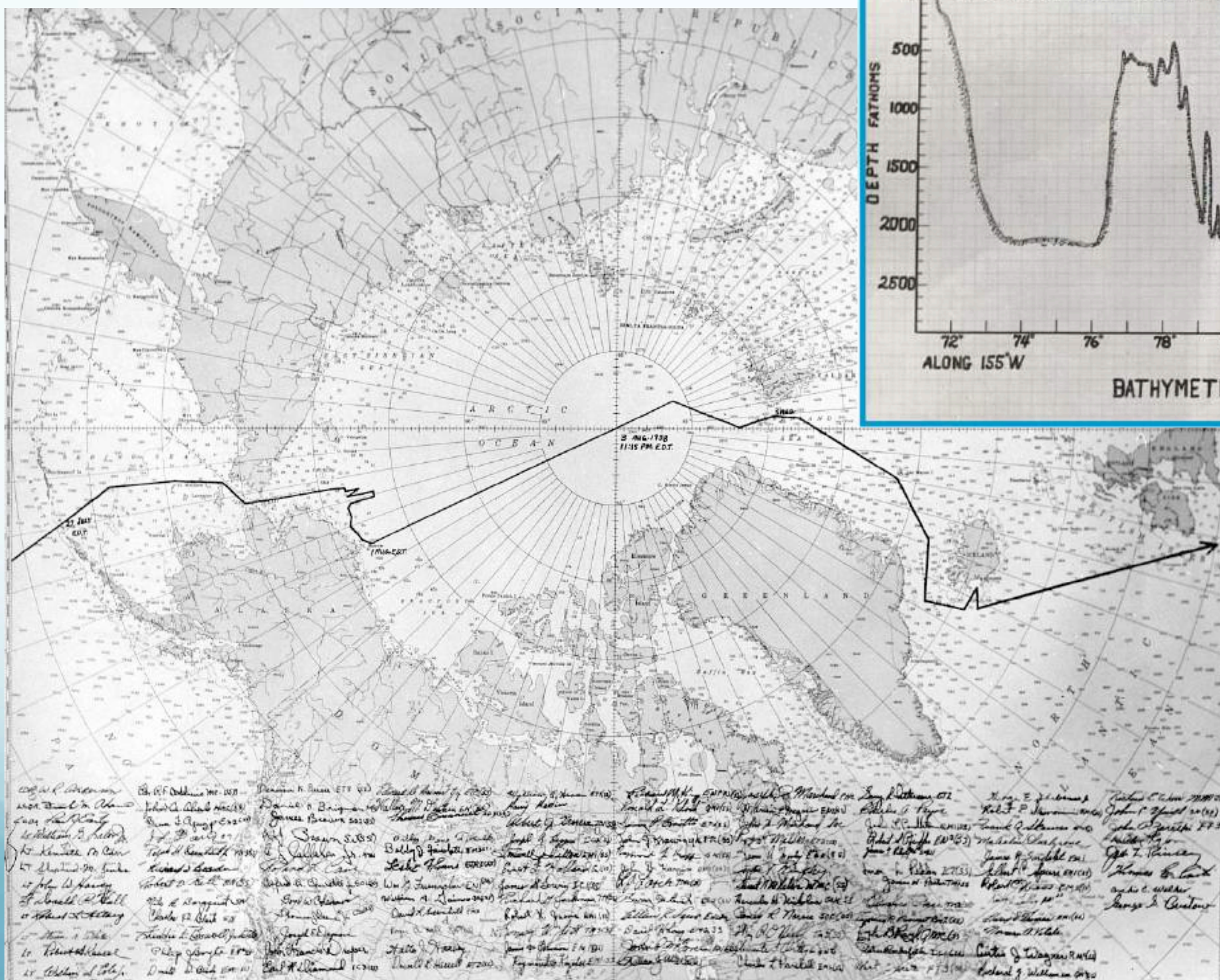
N6A
$\eta_x = 0$
$\eta_y = 0$
$\eta_z = 1'$

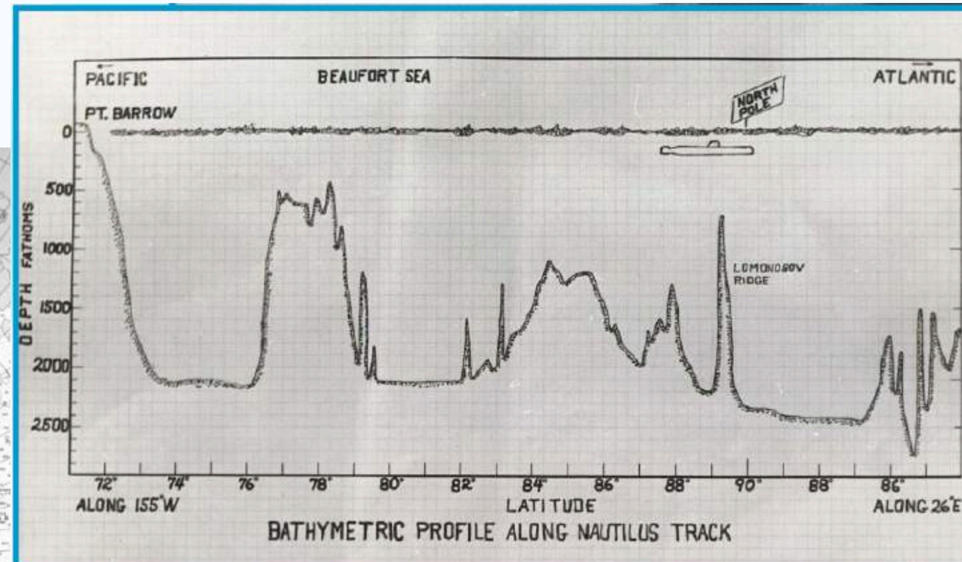
LT Shepherd M. Jenks, USN

Nautilus 90° North

3 Aug 1958

Nautilus' west-to-east track through the Arctic Ocean





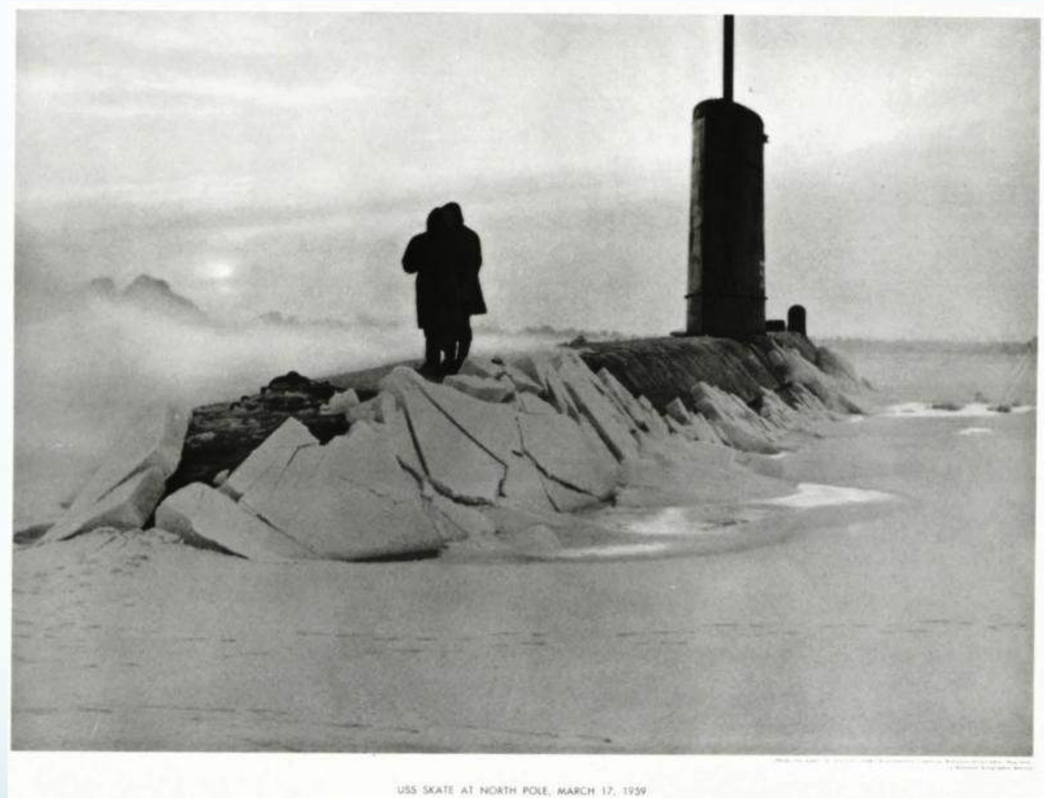
Source: http://www.navy.mil/navydata/

Source: http://www.navalhistory.org/category/arctic

USS Skate (SSN-578)

11 Aug 1958: 2nd submarine under the North Pole
17 March 1959: 1st submarine to surface at the North Pole

Capt. James Calvert Source: US Navy

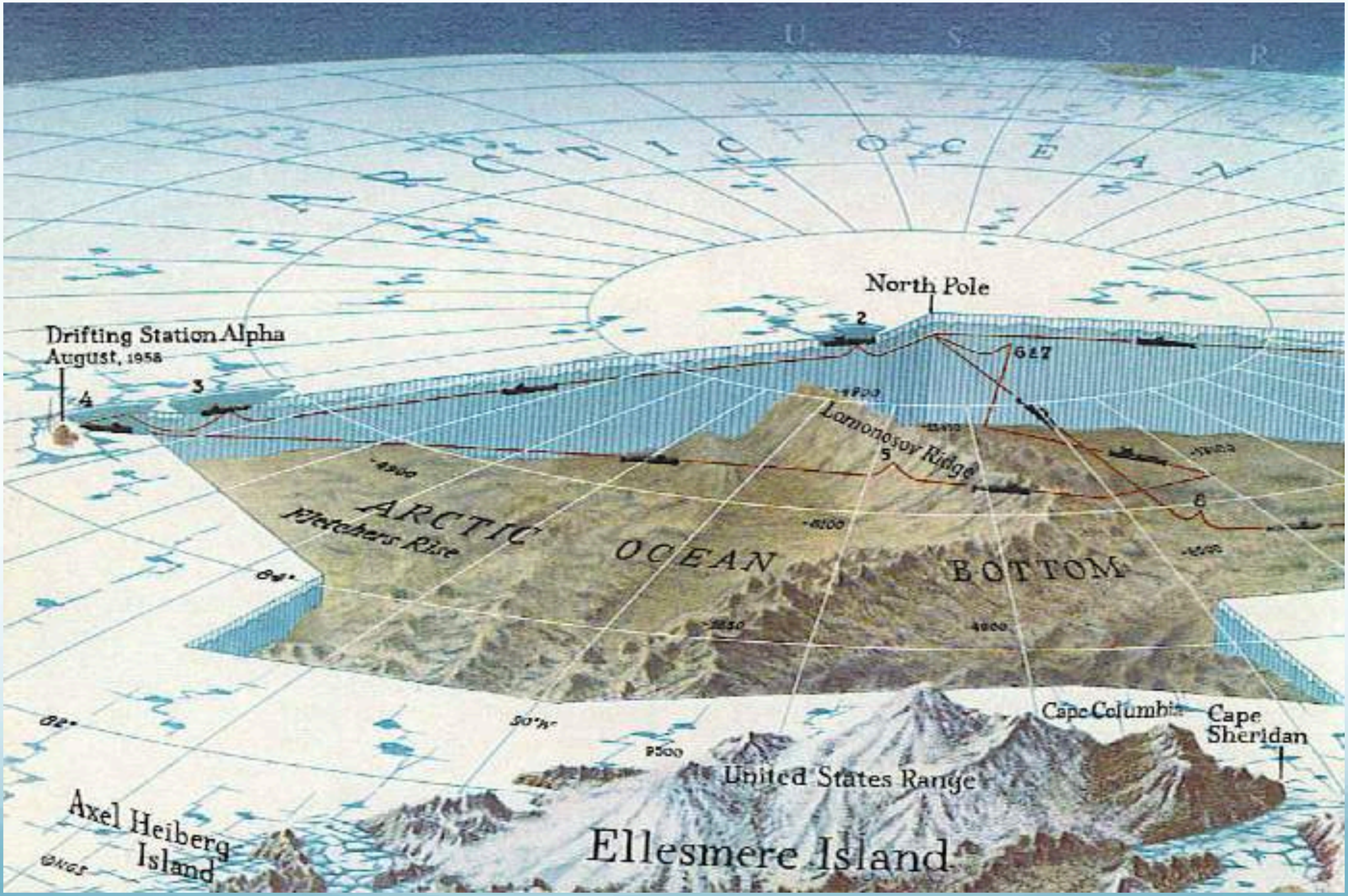


Source: http://archive.constantcontact.com

The crew held a ceremony for the late Arctic explorer Sir Hubert Wilkins and spread his ashes at the North Pole. *USS Skate* made three more voyages to the Arctic in 1962, 1969 and 1971.

USS Skate (SSN-578)

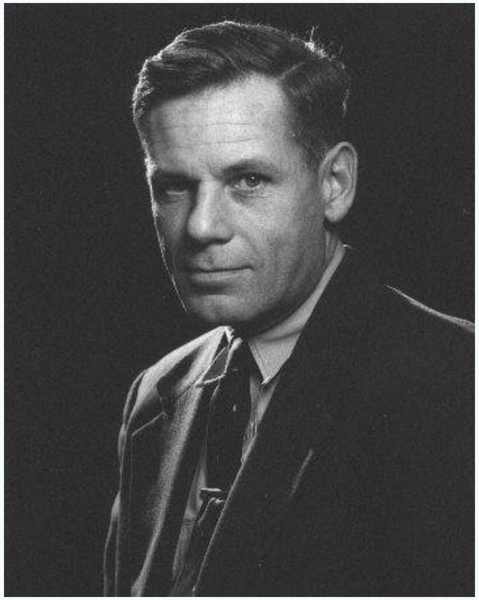
Aug 1958 East - West crossing of the Arctic Ocean



Source: navsource.com

Dr. Waldo K. Lyon and the Arctic Submarine Laboratory (ASL)

- Founder (1947) and chief research scientist of the ASL.
- Developed Battery Whistler (a converted mortar battery at the Naval Electronics Laboratory (NEL) on Point Loma as a unique arctic laboratory:
  - Grew sea ice and studied its physical properties
  - Developed test equipment and techniques to enable submarine operation in the Arctic.
- On 1 August 1947, Dr. Lyon, serving as the original ice pilot, guided the diesel-electric sub *USS Boarfish* (SS-327) on the first under-ice transit of an ice floe in the Chukchi Sea.
- He established an ASL field station at Cape Prince of Wales, Alaska in 1951.
- He embarked on *Nautilus* in 1958 for the 1st crossing of North Pole, and *Skate* in 1959 for 1st surfacing at the North Pole. Also embarked on scores of later under-ice cruises to gain scientific knowledge essential to Arctic submarine operations.



Source: ASL

Dr. Waldo K. Lyon and the Arctic Submarine Laboratory (ASL)

- Examples of ASL's contributions to submarine Arctic operations include:
  - Developed upward looking sonar and video systems for early Arctic voyages
  - Developed sonar technology for remote acoustic measurement of ice thickness and detection of ice ridges, including forward-looking under-ice sonar for Sturgeon (SSN-637)-class submarines.
- Dr. Lyon's ashes were scattered at the North Pole by *USS Hawkbill (SSN-666)* on 3 May 1999.
- Today, ASL is detachment (UWDC Det Arctic Submarine Lab) of Commander, Undersea Warfighting Development Center (UWDC), which is a flag command headquartered in Groton, CT. ASL remains physically located in San Diego, CA and has the following responsibilities:
  - Serve as the "Center of Excellence" for Arctic matters for the US submarine force.
  - Responsible for developing and maintaining expertise in Arctic-specific skills, knowledge, equipment, and procedures to enable the submarine force to safely and effectively operate in the unique Arctic Ocean environment.
- Since its founding in 1947, ASL has supported the US diesel-electric and nuclear submarine force for more than 70 years in conducting operations near and under the Arctic ice.

USS Sargo (SSN-583)

1960 Arctic exploration mission

- Based on experience with the 1957 – 59 Arctic voyages by *Nautilus* and *Skate, Sargo* was modified for Arctic operation during construction and after its first shakedown cruise.
  - Hardened sail
  - Autonetics A6A-1 inertial navigation system,
  - Under-ice sonar,
  - Scientific equipment, and more.
- 18 Jan 1960: *Sargo*, under the command of LCDR J. H. Nicholson, departed Pearl Harbor and headed north for an extended submerged exploration of the Arctic Ocean.
  - 25 Jan 1960: Reached Arctic ice pack in the vicinity of St. Matthews Island.
  - 10 Feb 1960: 2nd sub to surface at North Pole.
  - 17 Feb 1960: Visited Ice Island T-3 and conducted tests with scientists there.

Sargo at North Pole Source: US Navy

Source: http://www.navalhistory.org/2011

USS Sargo (SSN-583)

1960 Arctic exploration mission

- 3 Mar 1960: *Sargo's* winter mission, which covered over 11,000 miles, 6,003 miles under ice, returned to Pearl Harbor. Major accomplishments were:
  - Surveying previously uncharted shallow areas of the Bearing, Chukchi and Beaufort Seas.
  - Refining techniques for surfacing through the Arctic icepack and operating in shallow, ice-covered water.

Sargo visited ice station T-3. Source: dauntlessatsea.wordpress.com

USS Seadragon (SSN-584)

15–21 August 1960: 1st submarine transit of the Northwest Passage

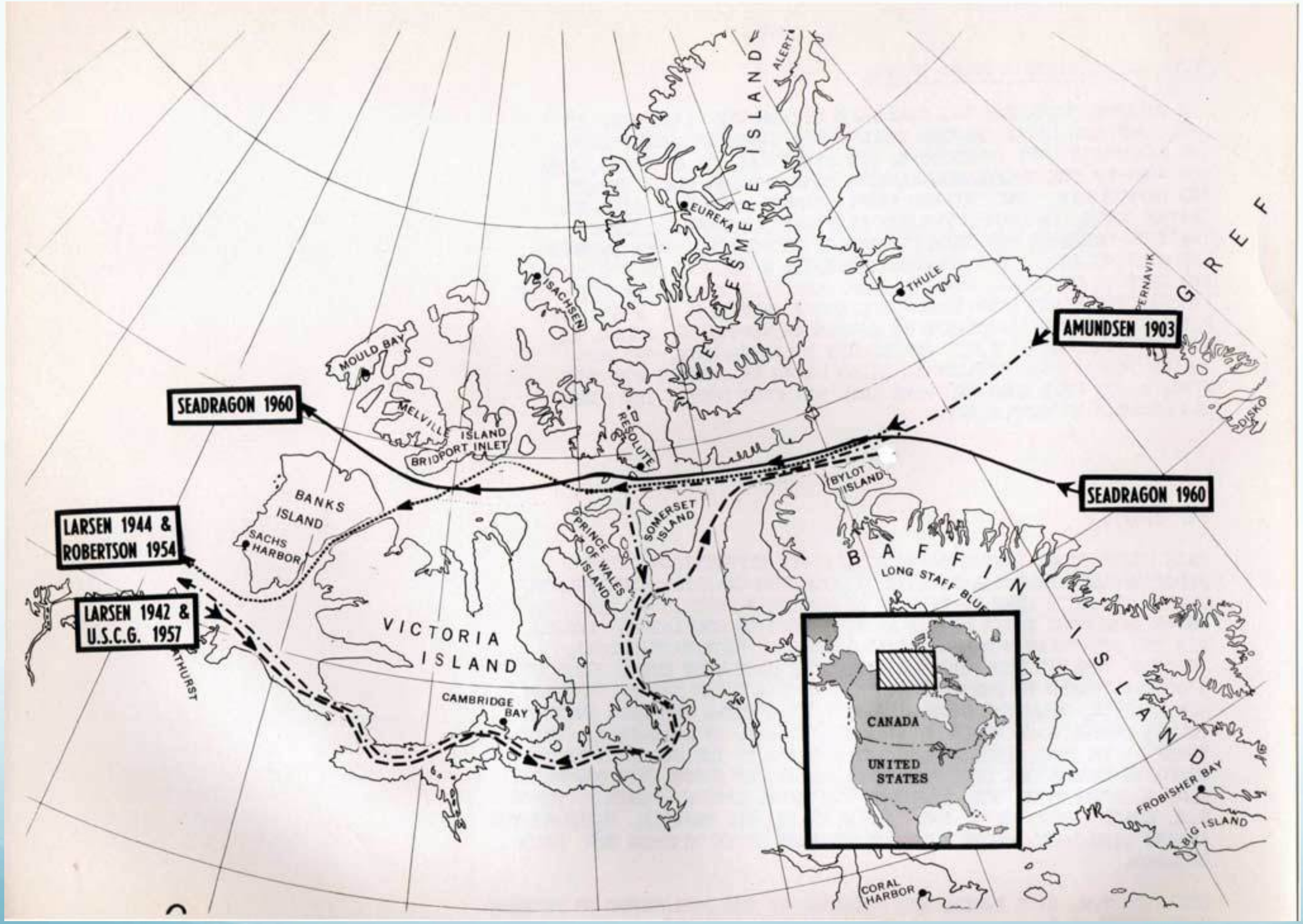
- *Seadragon* was the first sub to be equipped with what would become the standard under-ice suite for future US subs.
    - The major change from *Sargo*, was the 1st Arctic use of the Sperry Ships Inertial Navigation System (SINS) in place of the Autonetics N6A-1 used on prior Arctic subs.
- 1 Aug 1960: *Seadragon*, CDR George P Steele commanding, departed New London, CT, deploying via the Northwest Passage and the North Pole to Pearl Harbor.
    - Enroute, charted poorly known portions of the Northwest Passage; conducted first-ever examination of the undersides of many icebergs in Baffin Bay and Lancaster Sound
    - 25 Aug 1960: 3rd sub to surface at the North Pole.
    - Visited Ice Island T-3 and conducted tests with scientists at the station
    - 14 Sep 1960: Arrived Pearl harbor.
- Accomplishments include refining techniques for Arctic submarine operation, improving knowledge of Arctic hydrography and validating the SINS for Arctic operation.
- *USS Seadragon* made two more voyages to the Arctic in 1962 and 1973.

Under-ice view from bow video camera. Source: US Navy

Baseball at the North Pole. Source: US Navy

USS Seadragon (SSN-584)

15–21 August 1960: 1st submarine transit of the Northwest Passage



Source: US Navy

USS Seadragon was the first ship to transit the Parry Channel through the Canadian Archipelago. Approaching from the Atlantic, *Seadragon* entered the Parry Channel 15 Aug 1960 at Lancaster Sound, proceeded westward through Melville Sound and McClure Strait and completed the channel passage on 21 Aug 1960. *Seadragon* then continued northward to the North Pole, and then on to Hawaii. This chart shows the other successful expeditions that navigated the archipelago on the surface.

