60 Years of Marine Nuclear Power: 1955 – 2015

Part 3: Former Soviet Union & Russia

Peter Lobner
August 2015

Foreword

This is Part 3 of a rather lengthy presentation that is my attempt to tell a complex story, starting from the early origins of the U.S. Navy's interest in marine nuclear propulsion in 1939, resetting the clock on 17 January 1955 with the world's first "underway on nuclear power" by the *USS Nautilus*, and then tracing the development and exploitation of nuclear propulsion over the next 60 years in a remarkable variety of military and civilian vessels created by eight nations.

I acknowledge the great amount of work done by others who have posted information on the internet on international marine nuclear propulsion programs, naval and civilian nuclear vessels and naval weapons systems. My presentation contains a great deal of graphics from many internet sources. Throughout the presentation, I have made an effort to identify all of the sources for these graphics.

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

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

Best regards,

Peter Lobner
August 2015

Russia

- Current nuclear vessel fleet
- Nuclear marine infrastructure
- Marine reactors
- Non-military nuclear marine vessels:
  - Icebreakers
  - Ice-breaking merchant ship
  - Floating nuclear power plant
- Naval nuclear surface ships:
  - Cruisers
  - Command ship
  - Aircraft carrier
  - Multi-purpose destroyer
- Naval nuclear submarines:
  - Fast attack & multi-purpose subs (SSN)
  - Strategic ballistic missile subs (SSBN)
  - Cruise missile subs (SSGN)
  - Special subs
- Nuclear vessel decommissioning and environmental cleanup
- Marine nuclear power current trends

Russia's current nuclear vessel fleet

mid-2015

- The Russian Navy operates a mixed fleet of conventional and nuclear submarines. The nuclear submarine fleet is comprised of 49 vessels in the following classes:
  - 4 x Victor III SSNs
  - 4 x Sierra I & II SSNs
  - 10 x Akula & Improved Akula SSNs
  - 1 x Yasen multi-purpose SSN
  - 3 x Delta III SSBNs
  - 6 x Delta IV SSBNs
  - 1 x Typhoon SSBN, used as a testbed for the Bulava SLBM, which is deployed on the Borei SSBNs
  - 3 x Borei SSBN
  - 8 x Oscar SSGN
  - 8 x Small, deep-diving special operations submarines in several classes (Nelma / Paltus, Kashalot & Losharik classes)
  - 1 x Delta III-class SSBN conversion to "PLA-carrier" ("mothership") for the small spec-op subs, with one Delta IV conversion nearing completion in late 2015.
- The Russian Navy operates a single nuclear-powered surface combatant:
  - 1 x Kirov (Orlan)-class CGN, *Pyotr Velikiy*
- ROSATOMFLOT operates the Russian nuclear icebreaker fleet, which is comprised of seven vessels in the following classes:
  - 4 x Arktika-class deep-water icebreaker
  - 2 x Taymir-class shallow-water icebreaker
  - 1 x Sevmorput icebreaking cargo vessel

Russian nuclear marine infrastructure

Marine Reactor Design Bureaus

- Scientific Research and Design Institute NIKIET, Moscow
  - VM-A (PWR): November, Hotel, Echo subs
  - VM-4 (PWR): Victor, Charlie, Yankee, Delta subs
  - VM-5 (PWR): Papa subs
  - Small PWRs for Nelma / Paltus and Kashalot special operations subs
  - VAU-6 Auxiliary Nuclear Power Plant (ANPP): subs
- Experimental and Design Organization (OKB) Gidropress, Moscow
  - VT-1 (LMR): November ZhMT sub
  - BM-40A (LMR): 705K Alfa subs
- Special Design Bureau for Mechanical Engineering (OKBM) Afrikantov, Nizhniy Novogrod
  - OK-150 (PWR): Lenin icebreaker (original reactor)
  - OK-900 / 900A (PWR): Lenin, Arktika icebreakers
  - OK-650 (PWR): Mike, Oscar, Typhoon, Sierra, Akula, Borei, Yasen subs
  - KN-3 (VM-16 core) (PWR), Orlan (Kirov) cruisers
  - OK-550 (LMR): 705 Alfa subs
  - KLT-40 / 40S (PWR): Taimyr, Sevmorput icebreakers, PEB floating nuclear power station
  - RITM-200 (PWR): LK-60 icebreaker
  - E-17 (PWR): Losharik special operations sub

Submarine Design Bureaus

- Malakhit (Malachite) Central Design Bureau (SKB-143, merged with SKB-193 and SKB-16), St. Petersburg
  - Project 627A November-class SSN (SKB-143)
  - Project 645 November ZhMT class SSN (SKB-143)
  - Project 1710 Beluga (diesel, experimental teardrop hull)
  - Project 671 Victor-class SSN (SKB-143)
  - Project 705 & 705K Alfa-class SSN (SKB-143)
  - Project 661 Papa-class SSN (OKB-16)
  - Project 971 Akula-class SSN
  - Project 885 Yasen-class SSN
- Rubin Central Design Bureau for Marine Engineering (SKB-18), St. Petersburg
  - Project 658 Hotel-class SSBN
  - Projects 659 & 675 Echo-class SSGN
  - Project 667 Yankee and Delta-classes SSBN
  - Project 949 Oscar-class SSGN
  - Project 685 Mike-class SSN
  - Project 941 Typhoon-class SSBN
  - Project 955 Borei-class SSBN
- Lazurite Central Design Bureau (STB-122), Nizhniy Novogorod
  - Project 670 Charlie-class SSGN
  - Project 945 Sierra-class SSN

Russian nuclear marine infrastructure

Shipyards

- Admiralty Shipyard (*Soviet Shipyard-194),* St. Petersburg
  - From 1973 to 1998, built 298 subs, including:
    - 41 x 2nd-gen nuclear subs (Victor I, II, III & Project 705 Alfa)
    - Naval special operations submersibles: Lima, Uniform, X-ray, Beluga & Paltus classes
- Baltic Sea Shipyard (*Soviet Shipyard-189),* St. Petersburg
  - Arktika & Taimyr-class nuclear icebreakers
  - Project 1144.2 Orlan (Kirov) nuclear guided missile cruisers
  - Project 1941 Ural nuclear command ship
- Leninskiy Komsomol Shipyard *(Soviet Shipyard-199)*, Komsomolsk-on-Amur (Far East)
  - 18 x 1st-gen nuclear subs (Echo I & II classes)

Shipyards (continued)

- Sormovo Shipyard (*Factory-112),* Nizhny Novogrod
  - 17 x 2nd-gen nuclear subs (Charlie I & II classes)
  - Special operations submersibles
- Sevmash (*Soviet Shipyard-402*), Severodvinsk (abbreviation of *Severnoye Mashinostroitelnoye Predpriyatie*; "Northern Machine-Building Enterprise")
  - Largest shipbuilding enterprise in Russia, and currently the only shipyard producing nuclear subs
  - 38 x 1st-gen nuclear-powered subs (November, Hotel & Echo II classes & Project 645)
  - 63 x 2nd-gen nuclear-powered subs (Yankee, Delta, Papa, Project 705K Alfa)
  - 27 x 3rd-gen nuclear-powered subs (Oscar, Typhoon, Mike, Akula)
  - 4 x 4th-gen nuclear-powered subs (Borey. Yasen)
- Black Sea Shipyard (aka *Nikolayev South Shipyard* or *Soviet Shipyard No. 444),* Mykolaiv, Ukraine
  - Shipyard has its own design center
  - Project 1143.7 Ulyanovsk-class aircraft carrier. 1st unit of the class was laid down in late 1988. Project cancelled.

Russian nuclear marine infrastructure

Surface Ship Design Bureaus

- Severnoye Design Bureau, St. Petersburg
  - Project 1144.2 Orlan (Kirov-Class) nuclear guided missile cruiser
  - Project 2195.6 - Leader-class nuclear multi-purpose destroyer
- Central Design Bureau Iceberg OJSC, St. Petersburg
  - Project 22220 (LK-60) “universal” icebreaker
  - Also designs transportation icebreakers, nuclear reactor recharging ships, and special purpose vessels for the Navy

Nuclear Icebreaker Operating Organization

- ROSATOMFLOT, St. Petersburg
  - Operator of all Arktika and Taimyr-class icebreakers and Sevmorput LASH (lighter aboard ship) carrier and container ship
  - Future operator of new LK-60-class “universal” icebreakers

Naval Reactor Design Support & Reactor Prototypes

- I.I. Leypunsky Institute of Physics and Power Engineering (IPPE), Obninsk
  - LMR design support for Gidropress & Afrikantov
  - 27/VT LMR prototype reactor
- A.P. Aleksandrov Scientific Research Technological Institute (NITI), Sosnovyy Bor
  - KM-1 LMR prototype reactor
  - KV-1 & KV-2 prototype reactors

Marine Reactor Fuel Manufacturing

- TVEL Fuel Company of Rosatom, Moscow
  - Marine reactor fuel with uranium enrichment < 20% for nuclear-powered icebreakers, floating nuclear power plants
  - Main market is providing fuel for commercial nuclear power plants and research reactors worldwide.
- Machine Building Plant, Elektrostal, (“Mashinostroitelny Zavod,” part of TVEL) Moscow
  - Produces all naval reactor fuel

Russian nuclear marine infrastructure

Management of nuclear vessel decommissioning & waste management

- RosRAO (Moscow)
  - Northern Federal Enterprise for Radioactive Waste Management, SevRAO, (Gremikha, Murmansk Region)
  - DalRAO – Vladivostok Far East region

Nuclear Ship Decommissioning Facilities

- Ship Dismantling:
  - Nerpa Shipyard, Kola Peninsula,
  - Zvyozdochka Shipyard, Severodvinsk
  - Sevmash Shipyard, Severodvinsk (Alfa-class subs)
  - Zvezda Shipyard (Bolshoi Kamen), near Vladivostok

Nuclear Ship Decommissioning Facilities (continued)

- Reactor Section Storage
  - Northern Fleet's on-shore storage site at the Regional Centre for Radioactive Waste Conditioning and Long Term Storage, Sayda Bay, Kola Peninsula
  - On-shore storage of all liquid metal reactor cores at Gremikha Naval Base, Kola Peninsula
  - Far East temporary on-shore storage site at Chazhma Bay, near Vladivostok
  - Afloat storage at Razboynik Bay, near Pavlovsk Bay Submarine Base
  - Pacific Fleet's future Long-Term Storage Facility for reactor compartments of dismantled nuclear vessels, under development at Cape Ustrichny, near Vladivostok

Spent Fuel Processing Facilities

- Mayak Production Association, Chelyabinsk (Siberia)
  - Spent nuclear fuel is transported by rail to the Mayak for storage / reprocessing

Russian nuclear marine infrastructure

Other Nuclear Marine Facilities (Kola)

- Shipyard "Nerpa", Murmansk
  - Repair, maintenance & disposal of nuclear subs of the Northern Fleet
- 82nd factory ship repair, Murmansk
  - Repair nuclear subs, icebreakers & other vessels
- Icebreaker support vessels, Murmansk
  - Fuel transports *Imandra* & *Lotta* are used for refueling and spent fuel handling
  - *Serebryanka* is a tanker used for liquid waste
- Ship Repair Centre "Zvyozdochka," Severodvinsk
  - Repair, modernization & refurbishment of nuclear subs, dismantlement of nuclear subs

Other Nuclear Marine Facilities (Far East)

- Northeast Repair Center "Vilyuchinsk", Far East, near Petropavlovsk
  - Repair of nuclear and diesel subs & other vessels
- Chazhma Ship Repair Facility, Far East, near Vladivostok
  - Functions as a primary service, refueling, and waste storage site for the Pacific Fleet's nuclear subs.
  - Fresh fuel for nuclear subs is stored here on land and also in the PM-74 floating workshop.
- Nuclear support vessels, Far East
  - Technical tankers TNT-4, -16, -49, -50 & *Pinega*
  - Floating workshop PM-74
  - Floating radiation monitoring vessel PKDS-12

Rosatom

Division of Nuclear Munitions Development & Testing and Defense Power Facilities

- ROSATOM's mission is to maintain national interests in defense, nuclear safety and nuclear power by achieving global leadership in advanced technologies, competencies and innovations.

- ROSATOM Group includes the entire marine nuclear fuel cycle:
  - All marine reactor design bureaus:
    - OKBM Afrikantov, NIKIET (Dollezhal Research and Development Institute of Power Engineering), & OKB Gidropress
  - Nuclear icebreaker fleet operator:
    - ROSATOMFLOT
  - Marine nuclear fuel manufacturing:
    - TVEL Fuel Company (non-military fuel)
    - Machine Building Plant (Elektrostal) (naval fuel)
  - Nuclear waste management & naval vessel decommissioning
    - RosRAO (Moscow)
      - SevRAO – Murmansk, Kola region
      - DalRAO – Vladivostok, Far East region
  - Spent fuel reprocessing:
    - Mayak Production Association, Ozersk (near Chelyabinsk)
  - ROSATOM Emergency Service, St. Petersburg

ROSATOM FLOT

НИКИЭТ им.Н.А.Доллежаля JSC «NIKIET»

ОКБМ АФРИКАНТОВ ПРЕДПРИЯТИЕ ГОСКОРПОРАЦИИ «РОСАТОМ»

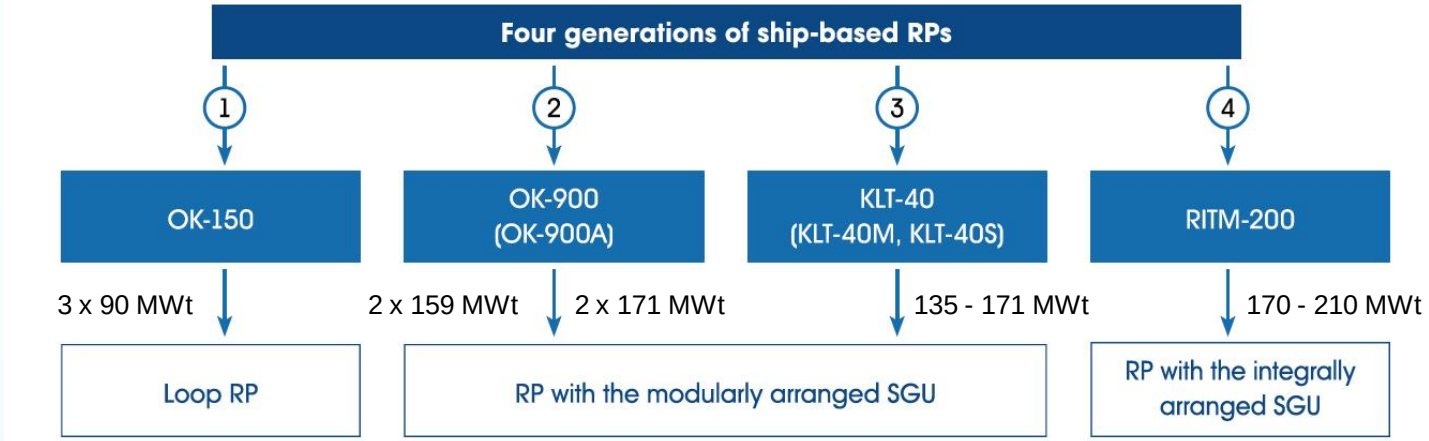
ОКБ «ГИДРОПРЕСС»

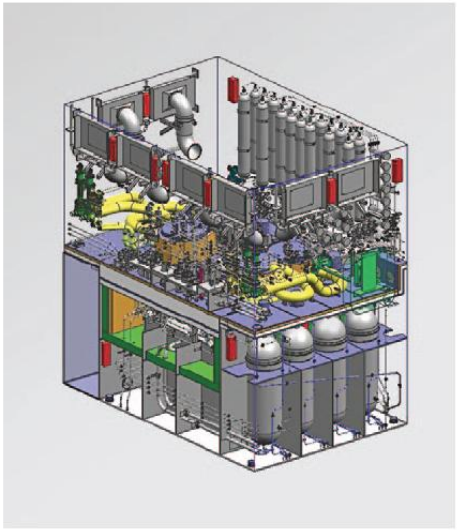
FUEL COMPANY OF ROSATOM TVEL

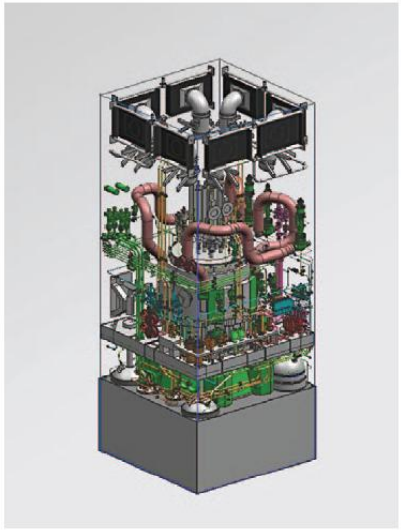
Sources: respective web home pages

OKBM Afrikantov

Marine reactors for icebreakers and floating nuclear power stations (PEB)







