Marine Nuclear Power: 1939 – 2018

Part 6: Arctic Operations

Peter Lobner
July 2018

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

Marine Nuclear Power: 1939 – 2018
Part 6: Arctic Operations
Table of Contents

Basic orientation to the Arctic region

What are the Arctic boundaries?

- The definition of the "Arctic region" has been evolving.
- There are several ways to define the Arctic region based on physical, geographical and ecological characteristics.
    - The area above the Arctic circle, where the sun can remain continuously above or below the horizon for twenty-four hours. Currently at 66°33′47.2″ north of the Equator, but varies due the slow precession of Earth's tilted axis.
    - The area where the average air temperature for the warmest month (July) is below 10°C / 50°F.
    - The transition between boreal forest and the tundra, with its underlying permafrost.
    - The marine boundary marks the convergence of cool, less saline waters from the Arctic Ocean with warmer, saltier waters from the oceans to the south.
    - The Arctic Council's Arctic Monitoring and Assessment Program (AMAP) area is a compromise that combines several factors.

For details, see the the AMAP Chapter 2, "Physical / Geographical Characteristics of the Arctic," (after Stonehouse 1989)
Source: http://www.amap.no/documents/download/88

Arctic boundary

As defined by the US Arctic Research and Policy Act

US Arctic Research Commission map based on the US Arctic Research and Policy Act of 1984 (Amended 1990).
Map source: https://www.arctic.gov/maps.html

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 identified eight Arctic States as members of the Arctic Council:
  - Canada
  - Kingdom of Denmark (for Greenland & Faroe Islands)
  - Finland
  - Iceland
  - Norway
  - Russian Federation
  - Sweden
  - United States

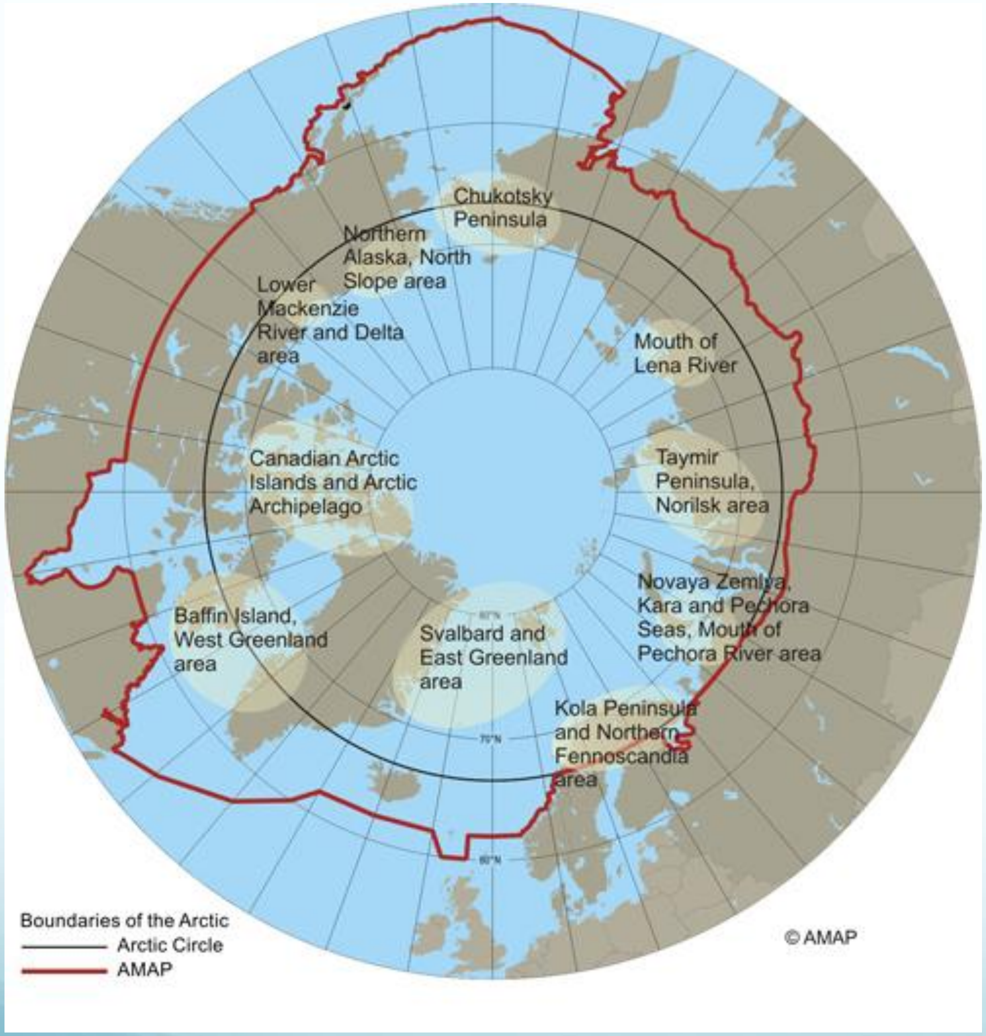
ARCTIC COUNCIL

- 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.
- 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

Arctic boundary

As defined by the Arctic Council's AMAP working group



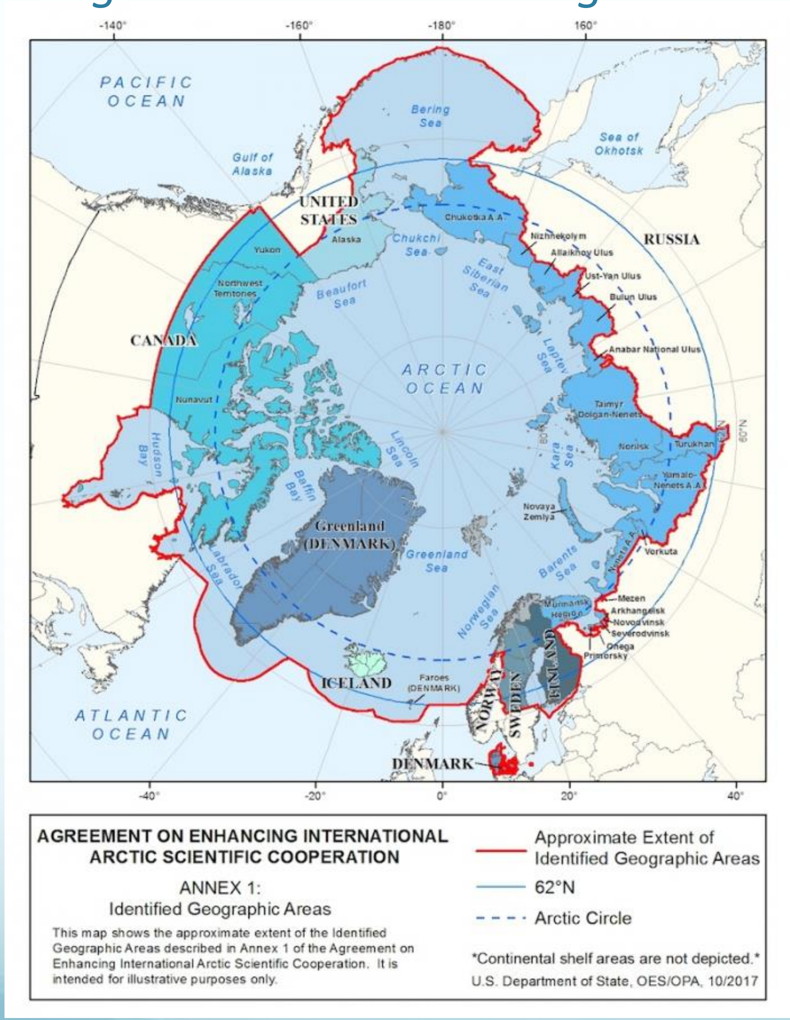
Source: https://www.amap.no/about/geographical-coverage

The Arctic Monitoring and Assessment Program (AMAP) geographical coverage extends from the High Arctic to the sub-Arctic areas of Canada, the Kingdom of Denmark (Greenland and the Faroe Islands), Finland, Iceland, Norway, the Russian Federation, Sweden and the United States, including associated marine areas.

This circumpolar region is the focus for AMAP's assessment activities. In the marine environment, this includes northern seas that extend as far south as 51.1 degrees N (James Bay, Canada). Within this region, 10 'key' areas have been identified for coordinated pollution monitoring studies.

Arctic boundary

As defined by the Arctic Council's 2017 *Agreement on Enhancing International Arctic Scientific Cooperation*

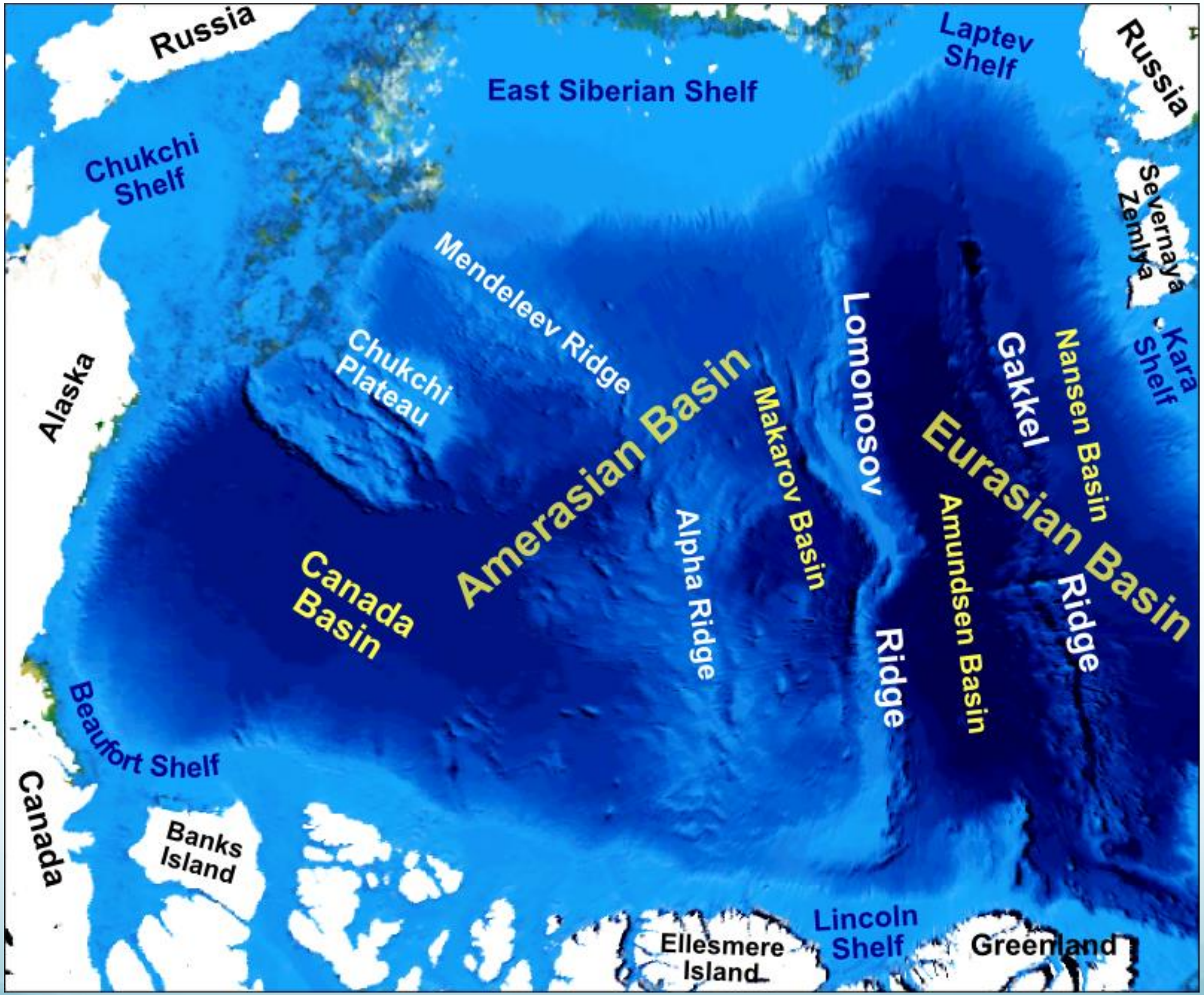


Source: https://www.arcus.org/witness-the-arctic/2017/2/article/27780

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 was signed on at the Arctic Council Ministerial meeting in Fairbanks, Alaska.

The goal of this agreement is to facilitate access, whether to territory and research areas, platforms, infrastructure, facilities, materials, samples, data, or equipment. The agreement is intended to ease the movement of scientists, scientific equipment and, importantly, data sharing across the North.

Basic bathymetric / topographic features in the Arctic Ocean



Source: https://en.wikipedia.org/wiki/Mendeleev_Ridge

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 were 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 to ports along the NSR accounted for 73% of total NSR traffic. The primary cargo delivered along the NSR was for construction of a liquefied natural gas (LNG) terminal at Yarmal.
    - When completed, Yarmal 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 ports along the NSR accounted for only 43% of NSR traffic, reflecting the growth in export traffic along the NSR.
    - Overall traffic on the NSR exceeded 7 million tons.
    - There were 19 complete transits of the NSR in 2016.
  - NSR traffic may reach 75 million metric tons by 2025.

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 in waters claimed by Canada. 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 do not maintain 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.
- In 1986 the Canadian government officially claimed the Northwest Passage as internal Canadian waters through the application of straight baselines.
- In 2009, Canada re-named this waterway the “Canadian Northwest Passage.”

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.
- 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, Canada has only one deep water port in the high Arctic; and that is private mining port.
  - In contrast, Russia has 16 deep water ports along its Northern Sea Route.
  - The lack of infrastructure along the Northwest Passage complicates Canada's efforts to exercise sovereignty over that part of the Arctic.
  - 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.

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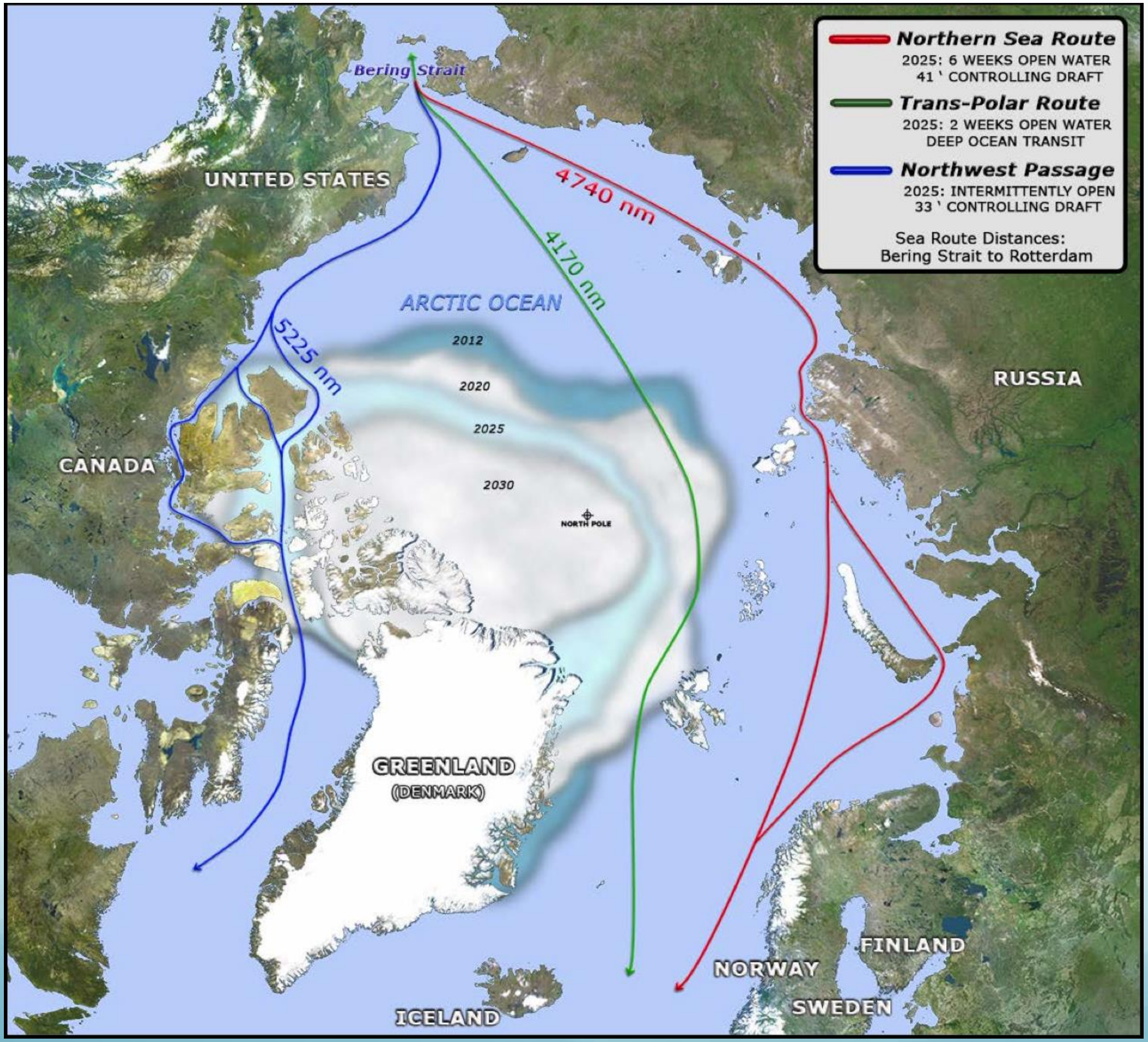
Extent of Arctic ice pack