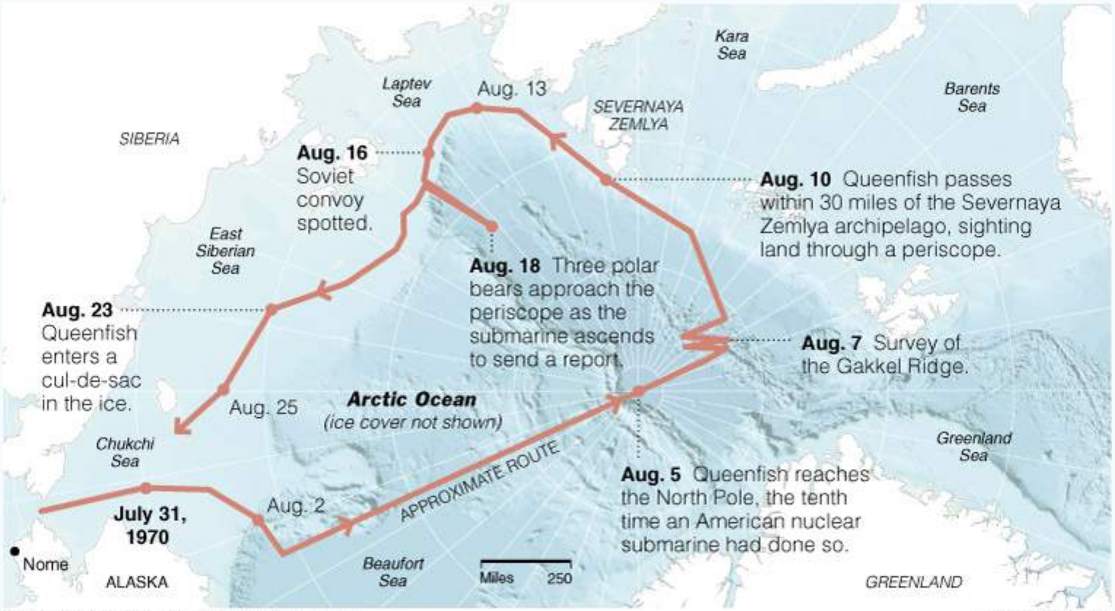
Later first-in-class nuclear submarine Arctic milestones

- 1967: 1st Sturgeon (SSN-637) class SSN
  - *USS Queenfish* (SSN-651) operated in the Davis Strait (between Greenland and Baffin Island, Canada). *USS Queenfish* was the first single-screw nuclear submarine to operate under the Arctic ice.
  - 27 different Sturgeon-class SSNs operated in the Arctic before *USS L. Mendel Rivers* (SSN-686) completed the last Sturgeon-class SSN Arctic mission 33 years later, in 2000.
- 1989: 1st Los Angeles (SSN-688) Flight I class SSN
  - *USS Augusta* (SSN-710) conducted operations in the Arctic.
  - In 2005, the *USS Salt Lake City* (SSN-716) was the 1st Flight I boat to surface through the Arctic ice.
- 2001: 1st Los Angeles (SSN-688) Flight II class SSN
  - *USS Oklahoma City* (SSN-723) conducted testing in the Arctic.
  - In 2008, *USS Providence* (SSN-719) surfaced at the North Pole to commemorate the 50th anniversary of the 1st submarine transit of the Arctic Ocean by *USS Nautilus* in 1958.
- 1992: 1st Improved Los Angeles (688i) class SSN
  - *USS Albany* (SSN-753) conducted operations in the Arctic.
- 2002: 1st Seawolf (SSN-21) class SSN
  - *USS Connecticut* (SSN-22) conducted testing in the Arctic.
- 2011: 1st Virginia (SSN-744) class SSN
  - *USS New Hampshire* (SSN 778) participated in ICEX-2011.

Note: Skipjack (SSN-585) class attack submarines (SSNs), Permit (SSN-594) class SSNs and Polaris / Poseidon class ballistic missile submarines (SSBNs) did not operate in the Arctic. Ohio-class ballistic missile / cruise missile submarines (SSBNs / SSGNs) do not operate in the Arctic.

USS Queenfish (SSN-651)

1970 Exploration of Laptev, East Siberian, and Chukchi Seas

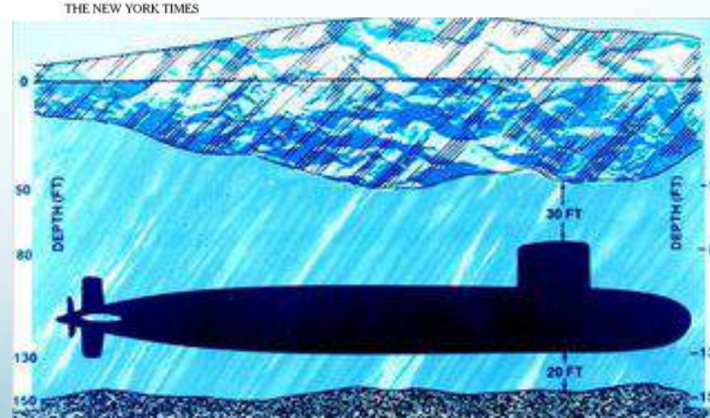


Source: "Unknown Waters" by Alfred S. McLaren THE NEW YORK TIMES

- All Sturgeon-class SSNs are Arctic-capable, equipped with under-ice sonar, a hardened sail and tail fin, and fairwater planes that rotate 90° for surfacing through the icepack.

- In 1970, *USS Queenfish* retraced Nautilus' 1958 route to the North Pole and continued to conduct extensive shallow water operations, aided by satellite navigation, along the Siberian continental shelf.

- Recommended reading: *Unknown Waters. A Firsthand Account of the Historic Under-Ice Survey of the Siberian Continental Shelf by USS Queenfish (SSN-651)*, 2008, Captain Alfred McLaren



Rendezvous at the North Pole

Source: http://www.csp.navy.mil/asl/1960.html

Source: http://web.mst.edu/

1st 2-sub rendezvous (both Skate-class) on 31 July 1962: *USS Skate* (SSN-578) and *USS Seadragon* (SSN-584)

Both subs were outfitted with the standard Arctic suite used by *USS Seadragon* in 1960.

1st 3-sub rendezvous (all Sturgeon-class) on May 6, 1986:
USS Archerfish (SSN-678) (top),
USS Ray (SSN-653)
USS Hawkbill (SSN-666) (bottom)

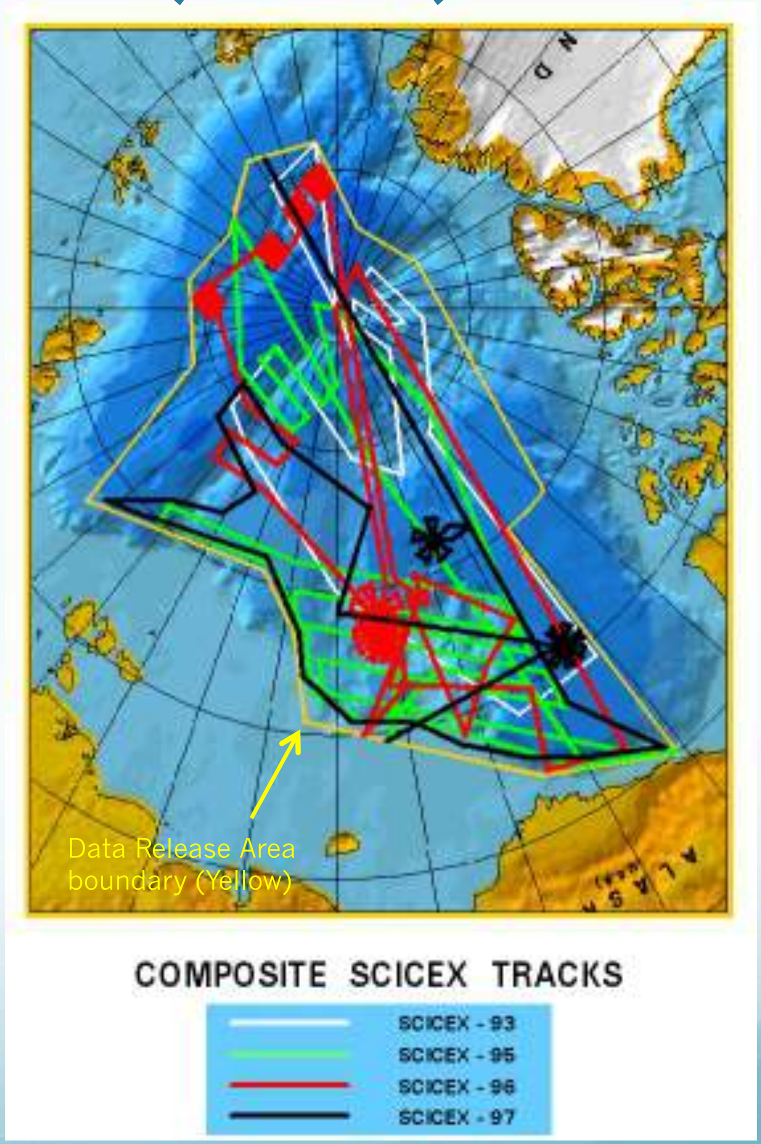
Ice Exercises (ICEX)

- The term "ICEX" applies to a variety of operation in the Arctic, with and without a drifting ice station. For example, an ICEX could be a single nuclear-powered submarine conducting a transit of the Arctic, or it could be a major biennial exercise with a drifting ice station / ice camp.
- In the 1980s and 1990s, there were science and research-sponsored ice camps, the last one being a small camp built in 1999 (Camp Lyon) to conduct personnel transfers.
  - 1993 was the last Applied Physics Laboratory Ice Station (APLIS) sponsored by the science community. The Navy rented/used these camps for specific tasks.
  - From 1993 – 1999, unclassified, dedicated Science Ice Exercises (SCICEX) were conducted with scientists embarked on Sturgeon-class SSNs.
    - The goal of the SCICEX program was to acquire comprehensive data about Arctic sea ice, water properties (biological, chemical, and hydrographic), and water depth (bathymetry) to improve our understanding of the Arctic Ocean basin and its role in the Earth's climate system.
    - A feasibility mission was conducted in 1993.
    - Regular missions were conducted from 1995 – 1999.
    - On the last SCICEX mission, *USS Hawkbill* (SSN-666) surfaced at the North Pole on 3 May 1999 and scattered the ashes of the Arctic submarine pioneer and ASL founder Dr. Waldo Lyon.

Source: http://nsidc.org/scicex/history.html

Ice Exercises (ICEX)

- SCICEX unclassified civilian research activities and supporting submarine operations occurred in the Arctic "Data Release Area" (DRA), which is the portion of Arctic waters outside the Exclusive Economic Zones of other Arctic nations (yellow area in the accompanying chart).
- During SCICEX missions, data were collected from over 100,000 miles (160,934 km) of shiptrack in the Arctic, providing samples from some regions that had never before been visited.



Source: http://www.ldeo.columbia.edu/res/pi/SCICEX/

Ice Exercises (ICEX)

- 2003 marked the start of the current ICEX "program of record" era in which the Navy sponsors an ice camp in conjunction with submarine force Arctic tactical development and torpedo exercises.
  - ICEX is part of the US Navy Submarine Arctic Warfare Program sponsored by the Chief of Naval Operations, Undersea Warfare Division (OPNAV N97).
  - Arctic Submarine Laboratory (ASL) is the Navy command that coordinates and provides logistics support for these biennial Arctic exercises.
  - Naval Undersea Warfare Center (NUWC) supports the torpedo exercises.
- An ICEX focuses on ensuring the safe operation and tactical capability of the current classes of US SSNs.
  - Regular Arctic exercises are the only way to ensure that each new submarine class and system upgrade has been tested in the unforgiving conditions of the Arctic.
  - Each successive ICEX helps ensure that the Submarine Force continues to have a sufficient number of officers and enlisted personnel with experience operating in Arctic ice conditions.
  - During the ICEX, ASL provides ice pilots (Arctic operations specialists, to provide guidance only) to the deployed submarines.
  - UK Trafalgar-class SSNs are regular participants in ICEXs. The newer UK Astute-class SSNs have not yet participated in an ICEX.
- Modern era ICEXs were conducted in 2003, 2007, 2009, 2011, 2014, 2016 and 2018. The next ICEX is expected to be in 2020.

ICEX 2011

Above: Virginia-class *USS New Hampshire* (SSN-778).
Source: US Navy

Seawolf-class *USS Connecticut (SSN-22)* during ICEX 2011.
Source: US Navy / Petty Officer 2nd Class Kevin O'Brien

ICEX 2018

Right: The Seawolf-class *USS Connecticut* (SSN-22) surfacing through the ice during ICEX 2018.
Source: US Navy / Daniel Hinton / Flickr

Three SSN rendezvous, left to right: Seawolf-class *USS Connecticut (SSN-22)*, Los Angeles 688i-class *USS Hartford (SSN-768)*, and UK Trafalgar-class *HMS Trenchant (S91)* surfaced in the Beaufort Sea. Source: US Navy / Darryl I. Wood / Flickr

ICEX 2018

Left: Recovering a torpedo in the Arctic.
Source: The Virginia-Pilot. https://pilotonline.com

Ice Camp Skate in the Beaufort Sea, March 2018.
Source: U.S. Navy / Mass Communication 2nd Class Michael H. Lee

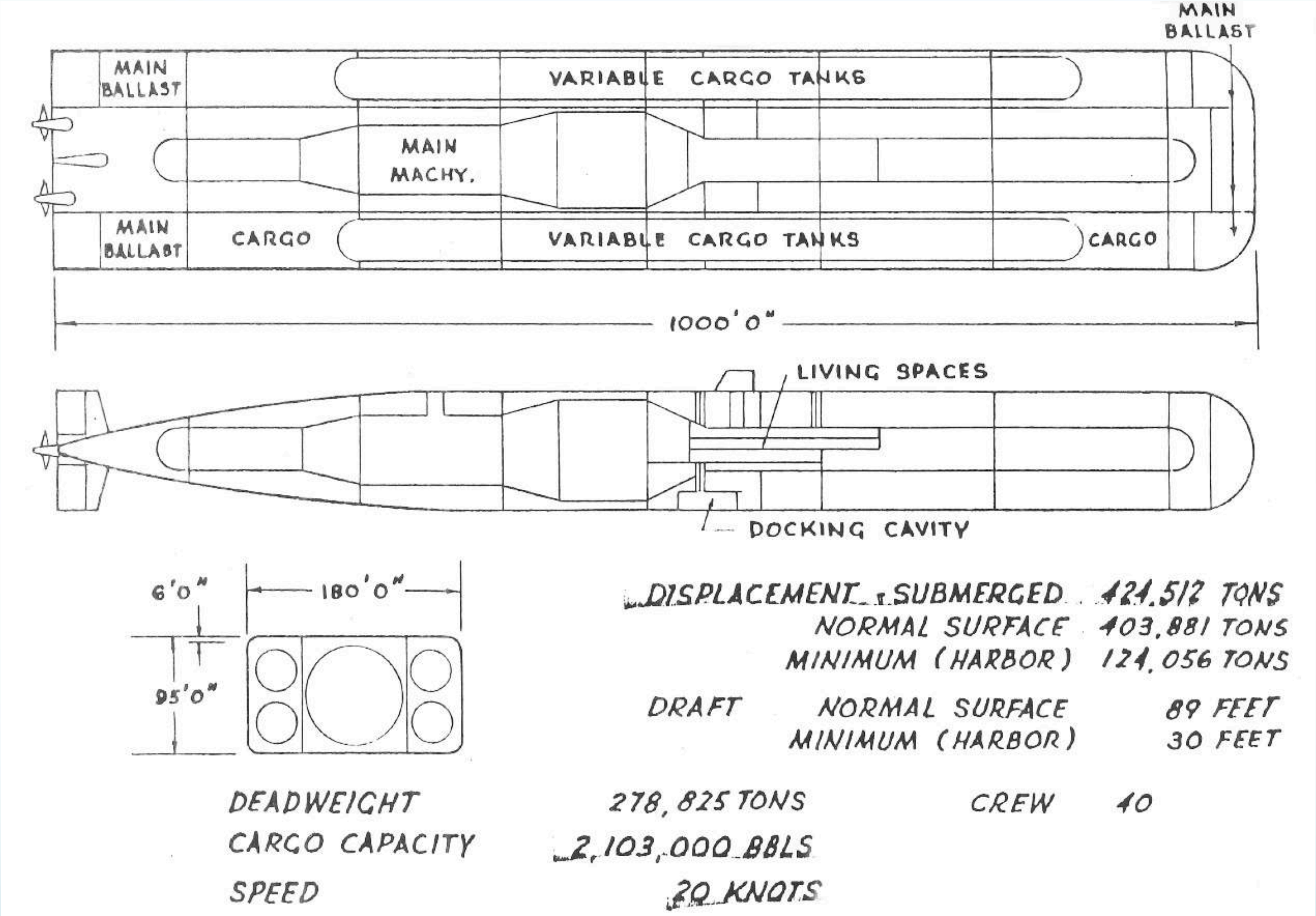
US submarine supertanker concepts *

- In 1958 and 1962, the US Maritime Administration contracted with General Dynamics (GD) to conduct feasibility studies of submarine tankers. These studies found that the concept was sound, but no action was taken to develop such tankers.
- In 1970, after discovery of oil and gas in the Alaskan North Slope around Prudhoe Bay in 1968, GD proposed developing a fleet of 16 nuclear-powered Arctic submarine tankers to five major oil companies.
  - Concerns about the ability to develop and operate large submarine tankers in the Arctic and to develop and operate a tanker loading facility in the relatively shallow waters off the North Slope were noted by the US Department of Interior in the 1972 Environmental Impact Statement for the competing Trans-Alaska Pipeline.
  - The oil companies declined GD's submarine tanker offer.
- In 1974, after the Arab oil embargo the preceding year, the US Department of Commerce commissioned another study of submarine tankers to load oil from an Arctic undersea terminal and deliver the cargo to a US east coast port.
  - The study was managed by the US Maritime Administration and conducted by an industry team comprised of Newport News Shipbuilding, Westinghouse, Bechtel, and Mobile Shipping and Transport Company.
  - The study considered Arctic submarine tankers ranging from in size from 100,000 to 900,000 tons submerged displacement, and developed details for a 1,000 foot (305 meters) long, tanker with a submerged displacement of 424,512 tons. The study addressed concerns raised previously by Department of Interior
  - Again, there was no interest from oil companies.

* Source: Capt. A. S. McLaren, "The Arctic Submarine – An Alternative to Ice Breaker Tankers and Pipelines," Master of Philosophy in Polar Studies Thesis, Scott Polar Research Institute, University of Cambridge, 1982

US submarine supertanker

Circa 1977 nuclear-powered Arctic oil tanker submarine concept



Source: P. K. Taylor & J. B. Montgomery, "Arctic Submarine Tanker System," presented at 9th Annual Offshore Technology Conference, Houston, May 1977; via Capt. A. S. McLaren, "The Arctic Submarine – An Alternative to Ice Breaker Tankers and Pipelines," Master of Philosophy in Polar Studies Thesis, Scott Polar Research Institute, University of Cambridge, 1982

US submarine supertanker

Circa 1977 nuclear-powered Arctic oil tanker submarine concept

Submarine supertanker model: Source: L. R. Jacobsen & J. J. Murphy, "Submarine transportation of hydrocarbons from the Arctic", 1983

- Vessel dimensions:
  - Length: 1,000 ft. (305 m)
  - Beam: 180 ft. (55 m)
  - Hull height: 95 ft. (30 m)
- Submerged displacement: 424,512 tons
- Cargo capacity: 2,103,000 barrels of oil (at API 27 to 37)
- Propulsion power: two shafts, unknown total shp
- Corresponding reactor power: unknown
- Maximum speed: 20 knots
- Crew size: 40

US submarine supertanker

Circa 1977 nuclear-powered Arctic oil tanker submarine concept

Source: https://www.flickr.com/

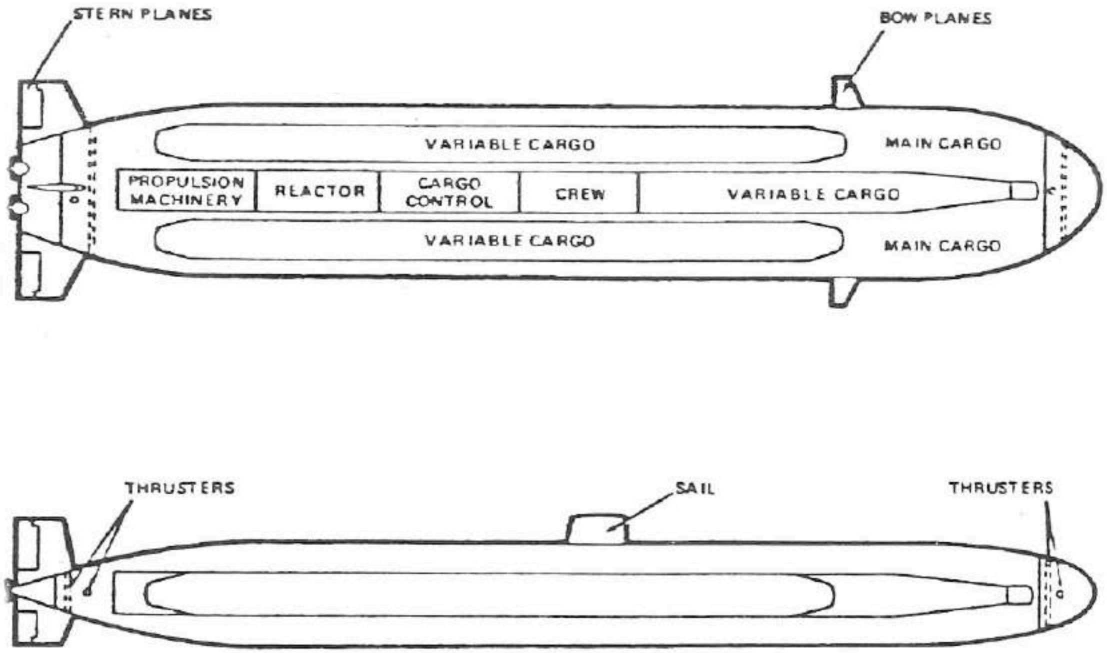
US submarine supertanker

1981 GD Arctic LNG supertanker submarine concept

- In 1981, GD proposed two versions of an Arctic submarine liquid natural gas (LNG) supertanker with similar cargo capacities: a nuclear-powered version and a somewhat larger conventionally-powered version fueled by LNG (methane) drawn from the cargo and stored liquid oxygen.
  - The proposed submarine tankers were intended to transport LNG from submerged terminals located about 40 miles north of Alaska in the Beaufort Sea to ice-free ports in Canada and Europe, offering year-round cargo delivery regardless of ice and weather conditions in the Arctic.
    - The tankers required a complex cooling system to maintain the LNG at a temperature of minus 259 degrees Fahrenheit (-162 °C).
  - The GD proposal calls for 14 nuclear-powered or 17 conventionally-powered ships, loading terminals and repair facilities, at a total capital cost of $13.9 billion for a nuclear fleet or $16.2 billion for a conventionally-powered fleet.
  - This submarine tanker also was discussed with the German government as a possible alternative to the Siberian pipeline, which, at the time, was being considered as a source of natural gas for Germany and other European nations. Europe selected the Siberian pipeline.
  - The GD Arctic LNG supertanker submarine was not built.

US submarine supertanker

1981 GD nuclear-powered Arctic LNG tanker submarine concept



GENERAL DYNAMICS 181,400 DWT SUBMARINE OIL TANKER DESIGN
(NUCLEAR PROPULSION)

Source, diagram: Oilweek, 14 December 1981
Source, data: P. Veliotis & S. Reitz, "US Submarine Tanker Plan for Arctic LNG," Lloyd's List, 19 Oct 1981
Both via Capt. A. S. McLaren, "The Arctic Submarine – An Alternative to Ice Breaker Tankers and Pipelines," Master of Philosophy in Polar Studies Thesis, Scott Polar Research Institute, University of Cambridge, 1982

- Liquefied natural gas (LNG) tanker concept first proposed by General Dynamics (GD) in 1981.
- Vessel dimensions:
  - Length: 1,270 ft (387 m)
  - Beam: 228 ft (69.5 m)
  - Hull height: 92 feet (28 m)
- Submerged displacement: 713,122 metric tons (MT)
- Cargo capacity: 140,000 cubic meters LNG
- Propulsion power: 75,000 shp total from two shafts
- Corresponding reactor power: about 390 MWt total
- Maximum speed: 15 knots
- Crew size: 32
- Vessel cost: $725 million

US polar icebreaker fleet

- The USCG describes the roles of U.S. polar icebreakers as follows:
  - Conducting and supporting scientific research in the Arctic and Antarctic;
  - Defending U.S. sovereignty in the Arctic by helping to maintain a U.S. presence in U.S. territorial waters in the region;
  - Defending other U.S. interests in polar regions, including economic interests in waters that are within the U.S. exclusive economic zone (EEZ) north of Alaska;
  - Monitoring sea traffic in the Arctic, including ships bound for the United States; and
  - Conducting other typical Coast Guard missions (such as search and rescue, law enforcement, and protection of marine resources) in Arctic waters, including U.S. territorial waters north of Alaska.
- In 2006, the G.W. Bush administration moved budget and management authority for the U.S. polar icebreaker fleet from the USCG to the National Science Foundation (NSF).
  - Under this arrangement, the USCG retains custody of the polar icebreakers, which continue to be operated by USCG crews.
  - NSF assigns icebreaker missions.
  - This arrangement is recorded in the 2006 "*Memorandum of Agreement Between United States Coast Guard and National Science Foundation Regarding Polar Icebreaking Support and Reimbursement*."