Modular arrangement

Integrally arranged SGU

Source: OKBM Afrikantov

OKBM Afrikantov

Marine reactors for naval application

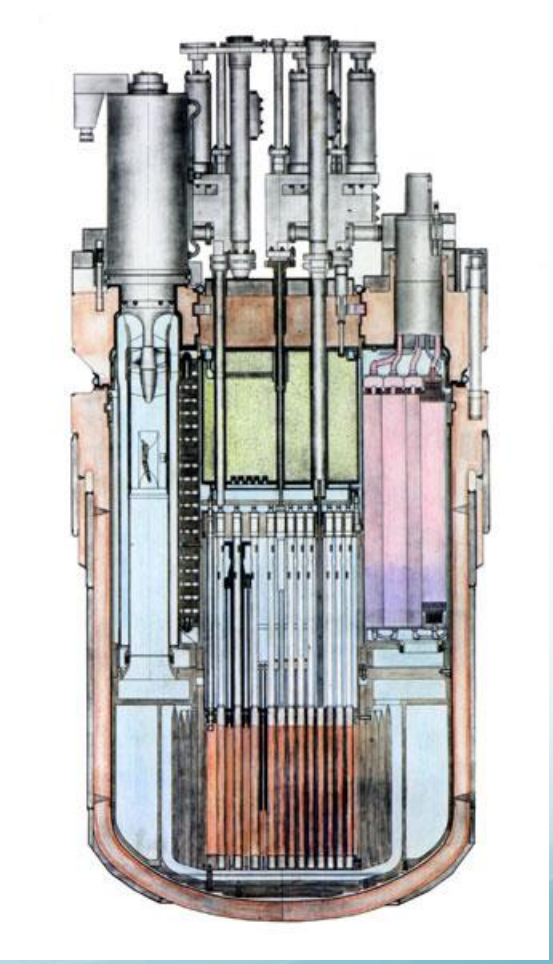
- OK-550 LMR, liquid metal cooled reactor, rated @ 155 MWt
  - Employed on four Project 705 Alpha SSNs, as an alternate to the Gidropress BM-40A LMR.
  - All Alfa-class subs have been decommissioned. Reactors of this type are no longer in use.
- OK-650 PWR, Rated @ 190 – 200 MWt
  - Widely used in modern Russian submarines:
    - SSNs: Project 945 Sierra, Project 971 Akula, Project 685 Mike, and the initial Project 885 Yasen
    - SSBNs: Project 941 Typhoon and Project 955 Borei SSBNs
    - SSGNs: Project 949 Oscar SSGNs
- KN-3 PWR surface ship propulsion plant
  - 2 x VM-16 PWRs, each rated at 300 MWt in a Combined Nuclear and Steam (CONAS) propulsion plant
  - Used in four Project 1144.2 Orlan / Kirov guided missile cruisers.
- OK-900 variant, similar to OK-900A icebreaker nuclear plant.
  - Used on one Project 1941 Ural command ship.
- E-17 PWR (Phoenix KTP-7I)
  - OKBM Afrikantov has been attributed as the designer of a small PWR used on the Losharik-class special operations sub. With propulsion power for Losharik cited at about 10,000 shaft horsepower, reactor power of about 52 MWt would be required.
- OKBM Afrikantov also operates two highly-enriched uranium critical facilities:
  - ST-659 (since 1963) and ST-1125 (since 1975)

NIKIET

Marine reactors for naval applications

- N.A. Dollezhal Scientific Research and Design Institute of Energy Technologies, Moscow
- Since the early 1950s, NIKIET has been one of leading organizations responsible for developing and manufacturing nuclear steam supply systems (NSSS) for Navy vessels, as well as operating and repairing these systems. NIKIET also designed the RBMK-series of early Soviet-era power reactors.
- NIKIET was Chief Designer of VM-A loop-type 70 MWt PWR NSSS.
  - Used on the 1st Russian nuclear submarine, November-class K-3, and more than 50 other 1st-generation Russian subs.
- NIKIET developed the VM-4 (aka OK-300, -350, 700, and 700A) compact 72 – 90 MWt PWR NSSS.
  - Used in more than 140 Russian 2nd-generation subs.
- NIKIET designed the VM-5 compact 177 – 200 MWt PWR NSSS.
  - Used in Project 661 Papa SSGN, fastest Russian sub.

Integral PWR identified by NIKIET as a naval reactor



Source: http://www.nikiet.ru/eng/

NIKIET

Marine reactors for naval applications

- NIKIET has been attributed as the designer of small nuclear power plants (most likely PWRs) for small special operations subs:
  - Project 1851/18511 Nelma / Paltus, 10 MWt (est.) reactor
  - Project 1910 Kashalot, 52 MWt (est.) reactor
- NIKIET designed VAU-6, a small, hermitically-sealed auxiliary nuclear power plant (ANPP) rated at about 2 MWt, that can serve as an auxiliary electric power source for diesel-electric submarines.
  - Used on diesel-electric sub B-68, delivered 600 kWe (net).
  - Similar unit likely used on diesel-electric sub B-90.
- NIKIET is one of leading Russian organizations for decommissioning the nuclear power plants on submarines and surface ships and cleanup and rehabilitation of nuclear and radiation hazardous sites.

OKB Gidropress

Marine reactors for naval applications

- VT-1 LMR (lead-bismuth cooled)
  - First Russian submarine liquid metal cooled reactor
  - Employed on the Project 645 K-27 SSN which entered service in 1963.
    - 24 May 1968: K-27 reactor accident at sea.
    - Summer 1981: VT-1 reactor dumped in the Kara Sea
- BM-40A LMR (lead-bismuth cooled)
  - Employed on three Project 705K Alpha SSNs, as an alternate to the OKBM Afrikantov OK-550 LMR
    - All Alfa-class subs have been decommissioned. Reactors of this type are no longer in use.

I.I. Leypunsky Institute of Physics and Power Engineering (IPPE)

- LMR design support for Gidropress & OKBM Afrikantov
- 27/VT LMR prototype reactor constructed at IPPE, Obninsk
  - Construction started in 1953; commissioned in Jan 1959
  - This was a ground-based submarine prototype of the VT-1 reactor design that was to be installed on submarine K-27.
  - 27/VT reactor rated at 70 MWt, with is a full-scale submarine engineering section, including reactor, steam generator, pumps, primary and secondary pipelines, turbine plant, control system and other service systems.
  - Constructed to support engineering development of nuclear steam supply system (NSSS) equipment and systems, refinement of reactor plant operational conditions and control, and for submarine crew training.
  - Prototype operated for 17 years with two different cores.
- Follow-on LMR prototype reactor installed at A.P. Aleksandrov Scientific Research Technological Institute (NITI)
- IPPE also operates four critical facilities:
  - BFS-1 (since 1962)
  - BFS-1 (since 1969)
  - FS-1M (since 1970)
  - OKUYAN (since about 2000)

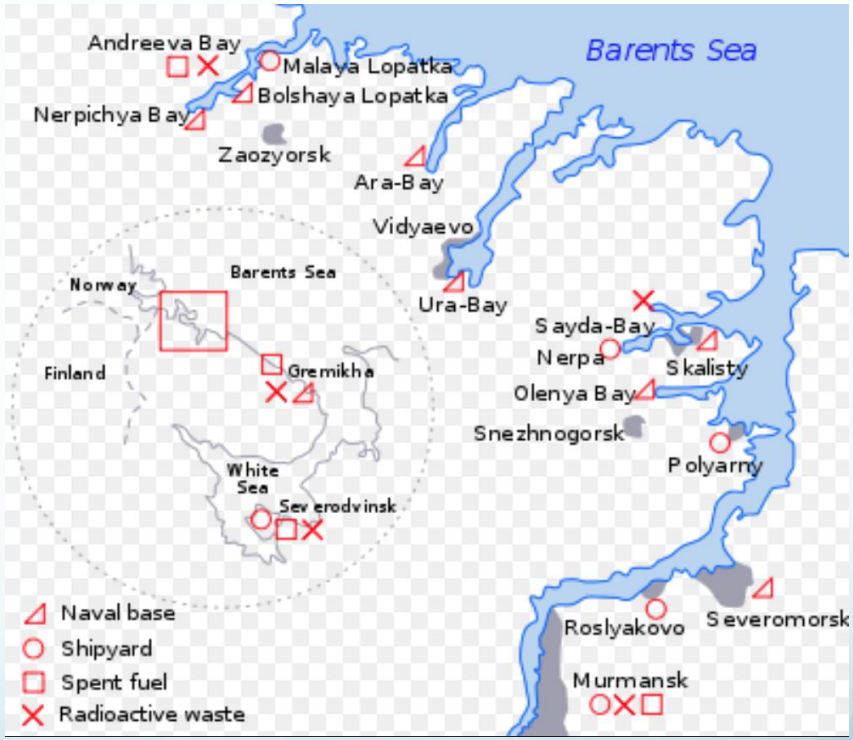
A.P. Aleksandrov Scientific Research Technological Institute (NITI)

- Established in 1962, initially as a subsidiary of the Kurchatov Institute
  - NITI has worked independently since 1979.
- Responsible for designing, testing, and supporting nuclear power and naval propulsion reactors as well as their systems and parts.
- NITI currently operates two naval reactor prototypes and training facilities:
  - KV-1: initial criticality 1975
  - KV-2: initial criticality 1995
- NITI previously operated the second full-scale liquid metal reactor (LMR) prototype; likely to have been the type used in Alfa-class subs.
  - KM-1: 1978

Russian naval bases for nuclear vessels

- Russian Navy is comprised of four fleets:
  - Northern Fleet (2/3 of the Russian Navy),
  - Pacific Fleet,
  - Baltic Fleet, and
  - Black Sea Fleet.
- Northern Fleet (mid-2015):
  - Gadzhiyevo Naval Base, Skalisty
    - 31st Submarine Division of 6 x Delta IV SSBNs + 1 x Borei SSBN
    - 24th Submarine Division of 6 x Akula I / II SSNs
    - 1 x Yasen SSN is believed to be based here
  - 7th Submarine Division, Vidyaevo
    - 3 x Sierra I / II SSNs and 1 x Victor III SSN
  - Oscar-class SSGNs are based at Ara Bay
    - 3 x Oscar-class subs are believed to be based here
  - Special operations subs (Kashalot & Losharik) and PLA-carriers ("motherships") are based at Olenya Bay
  - Typhoon-class SSBN *Dimitry Donskoy* and two reserve Typhoon SSBNs are at Nerpichya Bay
  - The Kirov-class guided missile cruiser (CGN) *Pyotr Velikiy* is based at Severomorsk, which is the Northern Fleet's main administrative base.

Northern Fleet naval bases & nuclear facilities



Source: https://commons.wikimedia.org

Russian naval bases for nuclear vessels

- Pacific Fleet (mid-2015)
  - Kamchatka Rybachiy Nuclear Submarine Base (Krasheninnikov Bay, south of Petropavlovsk)
    - SSBNs are in the 16th Squadron:
      - 2 x Borei SSBNs
      - 2 x Delta III SSBNs
    - Also at the sub base:
      - 5 x Oscar II SSGNs
      - 4 x Akula I SSNs
  - Pavlovsk Bay Submarine Base (eastern shore of Strelok Bay, near Bolshoy Kamen)
    - Once the home of the 26th nuclear submarine division, which has been disbanded.
    - Now home port of several PM-124 class (PM-80, PM-125, PM-133) nuclear service ships and retired submarines awaiting final processing.
    - In Dec 1985, Project 675 Echo II sub K-431 had a reactor accident while returning to Pavlovsk Bay. K-431 is now laid up at the naval base.
- Baltic Fleet & Black Sea Fleet do not have any nuclear-powered vessels.

Pacific Fleet naval bases & nuclear facilities

Source: Center for Nonproliferation Studies

Russian marine reactors

Four generations of Russian submarine reactor plants

- 1st generation:
  - VM-A PWR: All “HEN” (Hotel-Echo-November) 1st-generation nuclear subs
  - VT-1 LMR: 1-of-a-kind Project 645 sub K-27
- 2nd generation:
  - OK-300 (VM-4 series) PWR: All Victor SSNs
  - OK-350 (VM-4 series) PWR: All Charlie SSGNs
  - OK-700 (VM-4 series) PWR: All Yankee & Delta SSBNs
  - OK-550 LMR: All Project 705 Alfa SSNs
  - BM-40 LMR: All Project 705K Alfa SSNs
- 3rd generation:
  - VM-5 PWR: 1-of-a-kind Project 661 Papa SSGN
  - OK-650 PWR: All Sierra, Mike & Akula SSNs, Oscar SSGN and Typhoon SSBN. Also the initial Project 885 Yasen multi-purpose SSN and the three Project 955 Borei SSBN.
- 4th generation:
  - The specific reactor and design bureau have not been clearly identified
    - Several sources claim the Project 885 Yasen-M multi-purpose SSN will have a 4th generation reactor, which may be a PWR named KPM-6
    - The Project 955A improved Borei SSBNs also may be a candidate for a 4th generation reactor.

Russian submarine reactor plants

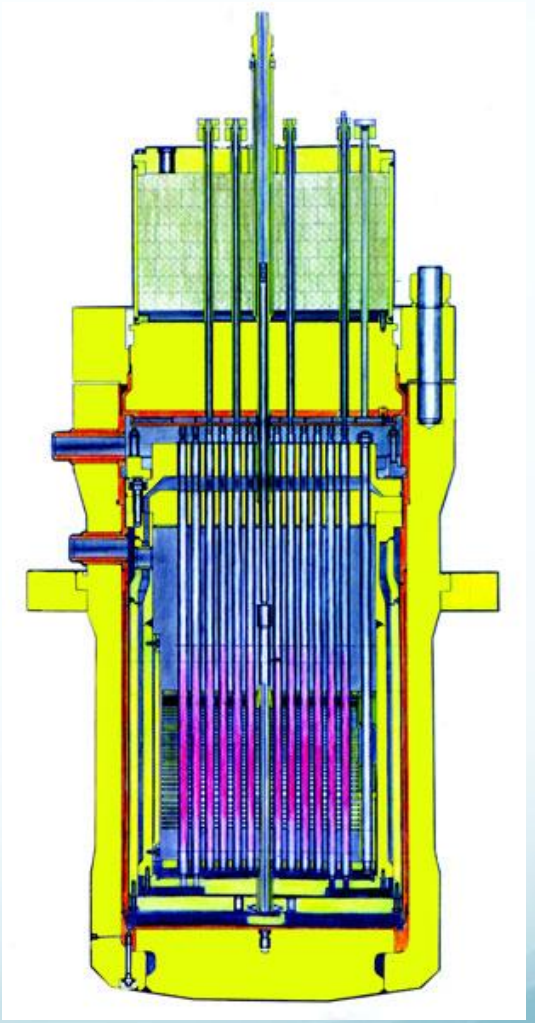
Reactor system	Reactors	Design bureau	Power (MWt)	Initial ops	Application
---	2 x VM-A PWRs	NIKIET	70	1958	All “HEN” (Hotel-Echo-November) 1st-generation nuclear subs; Project 658, 658M & 701 Hotel I, II & III SSBNs; Project 659 & 675 Echo I & II SSGNs, & Project 627 & 627A November SSNs.
---	2 x VT-1 LMR	Gidropress	72	1963	1-of-a-kind Project 645 sub K-27
OK-300	2 x VM-4 PWRs	NIKIET	72	1967	Project 671& 671RT Victor I & II SSNs
OK-300A	2 x VM-4A PWRs	NIKIET	75	1972	Project 671RTM Victor III SSNs
OK-350	1 x VM-4-1 PWR	NIKIET	89	1968	Project 670 & 670M Charlie I & II SSGNs
OK-700	2 x VM-4-2 PWRs	NIKIET	90	1964	Project 667A, 667AU & 667AM Yankee I & II SSBNs,
OK-700	2 x VM-4B PWRs	NIKIET	90	1964	Project 667B & 667BD Delta I & II SSBNs
OK-700A	2 x VM-4S PWRs	NIKIET	90	1976	Project 667BDR Delta III SSBNs
OK-700A	2 x VM-4SG PWRs	NIKIET	90	1984	Project 667BDRM Delta IV SSBNs
OK-550	1 x OK-550 LMR	Afrikantov	155	1976	Project 705 Alfa SSN
BM-40A	1 x BM-40A LMR	Gidropress	155	1977	Project 705K Alfa SSN

Russian submarine reactor plants

Reactor system	Reactors	Design bureau	Power (MWt)	Initial ops	Application
---	2 x VM-5M PWRs	NIKIET	177	1976	1-of-a-kind Project 661 Papa SSGN, fastest Russian sub
OK-650	2 x PWRs	Attributed to Afrikantov	190	1981	Project 941 Typhoon SSBN
OK-650B	1 x PWR	Attributed to Afrikantov	190	1987	Project 945 & 945A Sierra I & II SSNs; Project 971, 971i, 971U & 971M Akula I, Ii, II & III
OK-650B	2 x PWRs	Attributed to Afrikantov	190	1982	Project 949 & 949A Oscar I & II SSGNs; Project 955 Borei SSBNs
OK-650B3	1 x PWR	Attributed to Afrikantov	190	1984	1-of-a-kind Project 685 Mike SSN, very deep diving sub
OK-650V	1 x PWR	Attributed to Afrikantov	190	2016 expected	Project 955A Borei II SSBNs.
OK-650V	1 x PWR	Attributed to Afrikantov	200	2013	Project 885 Yasen; 3rd generation nuclear plant
KPM-6	1 x PWR	Not known	200 (est)	2016 expected	Project 885 Yasen-M SSNs; 4th generation nuclear plant
---	Small PWR	Attributed to NIKIET	10 MWt (est.)	1986	Project 1851/18511 Nelma / Paltus small special operations subs
---	Small PWR	Attributed to NIKIET	52 MWt (est.)	1986	Project 1910 Kashalot small special operations subs
	E-17	Attributed to Afrikantov	52 MWt (est)	2003	Project 10831 Losharik small special operations subs
---	VAU-6	Attributed to NIKIET	2 MWt (est)	1971	Hermitically-sealed auxiliary nuclear power plant (ANPP) used on diesel-electric subs B-68 and B-90