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

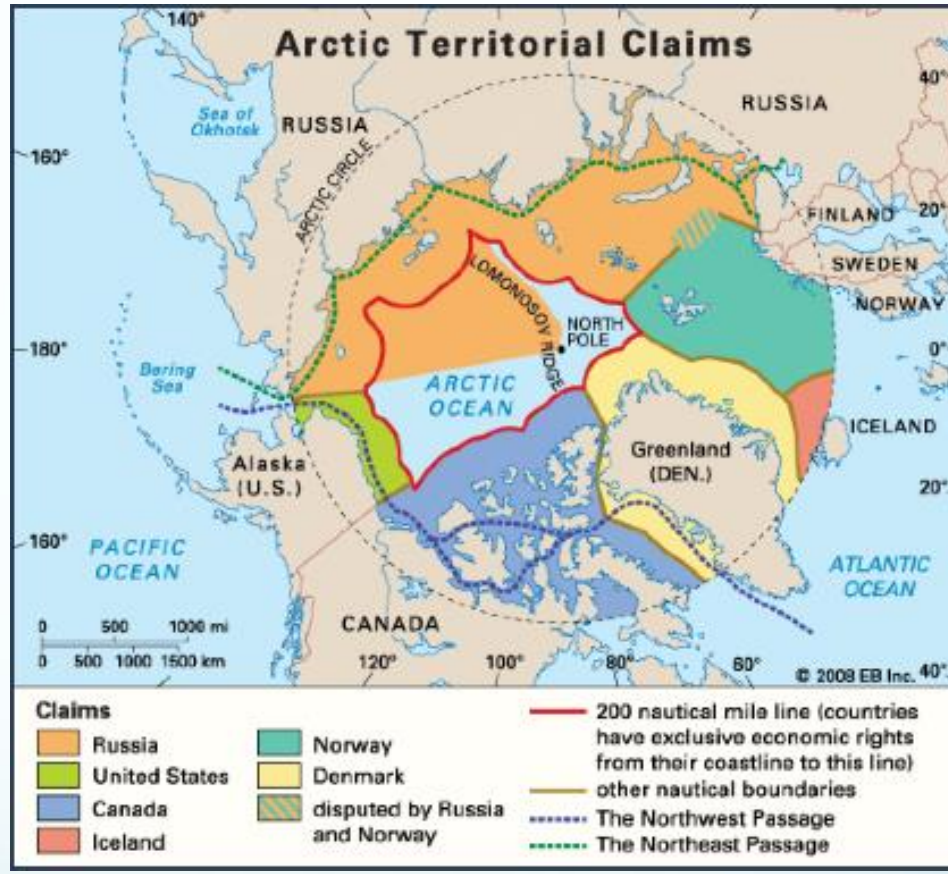


Routes superimposed over US Navy consensus assessment of sea ice extent Minima.

Source: US Navy
Arctic Roadmap 2014 - 2030

Arctic territorial claims

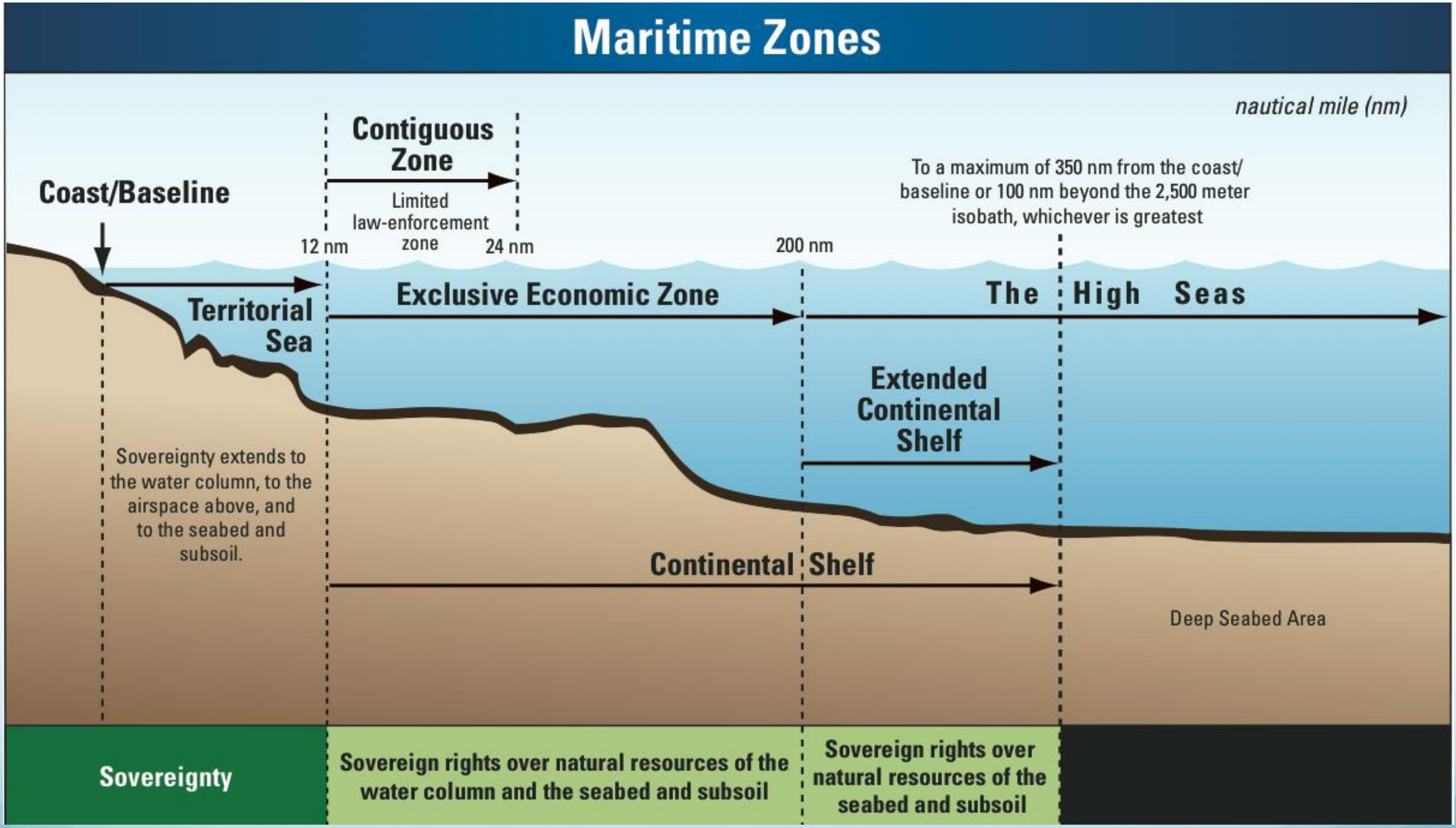
Source: www.wired.com



Source: Encyclopedia Britannica

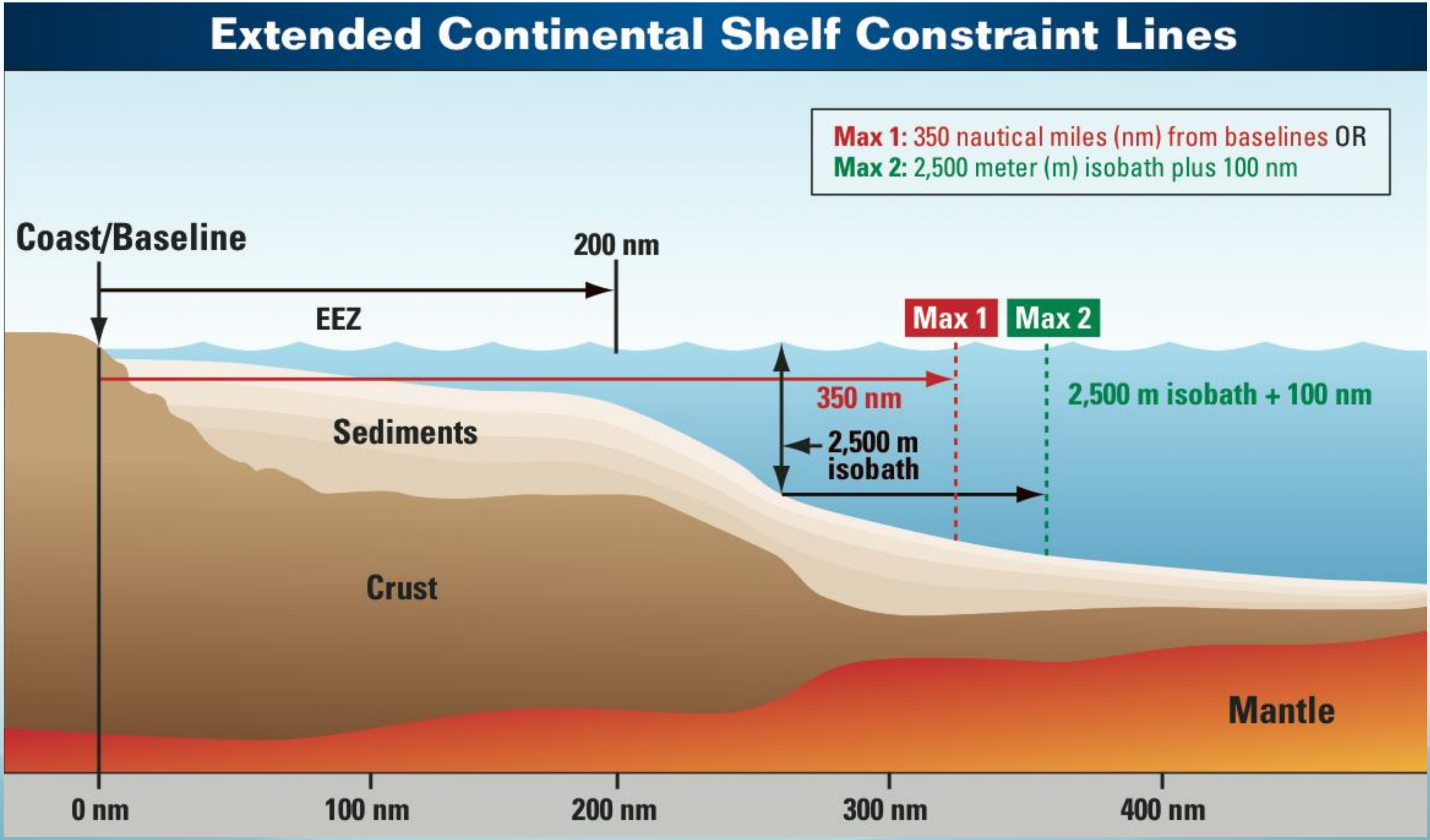
The issue of Arctic territorial claims is much more complex than portrayed in the above diagram, which serves mainly to identify the Arctic nations and the approximate extent of their respective claims. For a comprehensive summary of Arctic territorial claims, see the 21 May 2009 presentation, "National Maritime Claims in the Arctic," by Brian Van Pay, Office of Ocean and Polar Affairs US Department of State, which is available as a pdf document at the following website: http://www.virginia.edu/colp/pdf/Van_Pay-Arctic-Claims.pdf

Maritime zones & sovereignty



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

Basis for an extended continental shelf (ECS) claim



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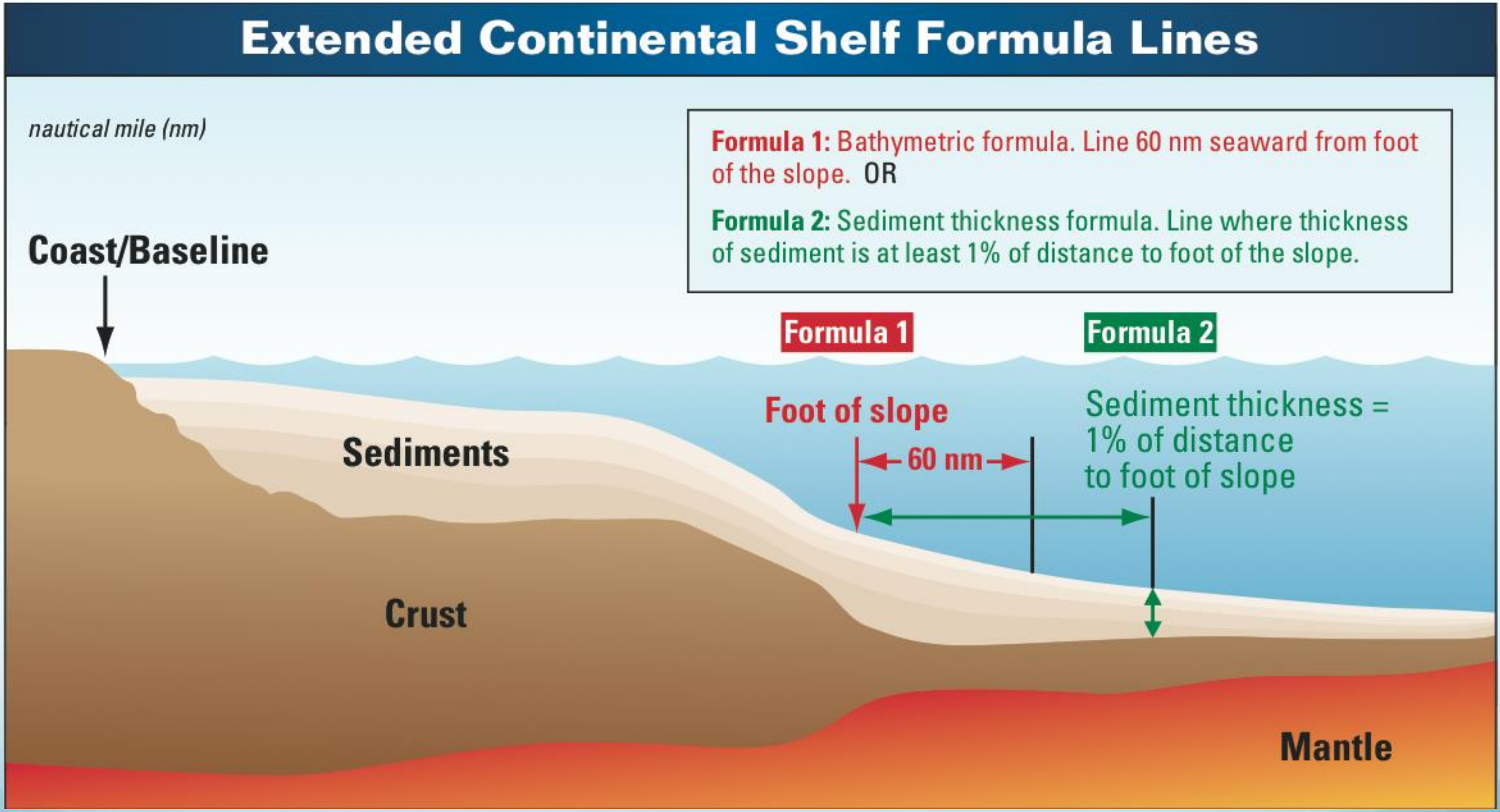
Basis for an extended continental shelf (ECS) claim



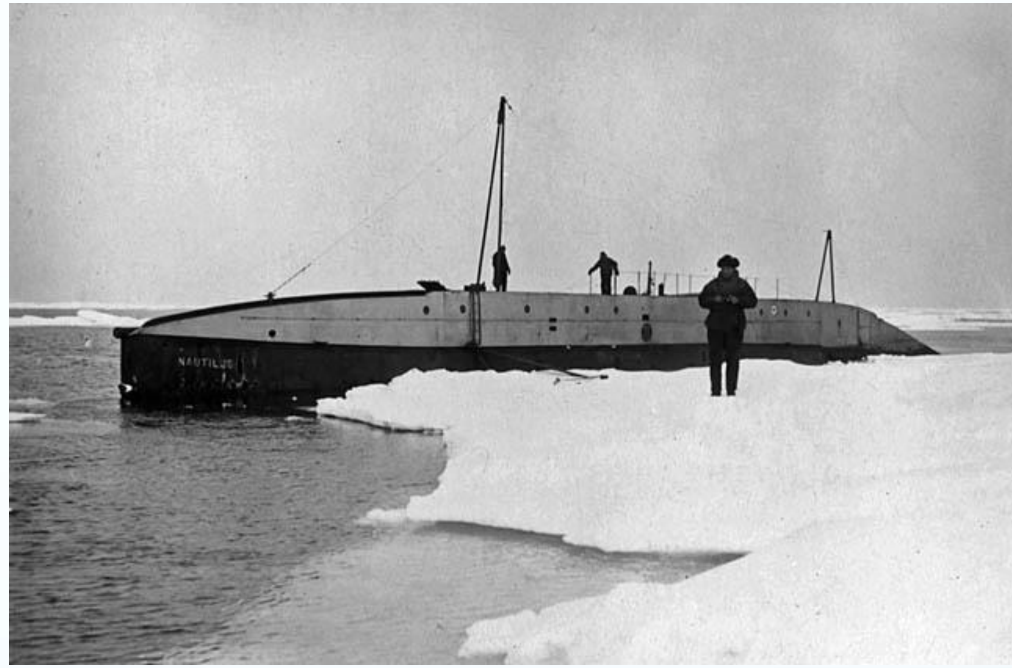
Source: http://continentalshelf.gov/media/ECSposterDec2010.pdf