US polar icebreaker fleet

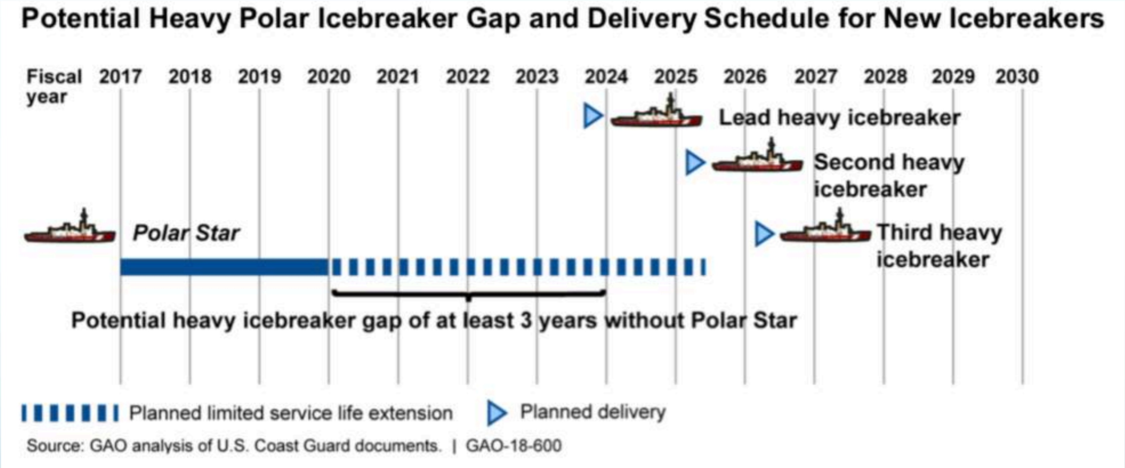
- As of early 2019, the entire U.S. national capability for Arctic and Antarctic icebreaking operations is found in a small “fleet” of three conventionally-powered ships:
  - One heavy polar icebreaker, Coast Guard Cutter *Polar Star,* commissioned in 1976
    - Assigned to support Antarctic operations. *Polar Star* spends the winter months breaking ice around Antarctica and then enters dry dock for maintenance and repairs in preparation for its next cycle of Antarctic operations.
  - One medium polar icebreaker, Coast Guard Cutter Healy, commissioned in 1999
    - *Healy* returned to it homeport in Seattle on 30 November 2018 after spending 129 days in the Arctic supporting research operations.
  - One smaller icebreaking research vessel, *Palmer*, built in 1992 and leased by the National Science Foundation to support Antarctic research.
- The U.S. also has an inactive heavy polar icebreaker; the *Polar Sea* (sister ship of *Polar Star*), which was commissioned in 1978 and placed in inactive status in 2010 after a major propulsion plant equipment casualty. It is being used for spare parts for *Polar Star*.

Photo left: *Polar Star* in McMurdo Sound, Antarctica, 2019. Source: USCG/Chief Petty Officer Nick Ameen

Photo right: Inactive *Polar Sea* in drydock, 2016. Source: Crowley Maritime Corporation

US polar icebreaker fleet

- Under its current heavy polar icebreaker acquisition program, the USCG plans to acquire three conventionally-powered "Polar Security Cutters."
  - In March 2018, the Navy issued a request for proposal (RFP) for a contract to design and construct up to three Polar Security Cutters.
    - While the USCG's heavy icebreaker mission traditionally has been to support scientific research, the RFP pointed to a possible future national security mission by requesting the ability to add deck-mounted weapons to the icebreaker in the future.
  - The Navy anticipates awarding the contract in the third quarter of FY 2019 with an accelerated (optimistic) acquisition schedule..
    - As a minimum, the proposed schedule will create a gap of three years during which the US has no operational heavy polar icebreaker after *Polar Star* is retired in about 2020.



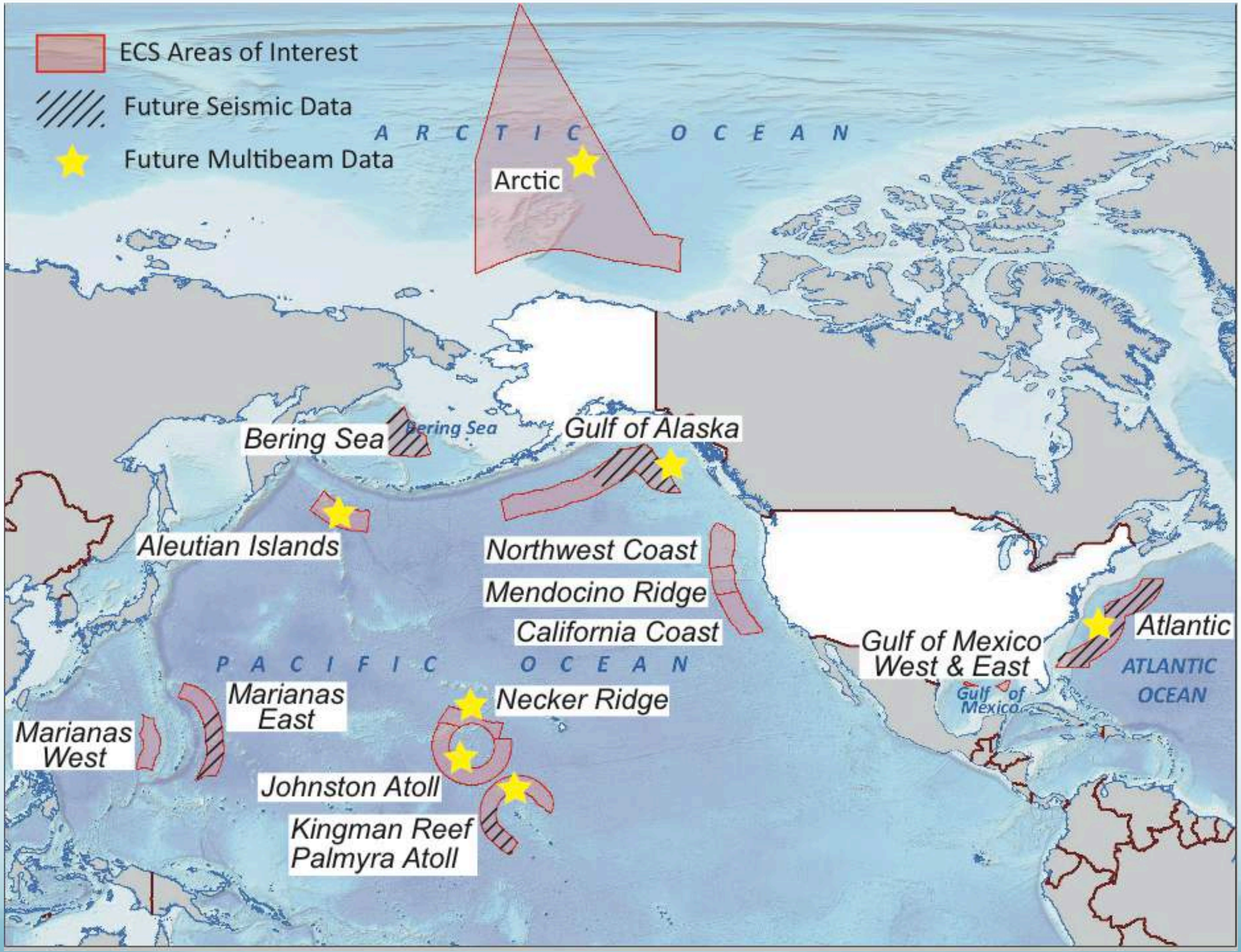
- For more information see General Accounting Office report GAO-18-600, *"Polar Icebreaker Program Needs to Address Risks Before Committing Resources,"* September 2018.
- The Coast Guard has no plans to acquire a nuclear-powered polar icebreaker.

US Extended Continental Shelf (ECS) Project

- The US Extended Continental Shelf Task Force directs and coordinates the Extended Continental Shelf Project, which is an effort to delineate the US continental shelf beyond 200 nautical miles.
  - A nation has sovereign rights over the resources on and under the seabed, including petroleum resources (oil, gas, gas hydrates), "sedentary" creatures such as clams, crabs, and corals, and mineral resources, such as manganese nodules, ferromanganese crusts, and polymetallic sulfides.
  - Defining those rights in concrete geographical terms provides the specificity and certainty necessary to protect, manage, and/or use those resources.
  - International recognition is important in establishing the necessary stability for development, conservation and protection of these areas.
- Since 2003, US agencies have been engaged in gathering and analyzing data to determine the outer limits of the US ECS.

Source: http://continentalshelf.gov/about.html

US ECS areas of interest



Source: http://continentalshelf.gov/media/ECSposterDec2010.pdf

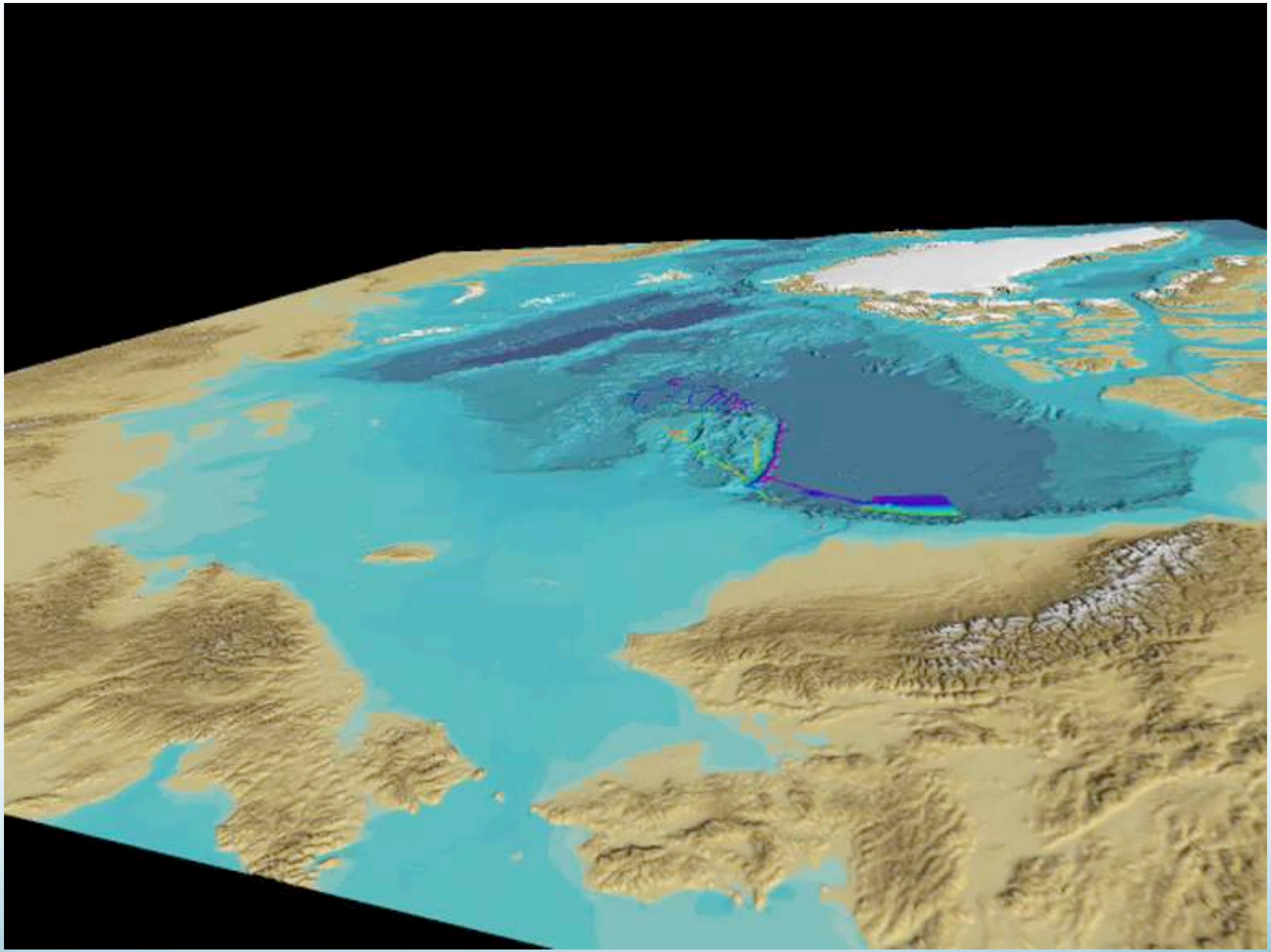
US ECS survey areas in the Arctic Ocean

Areas surveyed north of Alaska by National Oceanic and Atmospheric Administration (NOAA) and the University of New Hampshire (UNH) researchers during expeditions in 2003, 2004 and 2007.

Source: UNH/NOAA at http://continentalshelf.gov/gallery.html

Arctic basin flyover video

Highlights show areas mapped by 2003, 2004 & 2007 UNH/NOAA Arctic expeditions



Source: UNH/NOAA at http://continentalshelf.gov/media/Healy.mp4

UK nuclear marine Arctic operations

UK nuclear attack submarines operate in the Arctic

- On 3 March 1971, *HMS Dreadnought* (S-101), under the command of CDR A. Kennedy, became the 1st UK submarine to surface at the North Pole.
  - This voyage was a partial transit of the Northwest Passage (out-and-back to the UK).
- Another early UK nuclear submarine visitor to the Arctic was *HMS Sovereign* (S-108, Swiftsure-class) in 1976.
- As of 2018, nine UK nuclear subs have made voyages into the Arctic, often operating with their US counterparts during an ICEX. The later UK visitors were:
  - 1987: *HMS Superb* (S-109) and *HMS Turbulent* (S-87)

HMS Dreadnought at the North Pole. Source: Royal Navy

- 1989: *HMS Tireless* (S-88)
- 1991: *HMS Tireless* (S-88)
- 1996: *HMS Trafalgar* (S-107)
- 2004: *HMS Tireless* (S-88)
- 2007: *HMS Tireless* (S-88)
- 2018: *HMS Trenchant* (S-91)

HMS Tireless (S88)

Trafalgar-class SSN in the Arctic, ICEX 2007

Top left and right: *Tireless* at US Navy's Applied Physics Laboratory Ice Station (APLIS) during ICEX 2007.
Source: both from http://www.defenceimagery.mod.uk/
Bottom left: *Tireless* at the North Pole in 2004. Source: https://en.wikipedia.org/
Ship's crest source: Royal Navy via Wikipedia

HMS Trenchant (S91)

Trafalgar-class SSN in the Arctic, ICEX 2018

HMS Trenchant surfaces in the Beaufort Sea during ICEX 2018.

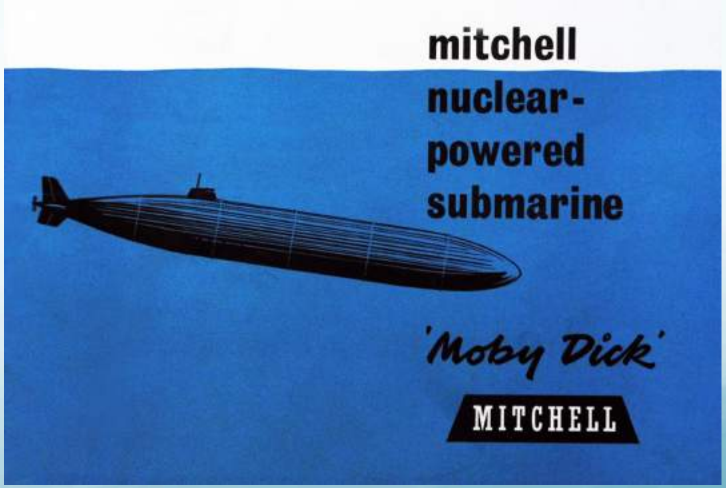
Source, photo left: Royal Navy photo by Car Charles Ball/MOD;
photo right: U.S. Navy photo by Mass Communication 2nd Class Michael H. Lee
Ship’s crest source: http://www.royalnavyresearcharchive.org.uk

Mitchell cargo submarine concept

P212 nuclear-powered Arctic submarine bulk cargo carrier

- In March 1959, the UK firm Saunders-Roe, Ltd. completed a preliminary design study for Mitchell Engineering, Ltd. of a nuclear-powered submarine bulk cargo carrier intended for operation between an Arctic port and the UK.
  - "The study considers submarines specifically designed for carrying iron ore, throughout the year, from the Diana Bay region of Northern Quebec, Canada, to Great Britain. All aspects of the operation are considered, including operational conditions, economic factors, and structural, mechanical and hydrodynamic design. A typical design of such a vessel is given in some detail. The possibilities of this type of vessel carrying other types of cargo and its use in wartime are examined briefly."
  - The study yielded a preliminary design for a 604 foot (184 meter) long, 50,000 ton submarine capable of carrying about 28,000 tons of pelletized iron ore.
- This submarine was not built.

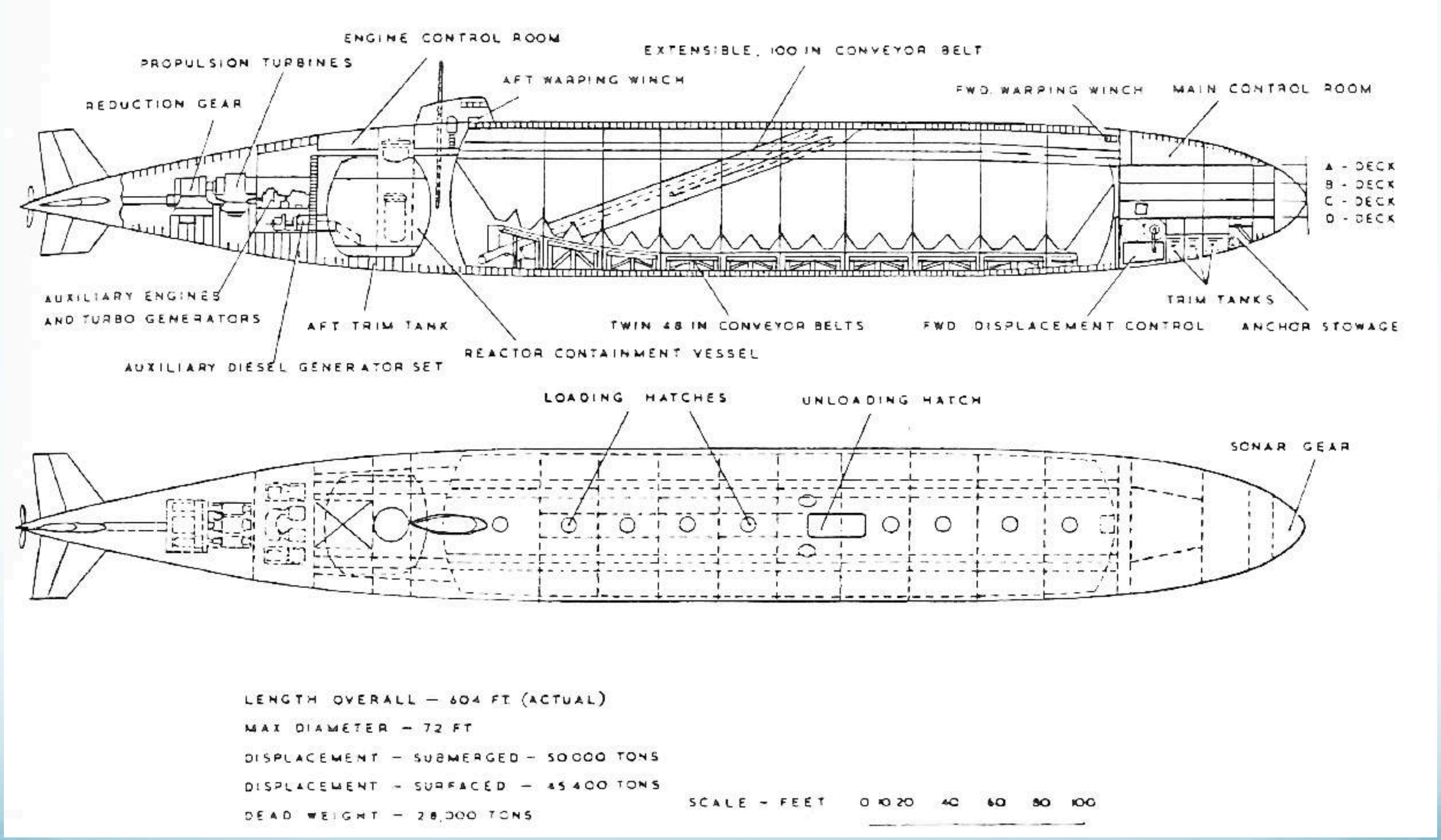
Source: Google maps



Source: Mitchell Engineering, Ltd. brochure circa 1959

Mitchell cargo submarine concept

P212 nuclear-powered Arctic submarine bulk cargo carrier



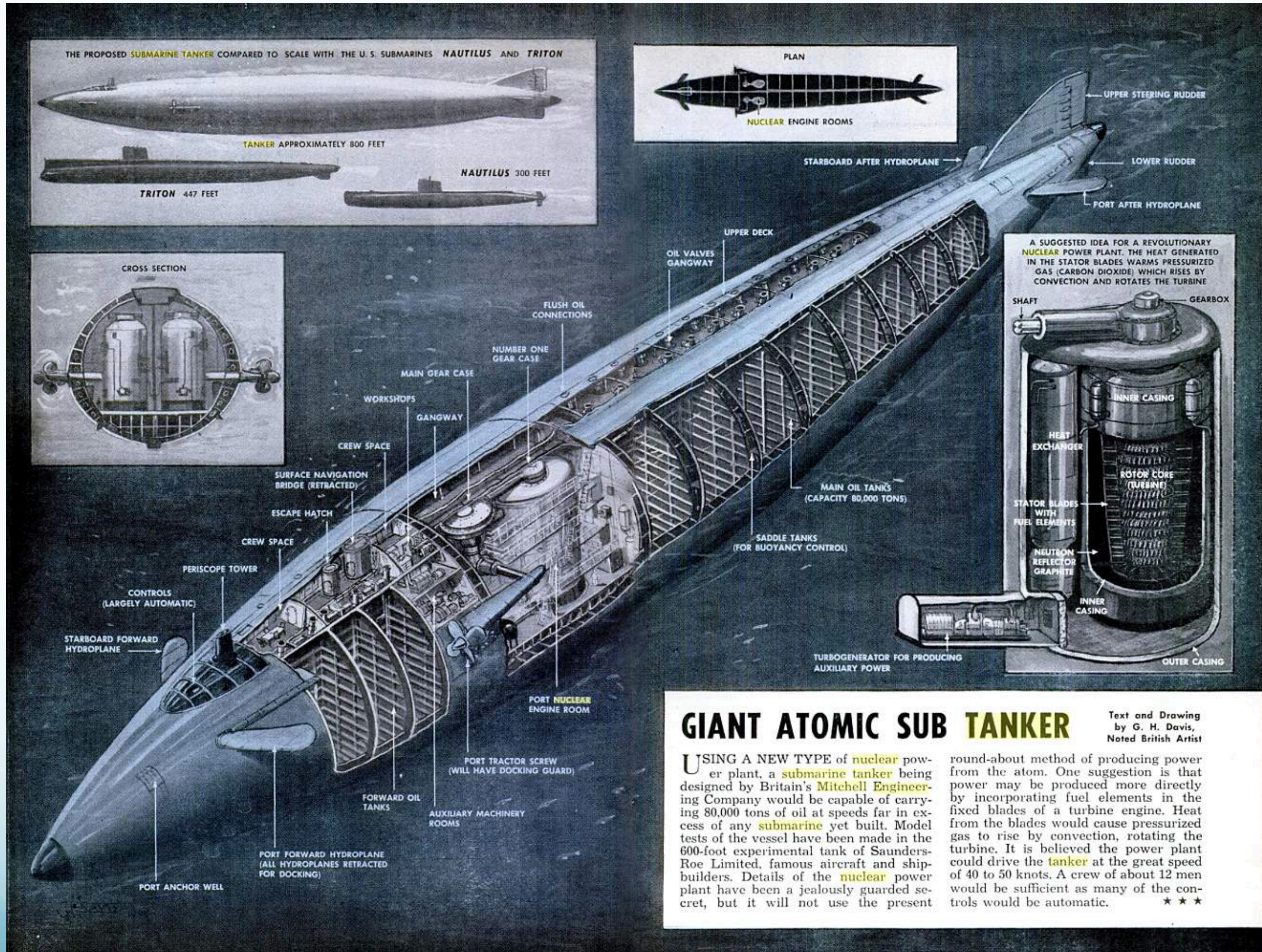
Source: Crewe, P. R. and Hardy, D.J., "The submarine ore carrier," Paper presented at a meeting of the Royal Institute of Naval Architects, 28 March 1962; via Capt. A. S. McLaren, "The Arctic Submarine – An Alternative to Ice Breaker Tankers and Pipelines," Master of Philosophy in Polar Studies Thesis, Scott Polar Research Institute, University of Cambridge, 1982