VM-A

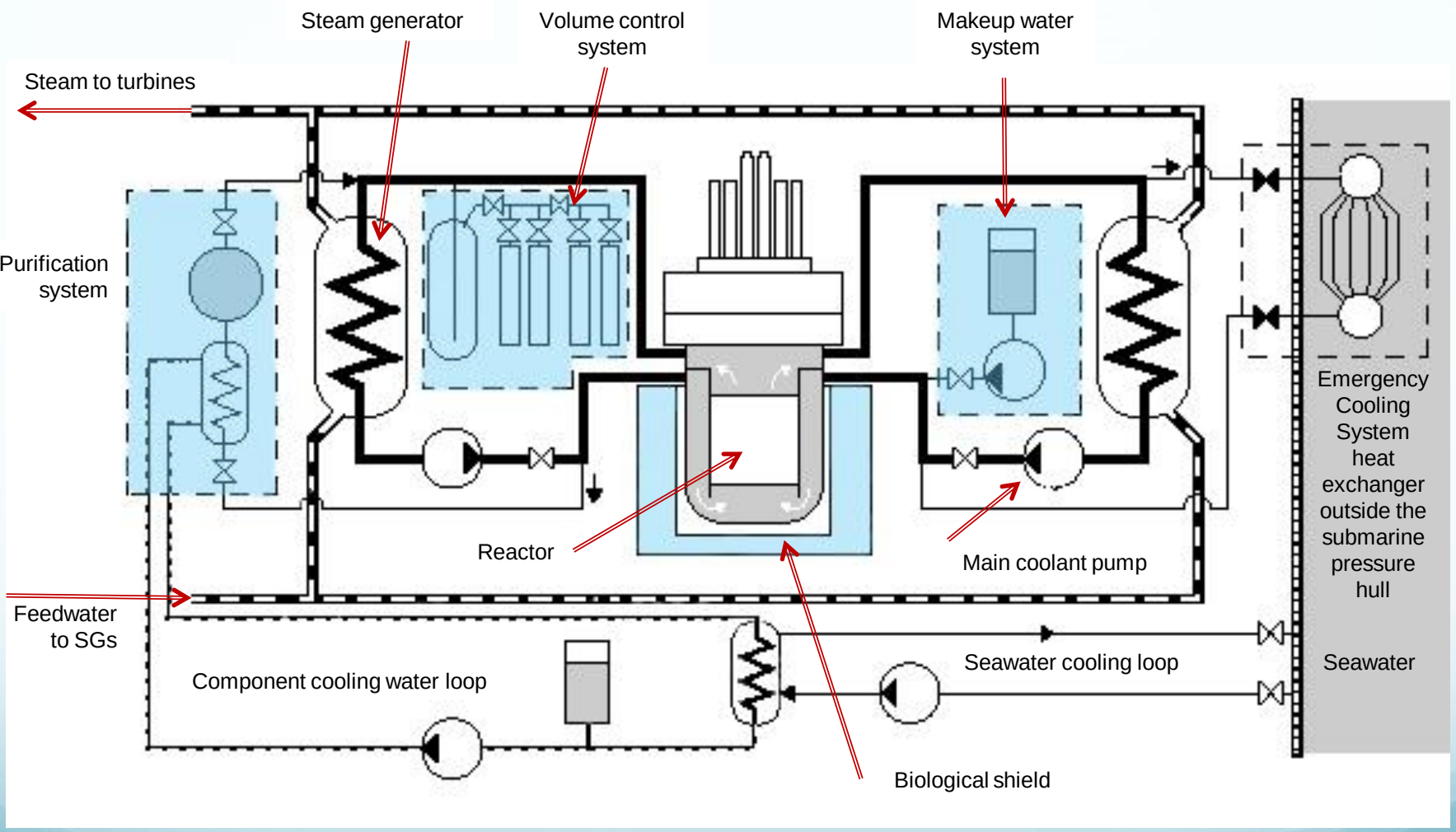
- Pressurized water reactor for 1st-generation Soviet submarine applications.
  - Developed by NIKIET
  - Loop-type primary coolant system
  - Produced from 1957 to 1968.
- Reactor:
  - Rated at 70 MWt
  - 20% enriched Uranium
- Short service life of the steam generators caused radioactive primary coolant leakage into the secondary (steam) system.
- Applications: 2 x VM-A reactors on each of the following submarines:
  - Project 627 / 627A November-class fast attack subs
    - Submarine K-3 made the first Soviet underway on nuclear power on 4 June 1958.
  - Project 659 & 675 Echo-class cruise missile subs
  - Project 658, 658M & 701 Hotel-class ballistic missile subs



Source: http://www.nikiet.ru/eng/

VM-A

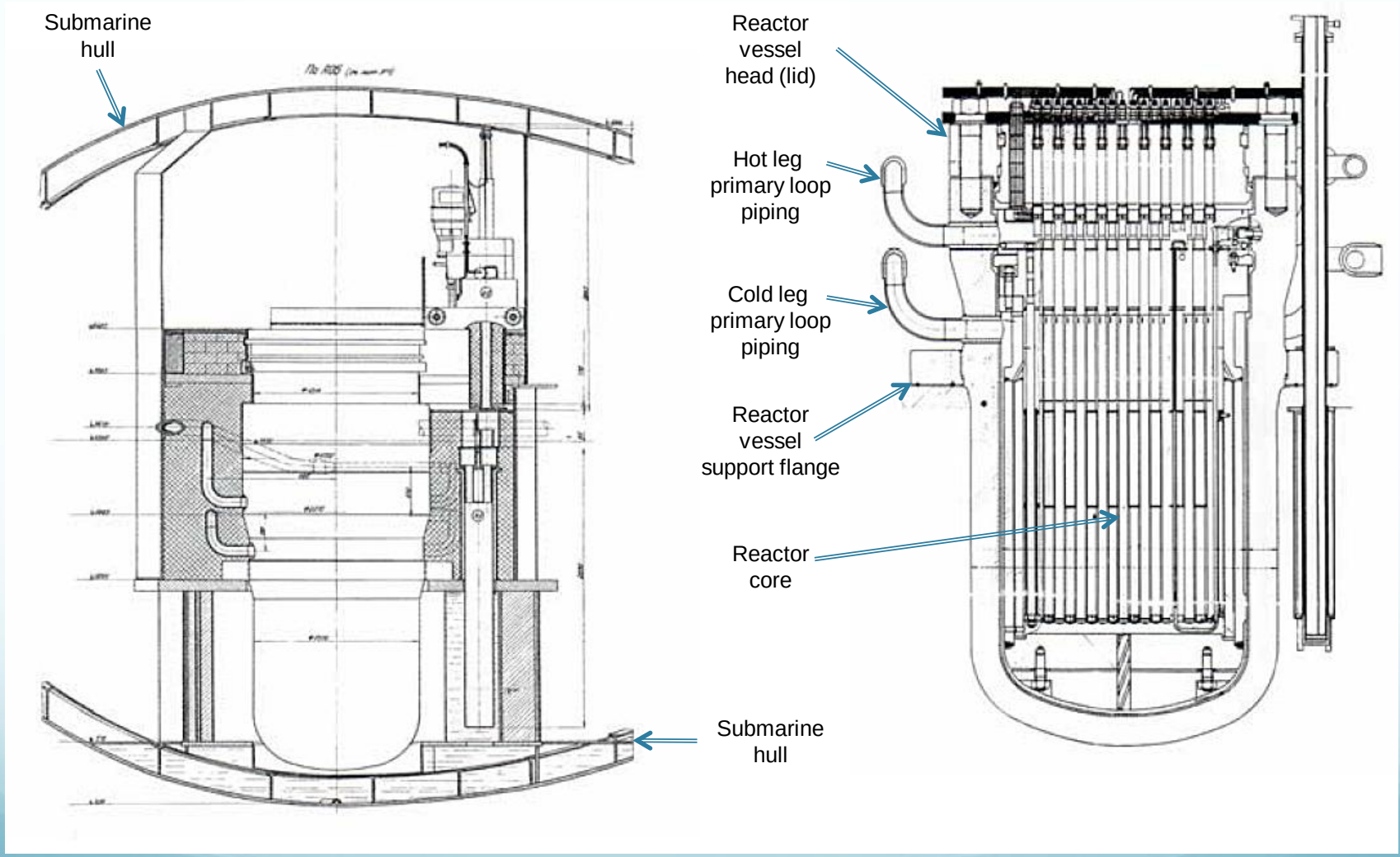
Process flow diagram for one reactor



Source: adapted from spb.org.ru/bellona

VM-A

Installation on a 1st-generation nuclear submarine



Source: adapted from NKS-138

VM-A

Four accidents in which a VM-A was irreparably damaged

- K-19 Hotel I-class SSBN, 4 Jul 1961, at sea
  - A primary system leak at sea resulted in inadequate cooling of one reactor. Makeshift repairs to restore some cooling succeeded, but required work in the reactor compartment and released radioactive steam and gas throughout the sub.
  - Eight crew died within a month after the accident.
  - The reactor compartment was completely removed and replaced. K-19 was converted to a Hotel II and returned to service in 1967
  - The damaged reactor compartment was dumped in Abrosimova Bay (east coast of Novaya Zemlya) in the Kara Sea

- K-11 November-class SSN, 7 & 12 Feb 1965, in the shipyard at Severodvinsk
  - On 7 Feb 1965, in preparation for refueling, the reactor vessel head was lifted, apparently with the control rods still attached. Releases of radioactive steam were observed, radiation monitors indicated high radiation levels, and all personnel were withdrawn. Five days later, the vessel head was lifted again, with similar results plus a fire broke out aboard the sub.
  - Eight workers received significant radiation doses, but there were no fatalities
  - The reactor compartment was removed, partially decontaminated and dumped in Abrosimov Bay in the Kara Sea in 1966
  - A new reactor was installed and K-11 returned to service in Aug 1968

VM-A

Four accidents in which a VM-A was irreparably damaged

- K-431 (formerly K-31) Echo II-class SSGN, 10 Aug 1985, Chazhma Bay naval facility, Vladivostok
  - After loading a new reactor core, the vessel head was improperly positioned and had to be adjusted. The vessel head, with control rods attached, was lifted too far, resulting in a prompt criticality and steam explosion.
  - The explosion expelled the new core, severely damaged the reactor compartment and adjacent machinery spaces, and partially destroyed dockside facilities supporting the refueling. A fire broke out on the submarine.
  - Radioactive contamination of the surrounding area was modest because the accident occurred in a new core and the only fission products released were those generated during the criticality.
  - There were ten fatalities from the steam explosion. It has been reported that 290 persons received radiation doses of more than 50mSv (5 Rem), 10 of whom suffered from acute radiation sickness.

- K-192 (formerly K-131) Echo II-class SSGN, 25 Jun 1989, at sea
  - One reactor plant developed a primary coolant leak.
  - Makeup water was added first from the submarine's water supply, then from a Soviet freighter that came to assist, and later from a Soviet Navy support ship.
  - The cooling water supply was temporarily lost and one reactor was severely damaged before the cooling water supply could be restored.
  - K-192 returned to port by was never operated again. Doses to the crew were on the order of 40mSv (4 Rem). There were no fatalities.

VT-1

(aka VT RM-1, 627/VT)

- Liquid metal-cooled (lead-bismuth) reactor for 1st-generation Russian submarine applications.
  - Developed by Experimental and Design Organization (OKB) Gidropress and I.I. Leypunsky Institute of Physics and Power Engineering (IPPE), Obninsk
  - Design work started in 1952
  - 27/VT prototype reactor to validate the reactor design was constructed at IPPE, Obninsk, and commissioned in January 1959
- Reactor:
  - LMR core rated at 73 MWt
    - Core diameter; 0.769 m (2.52 ft); core height: 0.853 m (2.80 ft)
    - 90% enriched uranium fuel in the form of uranium-beryllium (U-Be) alloy (7 – 16% U) sintered with BeO into ceramic fuel pellets clad in stainless steel
  - Lead-bismuth primary coolant solidified if temperature fell below 125 °C (257 °F), and if this happened, the reactor could be damaged.
    - The primary system needed supplementary heating when the reactor was shutdown.
  - Primary system parameters: pressure about 20 kg/cm^2 (284 psi), reactor outlet temp 440°C (824°F), reactor inlet temp 235°C (455°F)
  - Secondary system superheated steam parameters: pressure 38 kg/cm^2 (540 psi), temperature 385°C (725 °F)
- Applications:
  - 2 x VT-1 reactors were installed on Project 645 submarine K-27, which was a one-of-a-kind variant of the November-class SSN.
    - K-27 first deployed to sea in 1963
    - Reactor accident aboard K-27 occurred on 24 May 68

VT-1

(aka VT RM-1, 627/VT)

- Operational issues:
  - “Slag” buildup in the reactor noted in inspection of the 27/VT LMR prototype at IPEE
  - Coolant freezing occurred in some sections of the primary system
  - Primary system leaks release Polonium Po-210 (alpha emitter, 13.8 day half-life) and lead vapor
- Russians reported that they froze the undamaged core from K-27, kept it in that state for two years, then thawed the reactor core and successfully operated the reactor at high power.

VM-4

(OK-300, OK-350, OK-700, OK-700A)

- Pressurized water reactor for 2nd generation Russian sub applications.
  - Developed by NIKIET
  - Loop-type primary coolant system, but with reduced volume through introduction of compact pipe-within-pipe "loop" connections between the reactor vessel and the steam generators and primary coolant pumps.
- Reactor:
  - Rated at 72 – 90 MWt
  - 20% enriched Uranium
- Applications:
  - OK-300: 2 x VM-4 or 4A reactors @ 72 MWt on:
    - Project 671 Victor I, II & III-class fast attack subs
  - OK-350: 1 x VM-4-1 reactor @ 89 MWt on:
    - Project 670 Charlie I & II-class cruise missile subs
    - Some sources reported that one Project 705 Alfa-class fast attack sub was re-engined with a VM-4 reactor (original lead-bismuth cooled reactor removed and replaced by a VM-4 PWR)
  - OK-700: 2 x VM-4-2 or VM-4B reactors @ 90 MWt on:
    - Project 667 Yankee I & II-class ballistic missile subs
    - Project 667 Delta I & II class ballistic missile subs
  - OK-700A: 2 x VM-4S or VM-4SG reactors @ 90 MWt on:
    - Project 667 Delta III & IV-class ballistic missile subs
- Reactor accidents: From 1967 to the present, there have been three major accidents involving these PWRs, on the submarines K-140 in 1968, K-320 in 1970 and K-314 in 1983

VM-4

Accidents in which a VM-4 was irreparably damaged

- K-314, Victor I SSN, 10 August 1985, dockside in Chazhma Bay, near Vladivostock:
  - One of two reactors on the K-314 Victor-I class submarine was being refueled at Chazhma Bay, near Vladivostock.
  - A crane used to reposition the reactor head failed, dropping the head and triggering a prompt criticality of a new core. A steam explosion ejected the core. There were 10 fatalities from the steam explosion.
  - Significant radiation doses to many workers and significant release of radioactivity to the environment.
  - The sub was heavily damaged and never operated again.
- K-192 (formerly K-131), 25 Jun 1989, at sea, in the Barents Sea.
  - Primary coolant leak from one reactor, which was severely damaged before the cooling water supply could be restored.
  - The sub returned to port by never operated again.

VM-5

- Pressurized water reactor for 3rd generation Russian submarine applications.
  - Developed by NIKIET.
  - Believed to be an integral primary system design.
  - Believed to be able to operate on natural circulation alone at lower power levels.
- Applications:
  - VM-5M reactor rated @ 177 MWt:
    - One-of-a-kind Project 661 Papa-class cruise missile sub had 2 x VM-5M reactors installed, delivering a total of 80,000 shp to two shafts.
      - K-222 is the world's fastest sub @ 44.7 kts.
  - The OK-650 submarine reactor plant is attributed to OKBM Afrikantov. However, some sources incorrectly suggest that the OK-650 uses VM-5 reactors.

OK-550 and BM-40A

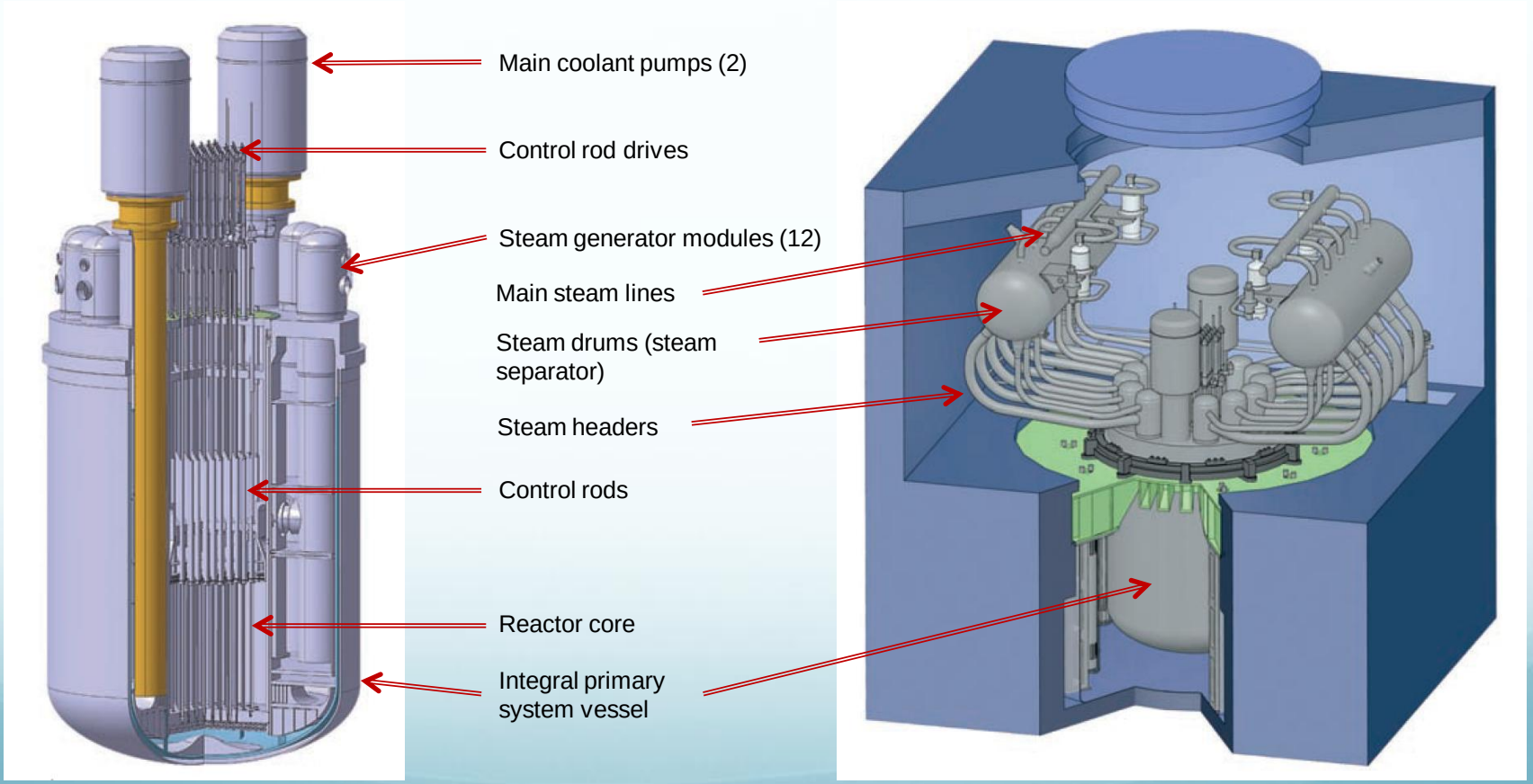
- Two liquid metal-cooled (lead-bismuth) reactor designs were developed to similar specifications for use on Project 705 / 705K Alfa submarines.
  - The two liquid metal cooled reactor plant designs, OK-550 & BM-40A, were smaller packages than a comparable PWR.
  - In both reactor plants, the reactor core was intended to be loaded or unloaded as a "Removable Reactor Core Unit" (RRCU).
    - Each RRCU included the core with fully inserted neutron-absorbing emergency protection rods, reflector, and some shielding material
  - Used highly-enriched uranium fuel.
    - Uranium-beryllium fuel in the form of ceramic fuel rods, was manufactured at the Ulba Metallurgical Plant in Kazakhstan into the 1970s.
    - Each reactor is believed to have contained about 200 kg (90.9 lb) of HEU
    - After the breakup of the Soviet Union, and with the cooperation of the Kazakhstan government, *"Project Sapphire,"* conducted in 1994, recovered a large quantity of HEU in various forms from the Ulba Metallurgical Plant and transported it to Oak Ridge National Laboratory to be blended down for commercial reactor fuel.
  - An LMR core operates at a higher power density and thermal efficiency than a PWR, with a a low-pressure primary system
  - Rated @ 155 MWt
  - Long-life core, possibly up to 7 years

OK-550 and BM-40A

- OK-550 was developed by OKBM Afrikantov, Nizhniy Novogrod
  - Three secondary (steam-side) loops
  - Application: 1 x OK-550 reactor on four Project 705 Alfa-class submarines built in Severodvinsk
- BM-40A was developed by OKB Gidropress, Leningrad (St. Petersburg)
  - Two secondary (steam-side) loops
  - Application: 1 x BM-40A reactor on three Project 705K Alfa-class submarines built in the Admiralty Shipyard in Leningrad
- I.I. Leypunsky Institute of Physics and Power Engineering (IPPE), Obninsk supported both reactor developers.
- A.P. Aleksandrov Scientific Research Technological Institute (NITI) operated the KM-1 full-scale liquid metal reactor prototype

BM-40A and SVBR-75 are related

- While the design of the 155 MWt BM-40A is not known, Gidropress makes the following claim regarding their land-based SVBR lead-bismuth cooled reactor design:
  - "SVBR-type reactors were designed within the framework of the conversion of unique Russian technology for lead-bismuth coolant marine reactors. Two land prototypes and eight submarines reactor with lead-bismuth coolant have been constructed. Total operating time of the installations is about 80 reactor-yrs".
- The SVBR-75, below, is rated at 280 MWt. General arrangement and some process parameters may be similar to a BM-40A: primary temperatures: cold leg 320 °C (608 °F) / hot leg 480 °C (896 °F).