Dream of the Arctic submarine

The dream of the Arctic submarine

Source: http://rsgs.org

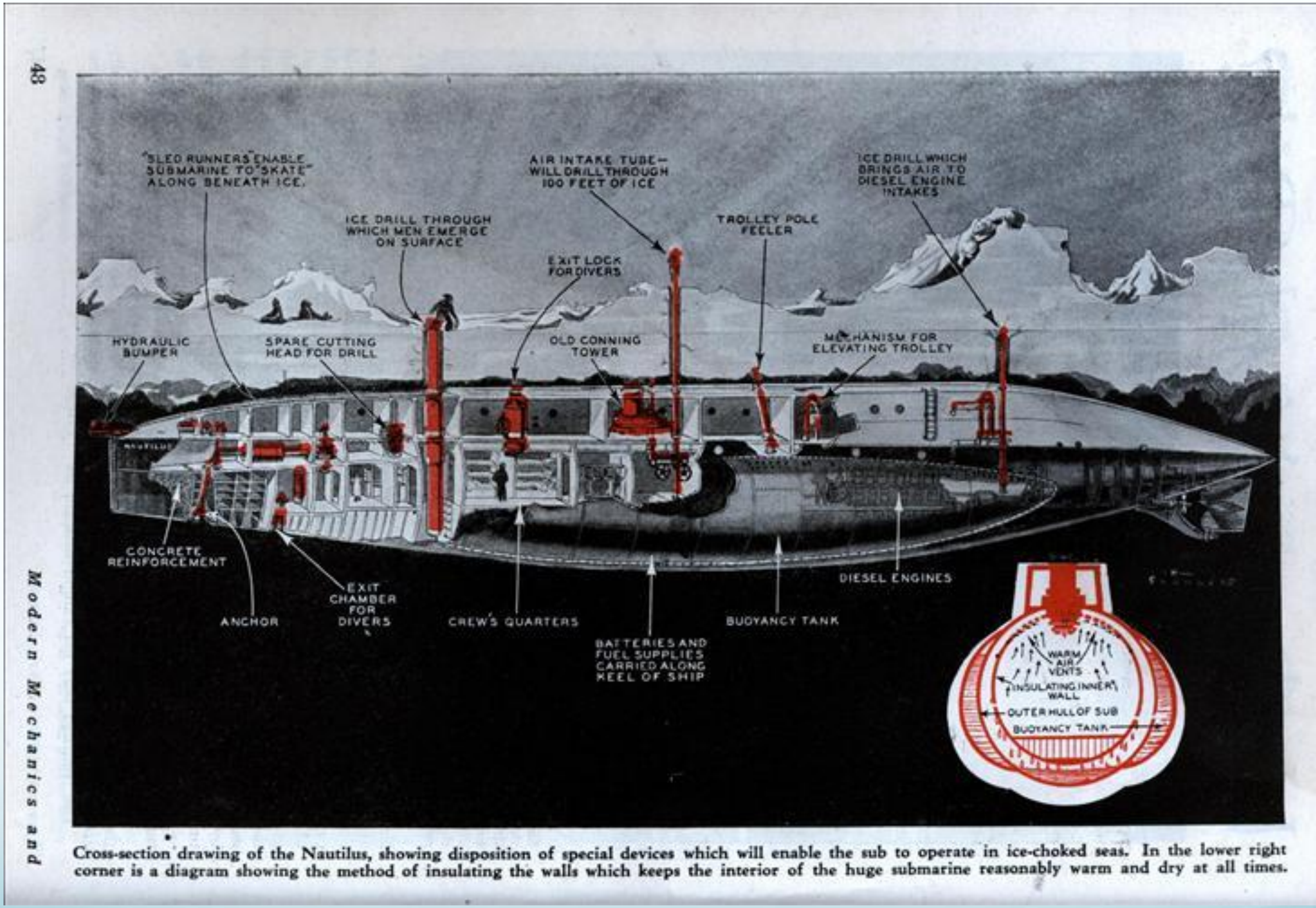
Sir Hubert Wilkins



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.

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

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

Sir Hubert Wilkins' *Nautilus*

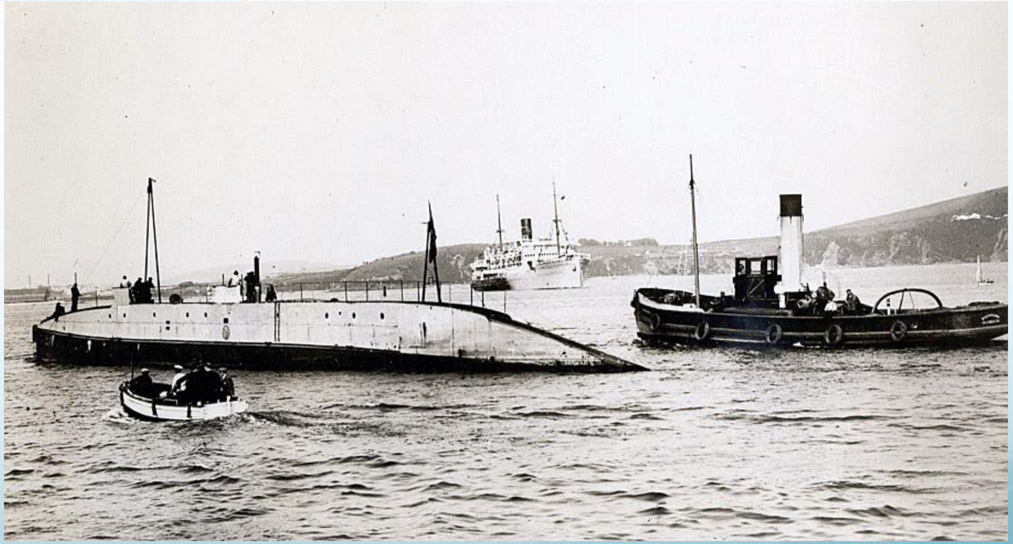
Source: http://www.delcampe.net/

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) 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

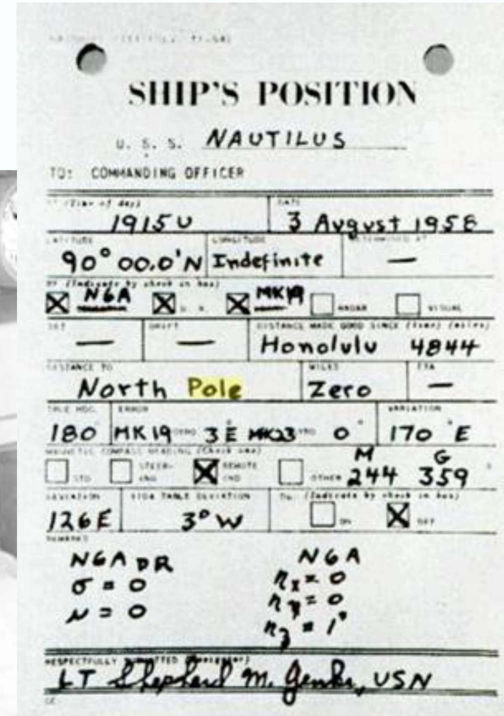
- Other modifications made to *Nautilus* included a hardened sail to help in penetrating the Arctic ice sheet and upward looking sonar and video systems developed by the Navy's Arctic Submarine Laboratory (ASL).
- 9 Jun 1958: Under the code name Operation Sunshine, *Nautilus* departed Seattle, WA for 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 3 Aug 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'* 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 ☐ RADAR ☐ VISUAL

— | — | Honolulu 4844

North Pole | Zero | —

180 | MK19 3E MK23 0° | 170°E

☐ ☐ ☐ ☒ ☐ M 244 G 359

126E | 3° W | ☐ ☒

N6A DR
σ = 0
ν = 0

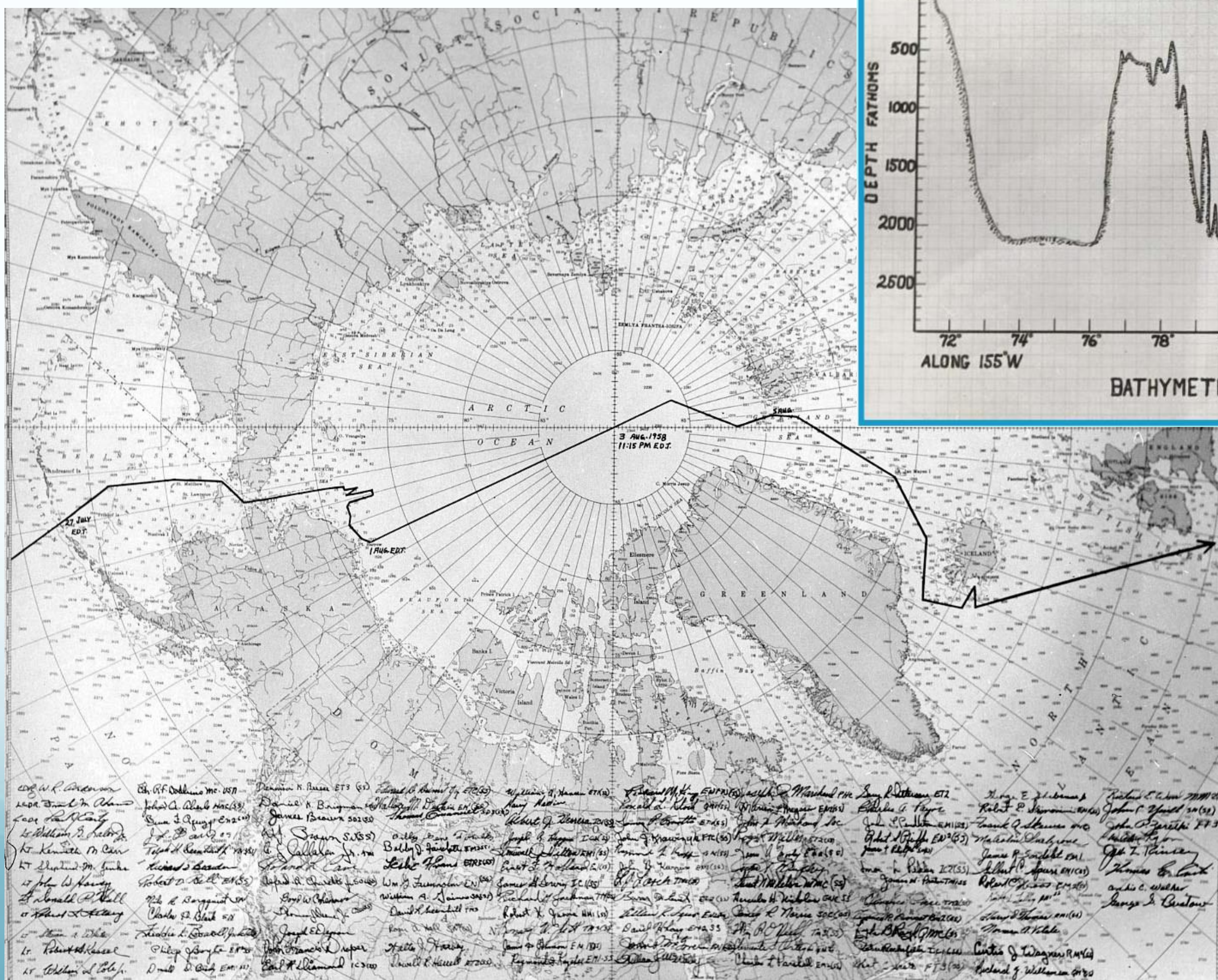
N6A
$\eta_x = 0$
$\eta_y = 0$
$\eta_z = 1'$