Mitchell submarine tanker concept

Source: Popular Mechanics, December 1958

- A substantially different and larger oil tanker version of a Mitchell Engineering, Ltd. cargo submarine was described in the December 1958 issue of *Popular Mechanics*.
- Overall length (approx.): 800 feet (244 meters). For comparison, the Hindenburg zeppelin was 803.7 feet long (245 meters).
- Cargo capacity: 80,000 tons of oil
- Propulsion: possibly two direct-cycle gas-cooled reactors of novel design driving two tractor propellers located amidships
- Maximum speed: 40 – 50 knots
- Popular Mechanics reported that model tests of the hull shape were made in a 600 ft. (183 meter) test tank at Saunders-Roe, Ltd.
- Crew size: 12

Mitchell submarine tanker concept



GIANT ATOMIC SUB TANKER

Text and Drawing by G. H. Davis, Noted British Artist

USING A NEW TYPE of nuclear power plant, a submarine tanker being designed by Britain's Mitchell Engineering Company would be capable of carrying 80,000 tons of oil at speeds far in excess of any submarine yet built. Model tests of the vessel have been made in the 600-foot experimental tank of Saunders-Roe Limited, famous aircraft and shipbuilders. Details of the nuclear power plant have been a jealously guarded secret, but it will not use the present round-about method of producing power from the atom. One suggestion is that power may be produced more directly by incorporating fuel elements in the fixed blades of a turbine engine. Heat from the blades would cause pressurized gas to rise by convection, rotating the turbine. It is believed the power plant could drive the tanker at the great speed of 40 to 50 knots. A crew of about 12 men would be sufficient as many of the controls would be automatic. ★ ★ ★

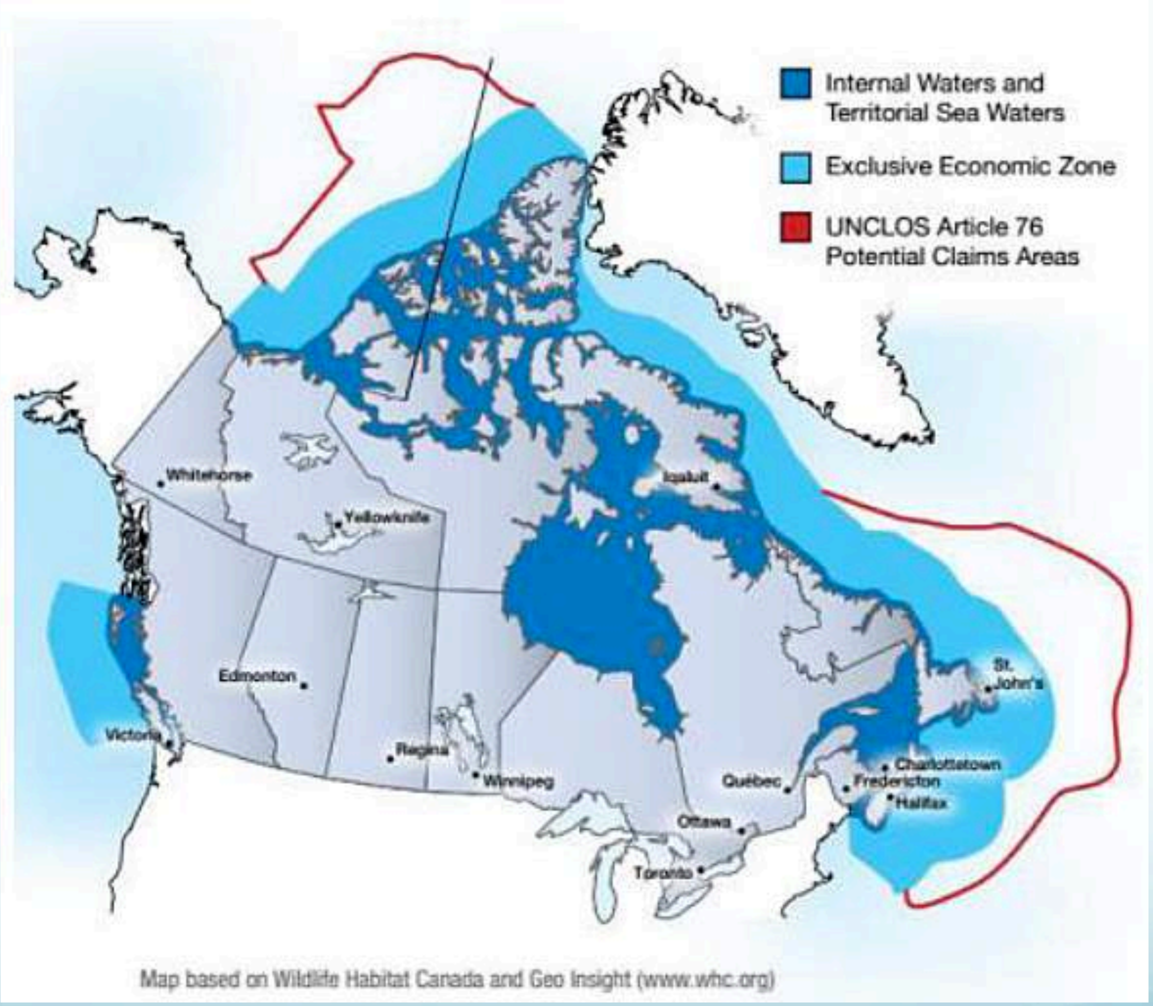
Source: Popular Mechanics, December 1958, p. 102 - 103

Canada's nuclear marine Arctic ambitions

Sovereignty over the Canadian Arctic

- In 1986, the Canadian government officially claimed the Northwest Passage as internal Canadian waters through the application of straight baselines.
  - The US, the European Union and other nations have refused to acknowledge Canadian sovereignty over these waters, claiming instead that the Northwest Passage is an international strait open to shipping, and its use does not require permission from Canada for transit.
- Canada has filed an UNCLOS Article 76 Extended Continental Shelf (ECS) claim that includes areas in the Arctic.
- Canada's intermittent interest in marine nuclear power has been driven largely by its concern about demonstrating Arctic sovereignty.
  - An important concern has been that a lack of Canadian surveillance, control, and physical presence in its northern waters might weaken some of its claims of sovereignty.

Sovereignty over the Canadian Arctic



Source: “LEADMARK 2050: Canada in a New Maritime World”

Nuclear-powered vessel studies

- The Canadian government studied, but did not proceed with the acquisition of any of the following nuclear-powered vessels that would have had operational roles in the Arctic:
  - 1970 - early 1980s: A nuclear-powered polar icebreaker for the Canadian Coast Guard, primarily to support economic development in the Canadian Arctic
  - 1987 - 1989: 10 to 12 nuclear attack submarines (SSNs) for the Canadian Navy, as announced in the Government's defense white paper, "*Challenges and Commitment – A Defense Policy For Canada*"
    - That Defense Policy offered a plan to plug the 'commitment capability gap' that had arisen between Canada's commitments to collective defense and national security and the Canadian Forces' ability to meet these responsibilities.

Nuclear-powered polar icebreaker study

- From the 1970s to the early 1980s, the Canadian Department of Transport (DOT), which includes the Canadian Coast Guard, investigated the design of a "Class 10" nuclear-powered icebreaker, with planned acquisition in the 1990s.
- In 1976, the Canadian government funded the design of a Class 10 nuclear-powered icebreaker with an "hybrid" powerplant, described as gas turbines powered by nuclear reactors, delivering a total propulsion power of 112 MW (150,000 shp).
  - All reactor proposals were from outside of Canada: US, UK, France, Switzerland & Germany.
  - Rolls-Royce offered a pressurized water reactor (PWR) for use on the proposed nuclear icebreaker, along with through-life maintenance and refueling services. The R-R nuclear propulsion plant design was reported to deliver 45 – 67.5 MWe. That implies a reactor power in the range of 145 – 210 MWt. Two Rolls-Royce reactors would have been needed on the polar icebreaker.
  - By 1980, all reactor vendors had dropped out except the French, which offered to transfer marine nuclear technology to Canada.

Nuclear-powered polar icebreaker study

- The project was cancelled in the early 1980s for several reasons, including:
  - Commercial exploitation of Canada's Arctic resources was occurring slower than expected, and thereby weakening the business case for the Class 10 icebreaker.
  - Canada's lack of a marine nuclear regulatory infrastructure led to delays in negotiating with the reactor vendor.
  - Acquisition of marine nuclear technology for a single ship came at a very high price.
  - Only the Soviet Union had actual experience operating a nuclear propulsion plant on an icebreaker.

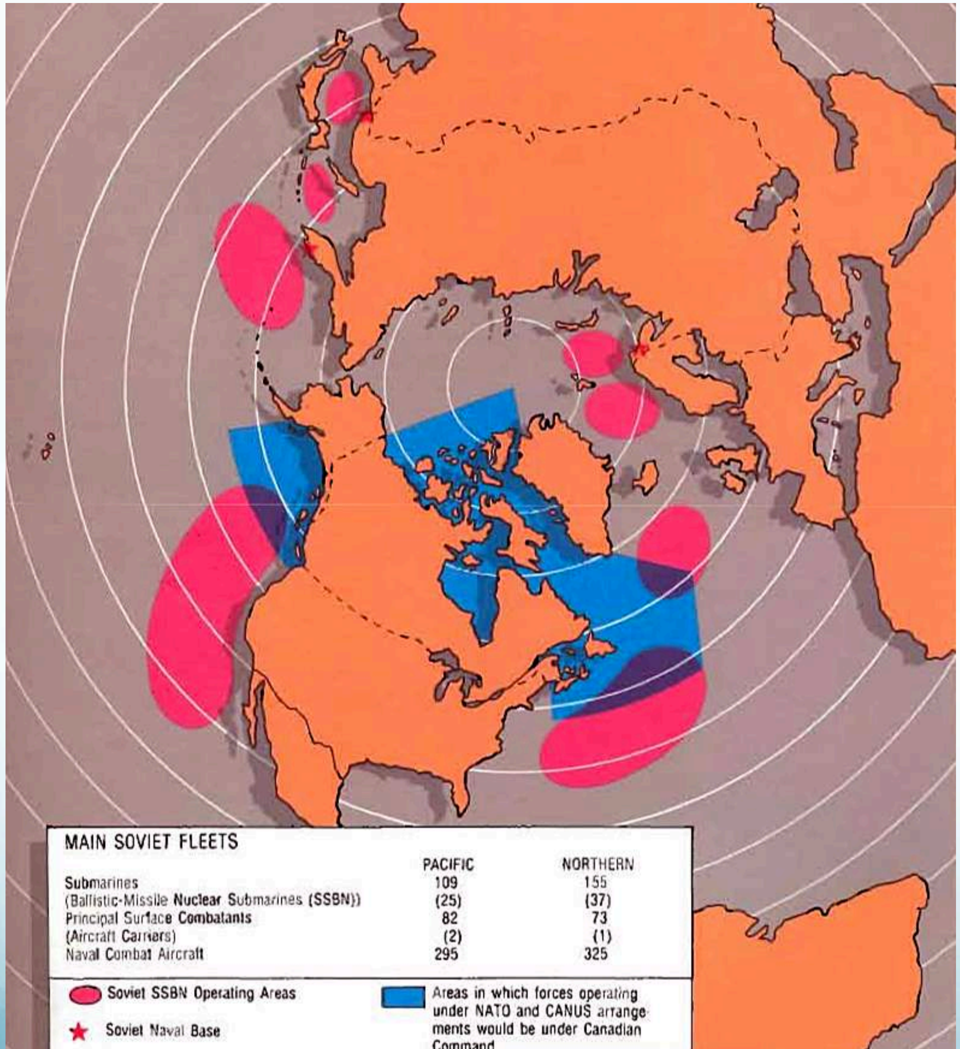
Nuclear submarine fleet plans

Canada’s 1987 defense white paper

- In June 1987, the Canadian defense white paper, *“Challenges and Commitment – A Defense Policy For Canada”* recommended the purchase of 10 to 12 nuclear-powered attack submarines, with the goals of building up a three-ocean Navy and asserting Canadian sovereignty over its Arctic territorial waters.
  - Submarine purchase was to be made under a technology transfer agreement.
  - The choice of the type of submarine was to be confirmed before summer 1988. The candidates were a French Rubis /Améthyste-derivative SSN and the UK Trafalgar-class SSN.
- The strongest American opposition to the U.K.-Canadian SSN deal came from Naval Reactors, which did not support the nuclear propulsion technology transfer from the UK (which was based on US-provided naval reactor technology) to Canada.
- The plan to purchase nuclear submarines was finally abandoned in May 1989.
- The Canadian Forces eventually acquired four of the UK Royal Navy's diesel-electric *Upholder / Victoria*-class subs in 1998, which they continue to operate as of mid-2018.
  - Unreliability has limited the operational utility of these submarines.

Nuclear submarine fleet plans

Canada's 1987 defense white paper

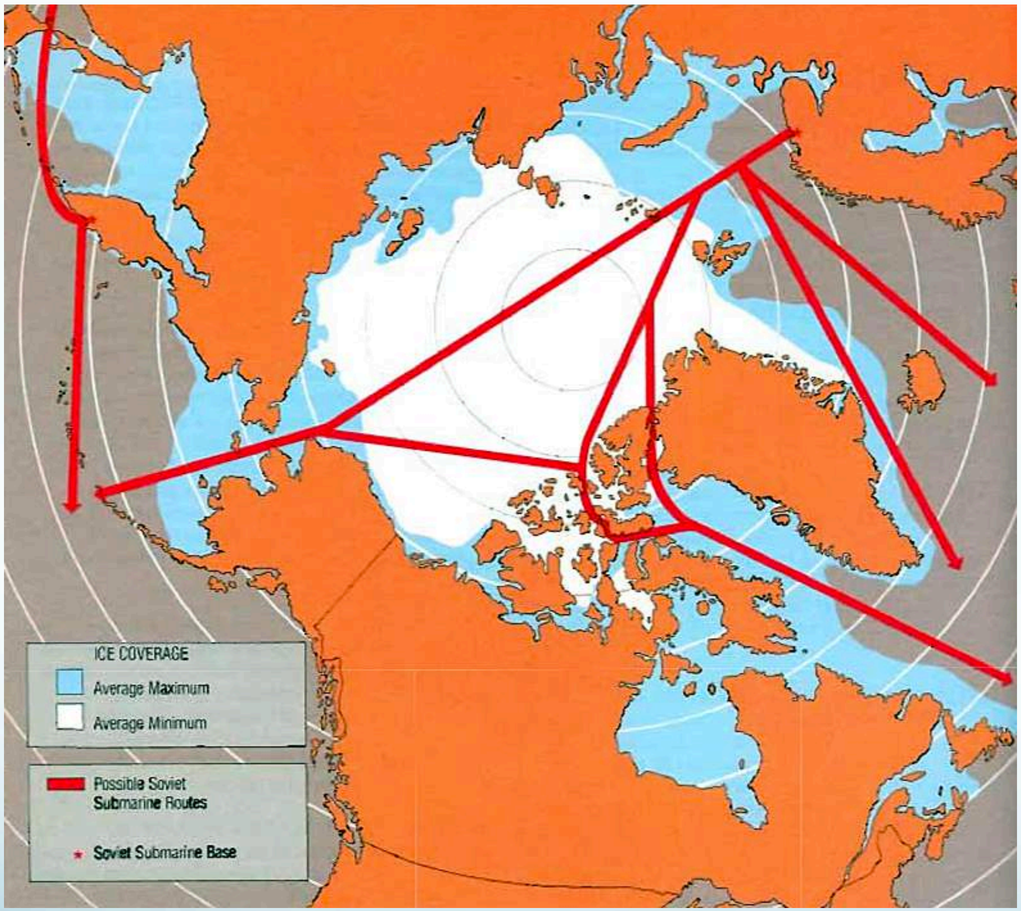


Source: June 1987 Canadian defense white paper, *"Challenges and Commitment – A Defense Policy For Canada*

- This figure from the 1987 defense white paper shows regions of the Arctic (blue) where Canada expected that forces operating under NATO and CANUS arrangements would be under Canadian command (i.e., while they are in Canada's claimed Arctic territorial waters)
- The red regions denote Soviet SSBN operating areas. The Soviet submarine bases at Murmansk, Petropavlovsk and Vladivostok are shown on the map.

Nuclear submarine fleet plans

Canada's 1987 defense white paper



Source: June 1987 Canadian defense white paper, *"Challenges and Commitment – A Defense Policy For Canada*

- This figure from the 1987 defense white paper illustrates possible routes taken by Soviet nuclear submarines transiting through the Arctic between the Atlantic and Pacific Oceans, passing through Canada's claimed Arctic territorial waters on some of the routes.
- Average Arctic ice coverage circa 1987 also is shown on the map (it's a bit more than the averages in 2018).

Canada polar icebreaker fleet

- Canada's only heavy polar icebreaker, *CCGS Louis St Laurent*, was commissioned in 1969 and continues in active duty 50 years later, in 2019.
- In 1994, *Louis St Laurent* and the US Coast Guard Cutter *Polar Sea,* operating together, were the first North American surface vessels to reach the North Pole.
- *Louis St Laurent* was to be replaced in 2017 by the Polar Class 2 (2nd highest ice-breaking rating) *CCGS John G. Diefenbaker.* From the initial estimate of $720 million Canadian dollars, the *Diefenbaker* is now expected to cost over $1.4 billion Canadian dollars, with delivery in as early as 2022 (although one estimate suggests delivery not before 2025).
- The Canadian government engaged the shipbuilding firm Chantier Davie Canada to convert three modern, existing Polar Class 4 icebreaking offshore vessels that originally were built to support Royal Dutch Shell Arctic projects that now have been cancelled: *Tor Viking II, Vidar Viking* and *Balder Viking*. These vessels are intended to help fill Canada's icebreaking "gap," at least until *John G. Diefenbaker* reaches full operational capability.

Leadmark 2050

Canada's 2016 defense policy review: "Canada in a New Maritime World"

- This is the Royal Canadian Navy's current long-range vision for its future missions.
- The document is not a firm plan, but rather is intended to encourage dialogue and debate about maritime issues, and to support the public discussions about the kind of naval force Canada needs now and in the future, with a 2050 planning horizon.
- LEADMARK 2050 calls for a "balanced" blue-water navy that includes the capability to operate in the high Arctic: "To meet the defense and security challenges in the coming decades, Canada's maritime forces will need to be better equipped for Arctic operations."
- This policy review makes no mention of nuclear-powered vessels.

Russian nuclear marine Arctic operations

Russia's Northern Fleet has extensive naval nuclear facilities in the Arctic

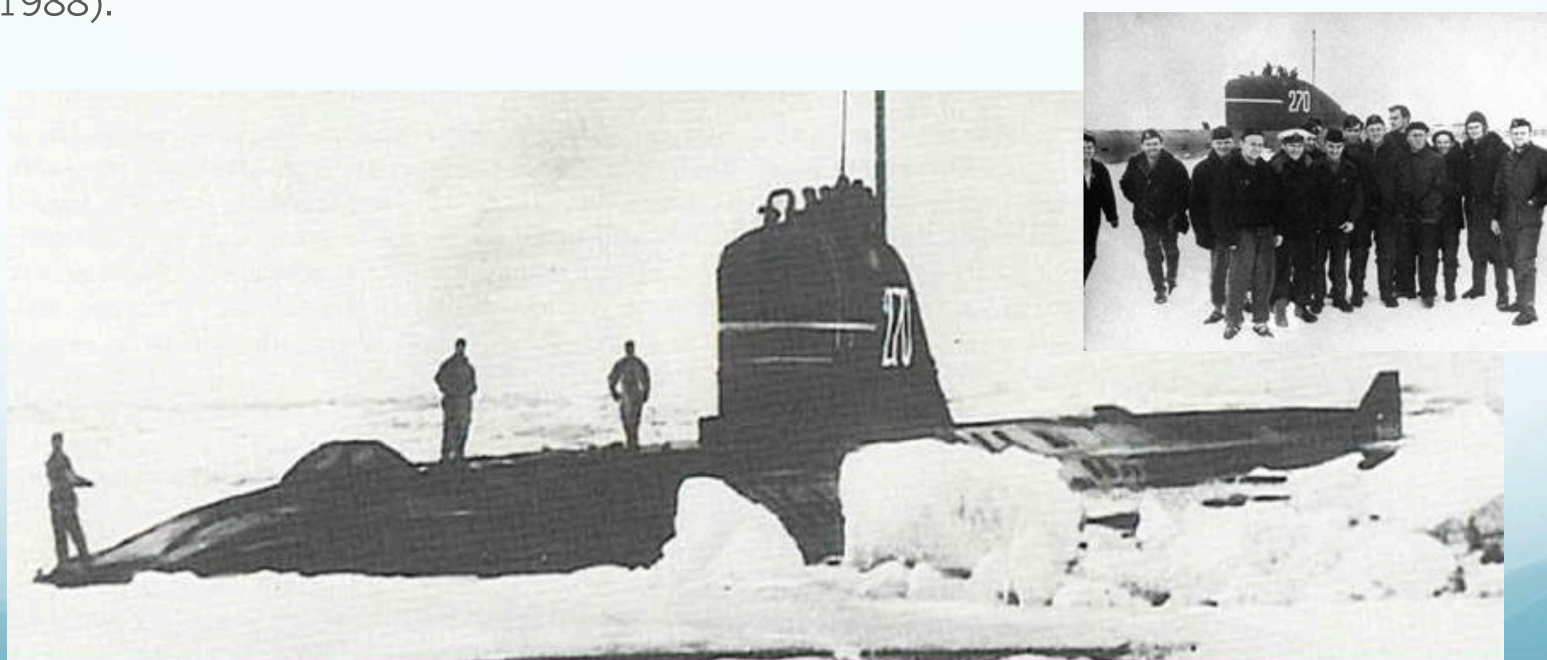
Source: https://commons.wikimedia.org

Source: Adapted from Wall Street Journal, 4 October 2016

Leninsky Komsomol (K-3)

1st Russian sub to reach the North Pole

- November 1959: Initial Arctic under-ice voyage by November-class sub K-3 ended with a damaged periscope. K-3 did not reach the North Pole on this voyage.
  - The early mission showed that improvements were needed in ice monitoring instruments and training for Arctic operations. This was similar to the results of *USS Nautilus'* first attempt to reach the North Pole.
- 17 July 1962: K-3, under command of Captain III Rank Lev Zhiltsov, reached the North Pole and surfaced nearby. He was awarded the Hero of the Soviet Union medal for this feat.
- K-3 performed 14 long-range cruises and covered 128,443 miles over 30 years (1958–1988).