Source: Gidropress

OK-650 & variants

(OK-650W, OK-650B, OK-650B3, OK-650V)

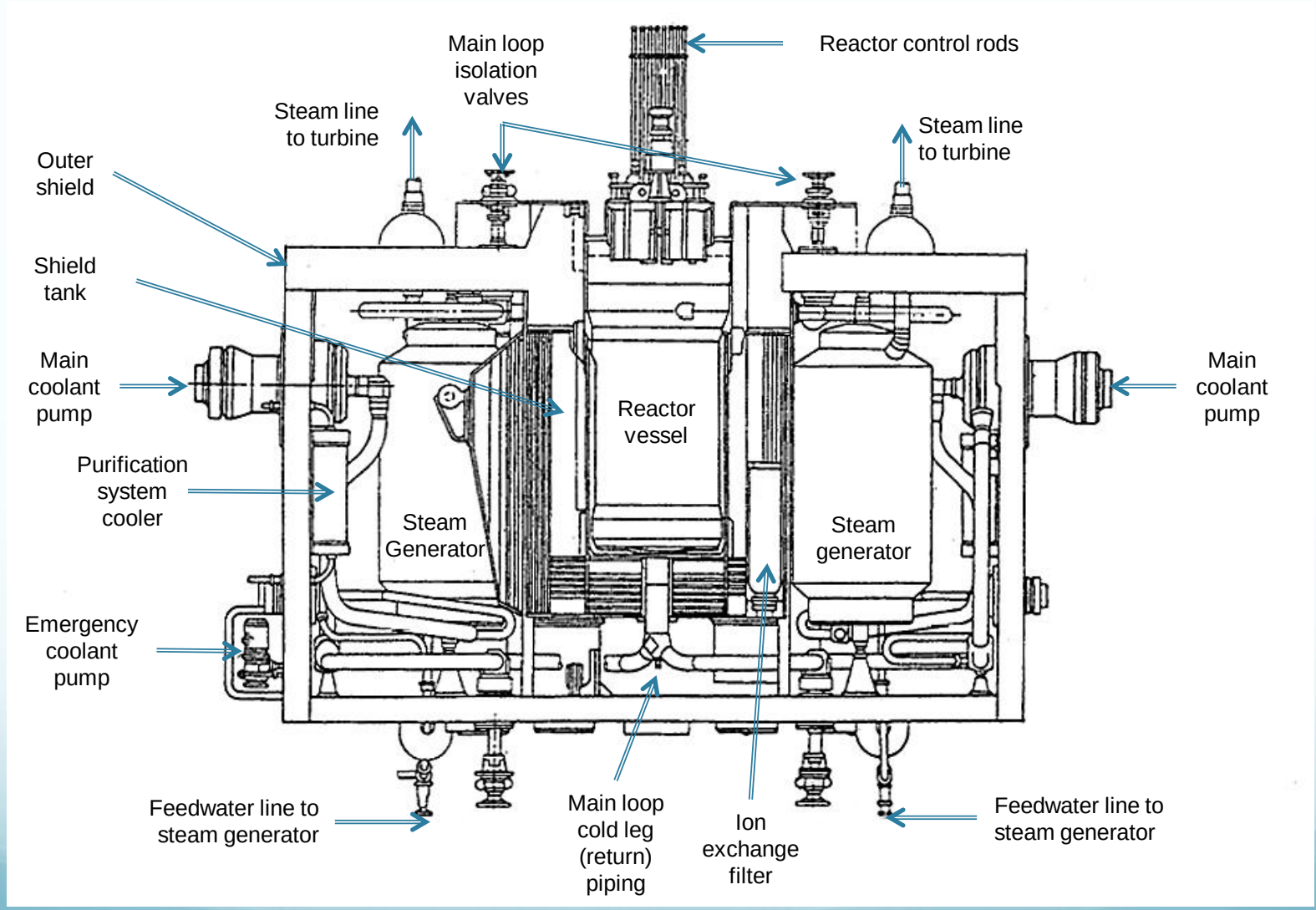
- Pressurized water reactor for 3rd generation Russian submarine applications.
  - Generally attributed to OKBM Afrikantov.
  - However, some sources incorrectly suggest that the reactor used in OK-650 plants is a VM-5, which was developed by NIKIET.
- Reactor:
  - Rated at 190 – 200 MWt
  - Uranium enrichment 20 – 45%
  - Primary coolant system operates on natural circulation. Pumps are only needed for high-power operation.
- Applications:
  - OK-650W: 2 x PWRs rated @ 190 MWt on:
    - Project 941 Typhoon-class SSBNs. These are the largest subs ever built.
  - OK-650B: 2 x PWRs rated @ 190 MWt on:
    - Project 949 Oscar I & II-class SSGNs
    - Project 955 Borei-class SSBNs
  - OK-650B & 650B3: 1 x PWR rated @ 190 MWt on:
    - Project 945 Sierra I & II-class SSNs (OK-650B)
    - Project 705 Akula I, II & III-class SSNs (OK-650B)
    - Project 685 Mike-class SSNs (OK-650B3)
  - OK-650V: 1 x PWR @ 200 MWt on:
    - Project 885 Yasen-class multi-purpose subs
    - Project 955A Borei II SSBNs.

Russian surface ship reactor plants

Reactor system	Reactors	Design bureau	Power (MWt)	Initial ops	Application
OK-150	3 x PWR	Afrikantov	90	1959	*Lenin* icebreaker, 1st reactor plant. Powered the world's 1st nuclear surface ship.
OK-900	2 x PWR	Afrikantov	159	1970	*Lenin* icebreaker, replacement reactor plant.
OK-900A	2 x PWR	Afrikantov	171	1975	Six Arktika-class deep-water icebreakers
KLT-40	1 x PWR	Afrikantov	135	1988	*Sevmorput* LASH icebreaking cargo ship
KLT-40M	1 x PWR	Afrikantov	171	1989	Two Taimyr-class icebreakers
KLT-40S	1 x PWR	Afrikantov	150	2015 expected	Floating nuclear power station *Akademik Lomonozov*
RITM-200	1 x PWR	Afrikantov	170 - 210	2020 Expected	LK-40-class "universal" icebreakers
KN-3	2 x VM-16 PWRs	Afrikantov	300	1980	Usually described as a Combined Nuclear and Steam (CONAS) plant. Used on four Project 1144.2 Orlan (Kirov)-class CGNs, and likely intended for the Project 1143.7 Ulyanovsk-class aircraft carrier. Sometimes referred to as an OK-900B, which suggests that KN-3 may be based on OKBM Afrikantov's OK-900A modular PWR plant used on the Arktika-class icebreakers.
OK-900 variant	2 x PWR	Afrikantov	171 (est)	1989	One Project 1941 (Titan) "Ural" command, control & communications ship; similar to the Arktika-class icebreaker OK-900A nuclear reactors.

OK-150

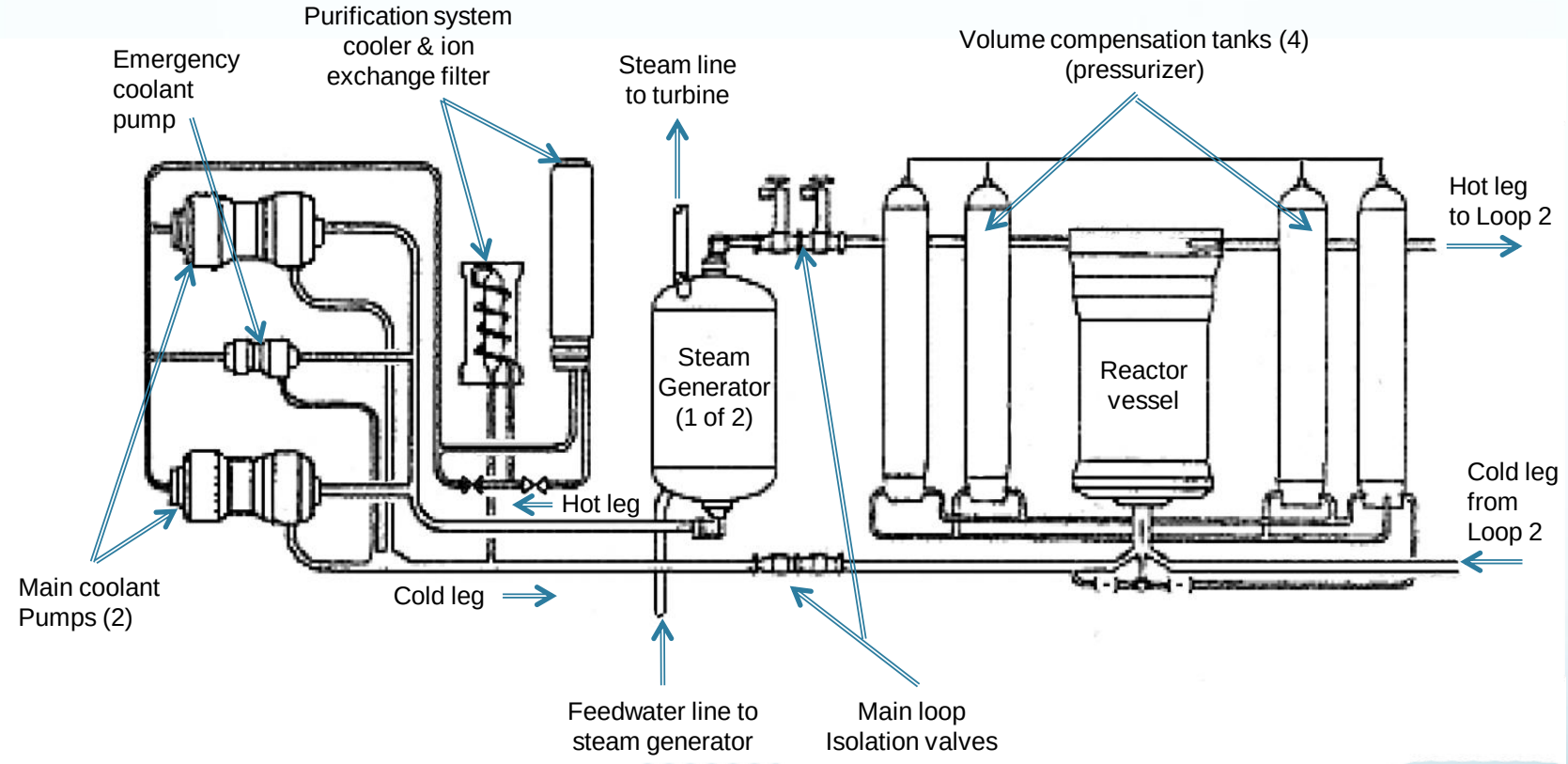
(typical of three reactor units on Lenin)



Source: adapted from atomicpowerreview.blogspot.com

OK-150

Process flow diagram for one of two primary loops for a single reactor



Adapted from Nordic Nuclear Safety, research report NKS-138

OK-150

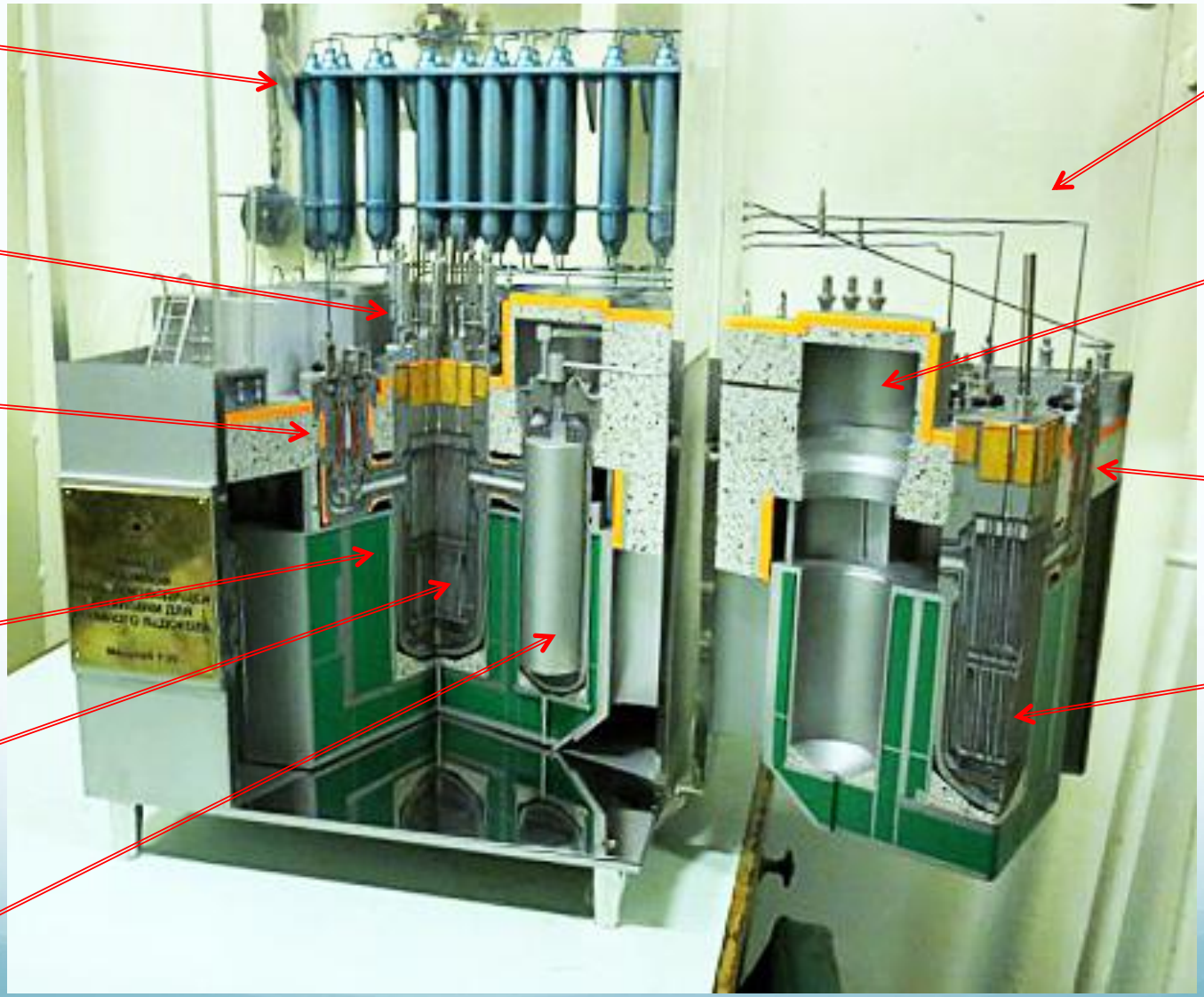
- Reactor plant developed by Russian Special Design Bureau for Mechanical Engineering (OKBM) Afrikantov
  - 3 x 90 MWt loop-type PWRs
- Primary system for each reactor consisted of 2 primary system loops:
  - Each loop with 1 x steam generator, 2 x main coolant pumps (one operating, one in standby), 1 x emergency coolant pump (in standby), main loop isolation valves, and a water purification loop with cooler and ion exchange filter
  - Volume compensation system (4 x pressurizer tanks)
  - Primary system cold loop (return) piping connects to the bottom of the reactor vessel.
- Reactor:
  - Fuel: 5% enriched uranium in ceramic uranium dioxide (UO_2) fuel, with various cladding (Zr, stainless steel, Zr-Nb alloy)
    - Fuel load: 85 Kg
    - Core life was 18 - 20,000 MWd (megawatt-days), 200 – 222 full-power days, for the first core.
  - Core dimensions: 1.58 m high by 1 m diameter
- In “single-loop” mode (one primary loop out of service), the reactor is allowed to operate at up to 50 MWt with 1 x main coolant pump + the emergency coolant pump operating.
- Application: Used only on the icebreaker Lenin

OK-900 and variants

- Reactor plant developed by Special Design Bureau for Mechanical Engineering (OKBM) Afrikantov
  - 2 x modular PWRs
- Each modular PWR has 4 primary system “loops”:
  - Pipe-inside-pipe (co-axial) load-bearing "loop" piping connects top of reactor vessel to each steam generator.
- Reactor fuel:
  - 55 - 90% enriched uranium in metallic U-Zr alloy fuel with Zr cladding.
  - Fuel burn-up in early cores 29–38,000 MWd (megawatt-days); increased to 88–96,000 MWd in later re-load cores
- A containment structure encloses the reactor system:
  - Release of radioactive material from the primary system is contained
  - Containment is designed to flood if vessel sinks, thereby maintaining structural integrity and containment function.
- Applications:
  - OK-900 with 2 x 159 MWt PWRs: Installed on icebreaker Lenin, replacing the original OK-150 nuclear power plant.
  - OK-900A with 2 x 171 MWt PWRs: Installed in all six Arktika-class deep-water icebreakers, with improved versions in the last three ships in the class.
  - An OK-900 variant also is likely installed on the Project 1941 *Ural* command ship.