LT [illegible], USN

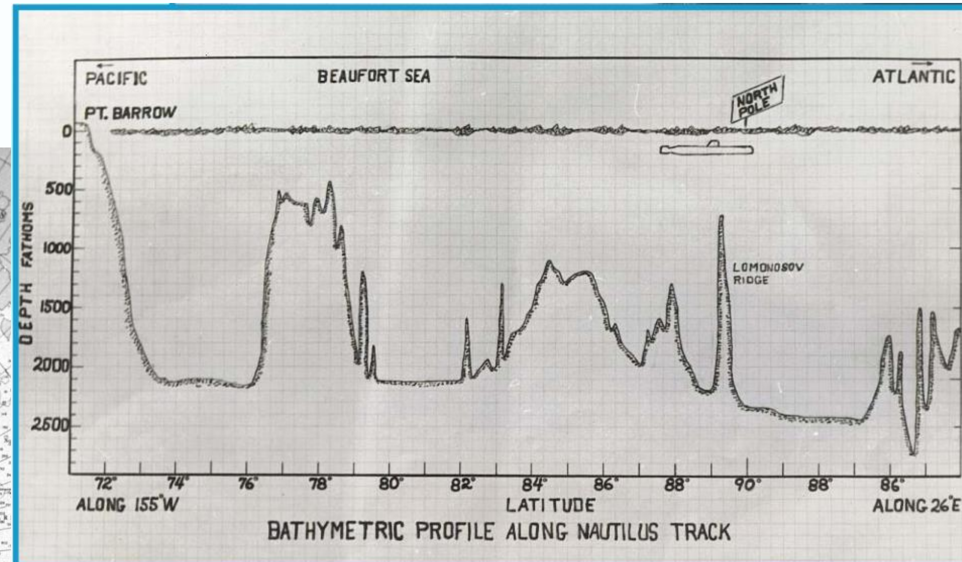
Nautilus 90° North

3 Aug 1958

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



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

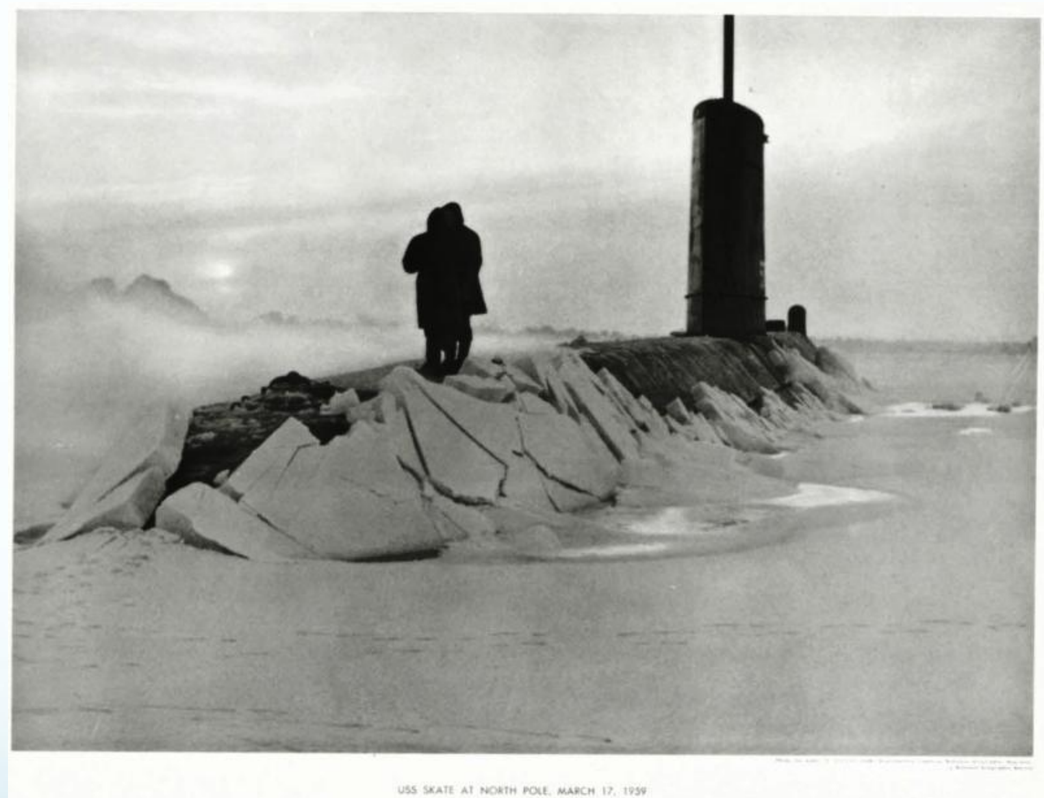


Source: http://www.navy.mil/navydata/

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

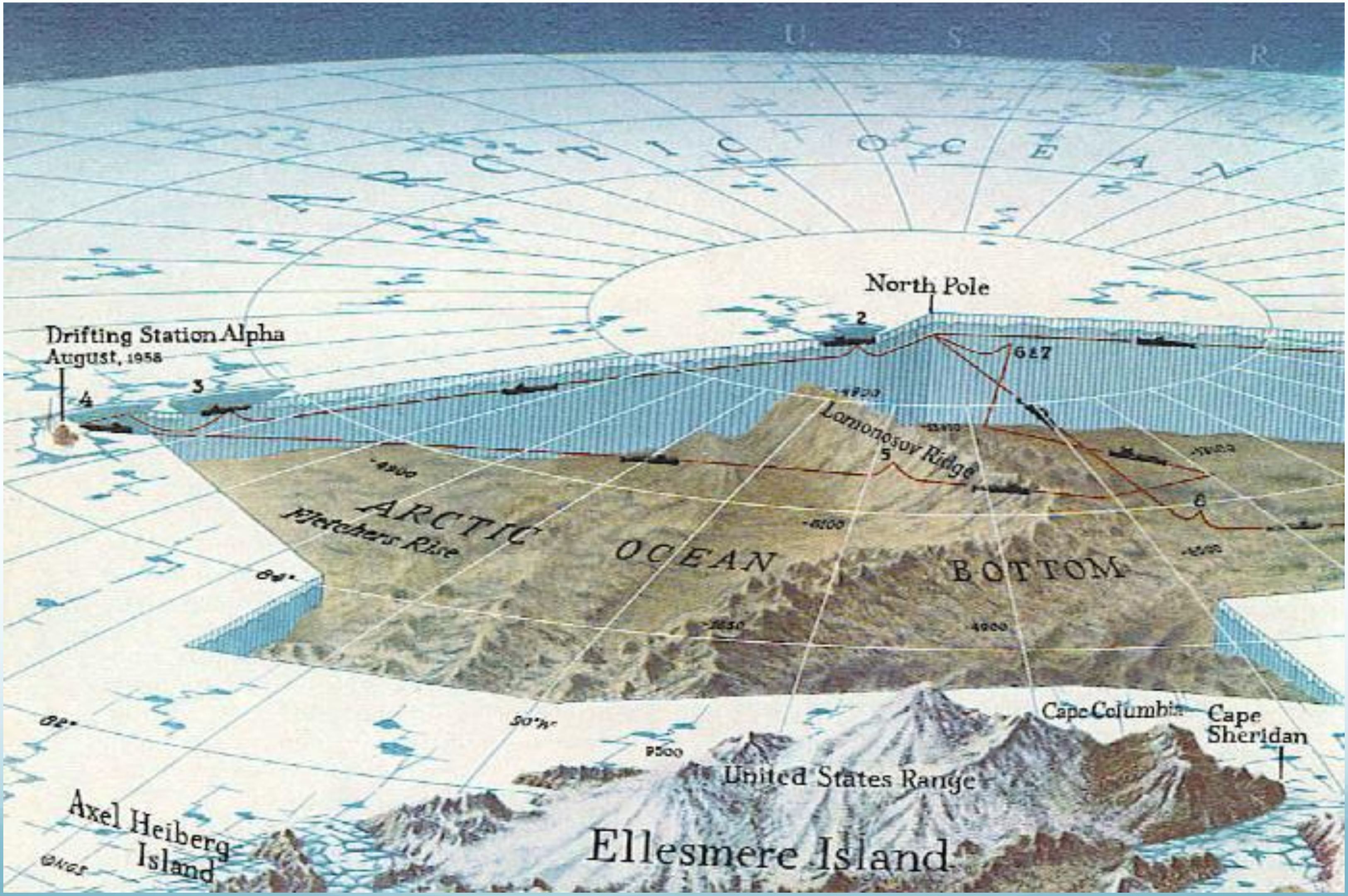


Source: http://archive.constantcontact.com

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)

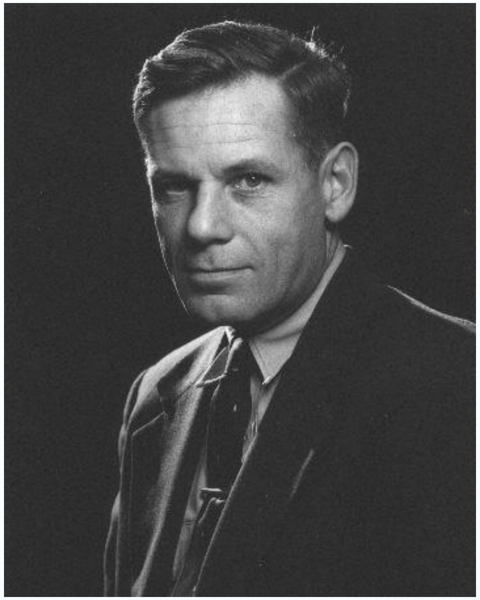
Aug 1958 East - West crossing of the Arctic Ocean



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* for the 1st crossing of North Pole, and *Skate* 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:
  - 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* 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 in San Diego, CA.
  - "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, ASL has supported the submarine force in over 120 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

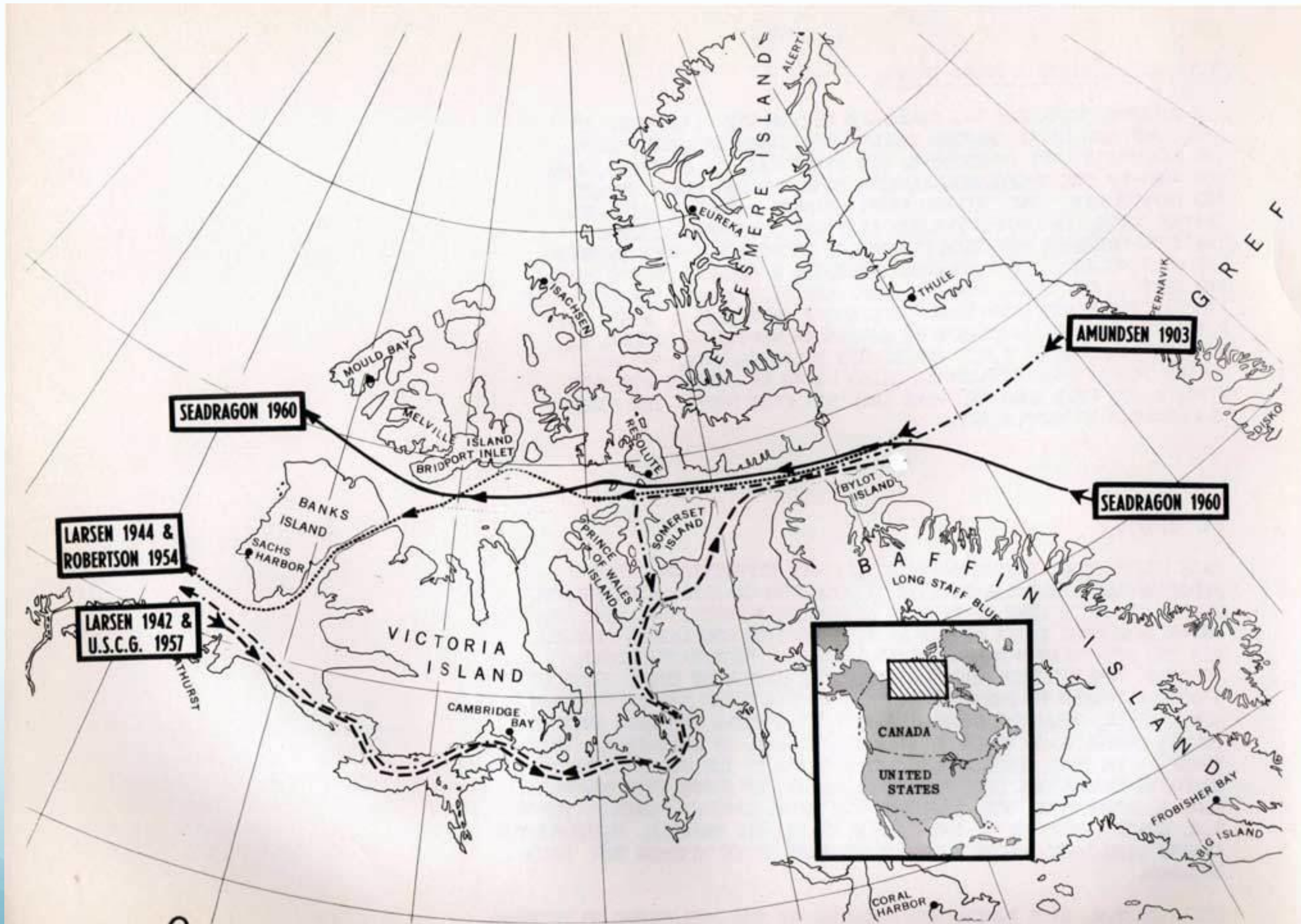
- *Seadragon* was the first sub to be equipped with what would become the standard under-ice suite for future US subs.
  - The major change from *Sargo*, was the 1st Arctic use of the Sperry Ships Inertial Navigation System (SINS) in place of the Autonetics N6A-1 used on prior Arctic subs.
- 1 Aug 1960: *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-578)

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

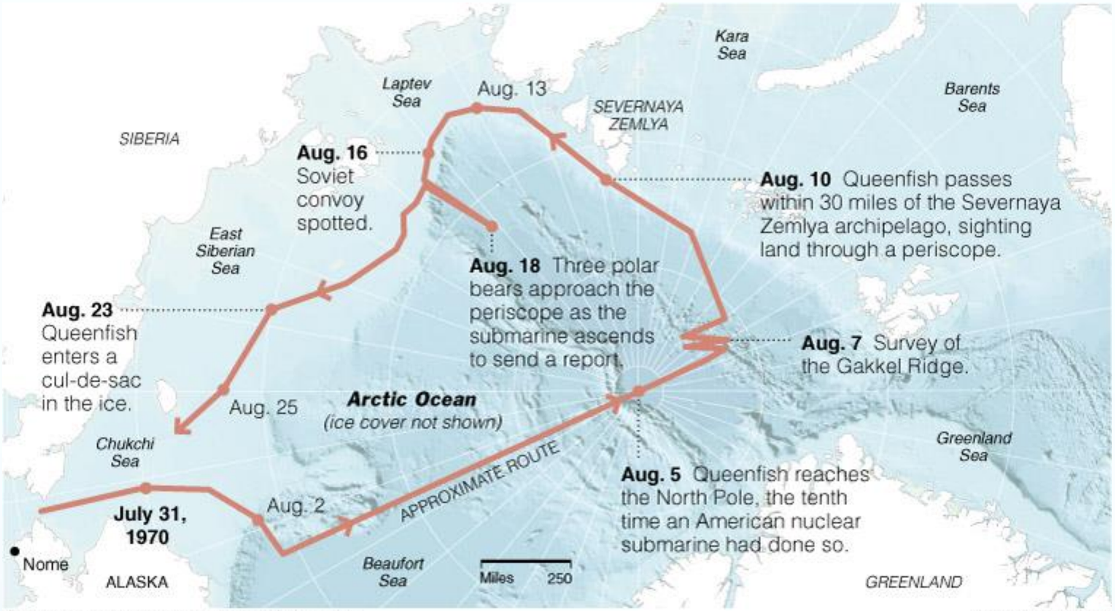


Source: US Navy

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.

USS Queenfish (SSN-651)

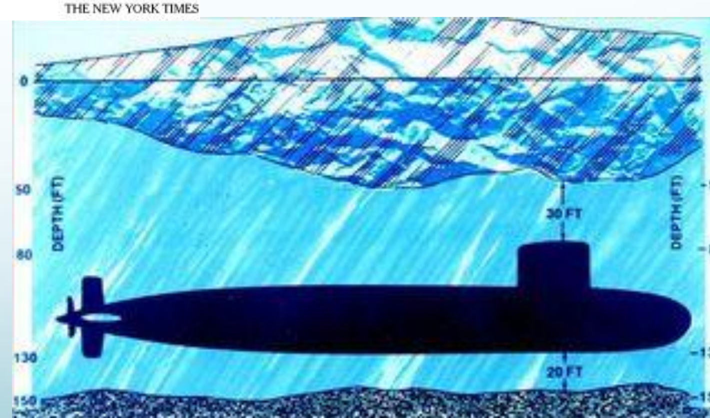
1970 Exploration of Laptev, East Siberian, and Chukchi Seas



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

- All Sturgeon-class SSNs are all Arctic-capable, equipped with under-ice sonar, a hardened sail and fairwater planes that rotate 90° for surfacing through the icepack.
- *USS Queenfish* retraced Nautilus' 1958 route to the North Pole.

- 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 (both Skate-class) rendezvous: *USS Skate* (SSN-578) and *USS Seadragon* (SSN-584) on 31 July 1962.

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

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

Science Ice Exercises (SCICEX)

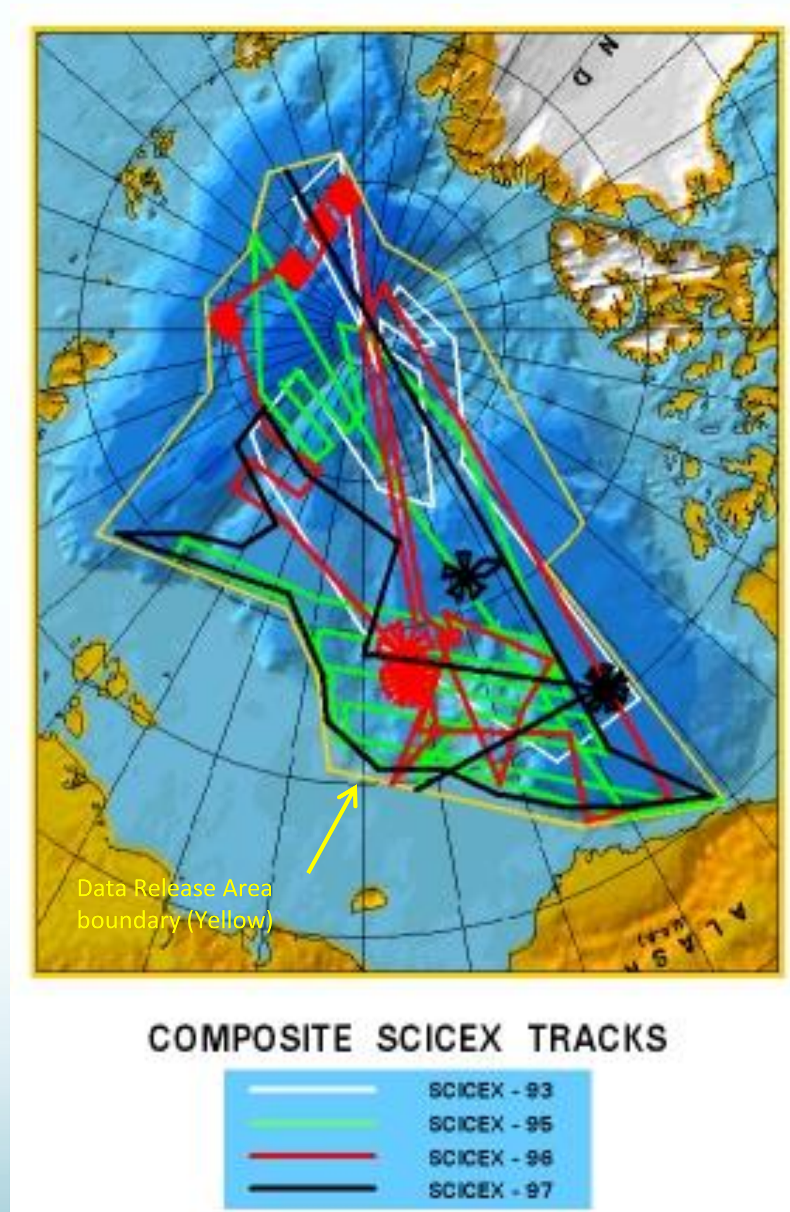
- The SCICEX program was conducted between 1993 – 1999 as a federal interagency collaboration among the operational Navy, research agencies, and the marine research community to use nuclear-powered submarines for unclassified, dedicated Arctic cruises with embarked scientists.
- The goal of the SCICEX 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.

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

- From 1993 - 1999, the Navy made available a Sturgeon-class, nuclear-powered attack submarine for the SCICEX cruises to the Arctic Ocean.
  - A feasibility mission was conducted in 1993
  - Regular missions were conducted from 1995 - 1999

SCICEX

- Unclassified civilian research activities and supporting submarine operations occurred in the "Data Release Area" (DRA), which is the portion of Arctic waters outside the economic exclusion zones of Arctic nations (yellow area in the accompanying chart).
- The unmatched mobility of submarines in ice-covered oceans allowed data to be 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.
- On the last SCICEX cruise, *USS Hawkbill* (SSN-666) surfaced at the North Pole on 3 May 1999 and scattered the ashes of the Arctic submarine pioneer Dr. Waldo Lyon.
- The term SCICEX was not used after 1999. Thereafter, the Navy used embarked Ice Pilots to collect Arctic science data on a not-to-interfere basis during ICEX missions.