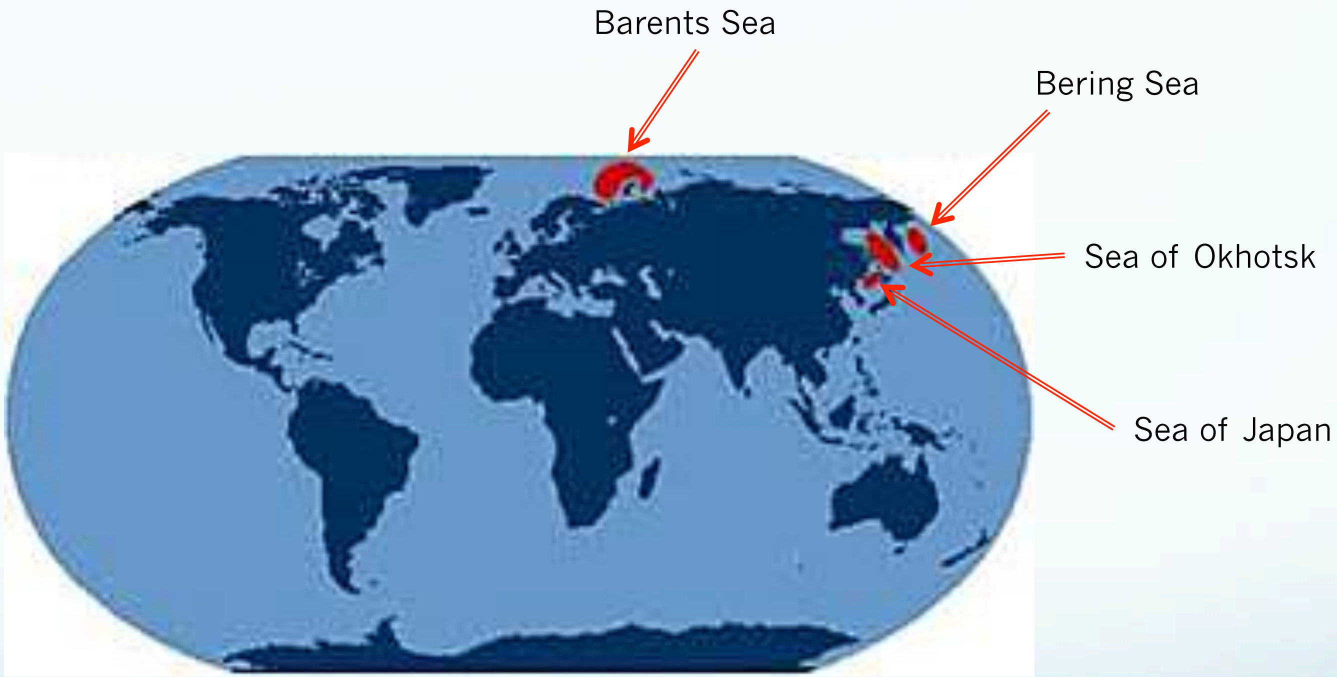
Source: rusnavy.com/history

Russian ballistic missile subs (SSBNs) operate in the Arctic

- The early Russian SSBNs (Hotel- and Yankee-class) had relatively short range submarine launched ballistic missiles (SLBMs) and had to patrol in areas of the Atlantic and Pacific Oceans that were close to their US targets.
  - On 20 October 1961, a conventionally powered Golf-class (Project 629) SSB conducted the first ever live test of a nuclear armed SLBM; launching an R-13 missile that detonated in the Novaya Zemlya test range in the Arctic Ocean. The R-13 SLBM also was carried on the nuclear powered Hotel 1-class (Project 658) SSBNs.
- The later Delta-class SSBNs were armed with longer range SLBMs (various versions of the R-29), which could reach US targets from patrol areas in the Barents and Norwegian Seas and the Arctic Ocean.
- All Russian Delta- and Typhoon-class SSBNs are capable of operating under the Arctic ice, surfacing through the ice, and then launching their missiles.
  - On 25 Aug 1995, a Typhoon SSBN surfaced at the North Pole, through 8 ft. (2.5 m) of ice, and launched an unarmed R-39 SLBM.
- It is likely that new Borei-class SSBNs have similar Arctic operating capabilities.

Example Russian SSBN deterrent patrol areas

Delta II and later SSBNs - late-1970s - present

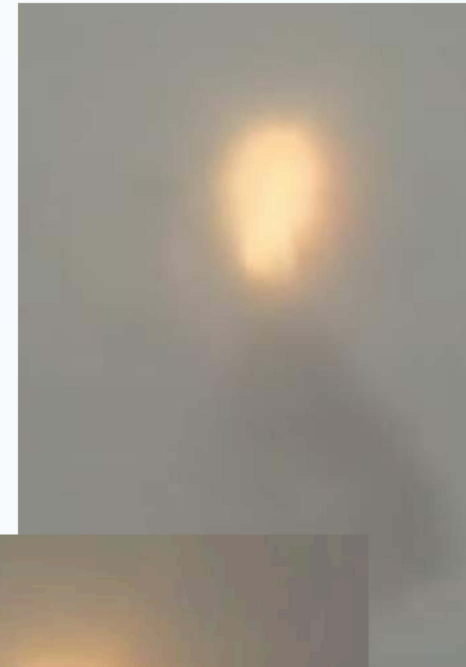


Source: fas.org

Depiction of Delta IV (667 BDRM) Arctic launch in a polynya

Source: http://misilactual.blogspot.com/2013/09/

Actual Typhoon (941) Arctic SLBM launch

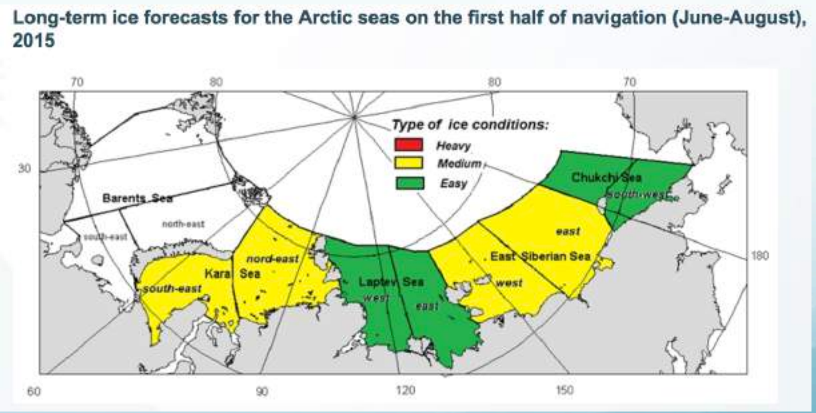


The Typhoon SSBN surfaced through thick ice, crew cleared the foredeck of ice, and the missile was launched

Source: screenshots from video
https://www.youtube.com/watch?v=3XLv9Uiy4J0

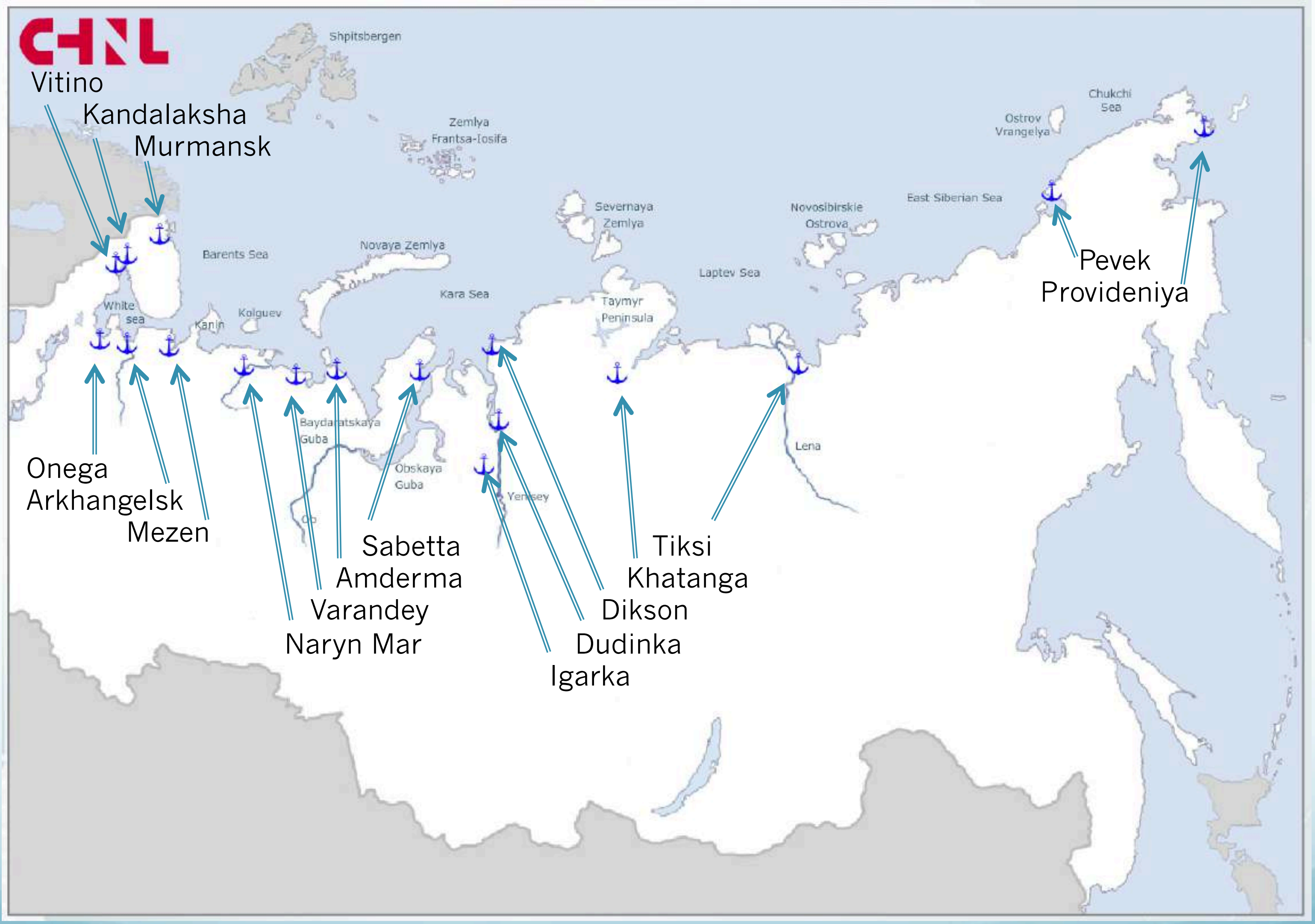
Northern Sea Route Information Office

- NSR Information Office is owned and operated by the Center for High North Logistics (CHNL) as a joint venture between CHNL and Rosatomflot, the Russian nuclear-powered icebreaker fleet operator.
- The mission is to provide businesses and international organizations with relevant and practical information in English for planning and arranging transit voyages on the NSR.
  - All of the requirements of the Russian NSR Administration are available in English on the NSR Information Office website.
- Provides ice forecasts for the NSR and maintains NSR traffic statistics
- Links to ARCTIS: Arctic Resources and Transportation Information System database.



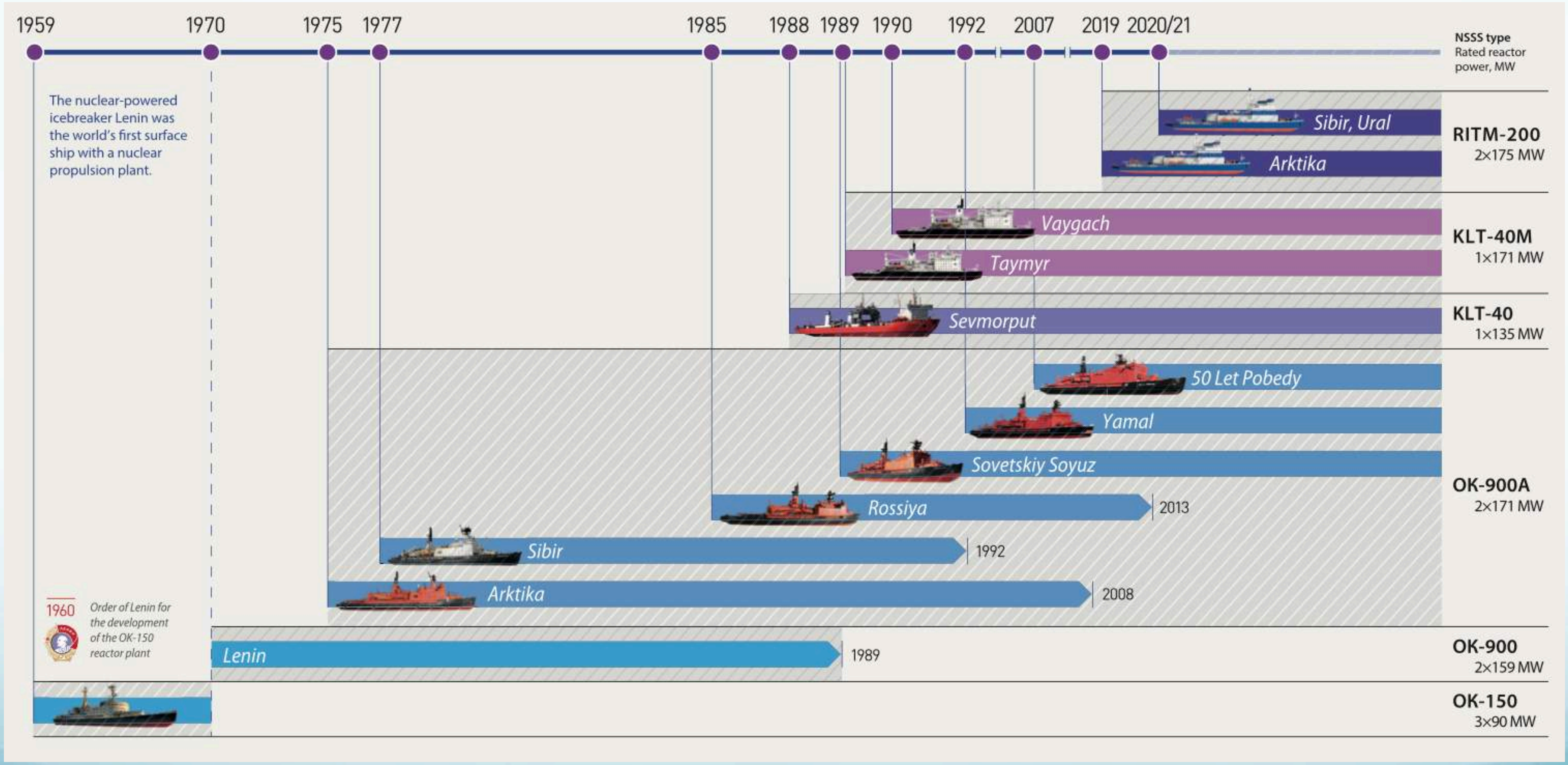
Source: http://www.arctic-lio.com/node/230

Russian ports in the Arctic



Source: adapted from http://www.arctic-lio.com/arcticports

Russian nuclear-powered icebreakers

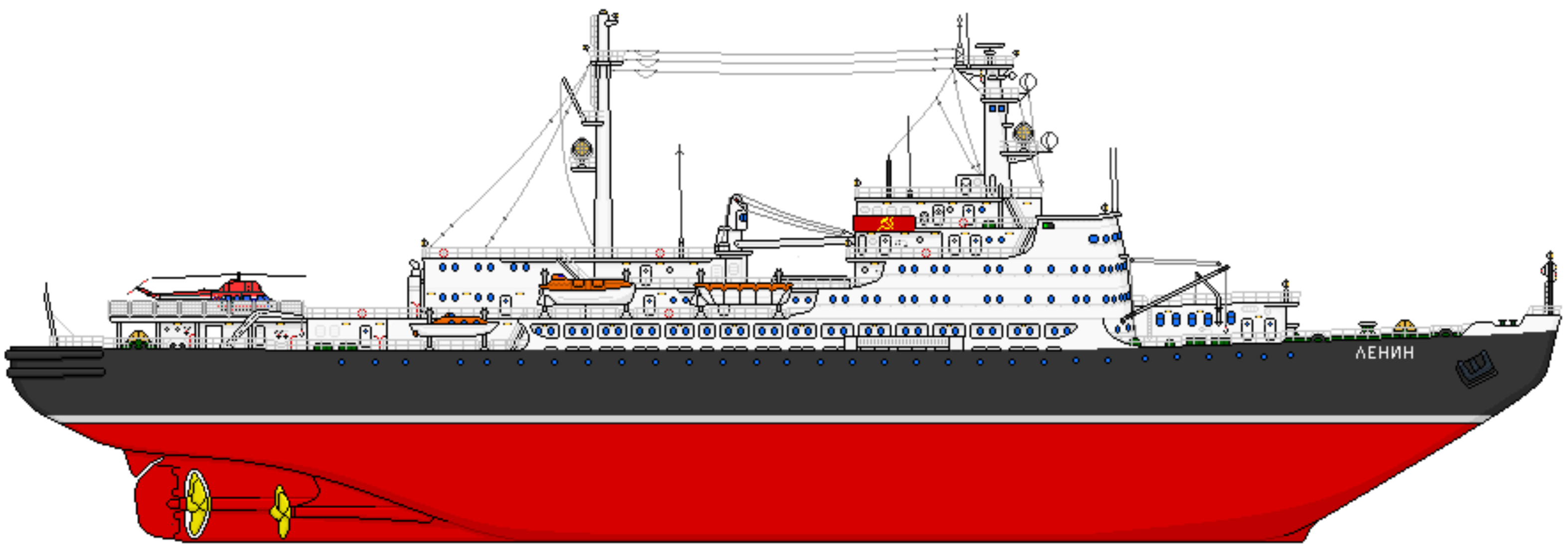


Source: http://www.okbm.nnov.ru/images/pdf/ritm-200_extended_en_web.pdf

Russian icebreaker *Lenin*

Russian nuclear-powered icebreaker & world's first nuclear-powered surface ship

Source: Lazer_one, http://www.shipbucket.com/drawings/2783



- Launched 5 Dec 1957 at the Baltic Shipyard, St. Petersburg, and completed in 1959. *Lenin* departed on its 1st voyage on 15 Sep 1959.
- Length: 134 m (440 ft); beam: 27.6 m (91 ft); displacement: 16,000 tonnes; max speed: 18 kts
- Designed to maintain 2 kts speed while breaking through 2 m (6.6 feet) of ice. This feat could not be matched by contemporary, large conventional icebreakers (typ. 10,000 ton, 20,000 shp ships).
- In service for 30 years, until 1989. Now a museum ship in Murmansk.

Russian icebreaker *Arktika*

1st surface ship to reach the North Pole

- On 17 Aug 1977, the Russian nuclear-powered icebreaker *Arktika* became the first surface ship to reach the North Pole.
    - This voyage was not reported, or repeated, for about a decade.
- The previous record for northernmost voyage by a surface ship was set at 85°57'N during the 1893–1896 Arctic expedition by Norwegian explorer Fridtjof Nansen's in the steam-powered sailing ship *Fram*.
    - *Fram* was purposely frozen in the Arctic ice pack and proved the existence of an east-to-west current in the Arctic Ocean as it slowly drifted northwest with the ice pack.

Source: peterstamps.com

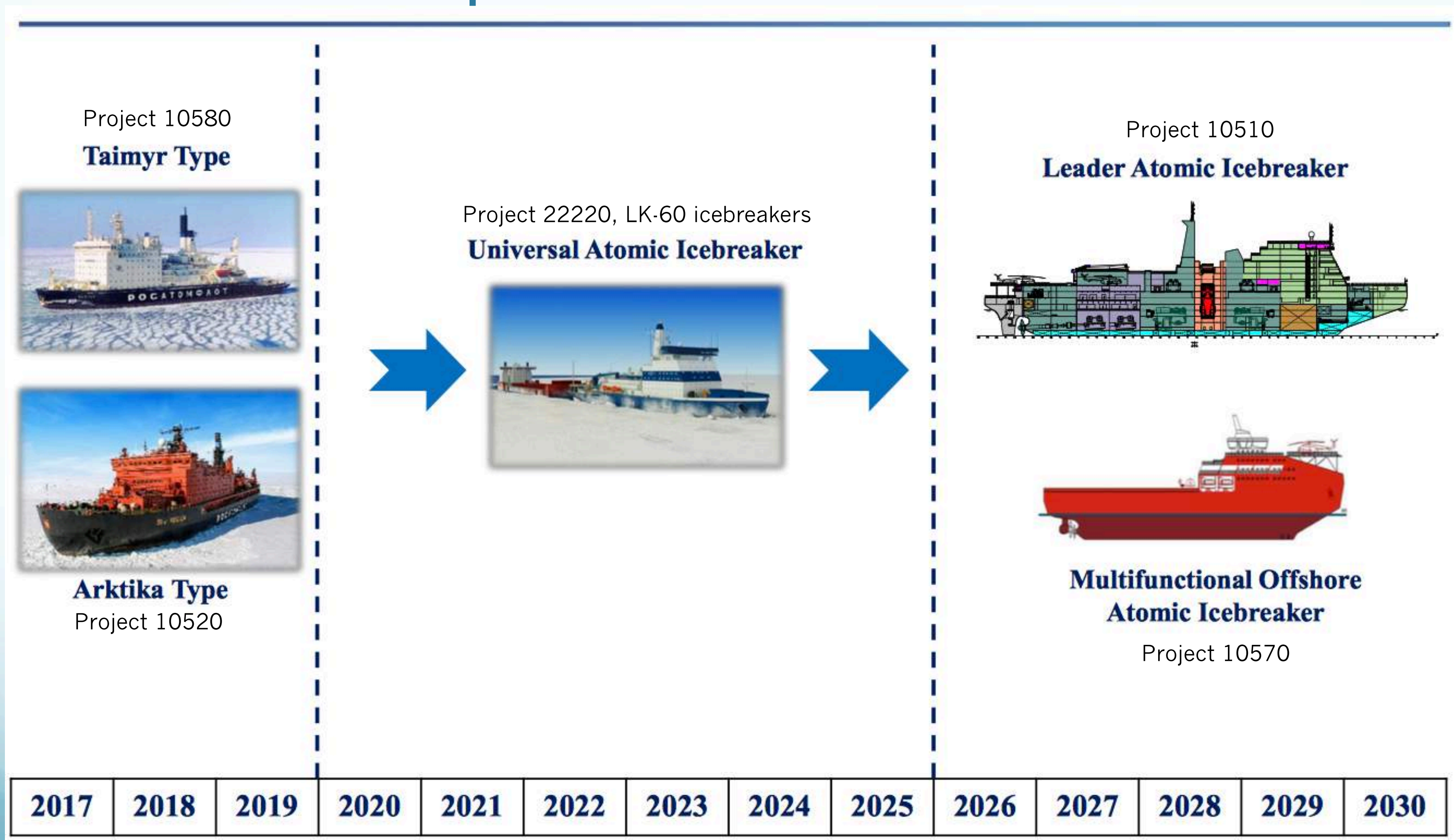
Source: en.wikipedia.org

Russian commercial cruises to the North Pole

Commercial polar cruises from Murmansk to the North Pole aboard Arktika-class nuclear icebreakers have been offered since 1989.