OK-900

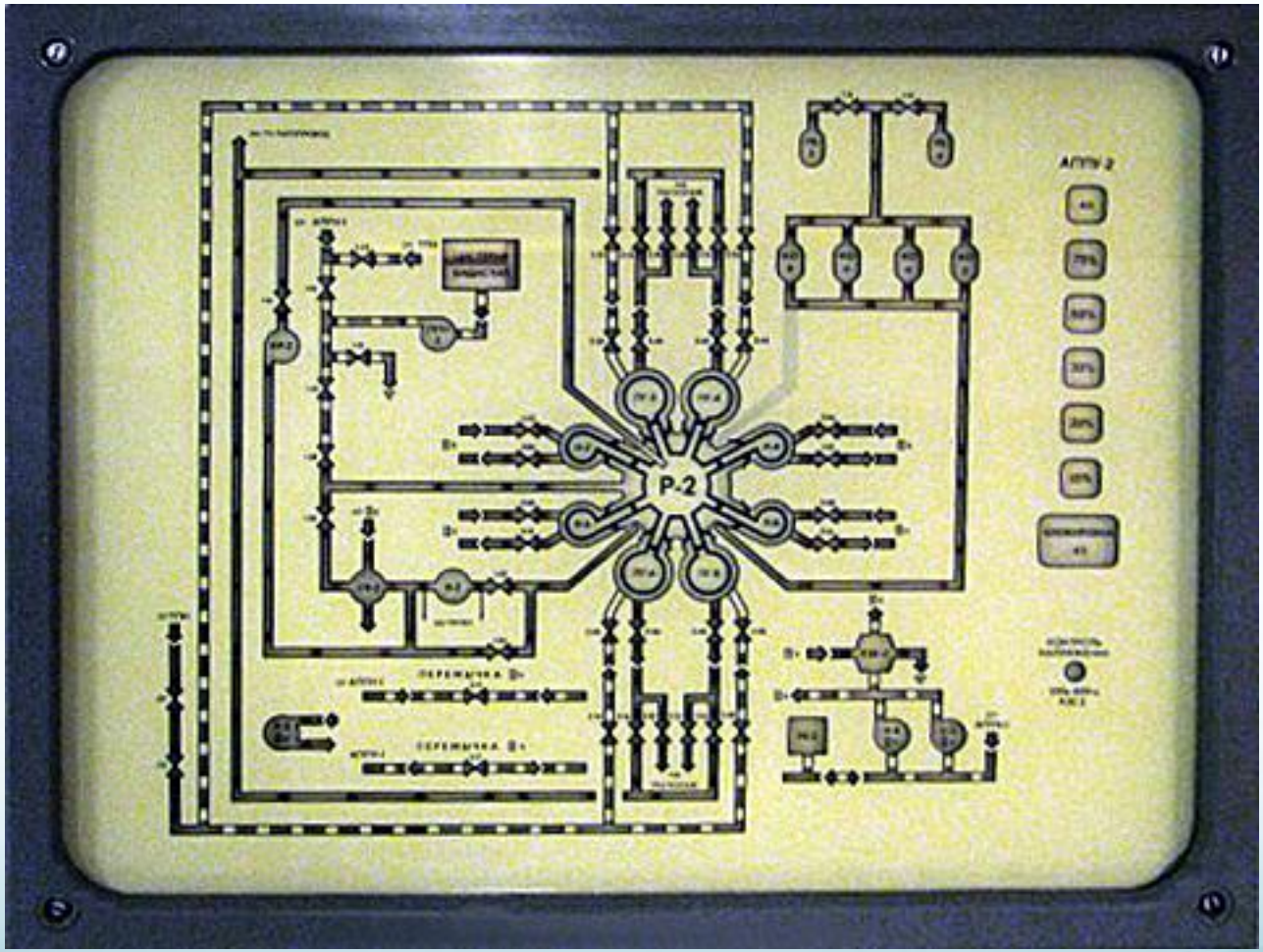
Model of installation of one reactor on Lenin



Source: https://leninicebreaker.wordpress.com

OK-900 status panel

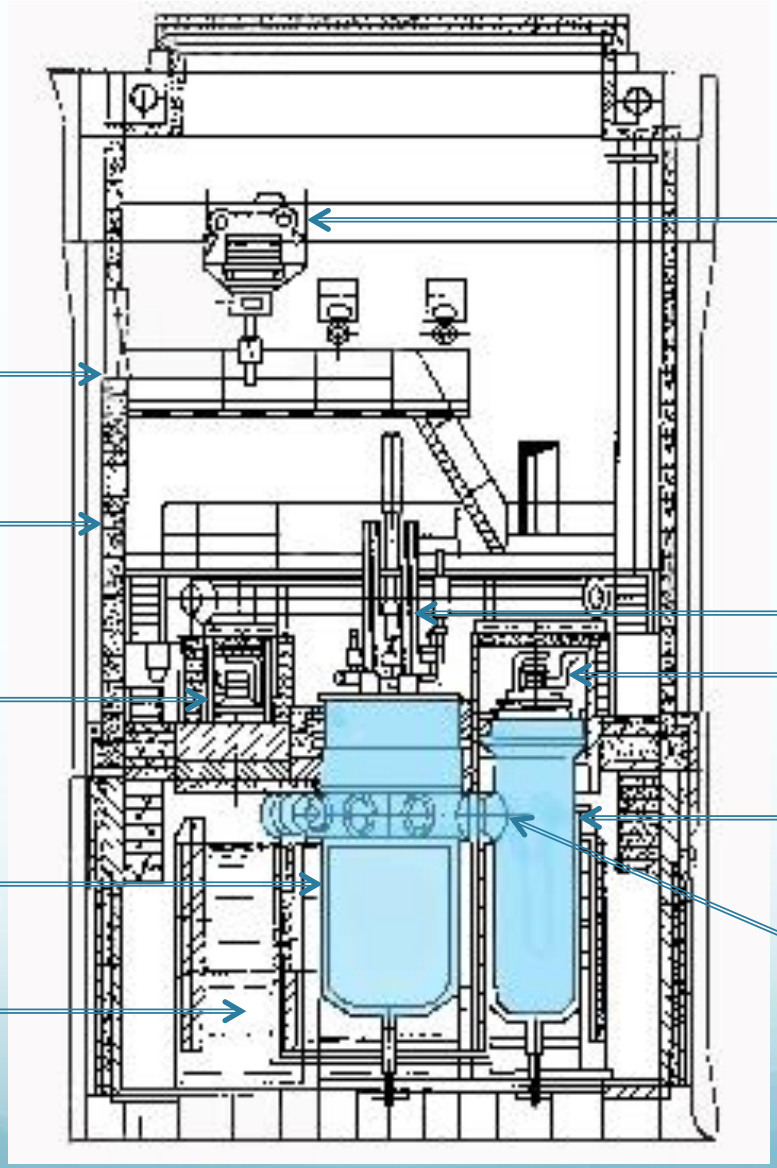
as installed on Lenin



Source: adapted from Arctic Expo Center – Icebreaker Lenin

OK-900A

as installed in Arktika-class icebreakers

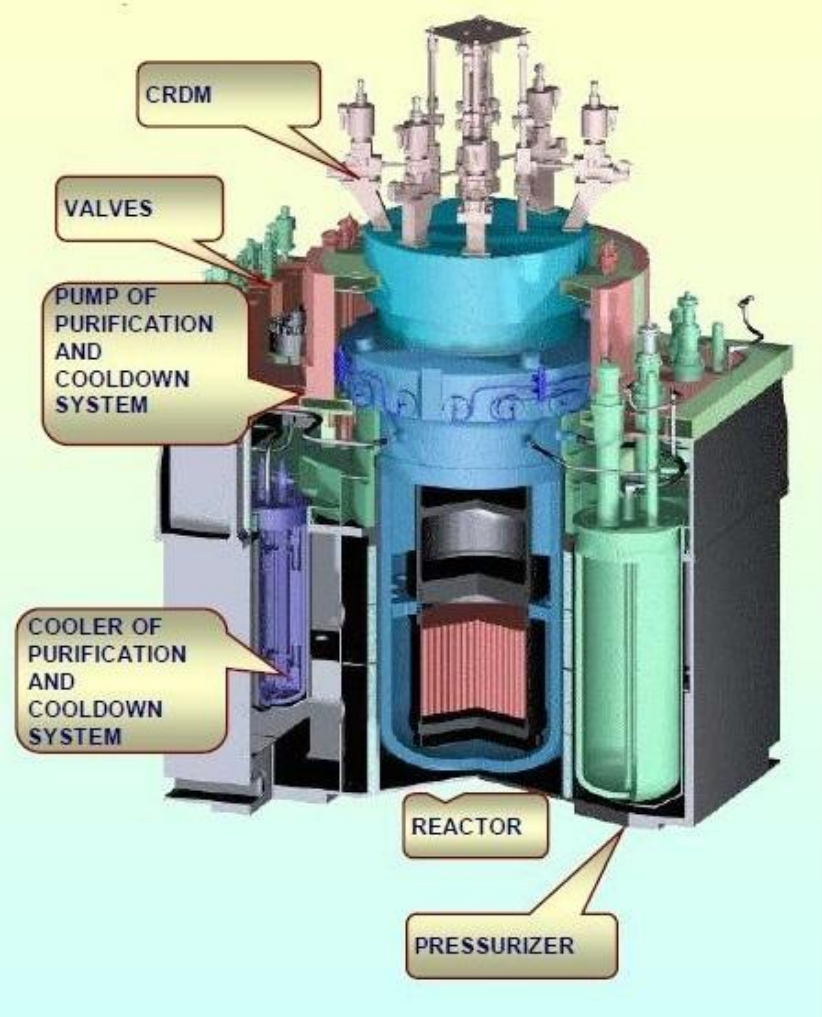


Source: adapted from spb.org.ru/bellona/

KLT-40 and variants

- Reactor developed by Russian Special Design Bureau for Mechanical Engineering (OKBM) Afrikantov
- Modular PWR, further development of the OK-900 design, with a more compact 4-loop primary system:
  - Pipe-inside-pipe load-bearing "loop" piping connects top of reactor vessel to each steam generator and main coolant pump.
- Fuel: Enriched uranium in U-Zr alloy with Zr cladding
- Core dimensions: about 1.0 m high by 1.21 m diameter
- Containment structure similar to OK-900, with additional pressure suppression features
- Applications:
  - KLT-40 rated at 135 MWt installed on Sevmorput
    - Fuel enrichment believed to be in the 30 – 40% U-235 range.
    - Core life reported to be 62,000 to 68,000 MWd (460–503 full-power days)
  - KLT-40M rated at 171 MWt installed on two Taimyr class icebreakers
    - Fuel enrichment believed to be in the 30 – 40% U-235 range.
  - KLT-40S rated at 150 MWt installed on Akademik Lomonozov floating power station
    - Fuel enrichment <20% to meet international proliferation standards; some sources cite 14.1%
    - Operation period at full power expected to be 611 days

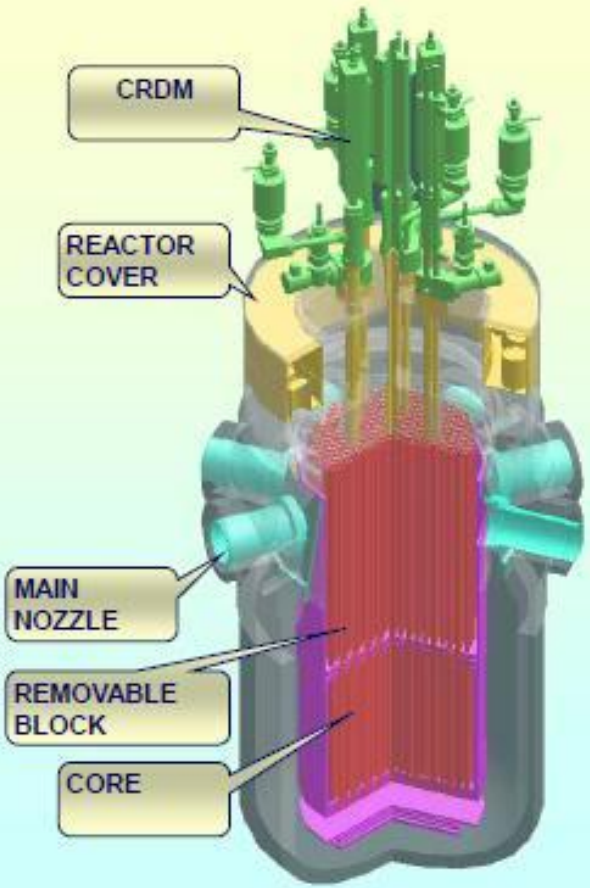
KLT-40



Source: OKBM Afrikantov

KLT-40S

KLT-40S REACTOR

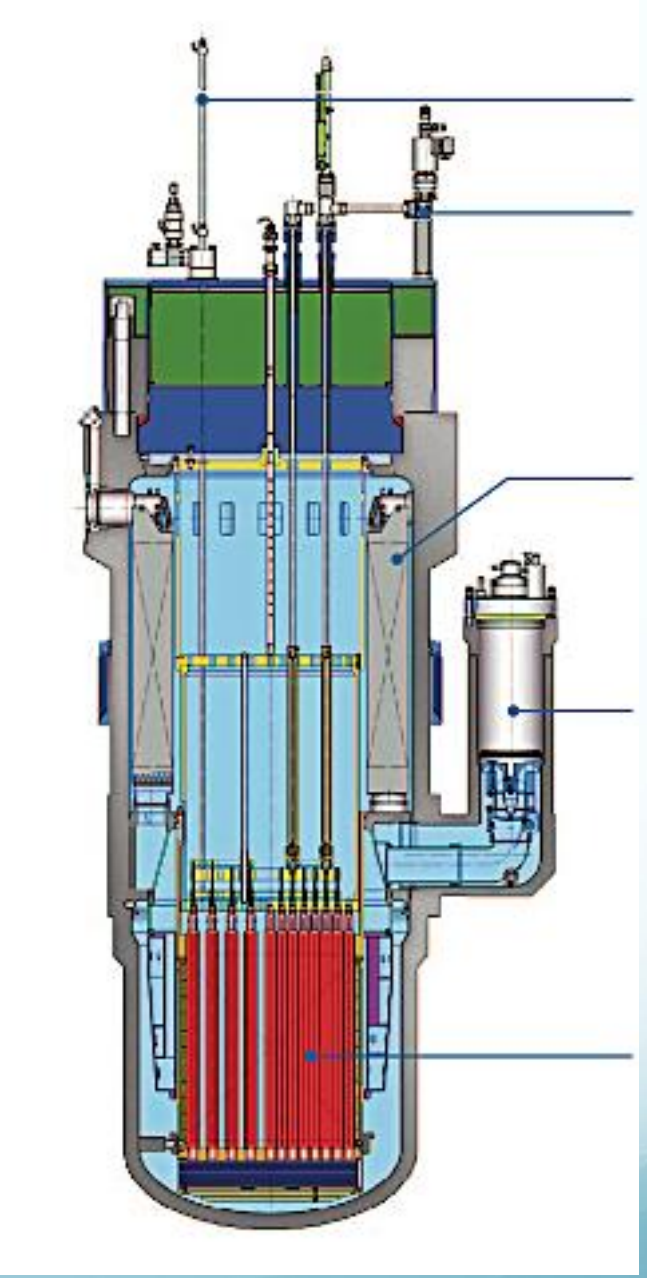


- **REACTOR TYPE** — VESSEL-TYPE PRESSURIZED WATER
- **THERMAL power, MW (t)** — 150
- **FUEL TYPE** — CORE, MEETING NON-PROLIFERATION REQUIREMENTS, DEVELOPED ON THE BASIS OF LONG-TERM OPERATION EXPERIENCE OF ICE-BREAKER CORES
- **FUEL ENRICHMENT, %** — <20
- **REFUELING CYCLE, YEARS** — 3
- **SERVICE LIFE, YEARS** — 40

Source: OKBM Afrikantov

RITM-200

- PWR, integral reactor plant, rated @ 170 - 210 MWt, 55 MWe (net)
- Reactor developed by OKBM Afrikantov
- Very compact, with steam generators internal to the reactor vessel
- Operates on metal-ceramic fuel enriched to less than 20% U-235
- A major challenge will be the reliability of steam generators and associated equipment, which is less accessible inside the reactor pressure vessel than in the modular KLT-40 design.
- Applications:
  - To be installed in new-generation LK-60 icebreakers. Refueling at 7 - 12 year intervals over a planned 40 year operating life.
  - Other potential applications include floating nuclear power plants (PEBs) and various industrial applications.