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

Ice Exercises (ICEX)

- The term "ICEX" is a modern term applied to any "non-deployed" 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 to the 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/events.
    - From 1993 – 1999, unclassified, dedicated Science Ice Exercises (SCICEX) were conducted with scientists embarked on Sturgeon-class SSNs.
  - 2003 marked the start of the current ICEX "program of record" era in which the Navy sponsors the ice camp itself in conjunction with Arctic naval exercises.
    - An ICEX is part of the US Navy Submarine Arctic Warfare Program sponsored by the Chief of Naval Operations, Undersea Warfare Division (OPNAV N97).
    - An ICEX is a biennial submarine force tactical development and torpedo exercise.
- Arctic Submarine Laboratory (ASL) is the Navy command that coordinates Arctic exercises involving submarines.
  - Modern era ICEXs were conducted in 2003, 2007, 2009, 2011, 2014, 2016 and 2018.
  - As a contractor to ASL, Applied Physics Laboratory at the University of Washington (APL-UW) provides field engineers to support logistics at the camp, from building the camp, to providing and cooking food, to the recovery of any torpedoes fired by the submarines.
  - A key advantage of establishing a camp on the ice itself is the stable venue it provides for deploying a tracking range and sensors for testing underwater weapons under the ice pack.

Ice Exercises (ICEX)

- The focus of each ICEX has been on ensuring the safe operation and tactical capability of the current classes of US SSNs, which in 2018 include the Los Angeles (SSN 688)-class, Improved Los Angeles (SSN 688i)-class, Seawolf (SSN 21)-class and Virginia (SSN 774)-class. In addition, UK SSNs are regular participant in ICEX.
  - Regular Arctic exercises are the only way to ensure that each new submarine class and system upgrade that becomes available for employment in real-world operations has been tested in the unforgiving conditions of the Arctic Ocean.
  - Each successive ICEX also 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 2018, the Seawolf-class fast attack submarine *USS Connecticut* (SSN 22) from Bangor, Washington, the Los Angeles-class fast attack submarine *USS Hartford* (SSN 768) from Groton, Connecticut, and the Royal Navy Trafalgar-class submarine *HMS Trenchant* (S91) conducted multiple arctic transits, a North Pole surfacing, scientific data collection and other training evolutions during their time in the region.

ICEX 2018

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

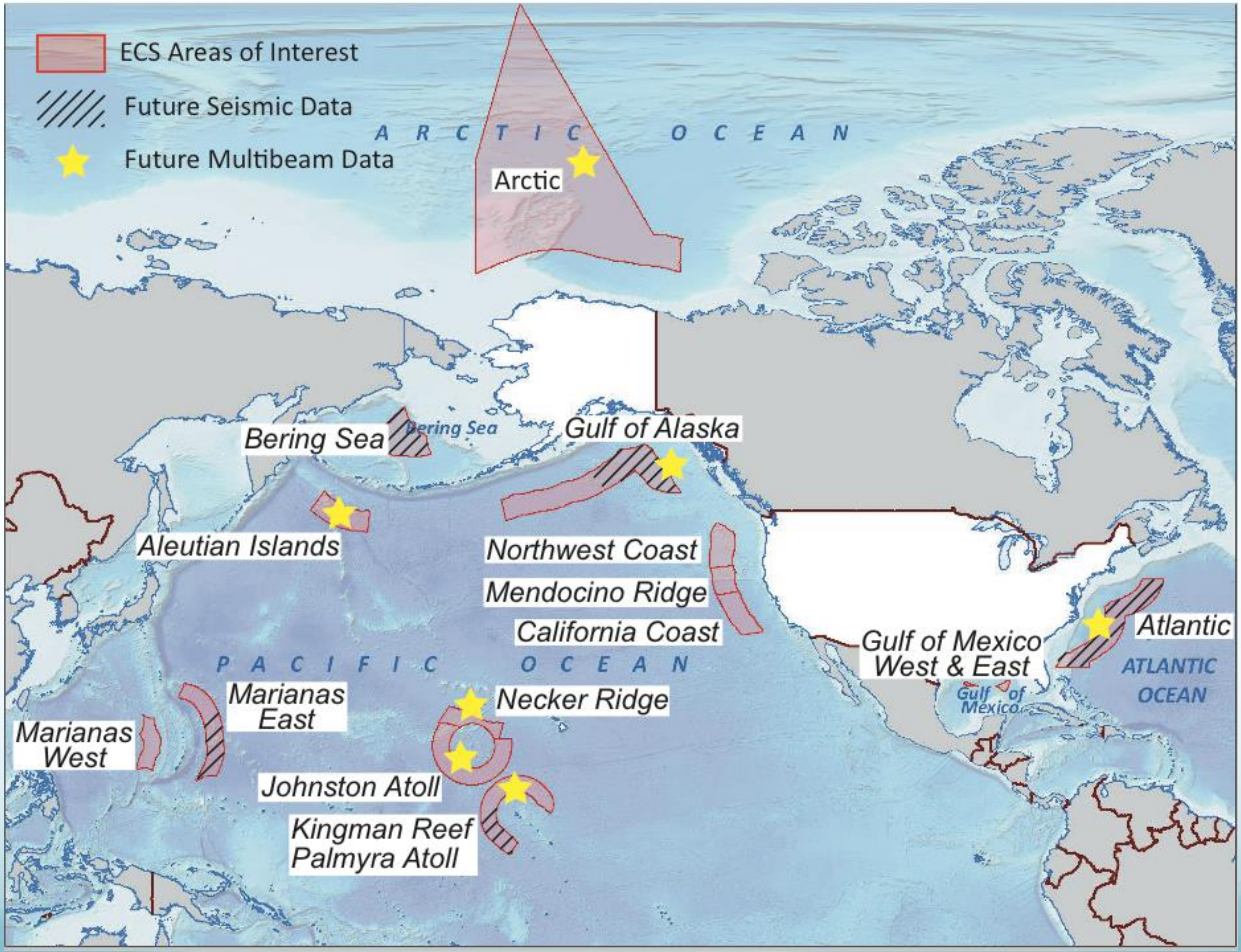
Above, from left to right: *USS Connecticut*, the *USS Hartford*, and the *HMS Trenchant* surface in the Arctic during ICEX 2018. Source: US Navy / Darryl I. Wood / Flickr

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

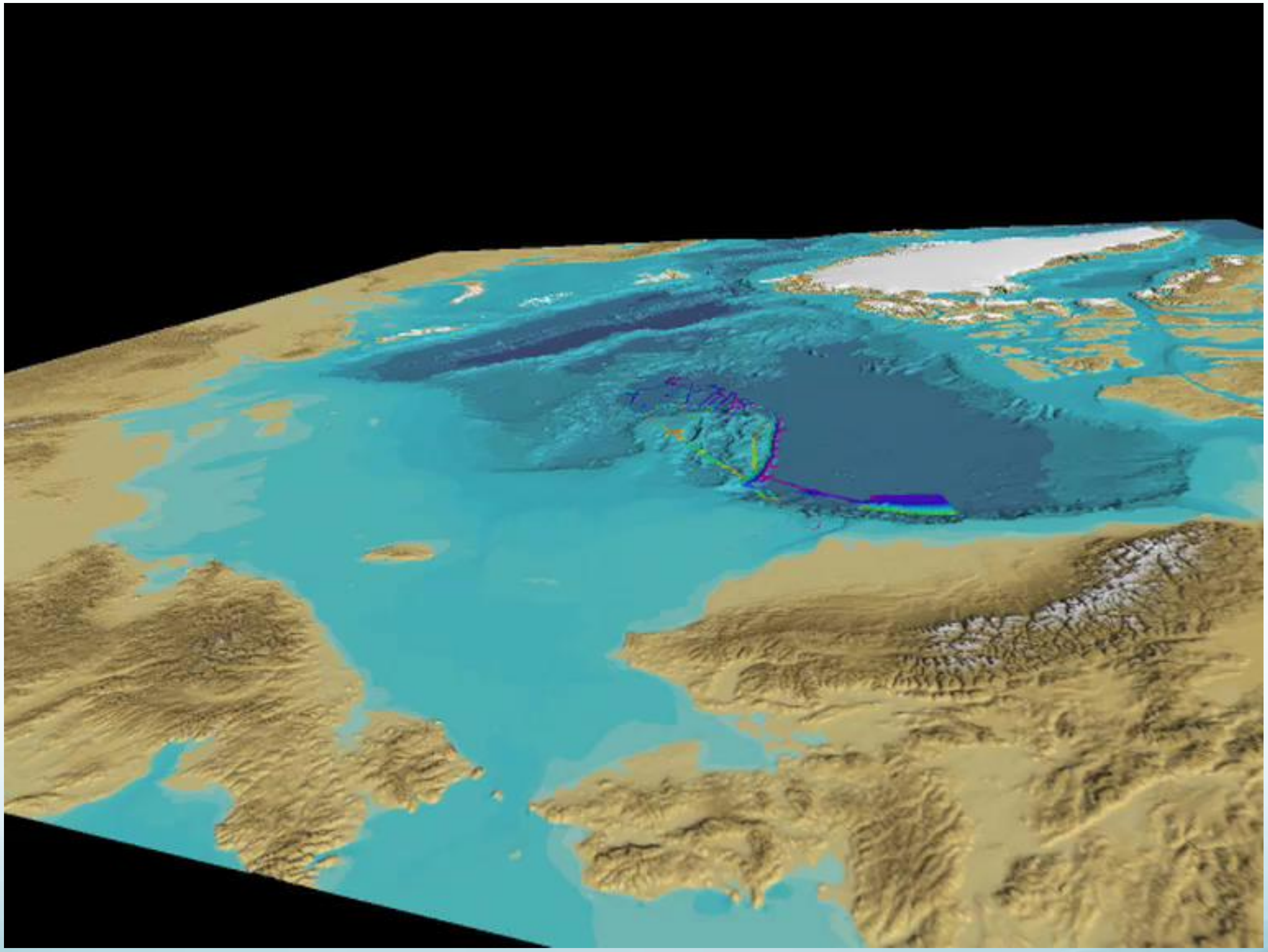
US ECS survey areas in the Arctic Ocean

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

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.

Arctic basin flyover video

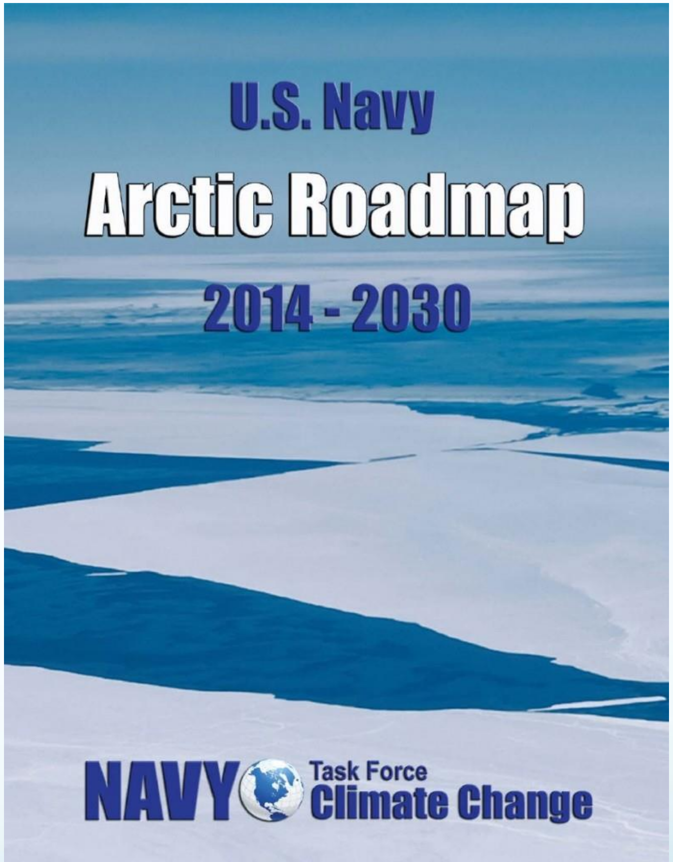
Highlights show areas mapped by 2003, 2004 & 2007 UNH/NOAA Arctic expeditions



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

US Navy Arctic Roadmap

- US Navy expects the Arctic "to remain a low threat security environment where nations resolve differences peacefully."
- It sees its role as mostly a supporter of US Coast Guard (USCG) operations and responder to search-and-rescue and disaster situations.
- However, 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."
- "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."



Source: US Navy

US polar icebreaker fleet

- The roles of U.S. polar icebreakers can be summarized 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.
- As of mid-2018, the entire U.S. national capability for Arctic and Antarctic icebreaking operations is found in a small "fleet" of three conventionally-powered icebreakers:
  - One heavy polar icebreaker, Coast Guard Cutter *Polar Star,* commissioned in 1976
  - One medium polar icebreaker, Coast Guard Cutter Healy, commissioned in 1999
  - One smaller icebreaking research vessel, *Palmer*, built in 1992 and leased by the National Science Foundation to support Antarctic research.
- In addition, 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*.

US polar icebreaker fleet

- The new Coast Guard polar icebreaker acquisition program plans to acquire three new, conventionally-powered heavy polar icebreakers, to be followed years later by the acquisition of up to three new medium polar icebreakers.
  - The Coast Guard wants to begin construction of the first new heavy polar icebreaker in FY2019, on an accelerated acquisition schedule that and have the first new icebreaker enter service in 2023.
    - As a minimum, this schedule will create a gap of three years during which the U.S. has no operational heavy polar icebreaker after *Polar Star* is retired in about 2020, after 44 years of service.
  - The Coast Guard and Navy believe that three heavy polar icebreakers could be acquired for a total cost of about $2.1 billion, or an average of about $700 million per ship.
- The Coast Guard has no plans to acquire a nuclear-powered polar icebreaker.

UK nuclear marine Arctic operations

HMS Dreadnought (S101)

1st UK nuclear submarine at the North Pole

- 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: https://www.elite-designs.co.uk/

Canada
nuclear marine
Arctic operations

Sovereignty over the Canadian Arctic

- Canada's intermittent interest in marine nuclear power has been driven largely by its concern about demonstrating Arctic sovereignty.
- The primary concern is that a lack of Canadian surveillance, control, and physical presence in its northern waters might seriously imperil its claims to ownership.
- In 1986 the Canadian government officially claimed the Northwest Passage as internal Canadian waters through the application of straight baselines.
- The US has 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 requiring permission from Canada for transit.
- The 1987 *"Challenge and Commitment: A Defence Policy for Canada"* was 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 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 – 1980s: A nuclear-powered polar icebreaker for the Canadian Coast Guard, primarily to support economic development in the Canadian Arctic
  - 1987: 10 to 12 nuclear attack submarines (SSNs) at a for the Canadian Navy, as announced in the Government's defense white paper, *"Challenges and Commitment – A Defense Policy For Canada*"

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 acquisition in the 1990s.
- In 1976, the Cabinet 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 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.