Source: picsant.com/11814528-north-pole-expedition.html

ROSATOM’s long-range plans for nuclear-powered icebreakers



Source: ROSATOMFLOT, “Development of Atomic Icebreaking Fleet and Support for Arctic Projects,” 2017

Deployment of new icebreakers supports LNG market growth

LNG transit via Northern Sea route subject to icebreakers commissioning

LK-60 nuclear icebreaker (60 MW)

LD-type icebreaker (120 MW)

ARC 130-type LNG-fueled icebreaker (21 MW, 40 MW, 60 MW)

Icebreaking fleet is being renewed: three new icebreaker types are being designed

LK-60 nuclear icebreakers:

- The ARKTIKA nuclear icebreaker was put afloat on June 6, 2016 (to be brought into operation in 2019)
- The SIBIR nuclear icebreaker was put afloat on September 22, 2017 (to be brought into operation in 2020)
- The URAL nuclear icebreaker (to be brought into operation in 2022)

The LD nuclear icebreaker – development of design documentation is underway. Expected completion date – December 2017

ARC 130-type LNG-fueled icebreaker – at the design stage

Source: NOVATEK, 2018, https://annualmeeting.bhge.com/sites/default/files/2018-02/2018_Gyetvay.pdf

Russian floating ice stations

- Russia has had floating research stations in the Arctic since 1937.
  - Many of these station was established on an ice floe in April-May with about two dozen scientists who would spend the winter there, measuring climate and weather conditions.
  - The stations have had numbers from North Pole-1 (1937-38) to North Pole-40 (2012-13).
    - Most of these ice stations operated for one to four years and drifted for 1,000 - 6,000 km (621 – 3,728 miles) on the Arctic Ocean.
    - The longest serving ice station was North Pole-22, which operated from September 1973 to April 1982, and drifted 17,069 km (10,606 miles).
  - In 2005, the nuclear-powered icebreaker *Arktika* evacuated North Pole-33.
  - North Pole-40 had to be evacuated ahead of schedule, because the ice floe the station was built on started to break apart.
- After two seasons with no floating research stations, Russia established floating research station "*North Pole-2015*" in April 2015.
  - 205 million rubles (about $3.5 million) was budgeted by the hydrometeorology authority, Roshydromet
  - This was Russia's most northern ice station (89°34' N) when it was established in April. When the ice station closed in August 2015, it had drifted 714 km (444 miles) to 86°15' N.
  - *North Pole-2015* is likely to have been Russia's last floating ice station on an ice floe.

Source: www.rcinet.ca/eye-on-the-arctic/2015

Russian floating Arctic base

- In 2013, Russian authorities announced plans to construct a self-propelled, ice-strengthened, floating Arctic research station for use in place of the traditional ice stations on natural ice floes.
  - In 2013, 1.7 billion rubles (about $29 million) were allocated to this project.
- In April 2018, the Russian Hydrometeorological Service (Roshydromet) signed a contract with the Admiralty Shipyard in St. Petersburg for construction of the first floating Arctic research platform, named *North Pole*, with the following characteristics:
  - Dimensions: 67.8 meters (222.4 feet) long, 22.5 meters (73.5 feet) wide, deadweight of 7,500 tons.
  - Russian ice classification is Arc8 (aligns approximately between IACS Polar Class 2 and 3), permitting year-round navigation in Arctic waters. Arc9 and Polar Class 1 are the highest Arctic vessel classifications.
  - The top speed will be at least 10 knots.
  - Conventionally-powered, with fuel supplies sufficient for two years of autonomous sailing.
  - Crew of up to 14, with accommodations for up to 48 researchers.
  - Construction is expected to start in early 2019, with completion in 2020.

Source: https://thebarentsobserver.com/en/arctic/2018/04/russias-new-north-pole-base

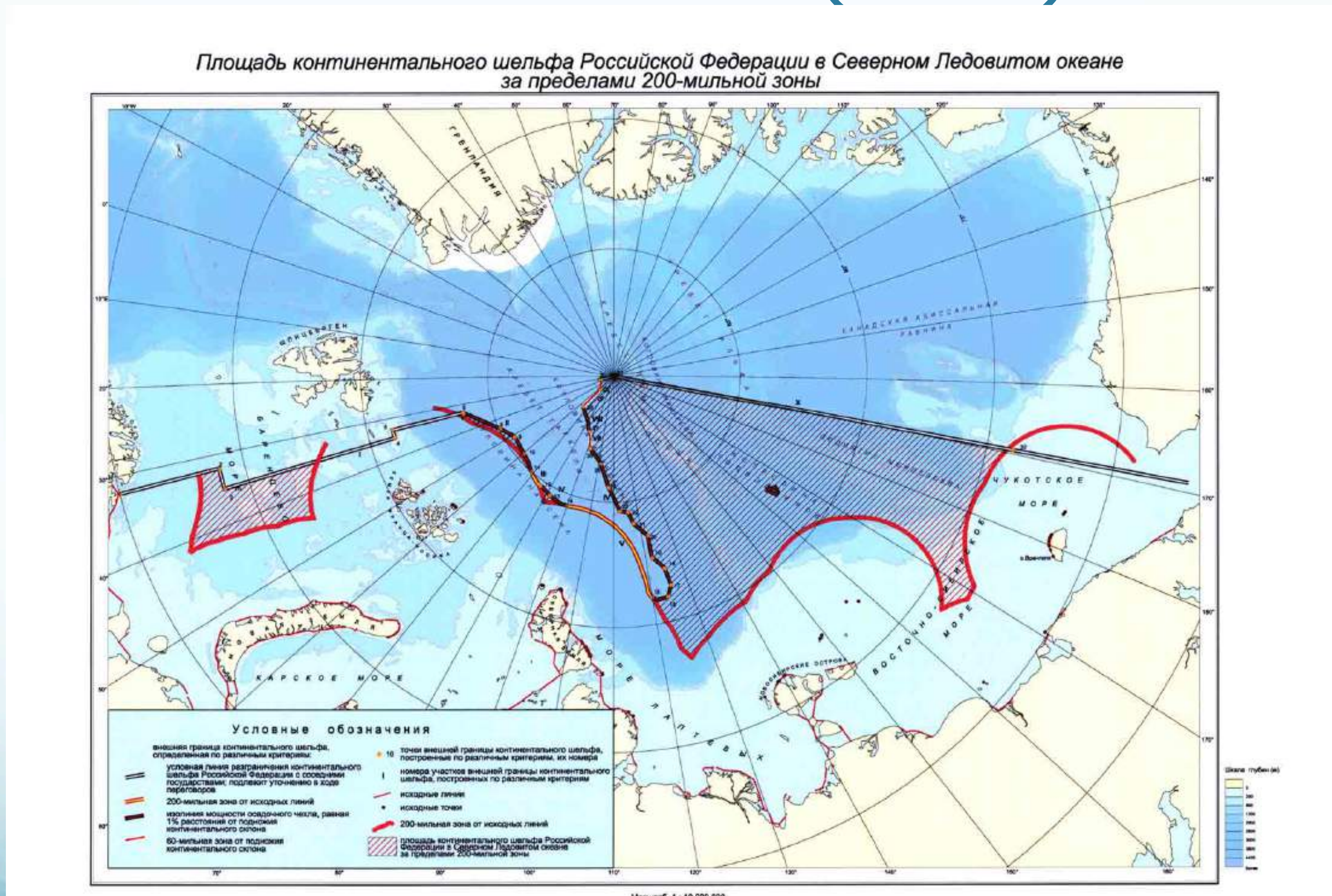
Russian floating Arctic base

Source: Admiralty Shipyard via the Barents Observer

Russian 2001 Arctic extended continental shelf (ECS) claim

- On 20 December 2001, Russia made a submission through the UN Secretary-General to the Commission on the Limits of the Continental Shelf, pursuant to Article 76 of the UN Convention on the Law of the Sea.
  - The submission contained information on the proposed outer limits of the Russian continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.
  - The matter has been under consideration, and further research is being conducted by Russia, US and other nations.
- There are two basic methodologies for defining the extent of the "extended continental shelf":
  - Constraint lines
  - Formula lines

Russian 2001 Arctic extended continental shelf (ECS) claim



Map 2

Source: www.un.org

Expedition Arktika 2007

- This expedition was described as a research program to support Russia's 2001 extended continental shelf claim to a large swathe of the Arctic Ocean floor.
- The expedition was led through the Arctic icepack by the Arktika-class nuclear-powered icebreaker *Rossiya*.
- Floating ice station North Pole-35 was established.
- 2 August 2007: First ever manned descent to the ocean floor at the North Pole, to a depth of 4,261 m (14,061 ft.).
  - The descent to the ocean floor was accomplished in two Mir mini-subs.
  - A Russian flag was planted on the ocean floor at the North Pole.
- *USS Nautilus*' 1958 measurement of the sea depth at the North Pole was only 4,087 m (13,410 ft.).

Mir mini-sub

Source: en.wikipedia.org

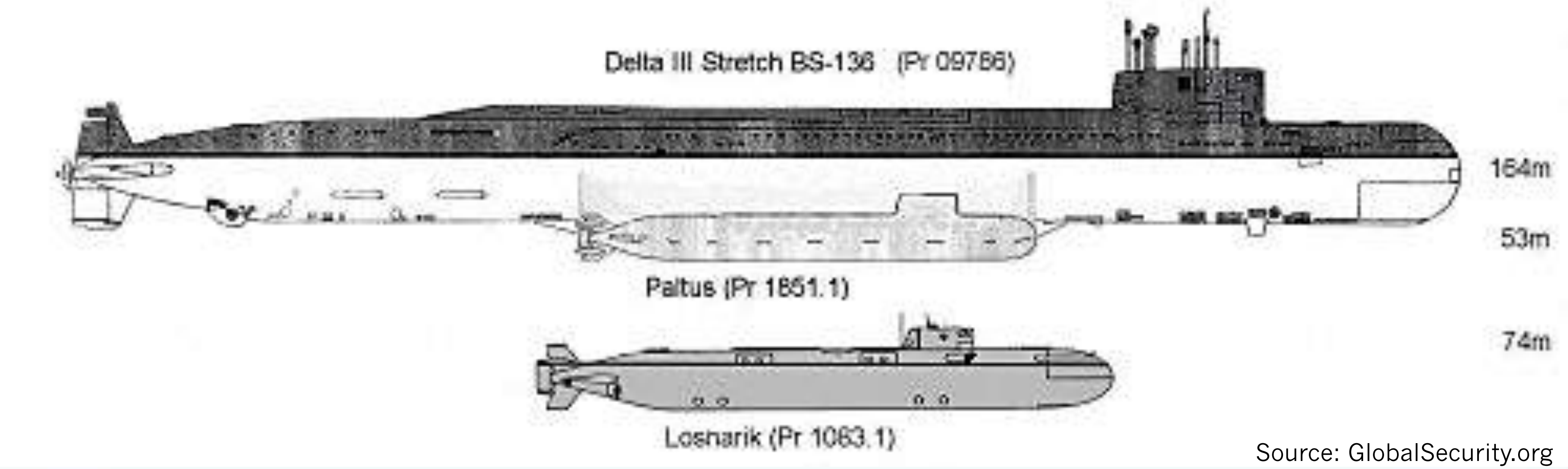
Source: Reuters UK

Expedition Arktika 2012

- The "Sevmorgeo" expedition was conducted by Russia in Aug - Oct 2012 to clarify the high-latitude boundary of the Russian continental shelf in the Arctic, focusing on the Mendeleev Ridge.
  - The neighboring Lomonosov Ridge was researched in 2010 and 2011 by the State Research Navigation and Hydrographic Institute of the Ministry of Defense of the Russian Federation.
- Vessels in the Arctic 2012 expedition were icebreaker *Dikson* serving as a research vessel and icebreaker *Kapitan Dranitsin*.
  - It is believed that the nuclear-powered submarine "mothership" BS-136 (Project 09786) and the nuclear-powered small, deep-diving submarine AS-12 (Project 10831) were part of the expedition (based on reference to the subs in expedition reports) and that they reached the North Pole. See details on these vessels in *"Marine Nuclear Power: 1939 – 2918, Part 3A: Russia – Submarines."*

Project 09786

PLA-carrier BS-136 "Orenburg II" (former Delta III K-129)

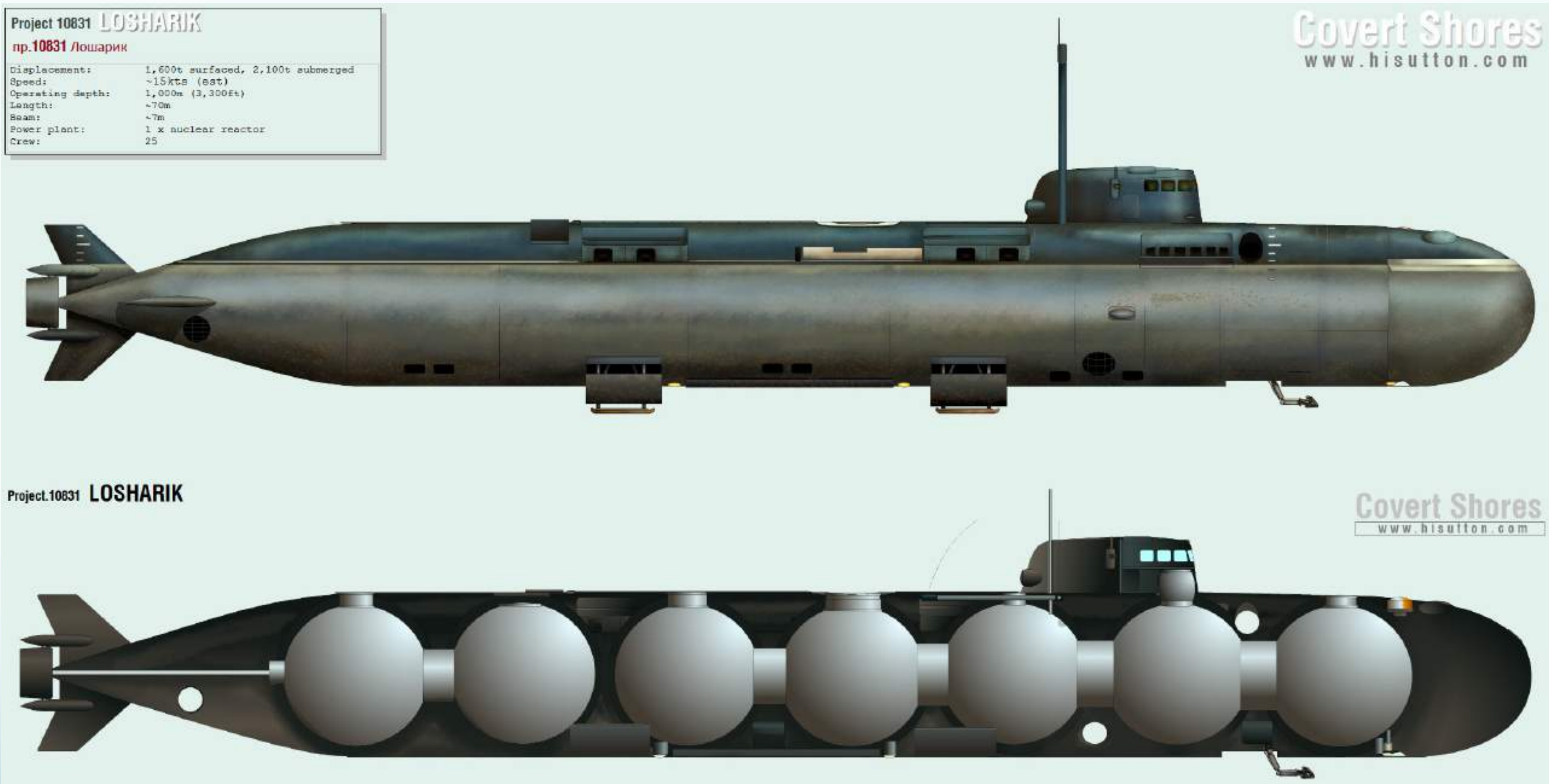


Source: GlobalSecurity.org

- "Delta III Stretch" conversion from 1994 to 2002 at Zvezdochka Shipyard, Severodvinsk.
- Missile compartment replaced by an extended hull section. Overall length length now 164.5 m (539.7 ft.).
- Also added 1 x bow and 1 x stern thruster and updated the sonar system.
- Serves as "mothership" to support a small special operations submarine.
- Assigned to the Northern Fleet.

Project 10831 Losharik

“Deep diving nuclear power station” notional arrangement



Source: www.hisutton.com

Expedition Arktika 2012

- Claimed results:
  - The seismic survey of the ocean bottom yielded results proving that the Mendeleev Ridge has the same nature as the continental structures.
  - The expedition performed the first deep-water drilling on the Mendeleev Ridge. About 22,000 rock and sediment samples were obtained from the bottom of the Arctic Ocean during the three months of work.
- All-Russian Research Institute of Geology and Mineral Resources of the World Ocean (VNII Okeangeologia) prepared an updated application of the Russian Federation, drawn up in compliance with the requirements of the UN Commission on the Law of the Sea, to claim expansion of the continental shelf borders.
  - That updated claim was filed in 2015.

Russian 2015 Arctic extended continental shelf (ECS) claim

- In November 2014, Artrur Chilingarov, Vladimir Putin's representative on international Arctic cooperation, stated at the 7th annual Arctic Development Conference, that, "Developing resources in the arctic zone of Russia has been called a fundamental national interest."
- On 4 August 2015, Russia's Foreign Ministry confirmed that Russia had re-submitted its extended continental shelf claim.
  - Russia is seeking recognition for its formal economic control of 1.2 million square kilometers (463,320 square miles) of Artic sea shelf extending more than 350 nautical miles from the shore.
  - The updated application cites the Lomonosov Ridge, Mendeleev-Alpha Rise and Chukchi Plateau as belonging to "submarine elevations that are natural components of the continental margin."
  - The Podvodnikov and Chukchi Basins separating the three areas also are listed in the claim.

Russian 2015 Arctic extended continental shelf (ECS) claim

- The area covered by Russia's 2015 ECS claim is estimated by Bellona Foundation to hold 258 billion tons of fuel equivalent, representing 60% of Russia's total hydrocarbon reserves. The area also is fertile fishing territory.
  - Bellona Foundation believes these oil and gas reserves, "would hardly be worth pursuing because its extraction from the central Arctic would simply cost too much."

Russian non-propulsion marine nuclear Arctic applications

- Small reactors for non-propulsion marine nuclear applications
- Floating nuclear power plants (FNPP)
- Transportable reactor units (TRU)
- Arctic seabed applications for marine nuclear power
- Radioisotope Thermoelectric Generators (RTGs)

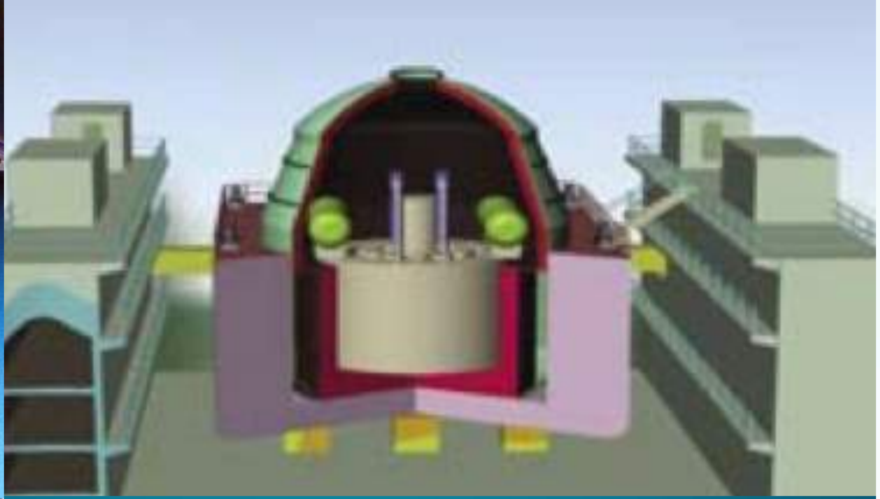
Non-propulsion nuclear marine Arctic applications

- Based on their experience in developing marine nuclear reactors, OKBM Afrikantov, Nikiet and OKB Gidropress offer a variety of small size reactors in relatively small packages that are designed for deployment in remote areas, particularly in the Arctic, for combined electricity and heat supply to isolated end-users and systems.
- Applications:
  - Floating nuclear power plant (FNPP)
    - Electric power with or without process heat supplied to coastal territories or ocean surface structures (i.e., oil & gas drilling and production facilities).
    - Minimum end-user infrastructure required to receive power.
  - Modular, transportable nuclear steam supply system (NSSS)
    - NSSS module is delivered by ship or barge to a coastal facility where permanent balance-of-plant (BOP) facilities have been constructed.
    - The NSSS module periodically is replaced by a new module and then transported to a remote factory for refueling and maintenance.
  - Power plant for an above-water industrial facility
    - Small reactor and power conversion system built into a major above-water industrial facility (i.e., oil & gas drilling / production facilities).
  - Underwater power generating complex:
    - Seafloor-sited autonomous power generating modules.
    - Power supply to underwater objects at great depths and under ice-bound conditions. Also capable of supplying power to ocean surface structures.
    - Multiple modules can be connected to an underwater transmission and distribution grid to support many end-user facilities and activities.