Source: OKBM Afrikantov

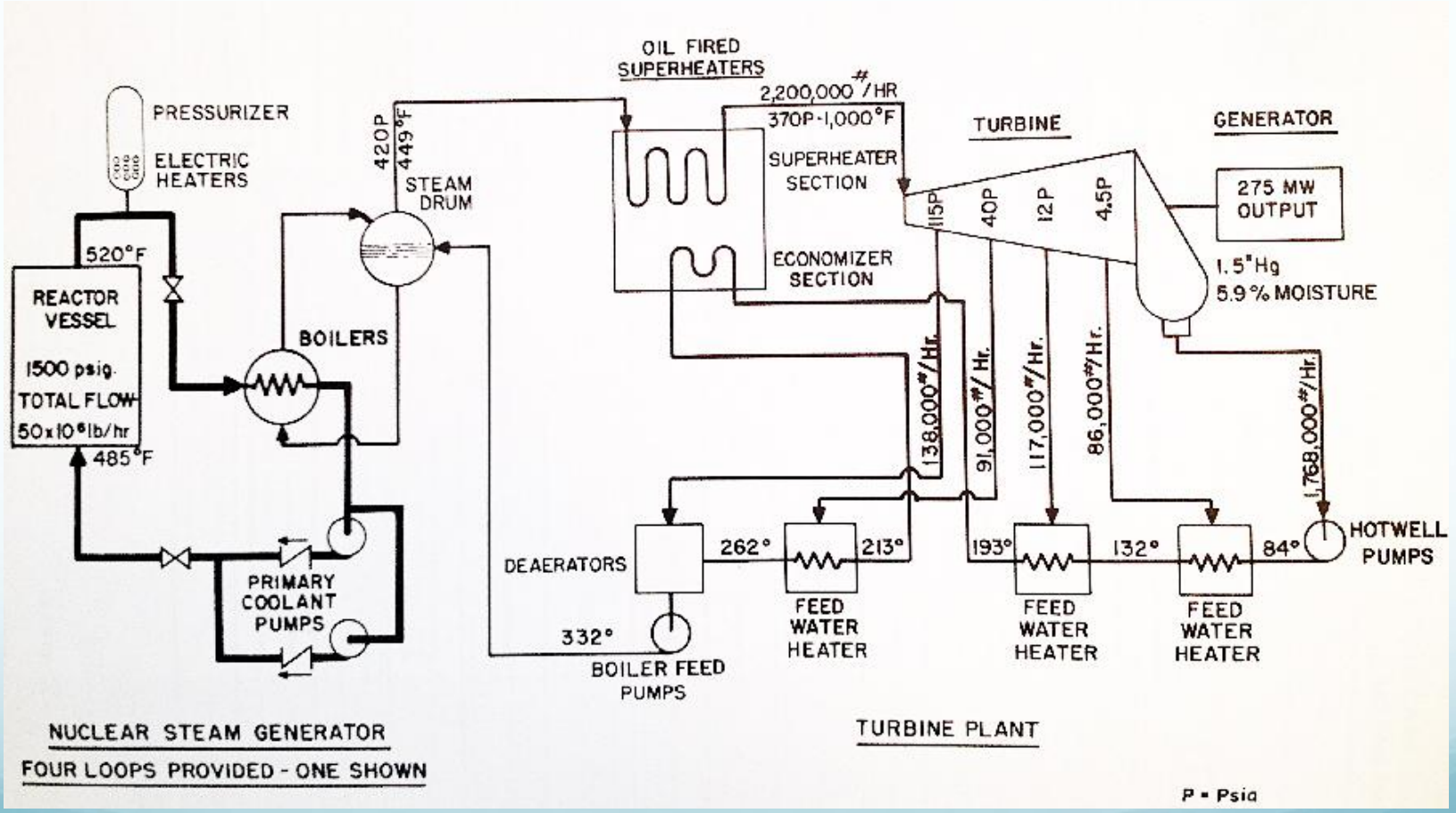
KN-3

Combined Nuclear and Steam (CONAS)

- The KN-3 is described in several sources as a CONAS propulsion system that consists of 2 x VM-16 PWRs each rated at 300 MWt and 2 x oil-fired auxiliary boilers each rated at 115 t/h steam capacity (at unspecified steam conditions)
  - OKBM Afrikantov is the KN-3 designer
  - The KN-3 sometimes is referred to as an OK-900B, which suggests that KN-3 may be based on OKBM Afrikantov's OK-900A modular PWR plant used on the Arktika-class icebreakers.
- Details of how this propulsion system operates are not known. Two possible CONAS alternatives are tandem or parallel operation of the reactor plant and the oil-fired steam plant.
- Tandem operation of reactor plant and auxiliary boilers:
  - The reactor plants operate in tandem with auxiliary boilers that superheat the steam going to the turbines, and together they yield the combined propulsion power output needed for high-speed cruise: 140,000 horsepower for Project 1144.2 Orlan (Kirov)-class CGNs.
  - The auxiliary boilers can operate independently to drive the ship at lower speed (max. 14 - 17 kts) with one or both of the reactors shutdown.
  - If this process description is correct, then the turbines would be designed for superheated steam conditions. This likely would preclude operation without the auxiliary boilers, which are needed to superheat the saturated steam delivered by the nuclear power plants.

Example PWR combined nuclear and steam (CONAS) process

Example of tandem operation with oil-fired superheat



This is the process flow diagram for the CONAS system at the original Indian Point nuclear power plant.

Source: atomicpowerreview.blogspot.com, reproduced from "Power Reactors 1959" published by ASME

KN-3

Combined Nuclear and Steam (CONAS)

- Parallel operation of reactor plant and auxiliary boilers:
  - Speculation exists that the auxiliary boilers actually operate in parallel with the reactor plants and both deliver saturated steam to turbines that are designed for those steam conditions.
  - Two 300 MWt reactor plants should be able to deliver a total of about 120,000 shaft horsepower via main turbines that are designed for saturated steam conditions.
  - The balance of propulsion power would be provided by the two auxiliary boilers.
    - This would be a minimum of 20,000 shaft horsepower for Project 1144.2 Orlan (Kirov)-class CGNs
- The KN-3 with CONAS is used on:
  - Project 1144.2 Orlan (Kirov)-class CGNs,
  - Was likely intended for the Project 1143.7 Ulyanovsk-class aircraft carrier.
- The KN-3 has been attributed in several sources as the propulsion plant for the Project 1941 *Ural* command ship.
  - However, a Russian report prepared in connection with dismantling the *Ural* disclosed that the *Ural's* reactor plant is similar to the reactor installations on nuclear icebreakers, but considerably different from the reactor installations on the Project 1144.2 Orlan (Kirov)-class CGNs.

Russian non-military nuclear marine applications

- Icebreaker
- Merchant ship
- Floating nuclear power plant

Northern Sea Route

Source: ArcticEcon.wordpress.com

- 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 Dudnika open all year.

Three generations of Russian nuclear-powered icebreakers

- 1st generation:
  - Project 92M – Lenin
  - World's first nuclear-powered surface ship
- 2nd generation:
  - Arktika-class deep-water icebreakers
  - Taimyr-class river (shallow water) icebreakers
  - Sevmorput icebreaking cargo carrier
- 3rd generation:
  - LK-60 class "universal" icebreakers

Source: ROSATOMFLOT

Russian nuclear icebreaker fleet

Russia's nuclear icebreaker fleet

Arctic-class icebreakers

Displacement	~23 000 tons
Hull height	17,2 m
Length	150 m
Beam	30 m
Shipyard	Baltiysky Zavod
Number of reactors	2
Main propulsion power	75 000 hp
Maximum speed	~20,8 Knots
Crew	150 People
Passengers	100 People

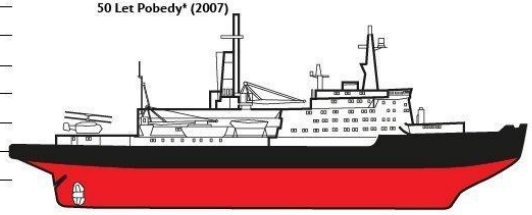
Rossiya (commissioned in 1985)

*modernized design for Arctic-class icebreakers

Sovetsky Soyuz (1989)

Yamal (1992)

50 Let Pobedy* (2007)

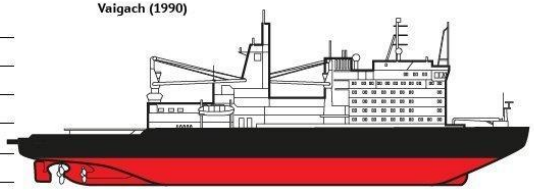


Taimyr-class icebreakers

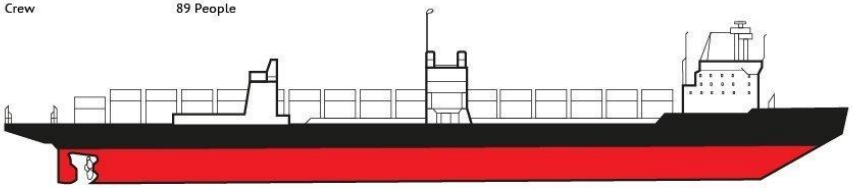
Displacement	61 880 tons
Hull height	15,2 m
Length	151,8 m
Beam	29,2 m
Shipyard	Wärtsilä, Finland
Number of reactors	1
Main propulsion power	50 000 hp
Maximum speed	~18 Knots
Mean draft	8,1 m
Crew	89 People

Taimyr (1989)

Vaigach (1990)



Nuclear lighter carrier ship Sevmorflot



Displacement	61 880 tons
Hull height	18,3 m
Length	260,1 m
Beam	32,2 m
Shipyard	Kerch Shipyard

Number of reactors	1
Main propulsion power	39 436 hp
Maximum speed	~21 Knots
Cargo carrying capacity	74 lighter ships (300 tons each)

SOURCE: ATOMFLOT

- The nuclear icebreaker fleet is under the administration of Rosatomflot, based about two km north of Murmansk.
- The nuclear icebreaker fleet is supplemented by many diesel-powered icebreakers and various types of ice-breaking cargo and utility ships.
- Icebreakers guide convoys of ships and tow other vessels if needed. The wide beam of the icebreaker cuts an ice channel wider than the following ships.
- Current nuclear icebreaker fleet consists of:
  - 4 x Arktika-class deep-water icebreakers
  - 2 x Talmyr-class shallow-water (and river) icebreakers
  - 1 x cargo ship (lighters and/or shipping containers)
- Construction authorized in 2014 for the new-generation LK-60 "universal" nuclear icebreaker.
  - 4 x LK-60-class currently authorized
- Three nuclear icebreakers are no longer in service as of mid-2015:
  - Lenin & Arktika (lead ship of Arktika class) decommissioned
  - Sibir laid up due to mechanical problems

Russian nuclear-powered icebreakers

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
92M	Lenin	1	134 m (440 ft)	27.6 m (91 ft)	16,000	3 x OK-150 re-fit with 2 x OK-900	44,000	18	1959	1959 - 89
--	Arktika	6	148 – 159 m (486 – 522 ft)	30 m (98 ft)	23,000 – 25,000	2 x OK-900A	75,000	20.6	1975 - 2007	1975 – present, 2 retired
--	Taimyr	2	149.7 m (491 ft)	28.9 m (94.7 ft)	20,790	1 x KLT-40M	52,000	16.5	1989 - 90	1989 - present
--	Sevmorput	1	260.3 m (854 ft)	32.2 m (105.6 ft)	61,880	1 x KLT-40	39,450	20.8	1988	1988 - present
22220	LK-40	3 under contract	173.1 m (568 ft)	33.8 m (111 ft)	33,540	2 x RITM-200	80,460	> 20	2017 expected 1st ship	

Project 92M - Lenin

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

- Launched 5 Dec 1957, 1st voyage 15 Sep 1959
- Length: 134 m (440 ft); beam: 27.6 m (91 ft); displacement: 16,000 tons; max speed: 18 kts
- Designed to maintain 2 kts speed while breaking through 2 m of ice.
  - This feat could not be matched by contemporary, large conventional icebreakers (typ. 10,000 ton, 20,000 hp ships)
- Original propulsion system:
  - 3 x OK-150 PWRs, each rated @ 90 MWt, driving 4 x steam turbine generators.

Source: Arctic Expo Center – Icebreaker Lenin

  - Normally two reactors were operating and one was in standby.
  - 44,000 hp (32.8 MW) DC electric motor propulsion system drove three shafts with fixed-pitch propellers.
  - Steam dumps around the main turbines allowed for rapid changes in propulsion power demand without requiring rapid load-following by the reactors.
  - Two diesel generator auxiliary electric power systems provided supplementary power and propulsion.
- First refueling occurred in 1963.
- Nuclear accidents occurred in 1965 and 1967.

Project 92M - Lenin

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

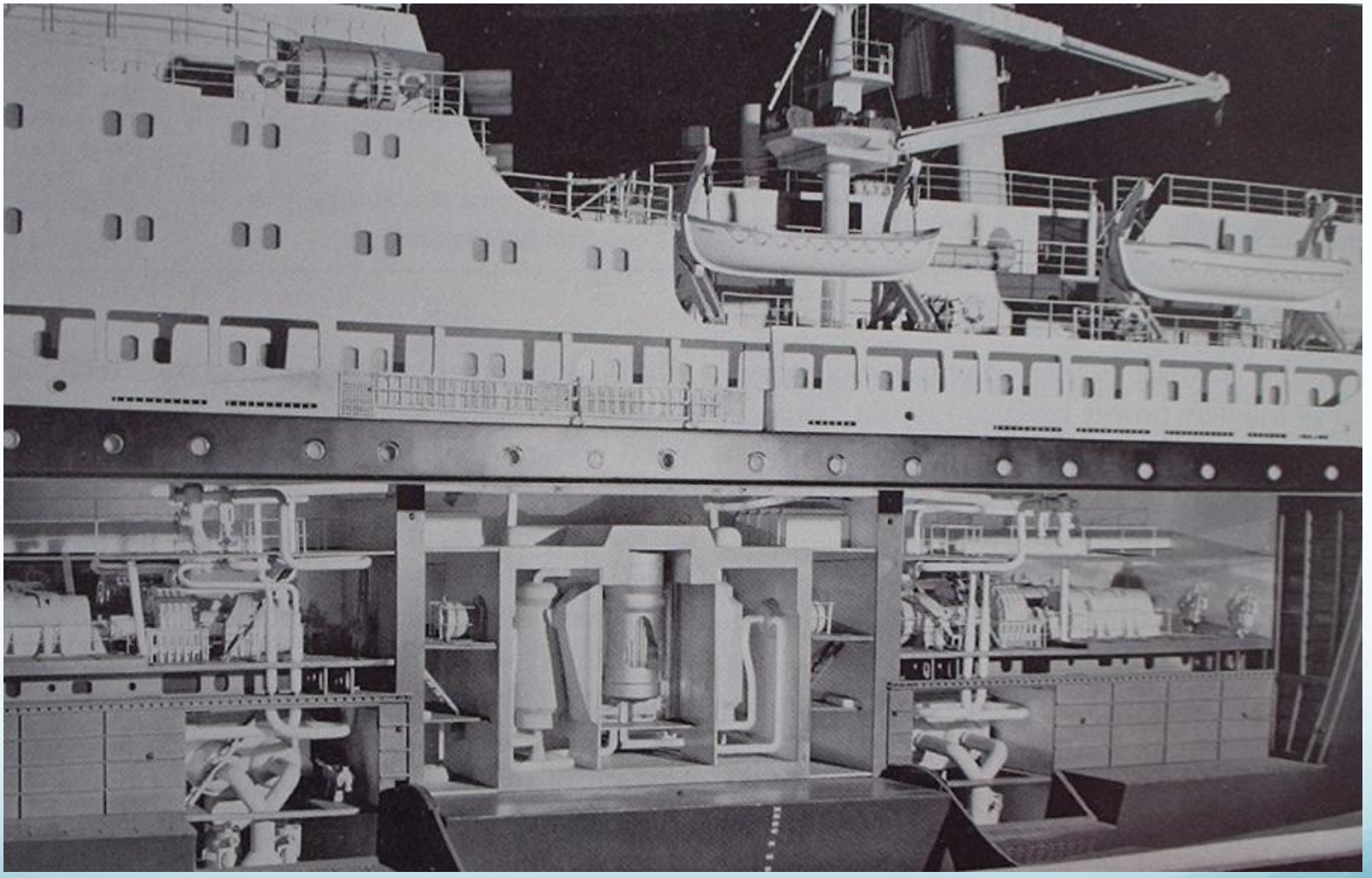
- Replacement propulsion system:
  - After the 1967 accident, the OK-150 nuclear power plant was replaced by a two-reactor OK-900 nuclear plant; each reactor rated at 159 MWt.
  - Normally one reactor was operating and one was in standby
- Returned to service in 1970; operated until 1989
  - Cruised 650,400 miles, 560,000 miles in ice.
- Conversion to a museum ship in Murmansk was completed in 2005.

Lenin museum ship

Source: Arctic Expo Center – Icebreaker Lenin

OK-150 installed on Lenin

(one of three reactor units shown)



Note: The three reactors are installed side-by-side, amidships. One secondary plant with two steam turbine generators is located forward and the other is located aft of the reactor compartment.

Source: atomicpowerreview.blogspot.com

Lenin OK-150 nuclear accidents

February 1965 accident

- Due to an operator error in preparation for refueling, water was drained from the shutdown second OK-150 reactor and the core was left without water for some time.
- The reactor coolant inlet is at the bottom of the reactor vessel. This arrangement could have contributed to the inadvertent draining of the primary system.
- The decay heat of the core and the lack of cooling caused deformation and/or melting in part of the core.
- Only 94 of the irradiated fuel elements could be removed.
- The remaining 125 elements were stuck in the core and had to be removed as a unit along with control rods and the "core basket" consisting of the bottom grid plate and the cylindrical thermal shield.
- The removed components were placed in a shielded cask, stored for 2 years, and then in 1967 some or all of the items were dumped at sea near Novaya Zemlya.

1967 accident

- A primary coolant system leak occurred shortly after refueling.
- Finding the leak required breaking through the concrete and metal biological shield around the reactor with sledgehammers, which caused irreparable damage to the nuclear power plant.
- After being abandoned for about a year to allow radiation levels to decline, all three OK-150 reactors were removed, and replaced in 1970 by a two-reactor OK-900 nuclear plant.
- The removed OK-150 reactors may have been dumped at sea near Novaya Zemlia.