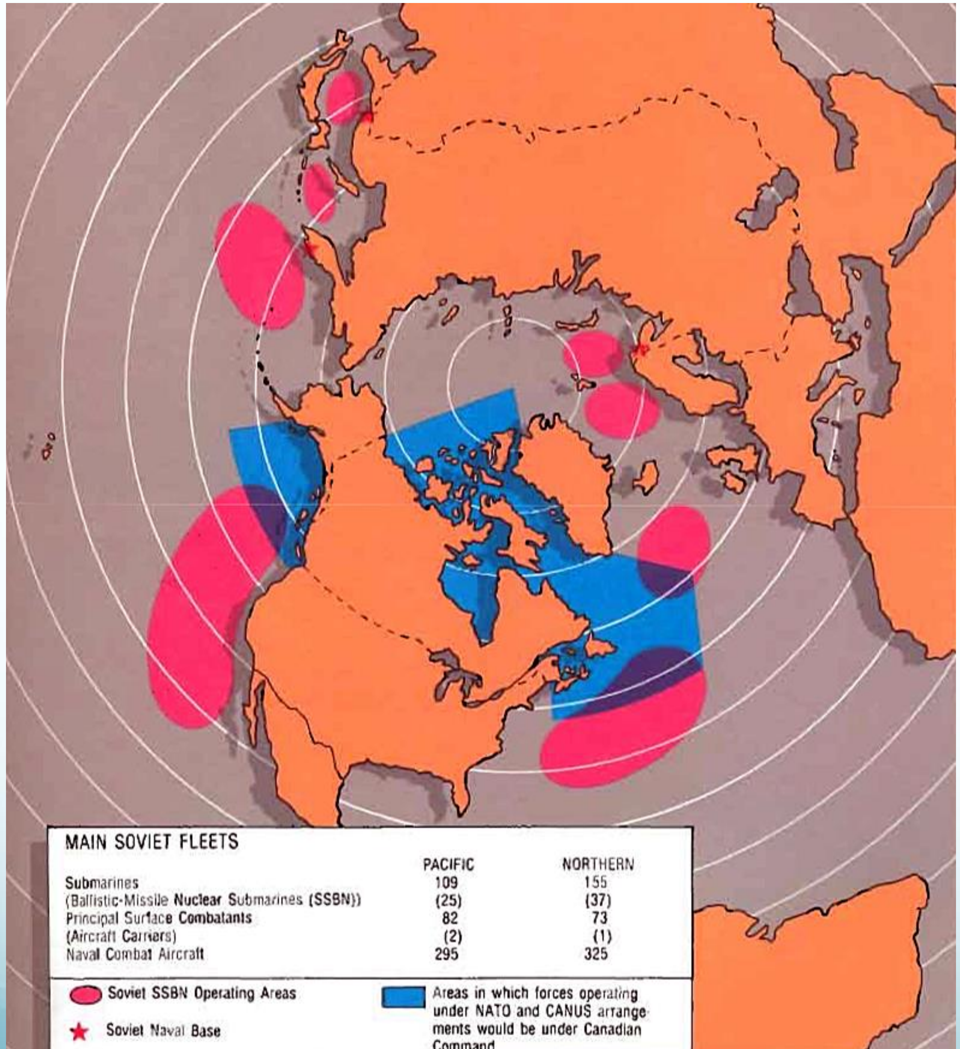
Nuclear submarine fleet plans

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

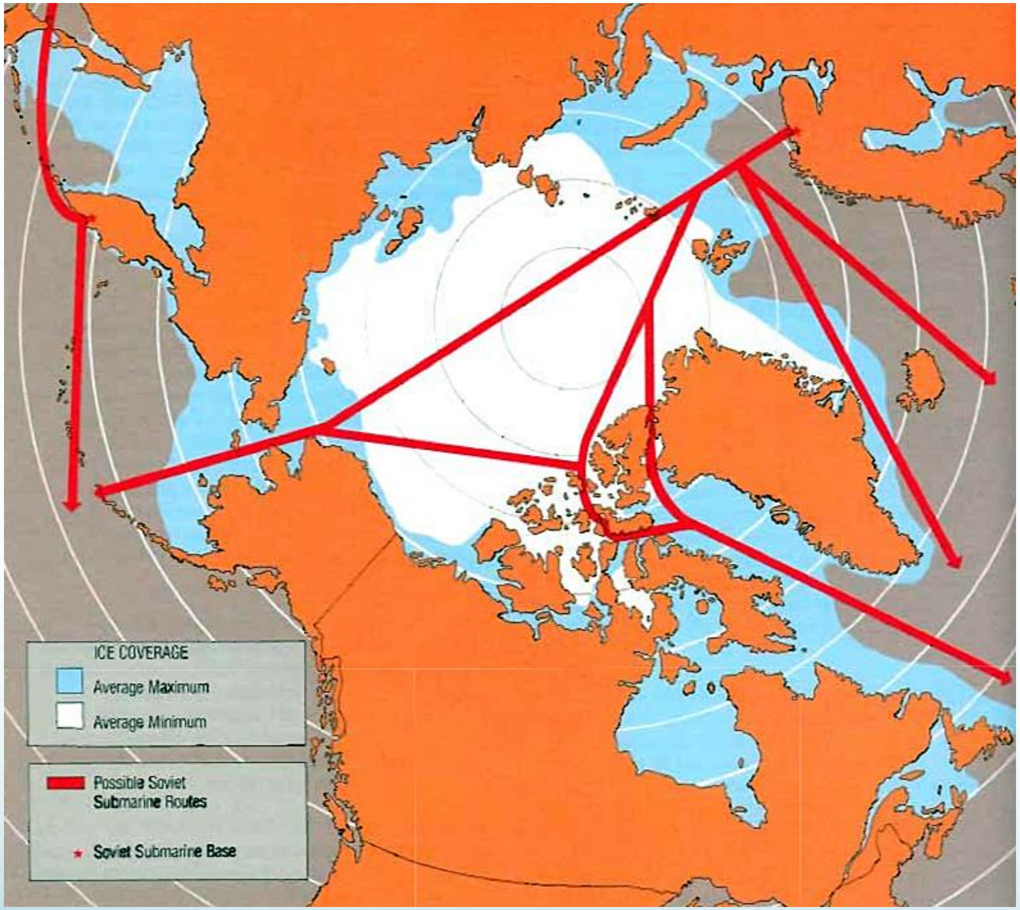


- This figure from the 1987 defense white paper shows regions of the Arctic (blue) where Canada expected that forces operating under NATO and CANUS arrangements would be under Canadian command (i.e., while they are in Canada’s claimed Arctic territorial waters)
- The red regions denote Soviet SSBN operating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

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

Nuclear submarine fleet plans

Canada’s 1987 defense white paper

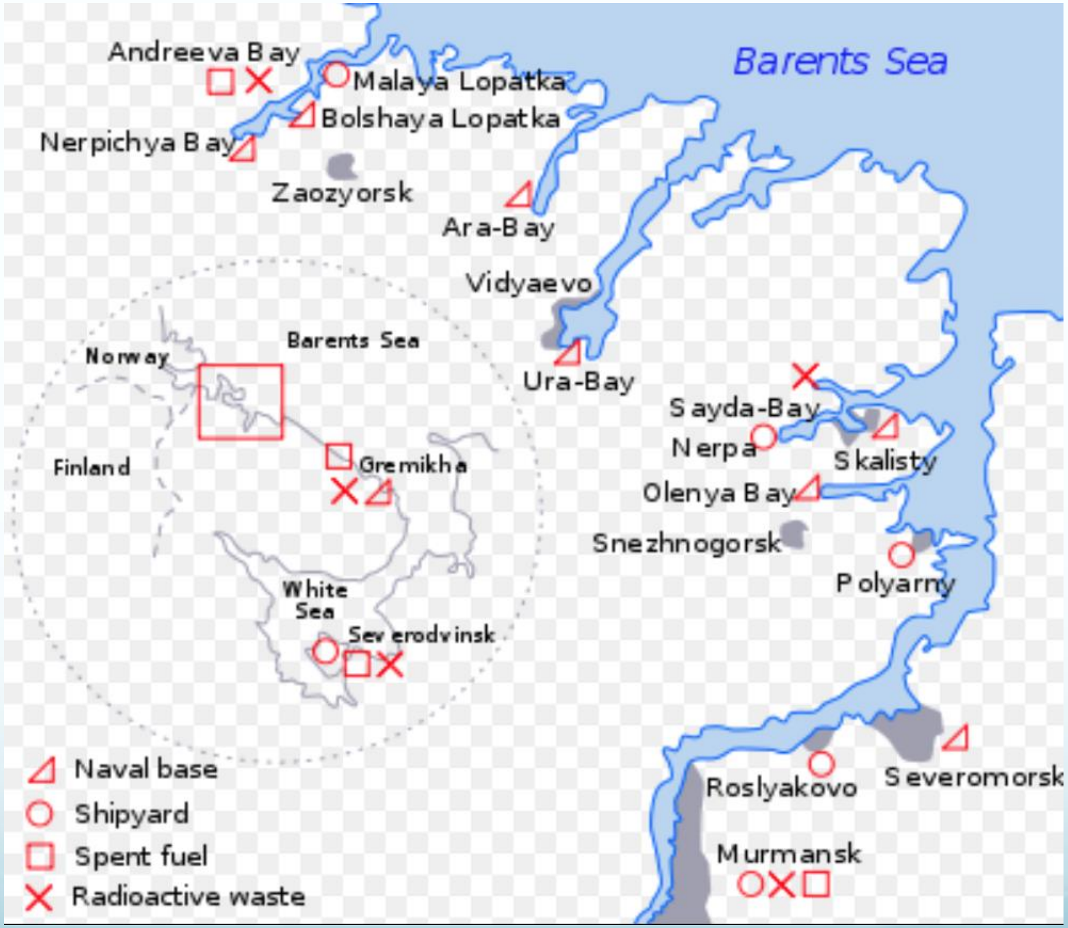


Source: June 1987 Canadian defense white paper, *“Challenges and Commitment – A Defense Policy For Canada*

- 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).

Russian nuclear marine Arctic operations

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



Source: https://commons.wikimedia.org

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).

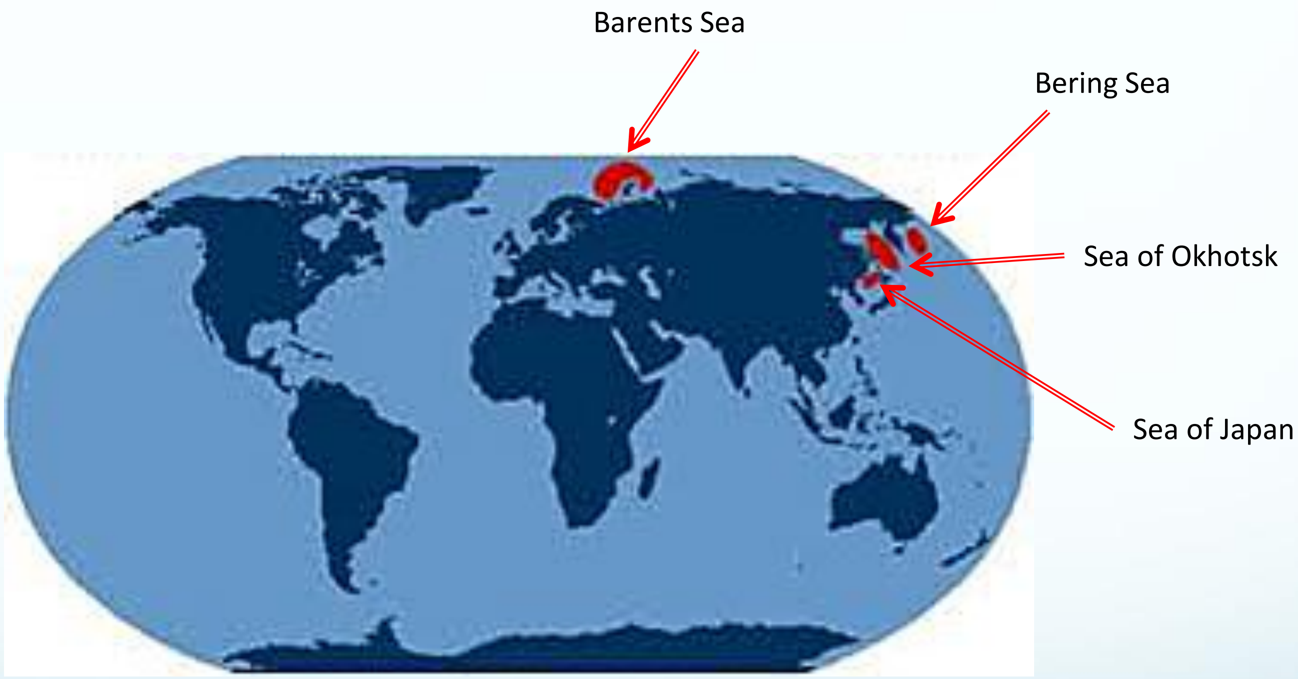
Source: rusnavy.com/history

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

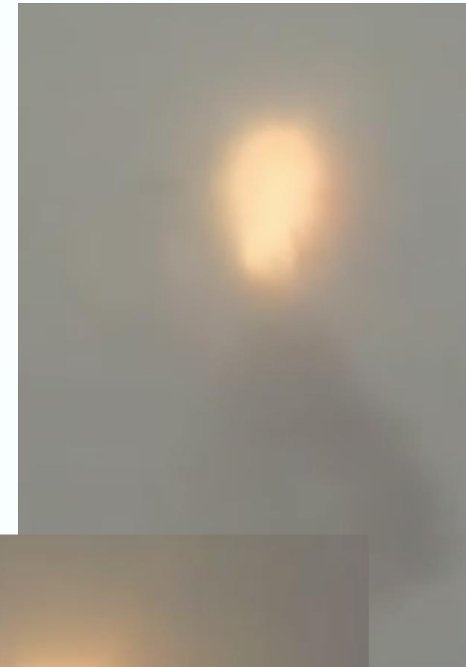


Source: fas.org

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

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

Actual Typhoon (941) Arctic SLBM launch

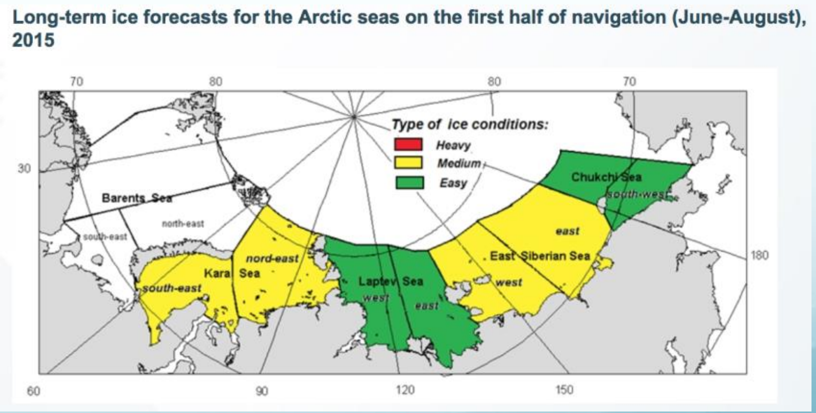


The Typhoon SSBN surfaced through thick ice, crew cleared the foredeck of ice, and the missile was launched

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

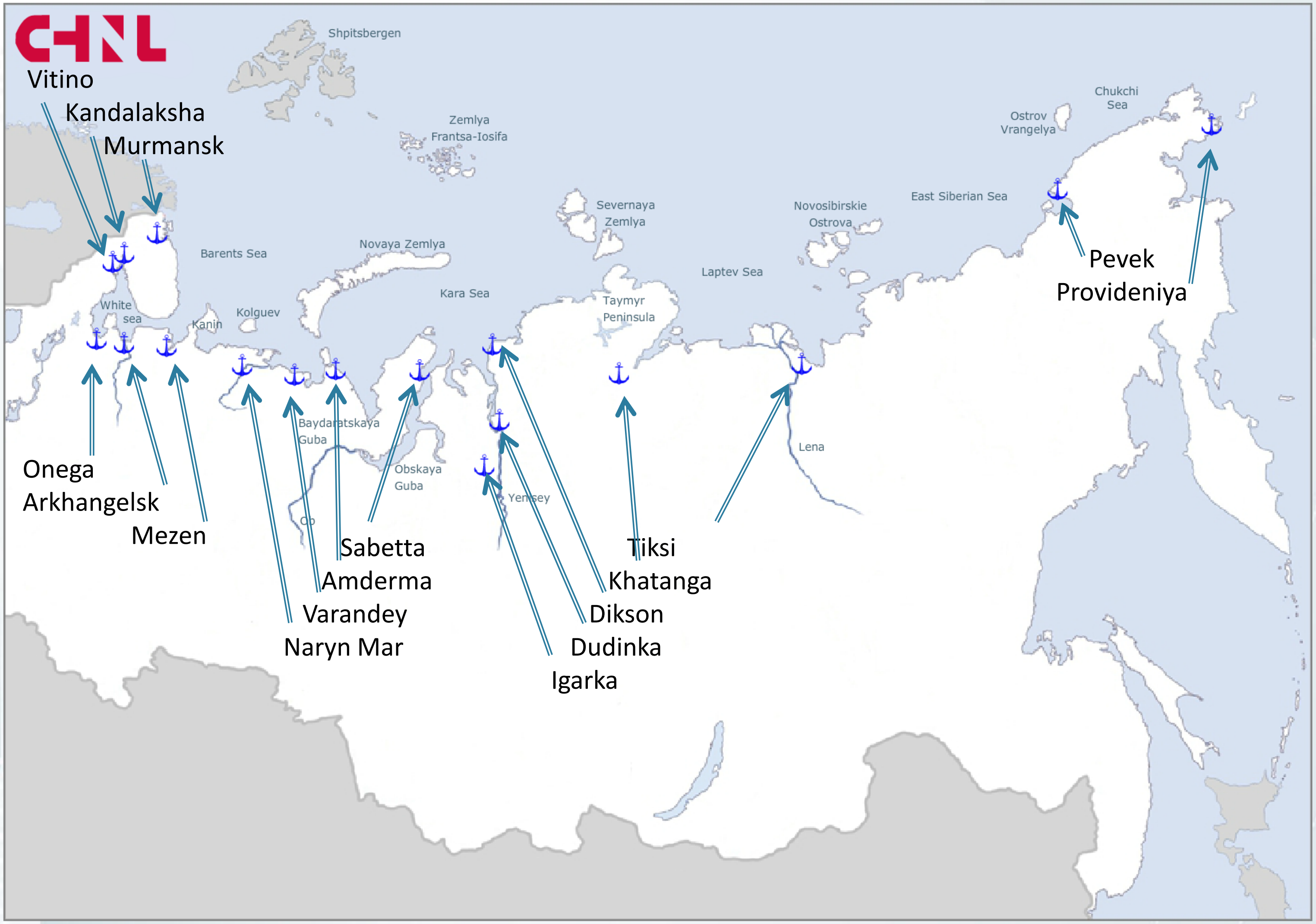
Northern Sea Route Information Office

- 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.