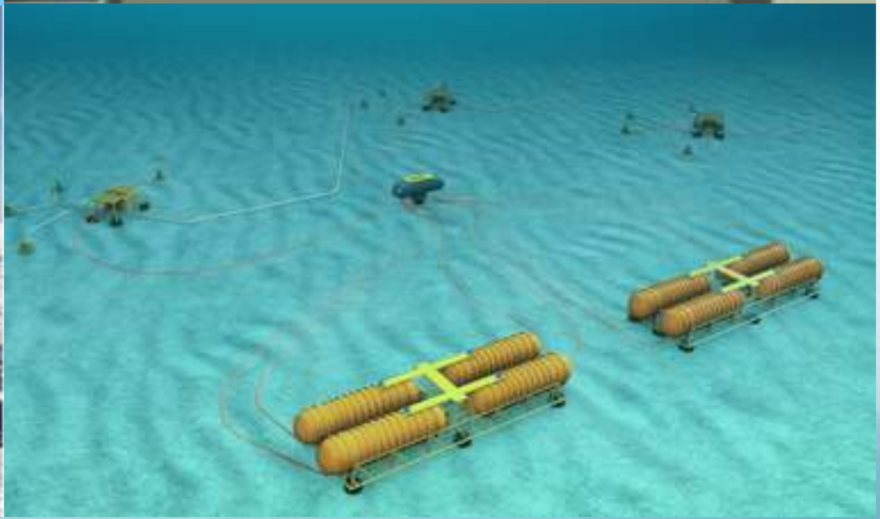
Non-propulsion nuclear marine Arctic applications

Floating nuclear power plant. Source: OKBM Afrikantov

Modular, transportable nuclear steam supply system (NSSS). Source: OKB Gidropress



Power plant on above-water industrial facility. Source: OKBM Afrikantov



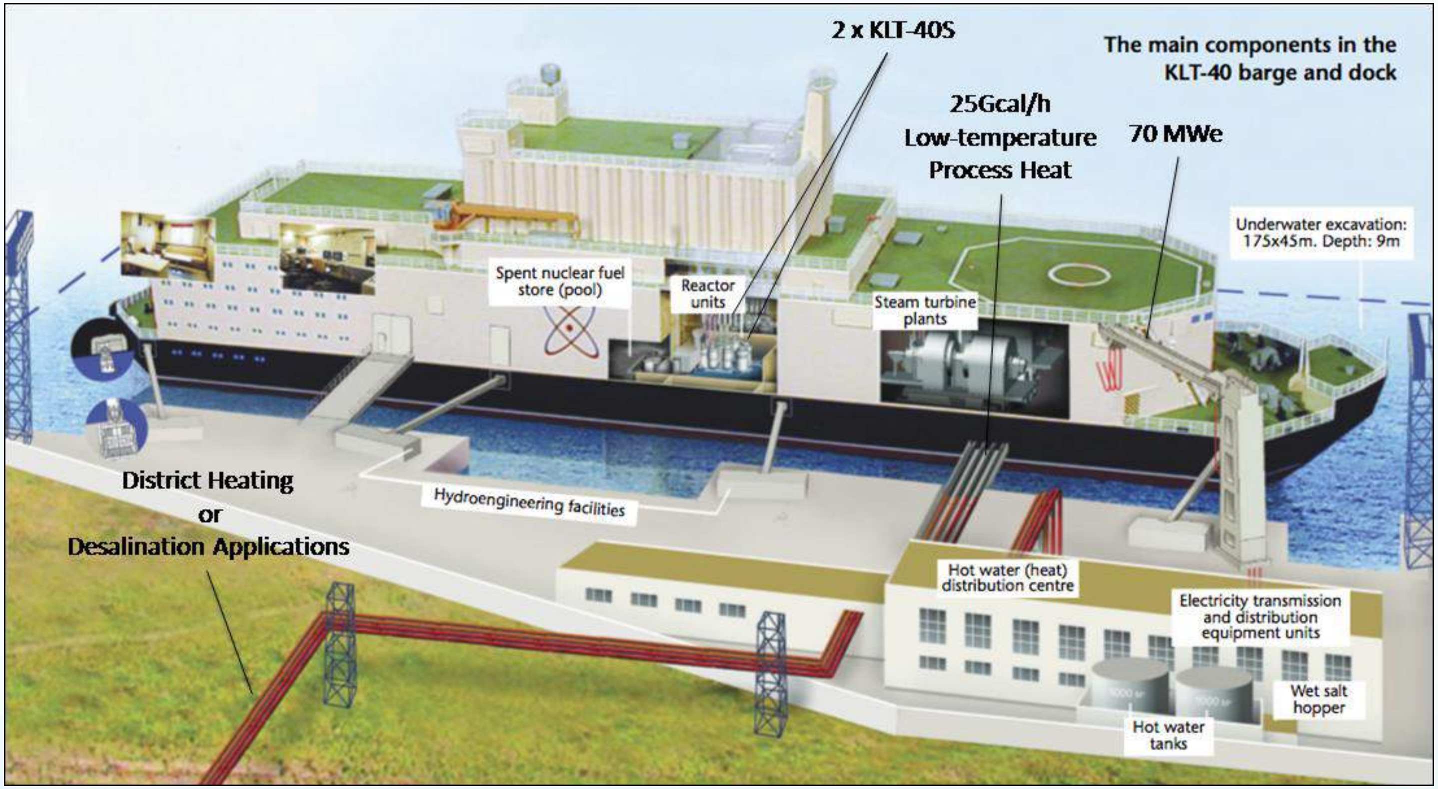
Underwater power generating complex. Source: OKBM Afrikantov

Floating nuclear power plant (FNPP) Arctic candidate sites

Source: World Nuclear Association

Project 20870 - *Akademik Lomonosov*

First Russian floating nuclear power plant (FNPP)



FNPP *Akademik Lomonosov* and its associated shore-side facilities. Source: OKBM Afrikantov

- *Akademik Lomonosov* was constructed at the Baltic Shipyard in St. Petersburg. The keel was laid in May 2009. Length: 140 m (459.3 ft); width: 30 m (98.4 ft); displacement: 21,000 tons.
- 2 x KLT-40S reactors, each rated at 150 MWt, will deliver up to 77 MWe net and low-temperature process heat to users on shore. The FNPP can deliver up to 25 Gcal/h (about 29 MW) of process heat with reduced electric generation.

Akademik Lomonosov

28 April – 19 May 2018: Tow from St. Petersburg to Murmansk

Source: Anton Vaganov / TASS

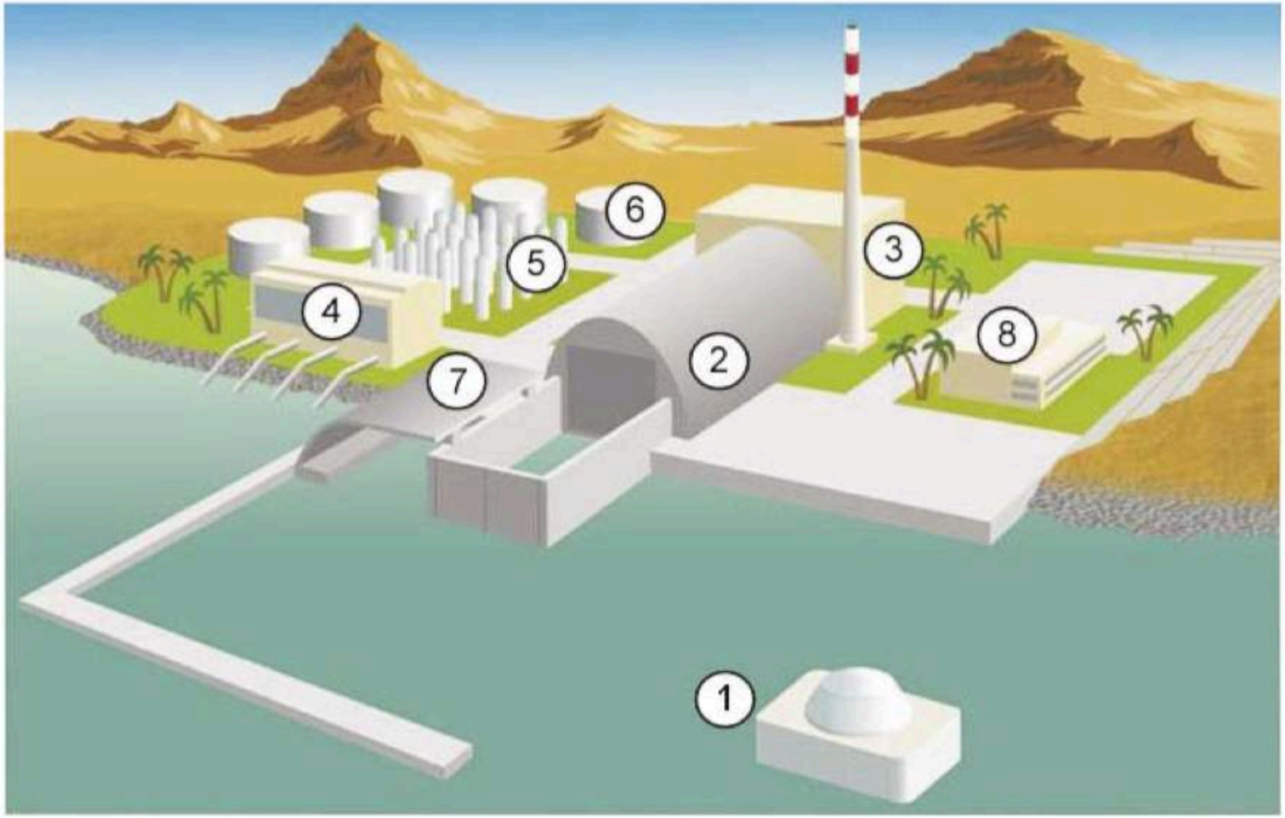
Source: https://www.trendsmap.com/

Source: http://en.prothomalo.com/science-technology/news/

Source: AP / http://betternews.info/

Transportable Reactor Unit (TRU)

Barge-delivered SVBR-75/100 integral LMR for coastal sites



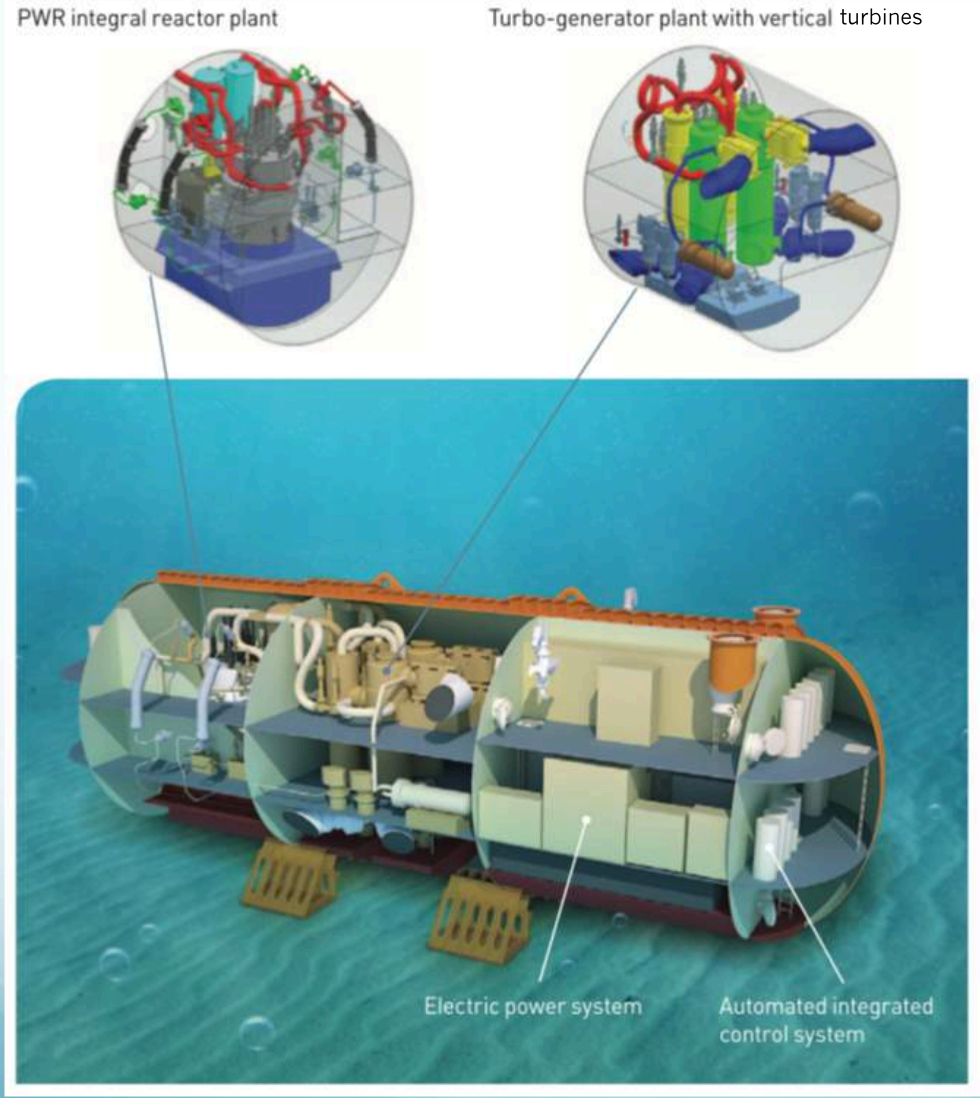
1 – transportable reactor unit (approaching dry dock)
2– protective dry dock
3 – building for steam-turbine plant
4 – building for desalinating plant pumps

5 – water-desalinating plant modules
6 – desalinated water storage tanks
7 – platform for reactor coolant solidification prior to transportation (this is a covered dock)
8 – office building

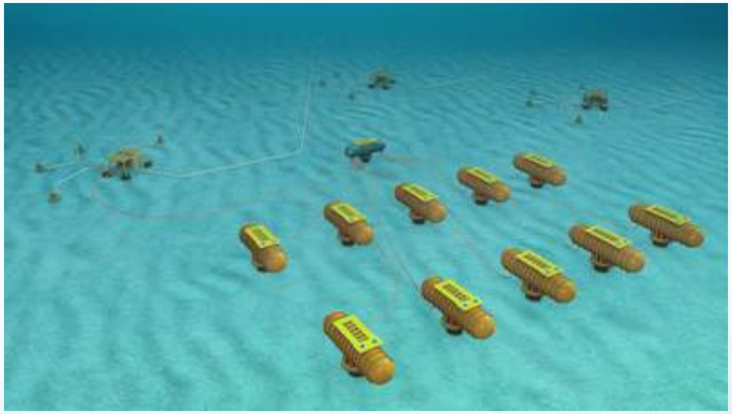
Source: http://www.gidropress.podolsk.ru/files/booklets/en/svbr75_100_en.pdf

Afrikantov Aisberg

Small integral PWR for a subsea power complex



Aisberg PWR module configuration. Source: OKBM Afrikantov



The electrical output from multiple reactor modules can be connected into a subsea power complex serving multiple end-users.

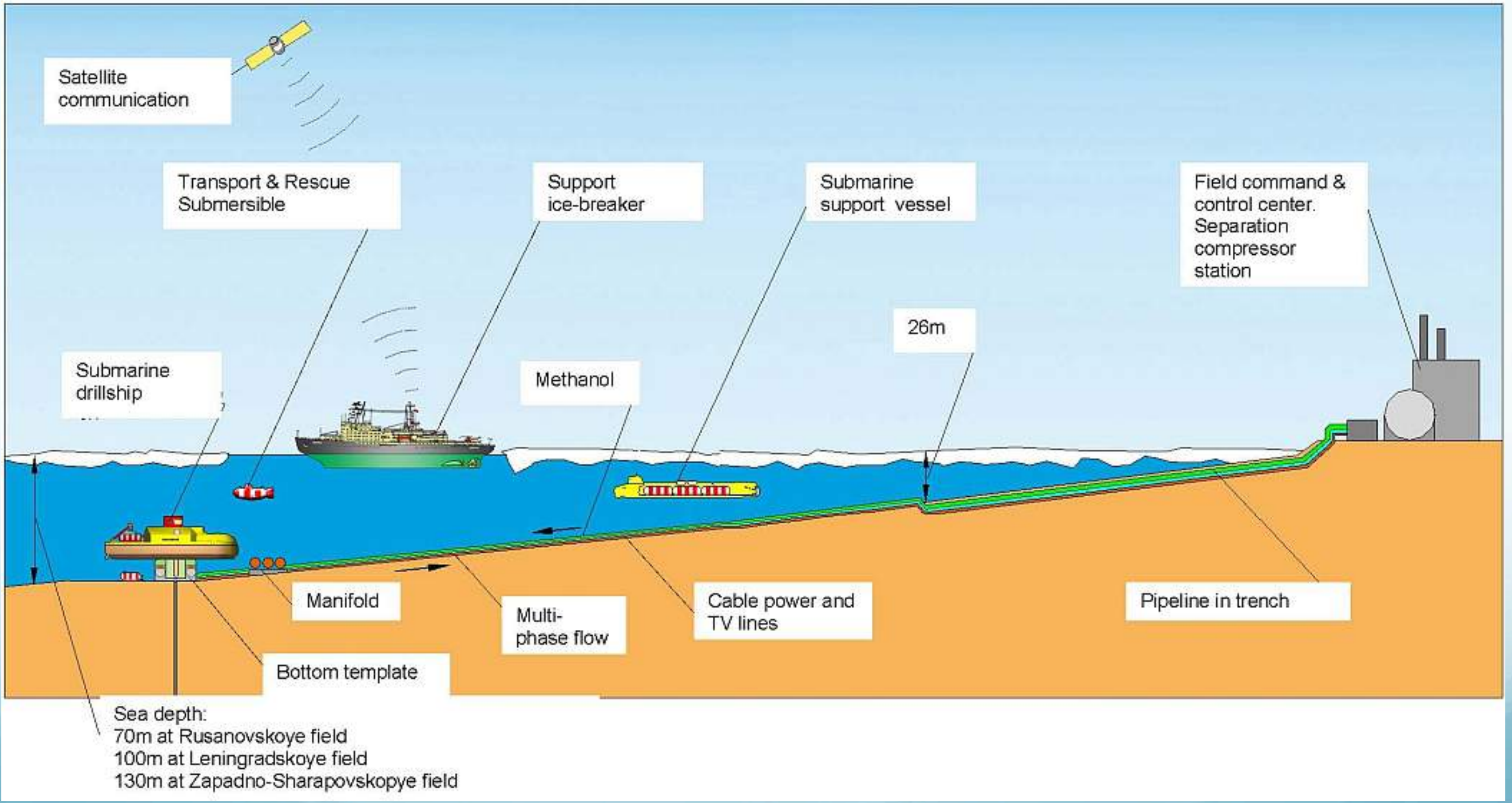
Arctic subsea drilling system (SDS) concept

- Submarine design bureau Lazurite Central Design Bureau, Nizhny Novgorod (designers of the Project 670 Charlie-class SSGN and Project 945 Sierra-class SSN), developed a concept for a Subsea Drilling System (SDS) that is intended for year-round drilling, irrespective of climatic and ice conditions when developing oil and gas fields in the deep offshore areas of the Russian Arctic seas.
- The SDS is comprised of a Submarine Drillship and a Bottom Template for operation at 60 to 400 m (197 to 1,312 feet) sea depth.
  - The Bottom Template defines the location of the well to be drilled, serves as a dock for the Drillship during drilling operations, and an interface between the new well and an undersea pipeline system for collecting and delivery the product.
  - The Submarine Drillship is powered from an external electrical source that us connected to the Drillship via an underwater cable. The power source could be a shore-side nuclear- or fossil-powered generator or a seabed-sited nuclear-powered generator.
- The oil and gas fields would be developed by drilling single wells and/or clusters of wells and installing the necessary manifolds and piping systems to connect the wells to subsea manifolds that will deliver the product to a shore-side facility.

Source: https://www.cdb-lazurit.ru/en_burovie_kompleksi.html

Arctic subsea drilling system (SDS) concept

This concept drawing developed by Lazurite Central Design Bureau shows an Arctic oil/gas field being developed using a Submarine Drillship and Bottom Template supported by a variety of vessels and a shore-side facility.



Source: https://www.cdb-lazurit.ru/en_burovie_kompleksi.html

Arctic subsea drilling system (SDS) concept

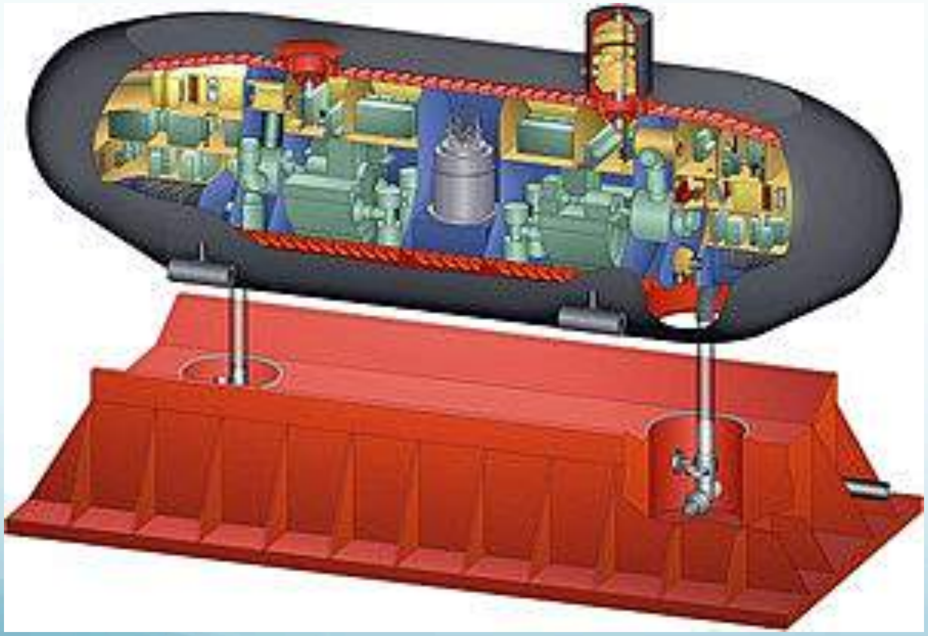
- The conceptual Lazurite Drillship is a large vessel, with a length of 98.6 meters (323 feet), a beam of 31.2 meters (102 feet) and a displacement of about 23,600 tonnes (26,014 tons).
- The Drillship houses a dry-type drilling rig with a stock of drilling consumables for construction of a 3,500 meter (11,482 feet) deep vertical well into the seabed. Consumables would be replenished periodically by a submarine cargo-container delivery system.
- Drilling operations are conducted under standard atmospheric pressure in the Drillship compartments. Underwater robotic devices perform outboard technological operations, while transport and rescue submersibles deliver personnel and supplies and conduct rescue operations if needed.

Drillship sitting on a Bottom Template.
Source: https://www.cdb-lazurit.ru/en_burovie_kompleksi.html

- The Drillship is powered and maintains communication with a coastal command and control centers via an underwater cable. Onboard storage batteries serve as a standby power source. It also may be possible to power the Drillship and underwater infrastructure from a seafloor nuclear power complex.

Subsea nuclear gas compressor station concept

- Rubin Central Design Bureau developed the design concept for a nuclear-powered subsea gas compressor station for use on subsea gas pipelines running from offshore production areas to shore-side facilities.
- The replaceable compressor station is connected via removable mating elements to the pipeline via a permanent mounting base on the seafloor.
- The station is designed for continuous safe automatic operation, maintaining the compression rate of the transferred gas for the required throughput.

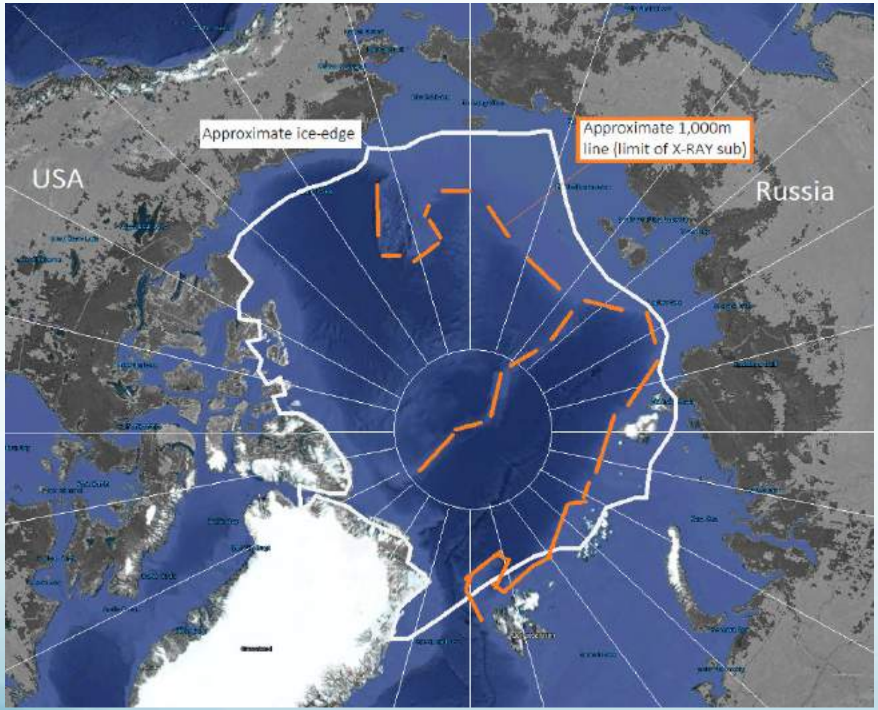


- An underwater vehicle enables regular visits by maintenance personnel to check the equipment and replace consumables.
- When the station reaches its end of service life, it is disconnected from the pipeline and replaced with a similar station.

Source: http://ckb-rubin.ru/en/projects/other_projects/subsea_nuclear_gas_compressor_station/

Arctic sonar arrays

- Naval analyst H. I. Sutton has postulated that Russia has plans to deploy a sonar network in the Arctic Ocean on deep ocean shelves and ridges, at a depth of about 1,000 meters (3,280 feet).
  - That depth is within the operating capabilities of the several small deep-diving, special operations nuclear submarines operated by the Main Directorate for Deep-Sea Research (GUGI).
  - Russian reactor suppliers are developing several small nuclear power plants designed for seabed siting. Such reactors could serve as long-term power sources for a distributed sonar array.