Arktika-class

Russian nuclear-powered icebreakers

- Six ships in the class entered service between 1975 & 2007. Two ships have been removed from service, *Sibir* in 1992 and *Arktika* in 2008.
- Length: 148-159 m (486-522 ft); Beam: 30 m (98 ft); Displacement: 23,000 - 25,000 tons; Max speed 20.6 kts
- Designed to maintain 4 kts speed while breaking through 2 m of ice; twice as fast as Lenin under these conditions.
- Propulsion:
  - OK-900A nuclear power plant with 2 x PWRs, each rated @ 171 MWt.
  - Normally one reactor is operating and the other is in standby.
  - 75,000 hp (55 MW) DC electric motor propulsion system drives three shafts with fixed-pitch propellers.
  - Two separate diesel generator auxiliary electric power systems provided supplementary power.

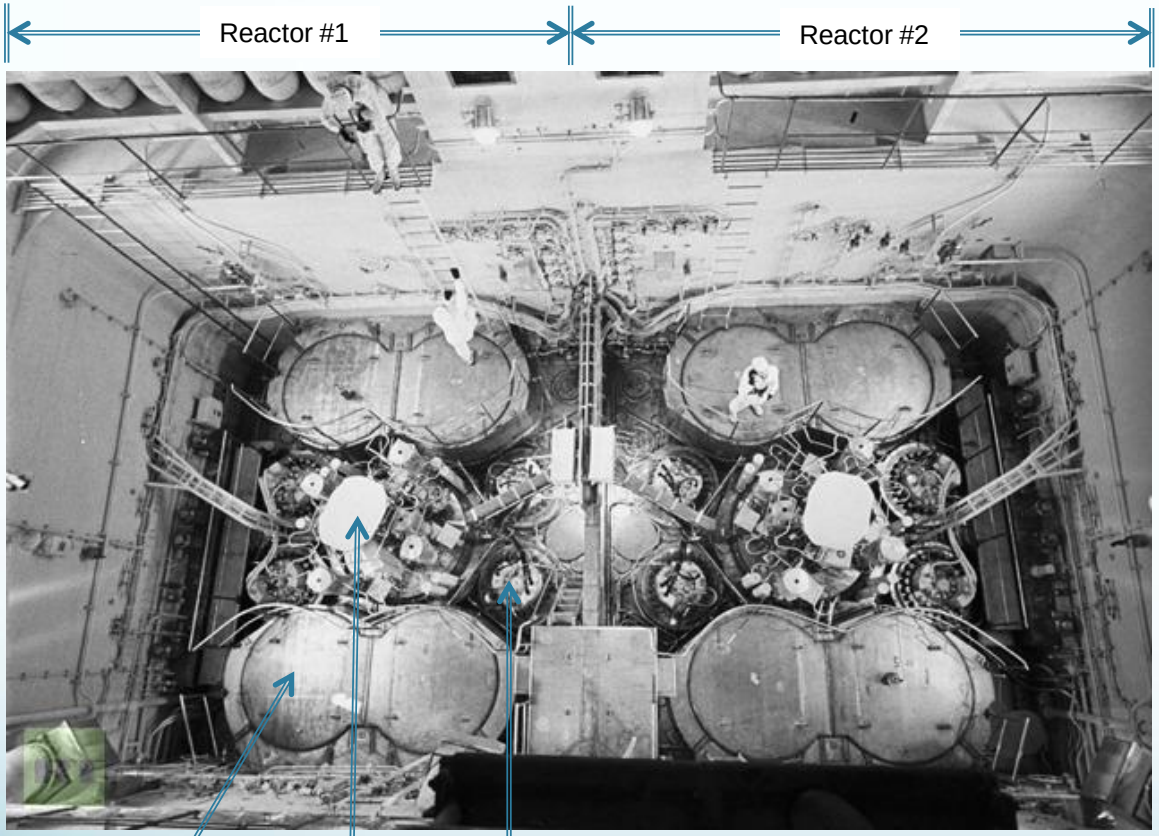
Source: ROSATOMFLOT

- Operational matters:
  - On 17 Aug 1977, NS Arktika was the first surface ship to reach the North Pole.
  - NS Arktika was withdrawn from service in 2008 after operating for 33 years with 175,000 hours of reactor operation and covering more than 1 million nautical miles.
  - Arktika may become a museum ship in St. Petersburg.
  - Commercial polar cruises from Murmansk to the North Pole aboard Arktika-class nuclear icebreakers have been offered since 1989.

OK-900A icebreaker installation

Right: Rosatomflot core reload on icebreaker

Source: ROSATOMFLOT



Above: Reactor compartment operating floor removed

Right: Reactor compartment operating floor installed

Taimyr-class

Russian nuclear-powered river (shallow water) icebreakers

- Two ships in the class, entered service between 1989 & 1990
- Length: 149.7 m (491 ft); Beam: 28.9 m (94.7 ft); Displacement: 20,790 tons; Max speed: 16.5 kts
- Propulsion:
  - One KLT-40M PWR rated @ 171 MWt
  - Normally one reactor is operating and the other is in standby.
  - Electric motor propulsion system drives three shafts with fixed-pitch propellers for a total 52,000 hp (38.8 MW)
  - Three diesel-driven alternators provide backup power. Two can be used to provide approximately 4 MW (5,350 hp) for the propulsion motors while the third takes care of the auxiliary load.

Source: ROSATOMFLOT

- Operational matters:
  - In March 2012, a leak occurred in one steam generator on NS Taimyr, resulting in about 6,000 liter water loss from the primary system. Two steam generators were replaced by steam generators taken from the decommissioned NS Sibir (an OK-900A nuclear plant). NS Taimyr returned to service in March 2013.

Sevmorput

Russian nuclear-powered icebreaking LASH (lighter aboard ship) carrier and container ship

- Launched Feb 1986, delivered Dec 1988
- Length: 260.30 m (854.0 ft); beam: 32.20 m (105.6 ft); max. displacement: 61,880 tons; max speed 20.8 kts
- Can carry 74 lighters (barges) or 1328 x 20 ft containers. Lighters enable cargo delivery at coastal sites that lack port facilities.
- Propulsion:
  - One KLT-40 PWR nuclear power plant, rated @ 135 MWt
  - Steam turbine delivering 39,450 shp directly drives a single ducted propeller

Source: ROSATOMFLOT

- Operational matters:
  - Refueled in 2001
  - Following the Chernobly accident in April 1986, few Russian arctic ports and international ports allowed this ship to dock. The ship was idle in Murmansk for several years, and has been used primarily on the sea route between Murmansk and Dudnika.
  - Decision to decommission was cancelled in Dec 2013. Ship is due back in service in Feb 2016.

Project 22220 (LK-60)

Russian nuclear-powered "universal" icebreakers

- New generation of icebreakers, 1st ship to enter service in 2017.
- Length: 173.1 m (568 ft): Beam 33.8 m (111 ft); Displacement: 33,540 tons; Max speed: > 20 kts
- Larger beam accommodates considerably larger cargo vessels, such as tankers up to 70,000 tons. Previously, two icebreakers working together were necessary to cut a wide enough channel for large ships.
- "Variable draft" ballast system allows LK-60 to replace both the deep water Arktika-class and shallow-draft Taymyr-class ice-breakers.
- Propulsion:
  - Two RITM-200 nuclear reactors, each rated @ 175 MWt
  - Secondary system can deliver 60 MW (80,460 hp) to an electric motor propulsion system driving three shafts.
  - Diesel generators provide backup electric power.

Source: ROSATOMFLOT

Project 22220 (LK-60)

Russian nuclear-powered "universal" icebreakers

- The 1st-in-class LK-60 icebreaker will be named *Arktika*.
- Contract for *Arktika* was placed in Aug 2012 and the keel was laid in Nov 2013.
- It is scheduled to be service-ready by Dec 2017, and will operate from the Atomflot icebreaker port in Murmansk.
- Contracts for two additional LK-60 ships were placed in May 2014. They are scheduled for delivery in 2019 & 2020.
  - The 2nd ship will be named *Sibir.*

Arktika's bow installed at
St. Petersburg's Baltic Shipyard
Aug 2015

Source: http://bellona.org/news/arctic/russian-nuclear-icebreakers-fleet/

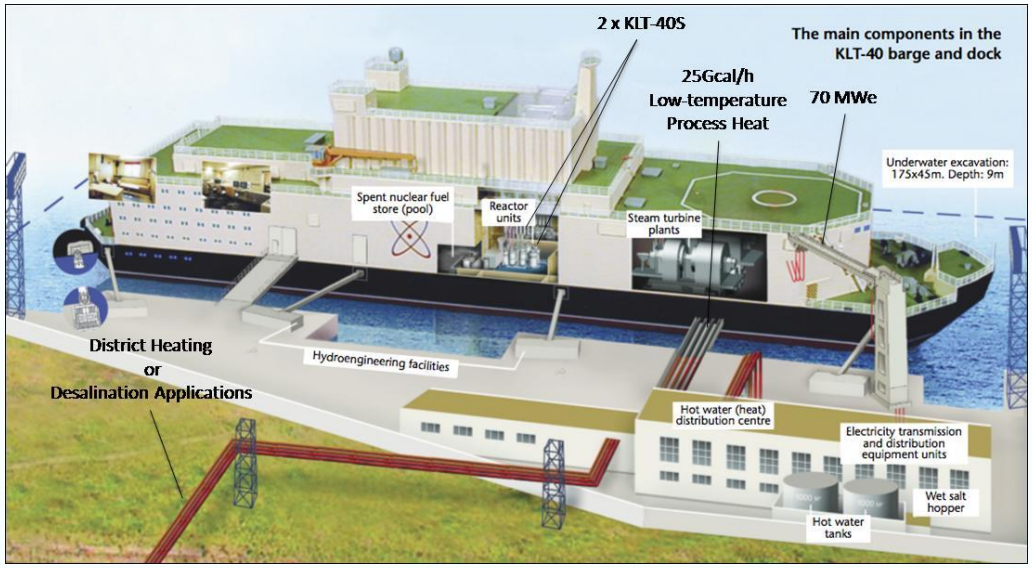
Russian floating nuclear power stations (PEBs)

Floating nuclear power station (PEB)

Source: World Nuclear Association

Project 20870- *Akademik Lomonozov*

First Russian floating nuclear power station (PEB)



Source: OKBM Afrikantov

- One vessel, *Akademik Lomonozov*, under construction at Baltic Shipyard, St. Petersburg.
- Length: 144 m (472.4 ft); width: 30 m (98.4 ft), displacement: 21,500 tons
- 2 x KLT-40S reactors providing 70 MWe net and low-temperature process heat.
- Reactors installed Sep - Oct 2013.

Source: www.shipspotting.com

- Expected completion in 2016. Nuclear fuel loading and reactor testing are expected to take place in St. Petersburg.
- Current plan is to deploy this PEB to the Russian far east Arctic port Pevek.
- The plant could start operation in 2017, but this could be delayed because of the current unavailability of the necessary shore-based infrastructure to accommodate the PEB and the interfaces needed to enable power and process heat transmission to end users on shore.

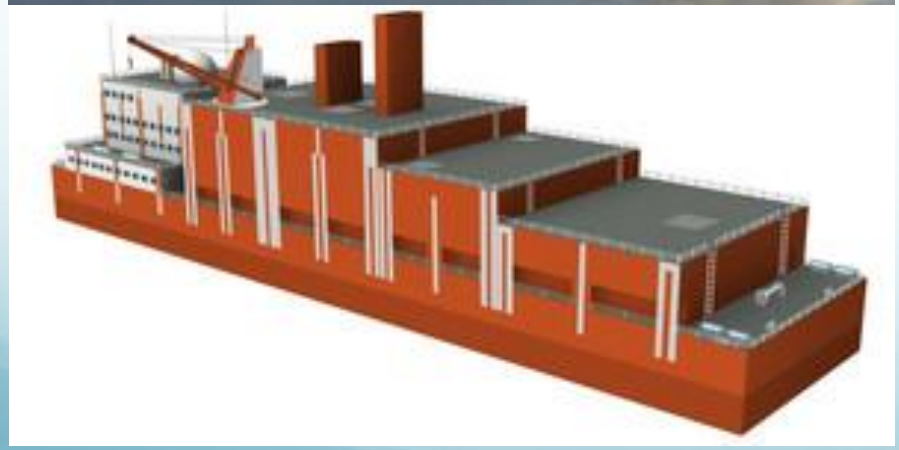
220 ton KLT-40S installation

PEB Akademik Lomonosov, Baltic Shipyard, St. Petersburg, Russia

Source: survincity.com

Rubin PEB design concept

Floating nuclear power station



Source: Rubin Central Design Bureau for Marine Engineering

- 2 x RITM-200 reactor providing 95 MWe net to the onshore power grid.
- The floating power unit is a non-propelled, moored, double-bottom and double-hull vessel with an extensive superstructure.
- Length: 104 m; width: 25 m, displacement: 10,146 tons
- The unit, fully packaged and with the reactor cores fueled, is towed or shipped by a barge to the operation site.
- Design lifetime for the floating power unit is 40 years with annual maintenance of main equipment. Medium overhaul and docking is to be done at 10 year intervals. During the overhaul, core refueling is also done.

Russian nuclear-powered naval surface ships

- Cruisers
- Command ship
- Aircraft carrier
- Destroyers

Russian nuclear-powered naval surface ships

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
1144.2 Orlan	Kirov cruiser (CGN)	4	252 m (867 ft)	28.5 m (94 ft)	26,500	KN-3 with 2 x VM-16 reactors + CONAS	140,000	31	1980 -98	1980 – present
1941 Titan	Ural (SSV-33) command, control, comm. ship	1	265 m (869 ft)	30 m (98 ft)	36,500	OK-900A variant	75,000	21.6	1989	1989 - 2001
1143.7	Ulyanovsk aircraft carrier (CVN)	1	321.2 m (1,054 ft)	Waterline 40 m (130 ft) Overall 83.9 m (275 ft)	75,000	KN-3 with 4 x VM-16 reactors, probably with CONAS	280,000	30	Not completed Scrapped in 1992	
2195.6	Leader destroyer (DDGN)	Not known	Not known	Not known	10,000	Reactor power of about 285 MWt needed. Specific reactor(s) not known	55,000	30	1st ship expected 2023 - 25	

Project 1144.2 Orlan (Kirov)-class

Nuclear-powered guided missile cruiser (CGN)

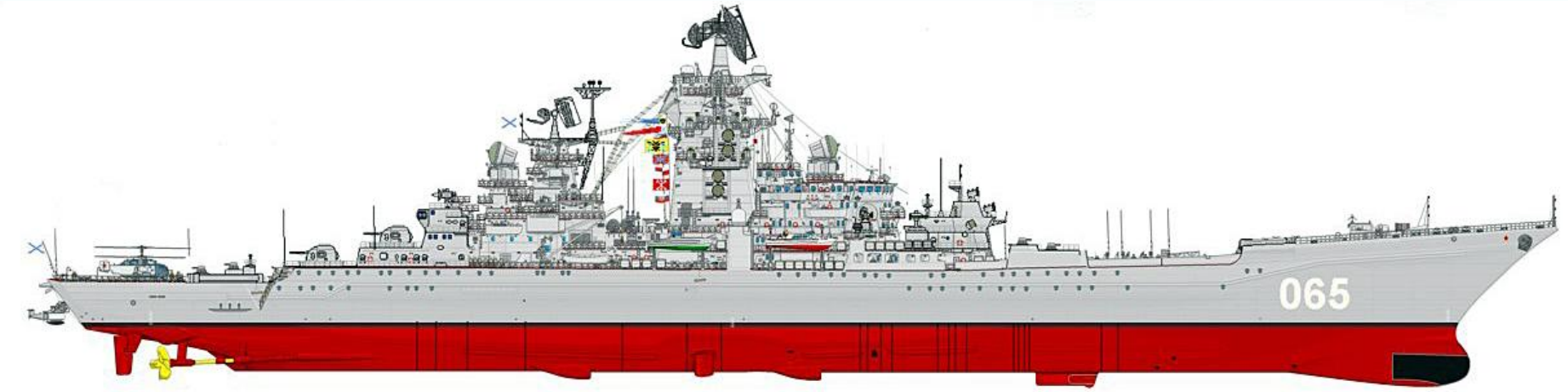
- Five Kirov-class cruisers were laid down between 1974 and 1989, four were completed and the fifth was scrapped.
  - One is in service (*Pyotr Veliky*, last Kirov-class ship, commissioned in 1998)
  - One is being modernized for return to service in 2018 (*Admiral Nakhimov,* commissioned in 1988)
  - Two have not yet funded for modernization (*Admiral Ushakov & Admiral Lazarev*, commissioned in 1980 & 1984, respectively)
- Length 252 m (867 ft); displacement 26,500 tons; maximum speed 31 kts.
- Propulsion: Combined nuclear and steam (CONAS) plant:
  - KN-3 nuclear power plant with 2 x VM-16 PWRs, each rated @ 300 MWt
  - 2 x oil-fired auxiliary boilers each rated at 115 t/h steam capacity (at unspecified steam conditions)
  - Steam output from two reactors and two oil-fired auxiliary boilers together yield the combined power output needed for high-speed cruise.
  - Two shafts, fixed-pitch propellers, combined total horsepower: 140,000 shp
  - 76 mm (3 in) steel plating around reactor compartment for “light splinter” protection during battle.