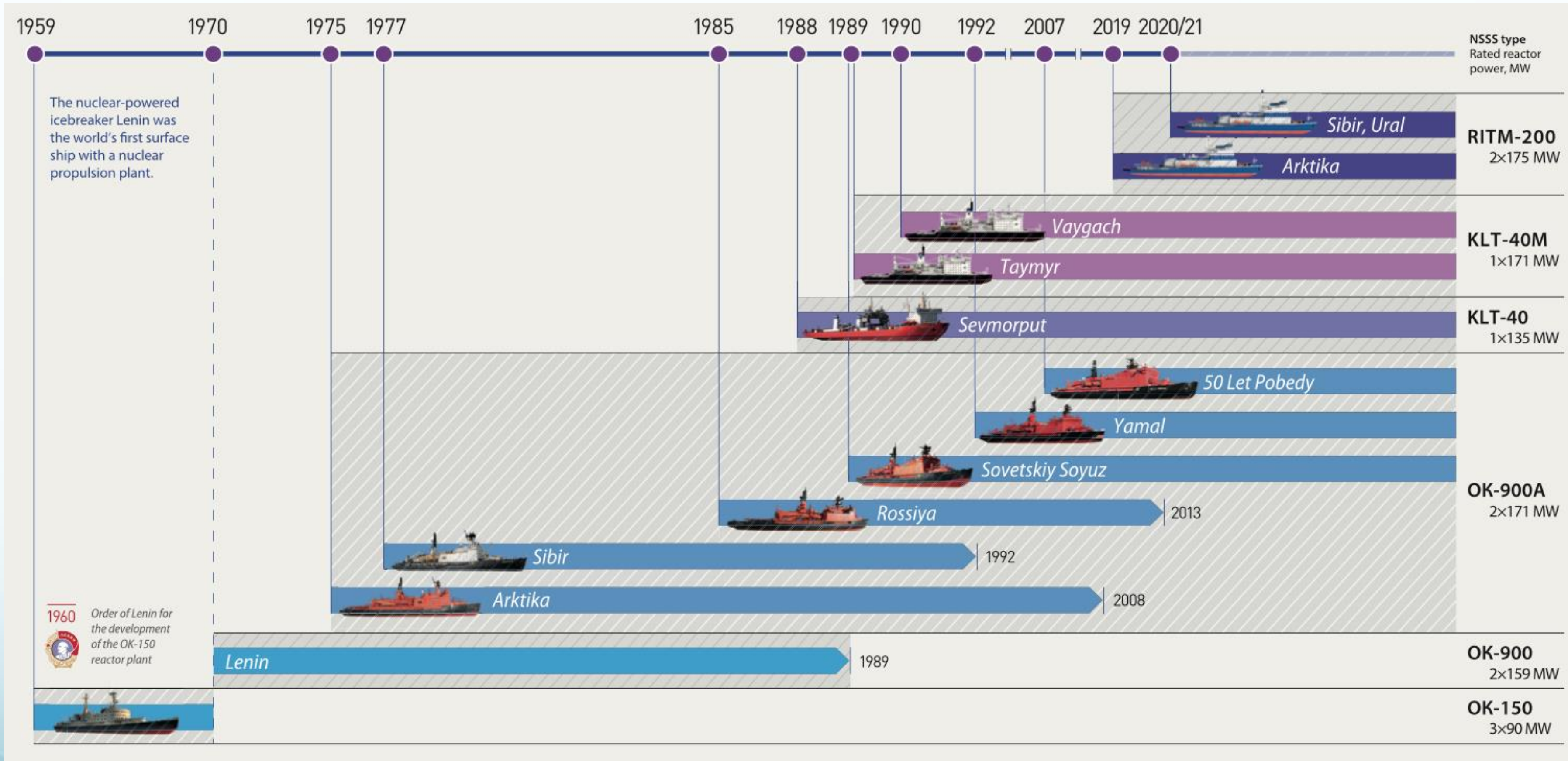
Source: http://www.arctic-lio.com/node/230

Russian ports in the Arctic



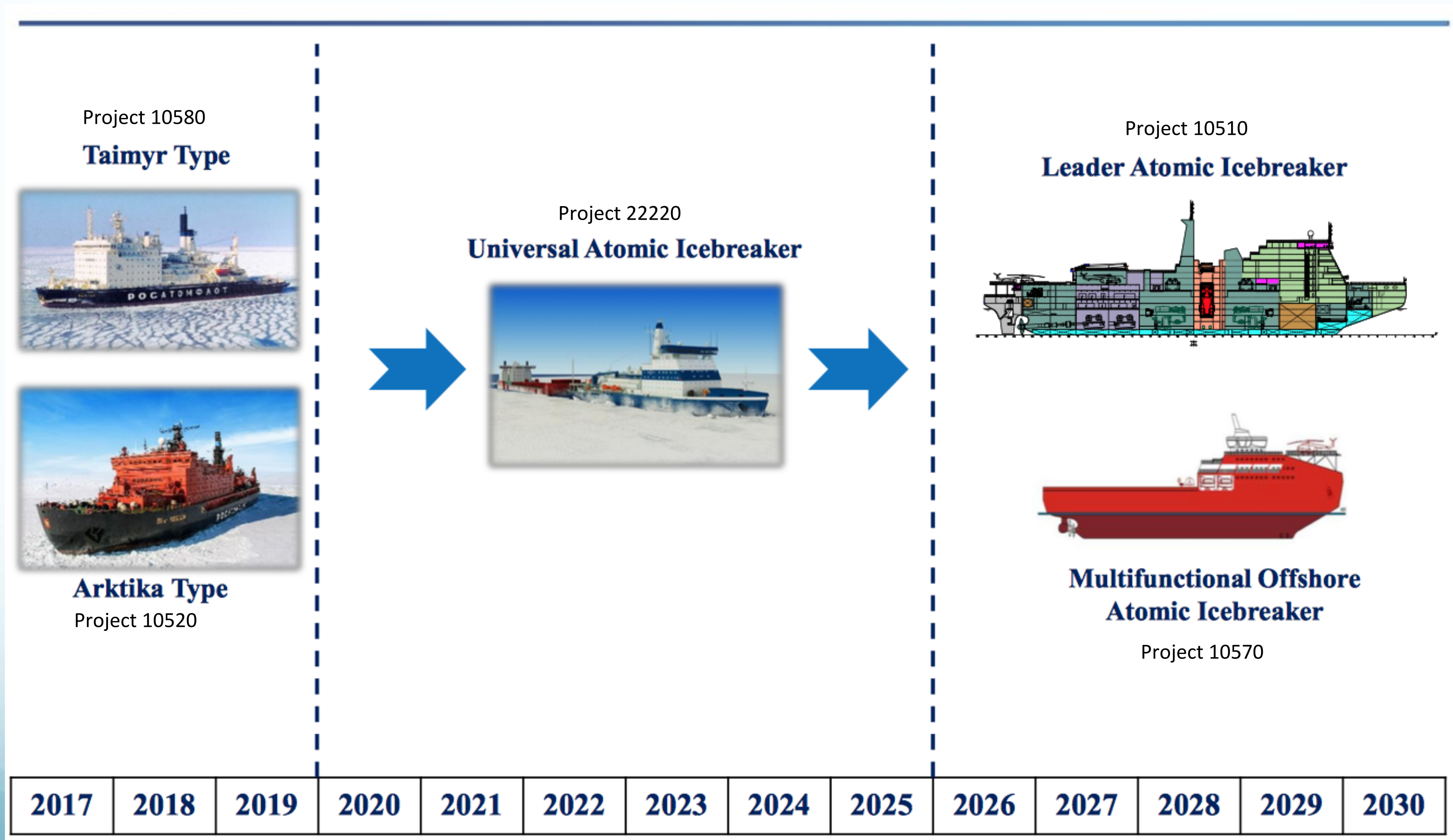
Source: adapted from http://www.arctic-lio.com/arcticports

Russian nuclear-powered icebreakers



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

ROSATOM long-range plans for nuclear-powered icebreakers



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

Russian icebreaker *Arktika*

1st surface vessel 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

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.

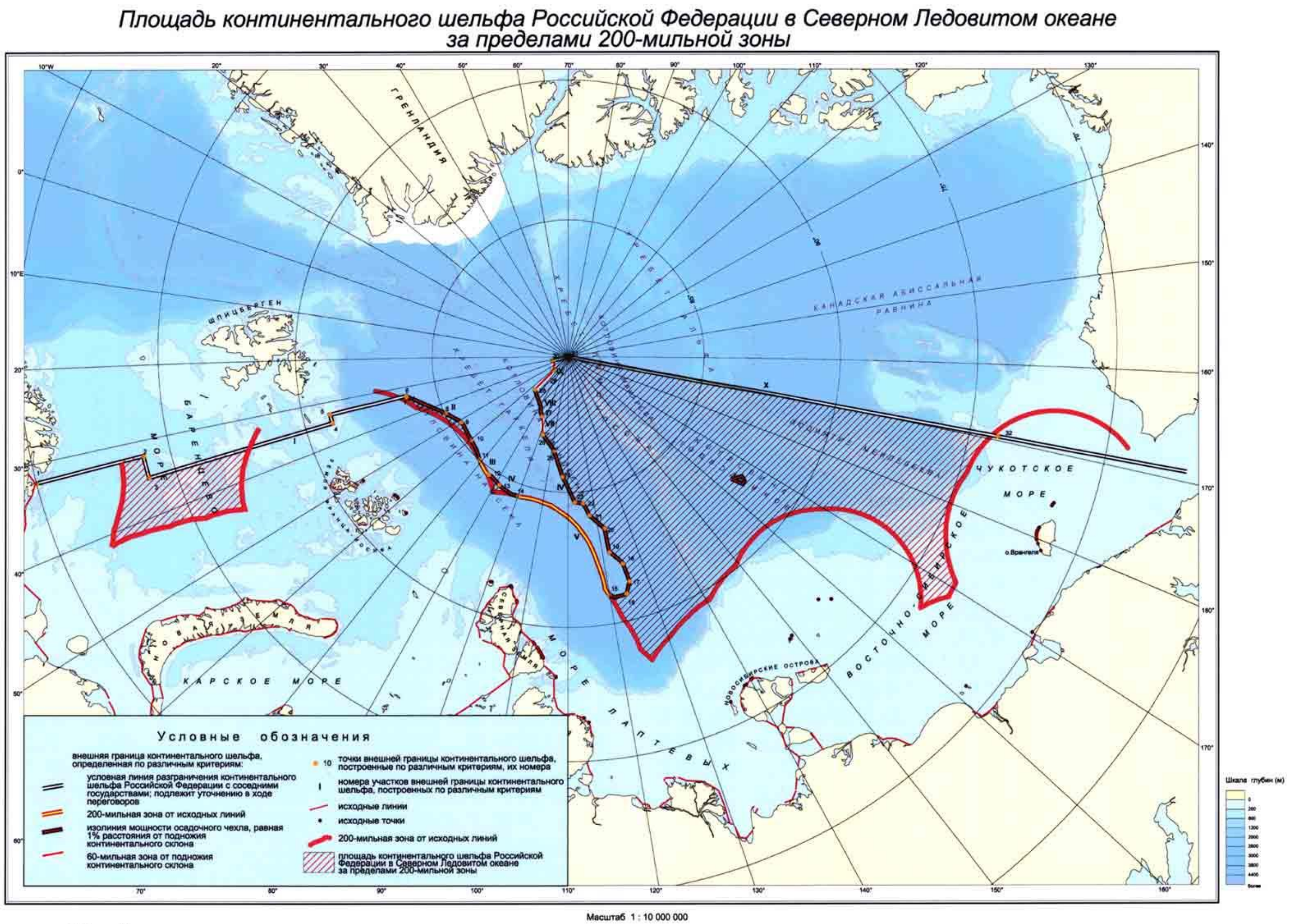
- Russian authorities announced plans for construction of self-propelled, ice-strengthened floating platform to replace the natural ice floes for future research stations.
  - In 2013, 1.7 billion rubles (about $29 million) were allocated to this project, but since then, there has been no news about the platform.

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

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.

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

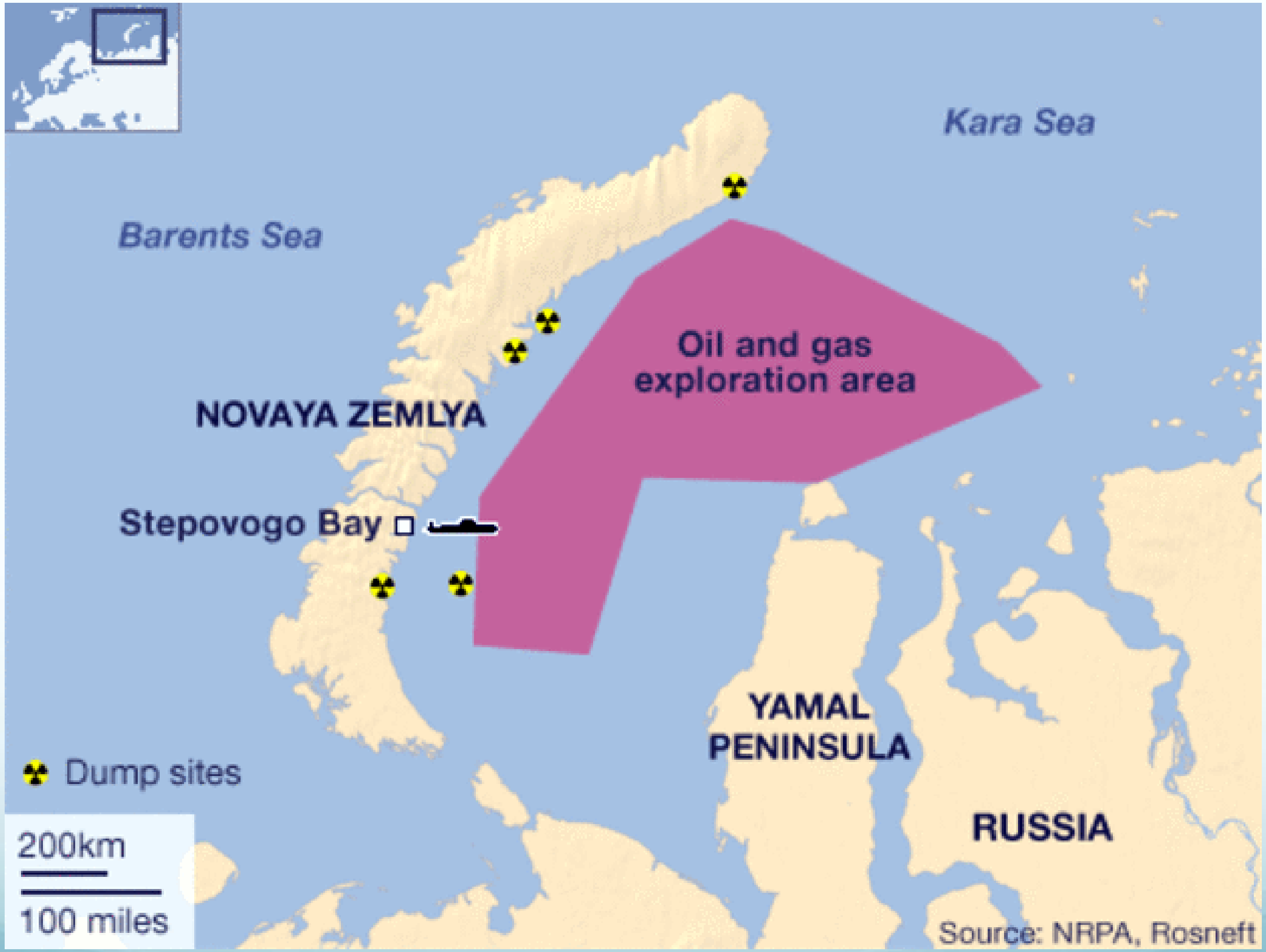
- The area covered by Russia’s 2015 ECS claim is estimated by Bellona Foundation to hold 258 billion tons of fuel equivalent, representing 60% of Russia’s total hydrocarbon reserves. The area also is fertile fishing territory.
  - Bellona Foundation believes these oil and gas reserves, “would hardly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

Barents Sea oil reserves

The Norwegian Atlantic Committee Report 4-2006

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

Russian Kara Sea oil & gas exploration area



Russian non-propulsion marine nuclear Arctic applications

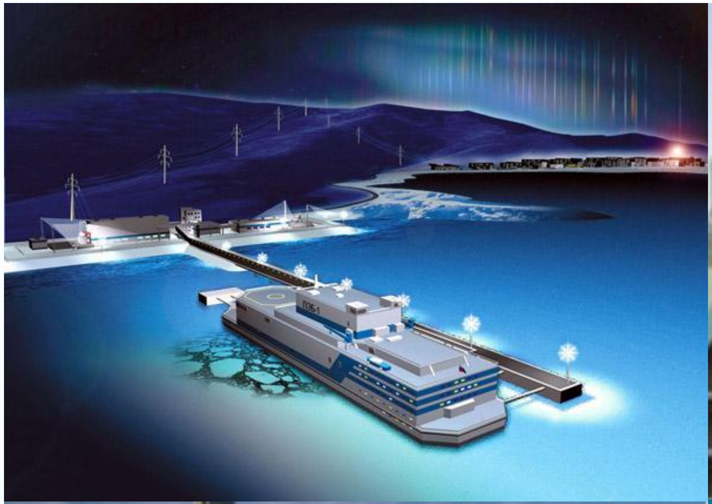
- Small reactors for non-propulsion marine nuclear applications
- Floating nuclear power plants (FNPP)
- Transportable reactor units (TRU)
- Arctic seabed applications for marine nuclear power
- Radioisotope Thermoelectric Generators (RTGs)