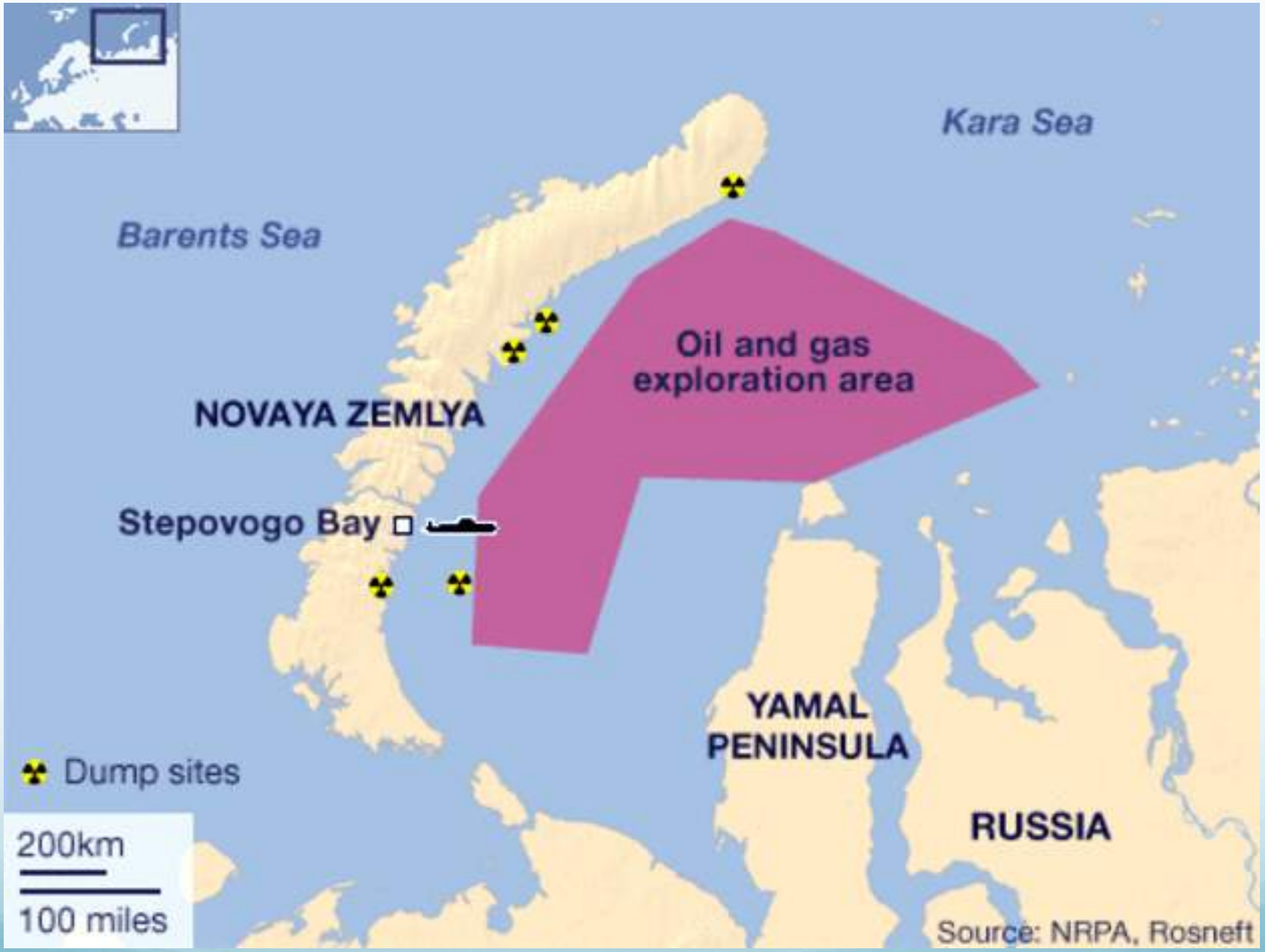
Source: http://www.hisutton.com/

- Such a sonar system would be roughly analogous to the Sound Surveillance System (SOSUS) deployed by the US in the 1950s in the Atlantic and Pacific Oceans to track Soviet submarines at long distances.
- Such a detection capability would support Russia's recent efforts to militarize their Arctic region with new military facilities along their north coast and orders for new, armed icebreaking (non-nuclear-powered) military vessels.
- If Russia's extended continental shelf claims in the Arctic are upheld, they will have the resources to enforce their expanded Exclusive Economic Zone (EEZ).

Arctic radioactive contamination
from marine nuclear power operations

- Kara Sea:
  - According to a report issued in 2012 by the Norwegian Radiation Protection Authority (NRPA), Russian nuclear waste in the Kara Sea includes:
    - 19 ships containing radioactive waste;
    - 14 nuclear reactors, including five that still contain spent nuclear fuel;
    - 735 other pieces of radioactively contaminated heavy machinery;
    - 17,000 containers of radioactive waste, and
    - Sunken submarine K-27, at a depth of 33 m (108 ft.)
- Barents Sea:
  - Two sunken Russian submarines; currently no indication of significant radioactive contamination of the ocean environment.
    - November-class K-159, at a depth of 248 m (814 ft.)
    - Mike-class K-278, at a depth of 1,680 meters (5,510 ft.)

Russian oil & gas exploration near radioactive contaminated sites



Russian sunken nuclear submarines on the Arctic seabed

Source: Adapted from Wikipedia.
The nuclear submarine K-141, *Kursk,* also sank in the Arctic, near the location of K-159.
K-141 has been removed from the seabed and salvaged.

K-27 Kara Sea disposal site

Source: http://bellona.org/

- The liquid metal coolant in each of the two reactors solidified around the fuel assemblies and control rods, forming a single, solid object that could not be removed from the reactor vessel.
- Before sinking the K-27, the reactors were sealed with a bitumen compound to isolate their 90 kg (198 lb.) of highly enriched uranium fuel from seawater.

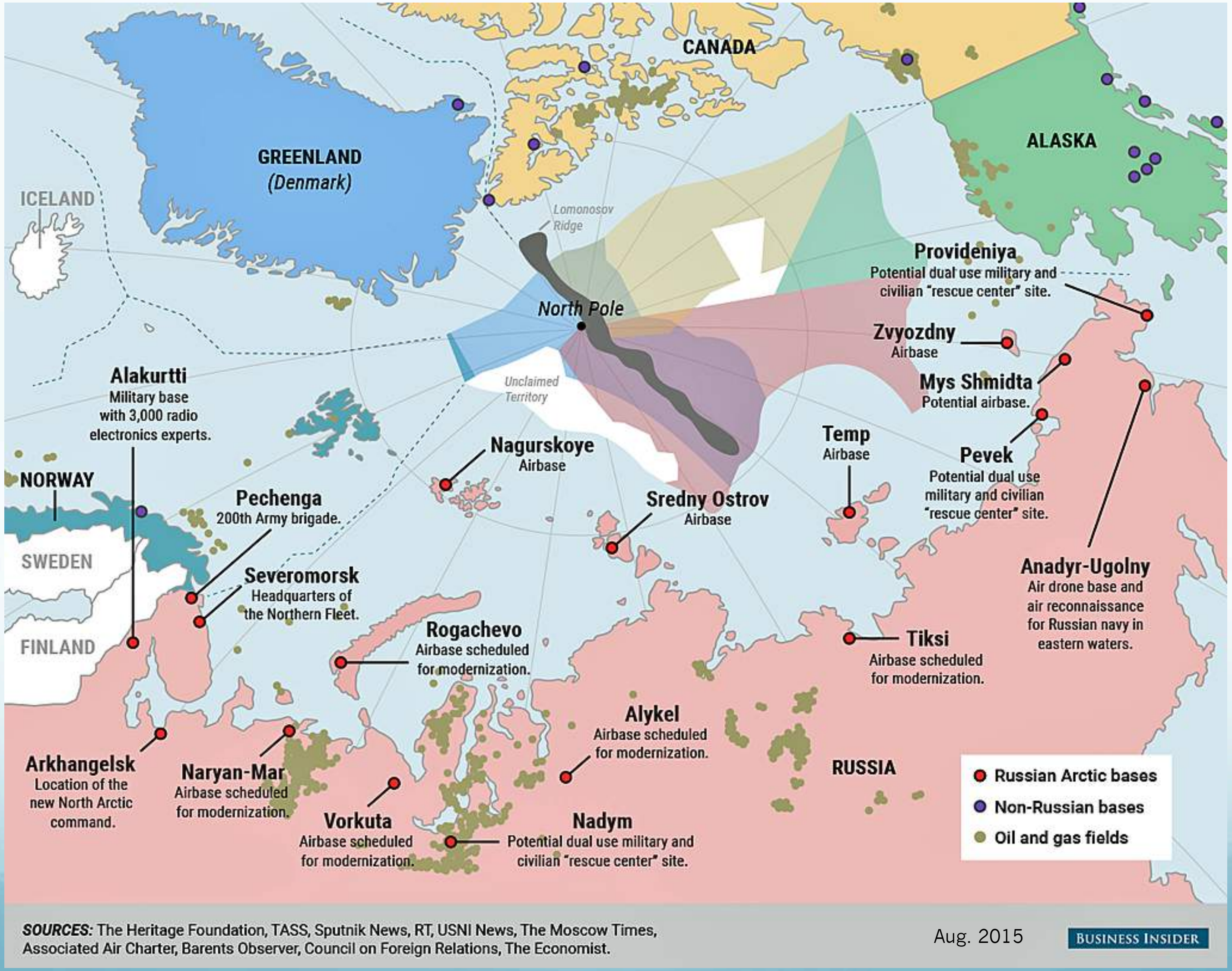
- K-27 was scuttled in the Kara Sea on 6 Sep 1982.
- Studies by the Kurchatov Institute have shown the bitumen seal is not performing as expected, posing the danger of seawater ingress to the reactor cores.
- Norway's Bellona Foundation has raised the concern of an uncontrolled criticality from water ingress to the reactor.
- In 2012, Justin Gwynn, an expert with the Norwegian Radiation Protection Authority (NRPA) said the K-27 is resting upright on the bottom and the hull is in good condition. These factors improve the chance of a successful salvage of the vessel.

Russian military buildup in the Arctic

- 1 December 2014: Russia's new Arctic Joint Strategic Command became operational, with a charter to protect Russian national interests in the Arctic.
  - This provides central management of all Russian military resources in the Arctic, and there are a lot of them.
  - The new command, based in the Northern Fleet and headquartered at Severomorsk, acquired military, naval surface, and strategic nuclear subsurface, air force and aerospace defense units, assets, and bases transferred from other Russian Military Districts

- 15 – 20 March 2015: Russia conducted a massive, five-day military exercise in the Arctic involving about 80,000 troops, 220 aircraft, 41 ships, and 15 submarines.
  - The exercise likely was a demonstration of the Arctic Joint Strategic Command’s ability to coordinate Russian military forces in the region.

Russian military buildup in the Arctic



2015 Russian Arctic military exercise naval deployment

Source: https://eurasiangeopolitics.com/arctic-maps/

- Long-range, “blue water” naval deployment along the Northern Sea Route by a surface battle group led by the nuclear-powered cruiser Pyotr Velikiy (Peter the Great).
- The US does not have a comparable capability to deploy a blue-water fleet in the Arctic.

Russian military buildup in the Arctic

- In February 2017, the Russian Ministry of Defense (MoD) announced that more than 100 capital military infrastructure facilities will be put into operation in the Arctic in 2017.
  - Distributed across six Arctic locations, including Franz Joseph archipelago, Novaya Zemlya archipelago, the Siberian archipelago and Wrangel Island.
- Russia's 7,000 – 8,500 ton diesel-electric Project 23550 military icebreaking patrol vessels (corvettes) will be armed combatant vessels capable of breaking ice with a thickness up to 1.7 meters (5.6 feet). The keel for the lead ship, *Ivan Papanin*, was laid down at the Admiralty Shipyard in St. Petersburg on 19 April 2017. Construction time is expected to be about 36 month, with Ivan Papanin being commissioned in 2020.

Project 23550 icebreaking patrol vessel. Source: naval-technology.com

- The second ship in this class should enter service about one year later. Both corvettes are expected to be armed with a mid-size naval gun (76 mm to 100 mm have been reported), containerized cruise missiles, and an anti-submarine capable helicopter.
- The U.S. has no counterpart to this class of Arctic vessel.

China's marine nuclear Arctic ambitions

China’s Arctic Policy

- On 26 January 2018, the State Council Information Office of the People’s Republic of China published a white paper titled “China’s Arctic Policy.”
- “China is an important stakeholder in Arctic affairs. Geographically, China is a ‘Near-Arctic State’, one of the continental States that are closest to the Arctic Circle. The natural conditions of the Arctic and their changes have a direct impact on China’s climate system and ecological environment, and, in turn, on its economic interests in agriculture, forestry, fishery, marine industry and other sectors.”
- China’s Arctic Policy whitepaper addresses the following five key issues:
  - Exploring and deepening their understanding of the Arctic
    - All States have the freedom of scientific research on the high seas of the Arctic Ocean
  - Protecting the environment of the Arctic and addressing climate change
    - China is committed to studying the interaction between the Arctic and global climate change
  - Utilizing Arctic resources in a lawful and rational manner
    - Participating in the development of Arctic shipping routes
    - Participating in the exploration for, and exploitation of, oil, gas, mineral and other resources
    - Participating in conservation and utilization of fisheries and other living resources
    - Participating in developing tourism resources
  - Participating actively in Arctic governance and international cooperation
    - China is an accredited observer to the Arctic Council
    - China stands for steadily advancing international cooperation in the Arctic. It has worked to strengthen such cooperation under the Belt and Road Initiative (the “New Silk Road”).
  - Promoting peace and stability in the Arctic
    - China supports the peaceful settlement of disputes over territory and maritime rights and interests by all parties concerned in accordance with such treaties as the UN Charter and the UNCLOS and general international law

China's icebreaker fleet

and plans for a nuclear-powered icebreaker

- China's currently operates a single, ocean-going, diesel-mechanical powered icebreaker, the 21,025 ton *Xue Long (Snow Dragon),* which entered service in 1994.
- On 10 September 2018, a new, smaller diesel-electric powered icebreaker, the 13,990 ton *Xue Long 2,* was launched and is expected to enter service in 2019.
- Both ships are managed by the Polar Research Institute of China and are intended to support Arctic and Antarctic scientific missions.
- On 21 June 2018, China National Nuclear Corporation announced that bids are welcome from domestic yards to build the country's first nuclear-powered icebreaker. The ship is said to be an "icebreaker support ship" indicating a multi-role purpose more than simply breaking the ice for other vessels in convoy.
- This icebreaker will be China's first nuclear-powered surface vessel. It is expected to have a displacement of about 30,000 tons, which is comparable to a Russian LK-60Ya-class nuclear-powered "universal icebreaker."
  - The Russian LK-60Ya icebreakers are powered by two RITM-200 integral PWRs, each rated at 175 MWt (350 MWt total) and delivering a combined 60 MW (80,460 shp) of propulsion power.
  - Comparable propulsion power should be expected on China's first nuclear-powered icebreaker.
- The experience from developing the powerful nuclear propulsion system for China's first indigenous nuclear-powered icebreaker will benefit plans for developing the propulsion system for a future nuclear-powered aircraft carrier.

Current trends in nuclear marine Arctic operations

- For research
- For military activities
- To exercise sovereignty over Exclusive Economic Zones (EEZ) and Extended Continental Shelf (ECS) regions in the Arctic
- For commercial exploitation
- For environmental cleanup
- For tourism

Trends in Arctic operations

- **For research:**
  - Access will continue at current or greater levels for studies related to Arctic bathymetry, hydrography, resource characterization and environment, including the impact on the Arctic of the broader matter of global climate change.
    - This includes research to support Extended Continental Shelf (ECS) claims by Arctic states.
    - Russia is uniquely capable of conducting this type of Arctic research with its nuclear-powered submarine "motherships" and deep-diving, nuclear-powered, small, manned submarines that can be equipped with a variety of exploration tools.
    - China will increase its research presence in the Arctic.
      - A second conventionally-powered icebreaker will be delivered in 2019, and a larger nuclear-powered icebreaker is expected to enter service in about a decade.
      - China's bilateral agreements with Arctic states will promote collaborative research with the expectation of yielding future economic benefits.
  - Continuing use of floating "ice camps" by the US, Russia, and others will support various research and military activities.

Trends in Arctic operations

- **For research (continued):**
  - Arctic-rated vessels will continue to have an important role in conducting and supporting Arctic research.
    - Russia's nuclear-powered icebreaker fleet and its fleet of nuclear-powered submarine "motherships" and smaller special mission submarines are unique national resources that support research and other activities in the Arctic.
      - The new generation of LK-60Ya ("universal") nuclear-powered icebreakers will start entering the Rosatom fleet in 2019.
      - The next generations of nuclear-powered icebreakers, including a larger heavy polar icebreaker, currently are in the design phase.
      - A large fleet of conventionally-powered icebreakers also supports Russian Arctic activities.
    - The current US icebreaker presence in the Arctic is very small, consisting of only one conventionally-powered medium icebreaker, *Healy*, managed by the National Science Foundation (NSF) and operated by the US Coast Guard.
      - The only US heavy polar icebreaker, *Polar Star,* is assigned to Antarctic missions.
      - The current US heavy polar icebreaker (Polar Security Cutter) procurement is for three new conventionally-powered vessels, with the first unit being delivered no sooner than 2023 (but more likely later). That new ship will take the place of the *Polar Star* and likely will be assigned to Antarctic missions. A new Polar Security Cutter for duty in the Arctic could enter service by the mid-2020s.
    - China will introduce its first nuclear-powered heavy polar icebreaker by 2030.

Trends in Arctic operations

- **For military activities:**
  - The Arctic is increasingly being viewed as a potential source of national security issues.
  - Russia:
    - Russian ballistic missile submarines (SSBNs) will continue to use the Arctic as a patrol area where the SSBNs may be better protected against detection than in the open ocean.
    - With the formation of the Arctic Joint Strategic Command in 2014 and subsequent large-scale Arctic military exercises, Russia has taken clear steps to militarize and demonstrate its capabilities to operate in its Arctic region.
      - Two new classes of conventionally-powered military icebreakers are being developed to conduct naval operations and support other naval vessels operating in the region.
      - By 2025, Russia expects to have 13 airfields and 10 air defense radar sites in the Arctic region.
  - US
    - The DoD Arctic Strategy and the Navy's Arctic Roadmap have not kept pace with Russia's rapid militarization of the Arctic. Congress requested an updated Arctic Strategy by mid-2019 to more clearly address the changing military situation in the Arctic and identify US capability gaps. An updated US Navy Arctic Roadmap should follow soon thereafter.
    - US nuclear submarine Arctic operations will continue as in previous years. No other US naval vessels can access ice-covered Arctic waters.
    - The future US large icebreaker (Polar Security Cutter) is expected to have a national security role and may be armed.

Trends in Arctic operations

- **To exercise sovereignty over Exclusive Economic Zones (EEZ) and Extended Continental Shelf (ECS) regions in the Arctic**
  - Six Arctic nations have filed an UNCLOS Extended Continental Shelf (ECS) claims and hope to expand their exclusive rights to Arctic resources beyond their respective Exclusive Economic Zone (EEZ). Some of these claims overlap.
    - The EEZ defines the region in which a nation has sovereign rights over the natural resources in the water column and the seabed and the subsoil.
    - The ECS defines the region further out to sea in which a nation has sovereign rights over the natural resources in the seabed and the subsoil.
  - This economic opportunity is driving research in the Arctic related to better characterizing the seabed and justifying the ECS claim.
  - Canada has very limited Arctic infrastructure to exercise sovereignty over their extensive holdings in the Arctic north.
    - Discussions regarding Canada's sovereign rights over the Northwest Passage will continue. The US, EU and other nations will continue to claim that this is an international strait that is open to shipping.
  - Russia's rapidly expanding Arctic infrastructure and militarization of the region may be a prelude to their behavior toward its Arctic neighbors during a conflict over Arctic sovereign rights.

Trends in Arctic operations

- **For commercial exploitation:**
  - Commercial development along Russia's Northern Sea Route will be significant:
    - There are many Russian deep-water ports along the Northern Sea Route
    - Russian deployment of the new generations of nuclear-powered icebreakers will support expanded use of the Northern Sea Route.
    - Commercial expansion of natural resource development along Russia's north coast is dependent on access to increased shipping traffic on the Northern Sea Route to deliver needed supplies and transport oil, gas, minerals, timber and other resources to worldwide markets.
    - Russian deployment of floating (barge mounted) nuclear power plants will bring reliable electric power and process heat to support economic development at remote sites along its north coast.
    - Increasing near-term Russian oil and gas exploration and development will occur in the Kara and Barents Seas, and exploration will occur in other areas of the Russian continental shelf.
      - The business case for this Arctic development is hampered by the availability of lower-cost shale oil and gas from the US and other nations.

Trends in Arctic operations

- **For commercial exploitation (continued):**
  - Increasing use by commercial shipping firms of the sea routes through Arctic waters, primarily the Northern Sea Route (NSR).
    - Russian icebreakers have a mission to maintain the NSR open for traffic for much of the year. Russia's fleet of powerful nuclear-powered icebreakers, supported by many conventionally powered icebreakers and other Arctic-rated ships, and the availability of many Arctic deep water ports and other marine infrastructure along the NSR, are testaments to the national importance placed on the NSR as a marine transportation route.
    - In contrast, Canadian and US icebreakers are not responsible for maintaining the Northwest Passage open for traffic and there is very little port infrastructure along that route to support commercial shipping traffic.
    - Russia has a different philosophy about the NSR than Canada has about the Northwest Passage.
    - The Russian government supports development and commercial exploitation of its Arctic resources. In comparison, the US and Canadian governments are more focused on Arctic environmental protection.
    - While climate change has resulted in more open water during summer months along the NSR and Northwest Passage, unpredictable conditions from shifting ice remains a major hindrance to trans-Arctic surface ship traffic. Other factors affecting Arctic ship traffic include severe storms, extreme cold and fog. As a consequence of the extreme environment, the Congressional Research Service notes that "commercial ships will face higher operating costs on Arctic routes than elsewhere."

Trends in Arctic operations

- **For commercial exploitation (continued):**
  - Commercial development along the Northwest Passage will lag until Canada invests in appropriate Arctic infrastructure.
    - After the successful September 2016 transit of the conventionally powered passenger cruise liner *Crystal Serenity* through the Northwest Passage, there may be increasing commercial pressure on Canada and the US to build Arctic deep water port infrastructure that can host such large vessels, particularly in the event of an equipment casualty or other emergency in the Arctic.
    - In the longer-term, similar commercial exploration and development will be undertaken by other Arctic nations in their own waters. They also will be hindered by their lack of Arctic port infrastructure and Arctic-rated vessels to support long-term, heavy industrial work in remote Arctic regions.
  - China has a clear interest in exploiting Arctic resources, initially through bilateral agreements with Arctic states as a means to secure economic benefits.

Trends in Arctic operations

- **For environmental protection and cleanup:**
  - Pressure on Russia from Arctic nations will continue for removal and/or remediation of radioactive contamination and radioactive items in the region, particularly sunken Russian nuclear submarines, nuclear waste and other radioactive items dumped in the Arctic Ocean.
    - Oil and gas exploration and development in the Barents and Kara Seas will need to consider the proximity of some of these contaminated sites.
  - The Arctic Council will continue to be the leading intergovernmental forum promoting cooperation, coordination and interaction among the Arctic States. The Council has a lead role in establishing standards for Arctic vessel operation and for Arctic pollution monitoring and control.
    - Focus is on conventionally-powered vessels
  - As industrial and military activities in the Arctic increase, the likelihood of oil spills and the quantity of non-nuclear pollution, including carbon black from fossil-fueled engine exhaust, will increase and affect the Arctic environment.
- **For tourism:**
  - Rosatomflot likely will continue to offer commercial cruises to the North Pole aboard one of their nuclear-powered icebreakers.
  - Conventionally-powered cruise ships operating in the Arctic, along the Northwest Passage and Northern Sea Route, may become more common.