Non-propulsion nuclear marine Arctic applications

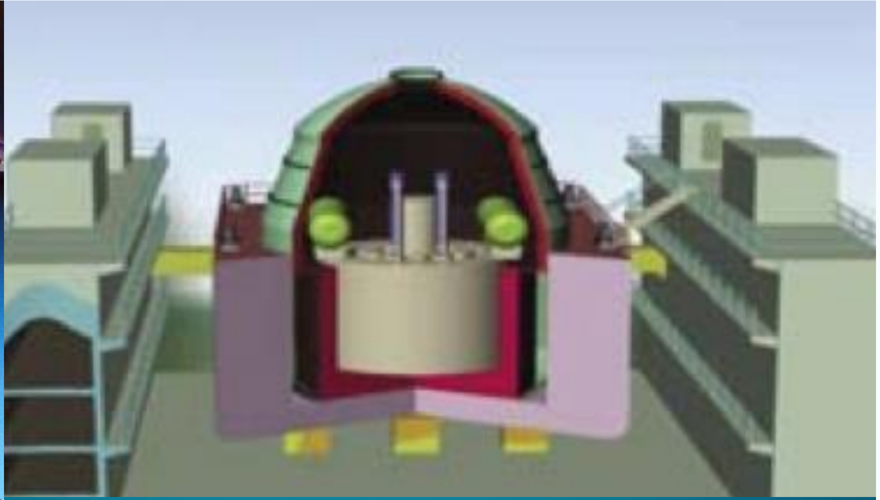
- Based on their experience in developing marine nuclear reactors, OKBM Afrikantov, Nikiet and OKB Gidropress offer a variety of small size reactors in relatively small packages that are designed for deployment in remote areas, particularly in the Arctic, for combined electricity and heat supply to isolated 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

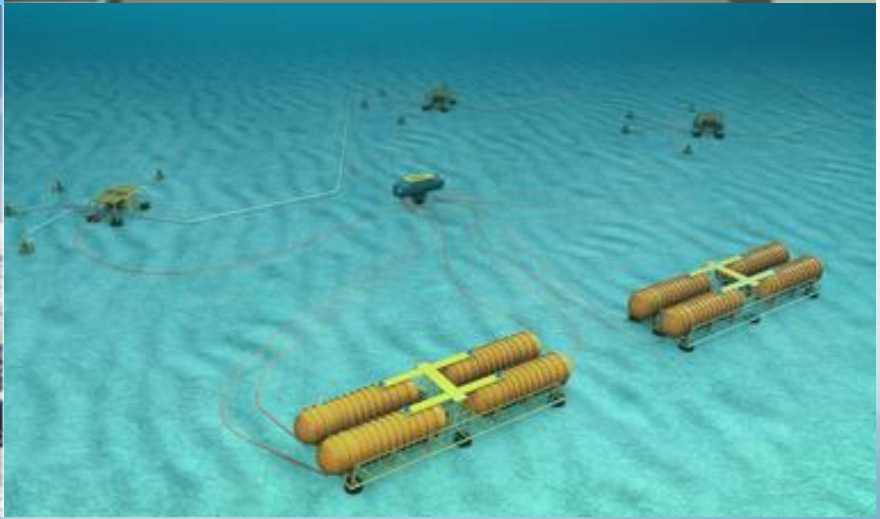
Floating nuclear power plant. Source: OKBM Afrikantov



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 plants (FNPP)

Source: World Nuclear Association

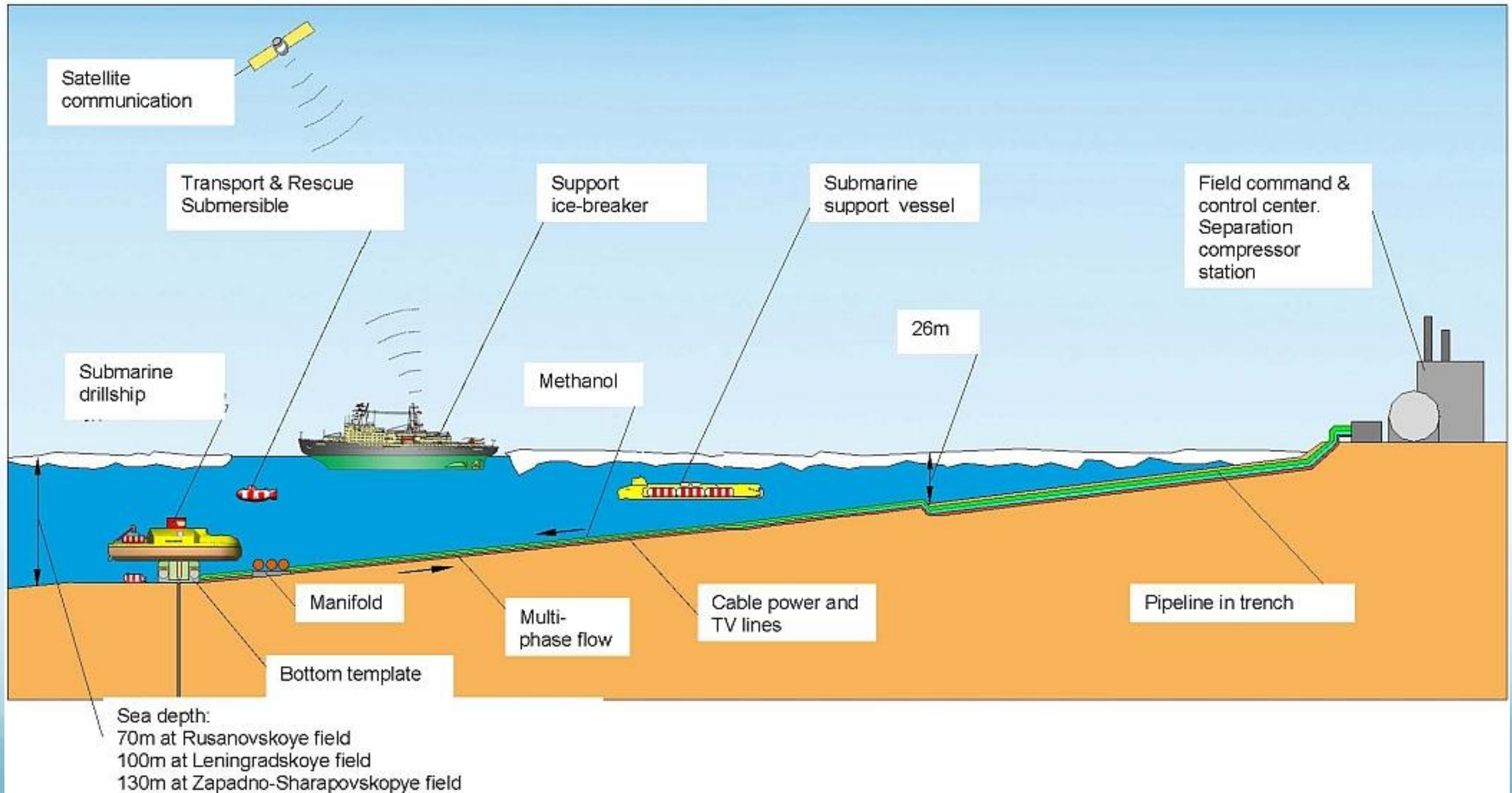
Arctic subsea drilling system (SDS) concept

- 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

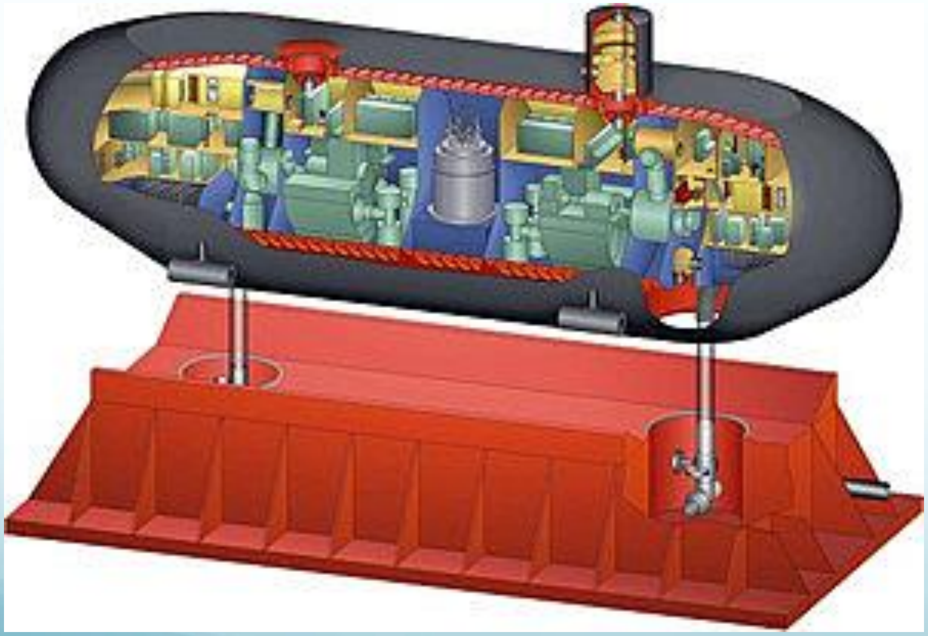
- The conceptual Lazurite Drillship is a large vessel, with a length of 98.6 meters (323 feet), a beam of 31.2 meters (102 feet) and a displacement of about 23,600 tonnes (26,014 tons).
- The Drillship houses a dry-type drilling rig with a stock of drilling consumables for construction of a 3,500 meter (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.

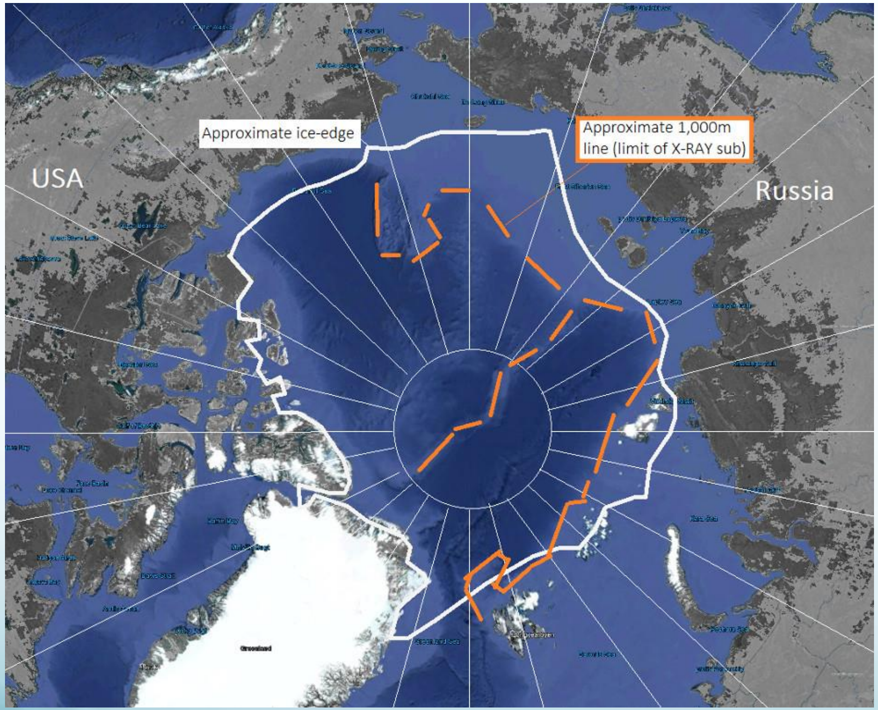


Source: http://ckb-rubin.ru/en/projects/other_projects/subsea_nuclear_gas_compressor_station/

- 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.

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.)

Sunken nuclear submarines

Above:
Sunken nuclear submarines in the Atlantic

Right:
Sunken nuclear submarines in the Arctic.

Note that K-141, Oscar II-class *Kursk,* was raised and salvaged.

Source, two maps: Wikipedia

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.

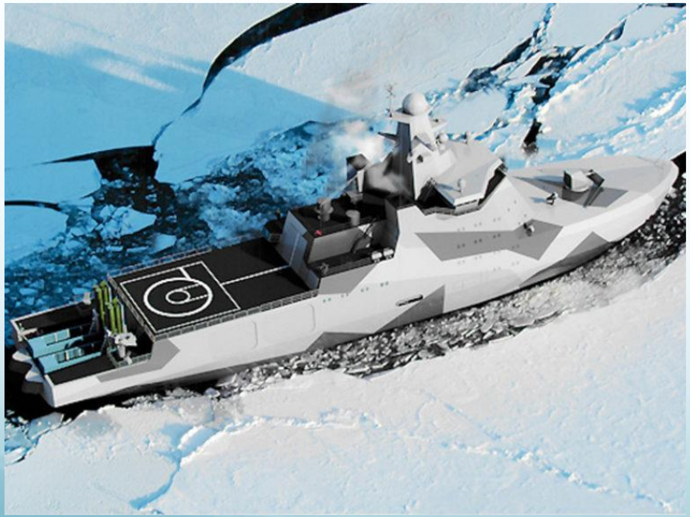
- K-27 was scuttled in the Kara Sea on 6 Sep 1982.
- Studies by the Kurchatov Institute have shown the bitumen seal is not performing as expected, posing the danger of seawater ingress to the reactor cores.
- Norway's Bellona Foundation has raised the concern of an uncontrolled criticality from water 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.

Recent 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, will acquire 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.

Recent 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.

Source: ForeignPolicy.com / Robbie Gramer / Senator Dan Sullivan

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 all nations bordering the Arctic Ocean.
    - 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.
  - Continuing use of floating "ice camps" by the US, Russia, and others will support various research and military activities.
    - Civilian Arctic research supported by US nuclear submarines will continue at some level as determined by the Navy's Arctic Submarine Laboratory.
  - Arctic-rated vessels will continue to have an important role in conducting and supporting Arctic research.
    - Russia's nuclear powered icebreaker fleet is a unique national resource for enabling research and other activities in the Arctic. A new generation of LK-60Ya nuclear icebreakers will start entering the Rosatom fleet in 2019.
    - The current US icebreaker "fleet" consists of one heavy (polar) icebreaker and one medium icebreaker. Both icebreakers are conventionally powered. These ships are managed by the National Science Foundation and also support US Antarctic operations. The US current icebreaker presence in the Arctic is very small. The upcoming new icebreaker procurement is not considering a nuclear vessel.

Trends in Arctic operations

- **For military activities:**
  - 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 large-scale Arctic military exercises in 2015 that included nuclear submarines, Russia has taken clear steps to militarize its Arctic region.
      - By 2025, Russia expects to have 13 airfields and 10 air defense radar sites in the Arctic region.
  - US
    - In its Arctic Roadmap, the US Navy describes its role in the Arctic as, "mostly a supporter of US Coast Guard (USCG) operations and responder to search-and-rescue and disaster situations."
    - US nuclear submarine Arctic operations will continue as in previous years. No other US naval vessels can access ice-covered Arctic waters without support from an icebreaker, which is in very short supply in the USCG fleet.

Trends in Arctic operations

- **To exercise sovereignty over Exclusive Economic Zones (EEZ) and Extended Continental Shelf (ECS) regions in the Arctic**
  - The eight Arctic nations (Canada, Russia, United States, Denmark, Norway, Sweden, Finland and Iceland) all have sovereign interests in the definition of their Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS) claims regions in the Arctic.
    - 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 interest is driving some of the research in the Arctic, to better characterize the EEZ and ECS.
  - Canada does not have the resources or 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 will continue to claim that this is an international strait that is open to shipping.
  - Russia's Arctic military development and exercises 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:**
  - Increasing use by commercial shipping firms of the shorter sea routes through Arctic waters, particularly the Northern Sea Route (NSR).
    - Russian icebreakers have a mission to maintain the NSR open for traffic for much of the year. Their 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 the Northwest Passage to support commercial shipping traffic.
    - Russia has a different philosophy about the NSR than Canada and the US have about the Northwest Passage.

Trends in Arctic operations

- **For commercial exploitation (continued):**
  - 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 a new generation of nuclear-powered icebreakers will support expanded use of the Northern Sea Route.
    - Commercial expansion of natural resource development along Russia's north coast will benefit from greater shipping traffic on the Northern Sea Route to deliver needed supplies and bring resources to market.
    - 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.

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 will 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, but they will be hindered by their lack of Arctic port infrastructure and Arctic-rated vessels to support long-term work in remote Arctic regions.

Trends in Arctic operations

- **For environmental protection and cleanup:**
  - 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.
  - Pressure on Russia from Arctic nations will continue for removal and/or remediation of radioactive contamination and radioactive items in the region: sunken Russian nuclear submarines, nuclear waste and other radioactive items dumped in the Arctic Ocean, and radioisotope thermoelectric generators (RTGs) used to power navigation lights, radio beacons, and other equipment along the NSR and elsewhere in the Arctic.
- **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.