Pyotr Veliky Source: foxtrotalpha.jalopnik.com

Kirov dockside Source: russiamil.wordpress.com

Project 1144.2 Orlan (Kirov)-class

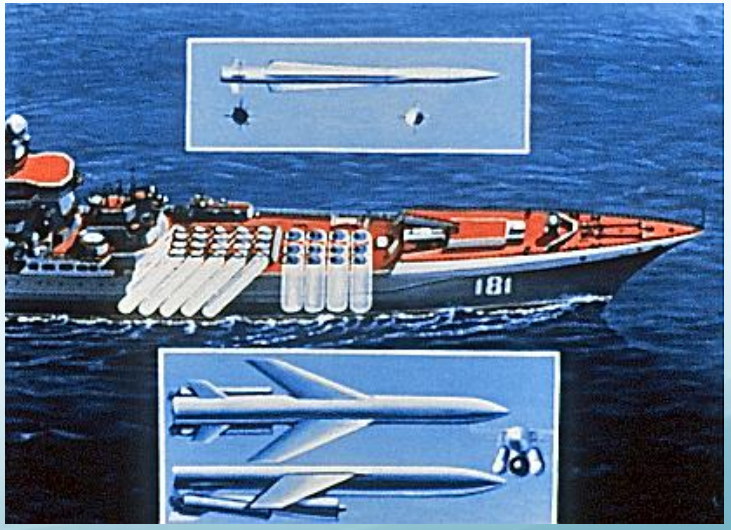
Nuclear-powered guided missile cruiser (CGN)



Source: www.deviantart.com/morelikethis/artists/379335768

- Armament (on *Pyotr Velikiy)*:
  - In foredeck vertical launch system (VLS):
    - 20 x P-700 Granit (SS-N-19) long-range anti-ship cruise missiles
    - 12 x octuple S-300FM (SA-N-6) long-range anti-air/anti-missile launchers; total of 96 missiles.
    - 16 x octuple 3K95 (SA-N-9) anti-air missile launchers; total of 128 missiles.
  - Comprehensive short-range anti-air system, including 2 x Osa-MA short-range SAM batteries (44 missiles); point defense guns & missiles
  - Comprehensive ASW system, including 3 x Ka-25 or Ka-27 helicopters; 10 x torpedo tubes for Type 53 torpedoes & SS-N-15 ASW missile; short-range ASW rocket launchers

Missile launch tubes of the foredeck



Source: U.S. DoD

Project 1144.2 Orlan (Kirov)-class

Nuclear-powered guided missile cruiser (CGN)

- Operational matters:
  - Except for aircraft carriers, Kirov-class CGNs are the largest surface combatants ships in the world.
  - Like the Oscar-class SSGNs, Kirov-class CGNs originally were designed to defeat an American aircraft carrier battle group by firing a salvo of many supersonic P-700 cruise missiles, which may overwhelm the battle group's defenses.
  - A reactor accident occurred on *Admiral Ushakov* (ex-Kirov) in the Mediterranean in 1990. Since then, the ship has been laid up in Severodvinsk awaiting core unloading and final disposition.
  - *Pyotr Velikiy (ex-Yuri Andropov)* currently is the only Russian ship with an anti-ballistic missile defense capability.
    - S-300FM / SA-N-20 Gargoyle missile
  - Modernization of *Admiral Nakhimov* is expected to include conversion of each P-700 missile launch tube to carry three P-800 Oniks cruise missiles or similar-sized weapons, for a total of 60 missiles.
    - In mid-2015, a similar modernization is being done on an Oscar-class SSGN
    - Other weapons systems also are expected to be updated on *Admiral Nakhimov*

Project 1941 (Titan)

Nuclear-powered command, control & communications ship

Source: http://thekristoffersuniverseinwar.wikia.com/

- SSV-33 *Ural* launched May 1983, commissioned Dec 1989. Known as “Kapusta” by NATO.
  - Intended roles included flagship, space / missile tracking, surveillance and communications relay.
- Hull based on Project 1144.2 Orlan/Kirov CGN.
  - Length 265 m (869 ft); Beam: 30 m (98 ft); displacement 36,500 tons.
- Propulsion:
  - A Russian report prepared in connection with dismantling the *Ural* disclosed that the *Ural’s* reactor plant is similar to the reactor installations on nuclear icebreakers, but considerably different from the reactor installations on the Project 1144.2 Orlan (Kirov)-class CGNs.
  - The Russian report stated that *Ural’s* reactor refueling would be conducted in Murmansk at "Atomflot” using the same equipment as the nuclear ice breakers. Therefore, special equipment for refueling "Ural" was not produced.
  - *Ural’s* reactor plant most likely is an Afrikantov OK-900A variant with 2 x PWRs, each rated @ 171 MWt, driving steam turbines that deliver a total of about 75,000 shp to two shafts.

Project 1941 (Titan)

Nuclear-powered command, control & communications ship

- Operational matters:
  - Deployed from Baltic Sea to Pacific Fleet in 1989, but was not used operationally thereafter because of various problems with the ship's nuclear power plant and other ship systems, and inadequate local port infrastructure.
  - Only 25 - 30% of the reactor core life was used before decommissioning.
  - The vessel was decommissioned in 2001, scrapping started in 2008, and the reactors were defueled in 2009. Dismantling is expected to be complete in 2016.
  - When removed from the ship, the reactor compartment will be sealed and put in "afloat storage" pending completion of the on-shore storage facility at Cape Ustrichny, near Vladivostok.

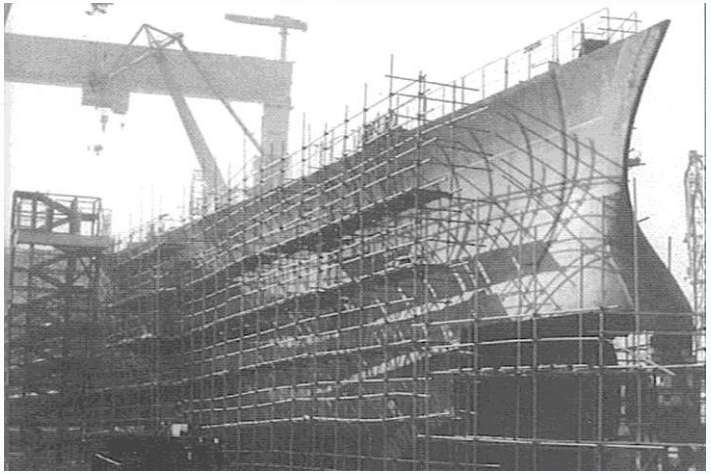
Source: en.wikipedia.org

Source: http://forum.keypublishing.com/

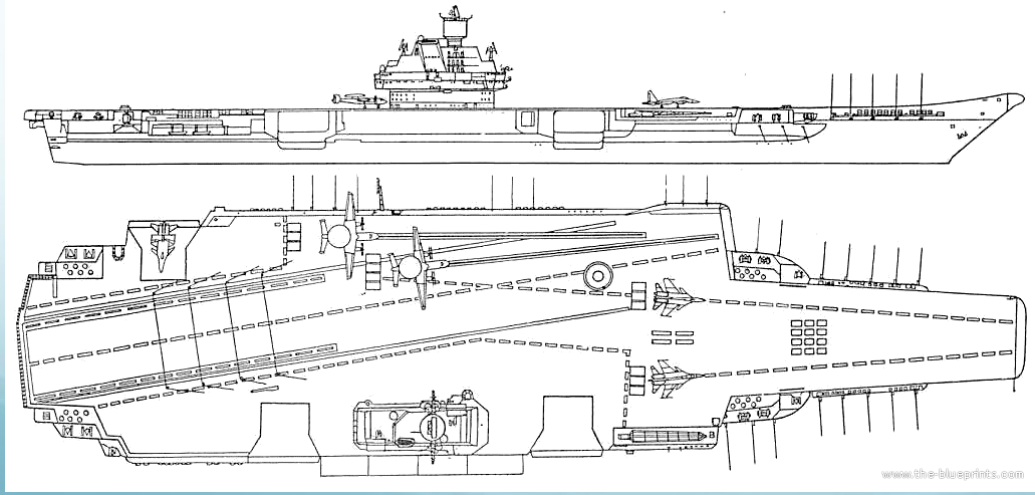
Project 1143.7 Ulyanovsk-class

Russian nuclear-powered large aircraft carrier

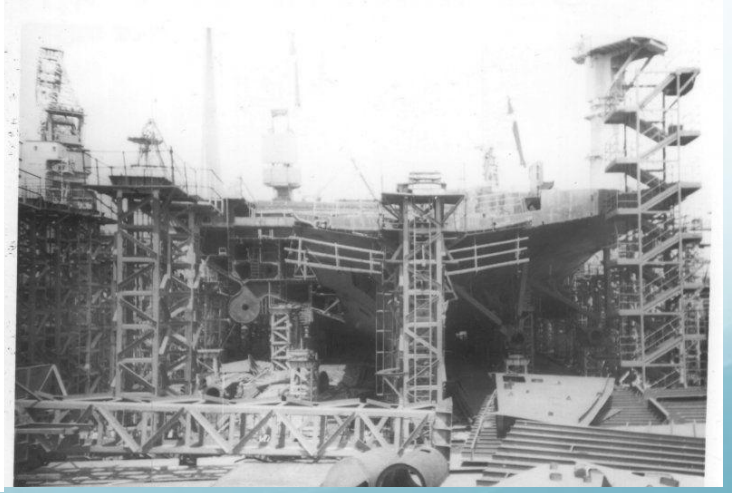
- Lead ship hull was laid down in 25 November 1988 at the Black Sea Shipyard in Ukraine, but cancelled at 20% complete in January 1991 and scrapped in 1992. Planned second hull was never laid down.
- Length 321.2 m (1,054 ft); full load displacement 75,000 tons; max. speed 30 kts.
  - KN-3: 4 x PWR reactors each rated @ 300 MWt
  - 4 x steam turbines
  - 4 x shafts, 280,000 hp (206 MW)
  - Likely to have had the same CONAS propulsion plant as on Orlan (Kirov)-class CGN.
- Basic characteristics were similar to U.S. Nimitz-class aircraft carriers, but with “ski-jump” bow.



Source: www.taringa.net



Source: www.the-blueprints.com



Source: survincity.com

Timeline for a future Russian aircraft carrier

- 2005: *Interfax* reported that the Russian Navy was planning a class of two to four new aircraft carriers.
- 2008: Russian President Dmitriy Medvedev reaffirmed Russian plans to build new nuclear powered aircraft carriers.
- 30 Jun 2011: The head of United Shipbuilding Corporation, a Russian state holding company, said his company expected to begin design work for a new aircraft carrier in 2016, with a goals of beginning construction in 2018, and having the carrier achieve initial operational capability by 2023.
- 3 Nov 2011: Russian newspaper *Izvestiya* reported the naval building plan now included the construction of a new shipyard capable of building large hull ships, after which Moscow will build four nuclear-powered aircraft carriers by 2023.
- mid-2015: No announcement yet on the start of construction on the new shipyard facilities or a new aircraft carrier.

Project 2195.6 - Leader-class destroyer

Source: defense-update.com

- The Navy of Russia intends to order 12 advanced 10,000 ton Leader-class destroyers.
  - Intended as a cruise missile (Kaliber) and anti-air / anti-missile (S-500) platform
  - Half will be designed for the Northern Fleet, and the other half for the Pacific Fleet
  - Lead ship of the class is expected join the Russian Navy not earlier than 2023-2025.
- The Severnoye Design Bureau has been given the engineering design preparation assignment; it plans to launch the work in 2015:
  - Two versions: one with a nuclear power plant and and one with a gas turbine power plant.
  - Either propulsion system is expected to generate about 55,000 shaft hp, for a speed about 30 kts. The nuclear-powered version will require a reactor rated at about 270 – 300 MWt.

Russian nuclear-powered submarines

Four generations of Russian nuclear-powered submarines

- 1st generation:
  - SSN: Project 627 (November); Project 645 (experimental November LMR)
  - SSGN: Project 659 (Echo I); Project 675 (Echo II)
  - SSBN: Project 658 (Hotel I & II); Project 701 (Hotel III)
- 2nd generation:
  - SSN: Project 671(Victor I, II & III); Project 705 (Alfa)
  - SSGN: Project 670 (Charlie I & II); Project 661 (Papa)
  - SSBN: Project 667A (Yankee I & II); Project 667B (Delta I, II, III & IV)
- 3rd generation:
  - SSN: Project 685 (Mike); Project 645 (Sierra I & II); Project 671 (Akula I, II & III),
  - SSGN: Project 649 (Oscar I & II)
  - SSBN: Project 641 (Typhoon)
- 4th generation (current new construction):
  - Multi-mission SSN: Project 885 (Yasen / Yasen-M)
  - SSBN: Project 955 (Borei / Borei II)

Key differences between Russian & U.S. nuclear submarines

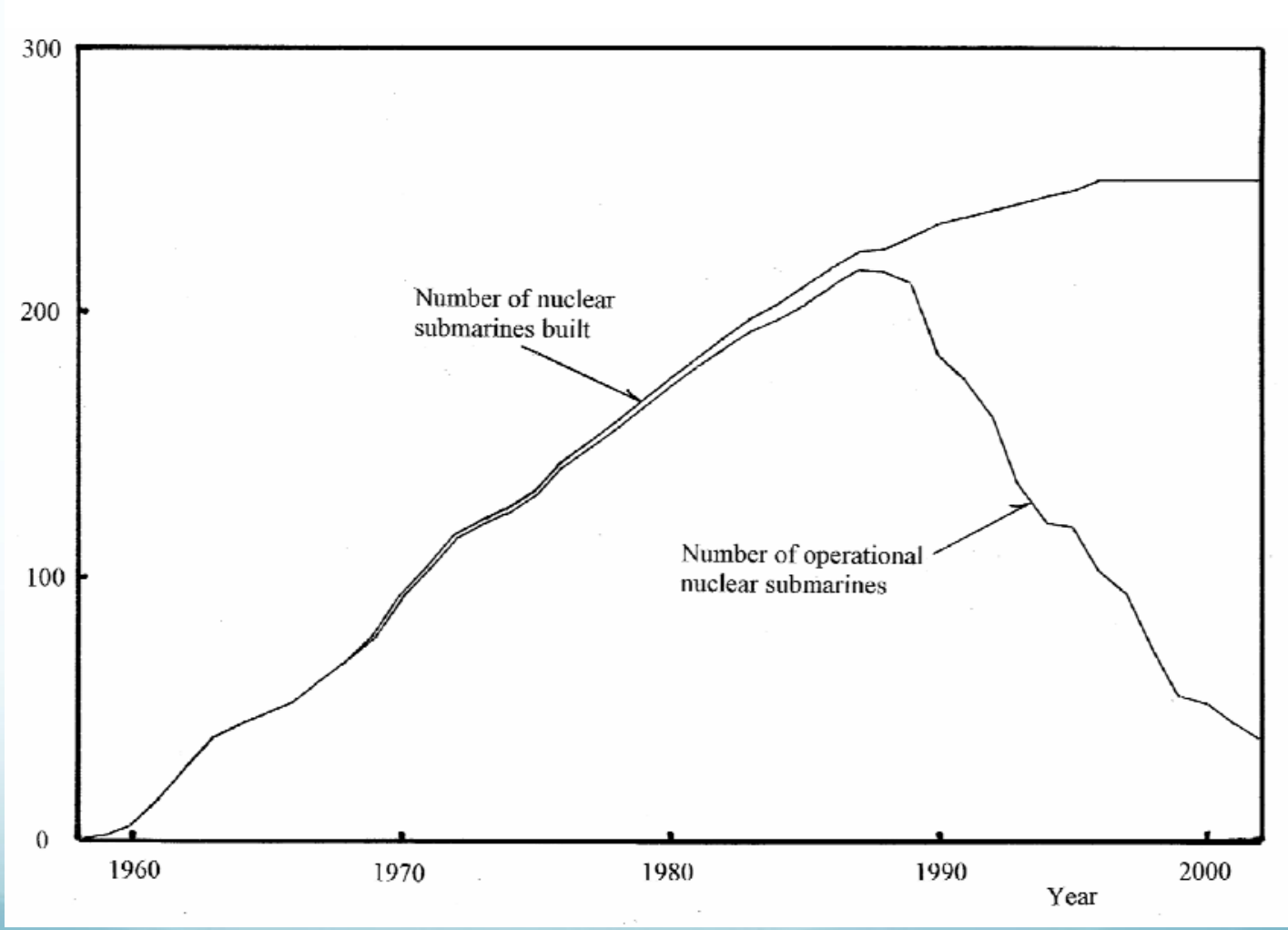
Russia

- Double hull: the pressure hull is enclosed in a streamlined outer hull.
- Greater reserve buoyancy. More space is available for ballast tanks between the pressure hull and the outer hull.
- Mostly steel hulls, but several titanium hulls
- Many sub classes are powered by two reactors
- Many sub classes have two propellers
- Until new Yasen class, all subs had cylindrical sonar arrays and bow torpedo tubes
- Greater number of compartments inside the pressure hull. Sub can survive flooding of the single largest compartment and adjacent ballast tank.
- Most subs have crew escape capsules.
- Greater automation, smaller crews.

U.S.

- Single hull: most of the pressure hull is the outside of the boat
- Less reserve buoyancy. Relatively small double-hull sections house the ballast tanks.
- All high-strength steel hulls
- All but one sub powered by a single PWR
- Except for the earliest subs, all have had single propellers
- Since Permit-class, all SSNs have had large, spherical array sonars and mid-ships torpedo tubes
- Few compartments inside the pressure hull. Sub not designed to withstand flooding of the largest compartment. Interior bulkheads not designed to same “test depth“ as hull.
- No crew escape capsules. Individuals escape via an escape trunk (airlock).
- Larger, well-trained crews.

Russian historical submarine construction & operational fleet



Source: Nordic Nuclear Safety Research report NKS-138

Russian nuclear-powered attack submarines (SSN)

Russian SSNs

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
627	November	1 (K-3)	107.4 m (352.4 ft)	7.9 m (25.9 ft)	3065 (surf) 4750 (sub)	2 x VM-A	27,000 (est)	30	1958	1958-90
627A	November	12	109.8 m (360.2 ft)	8.3 m (27.2 ft)	3118 (surf) 4069 (sub)	2 x VM-A	27,000 (est)	28	1959 - 63	1959-90
645	K-27 (1-of-a-kind)	1	109.8 m (360.2 ft)	8.3 m (27.2 ft)	3420 (surf) 4380 (sub)	2 x VT-1 LMRs	35,000	30	30 Oct 1963	1963-79
671	Victor I	16	92.5-95 m (303–312 ft)	10 m (32.8 ft)	3500 - 4300 (surf) 4750 - 6085 (sub)	OK-300: 2 x VM-4	31,000	32	1967	1967-97
671RT	Victor II	7	100-102 m (331-334 ft)	10 m (32.8 ft)	4245 – 4500 (surf) 5700 - 5800 (sub)	OK-300A: 2 x VM-4	31,000	30	1972	1972-97
671RTM	Victor III	25	102-107 m (334-351 ft)	10 m (32.8 ft)	4850 – 5200 (surf) 6300 - 7250 (sub)	OK-300A: 2 x VM-4A	31,000	29	1977 - 91	1977 - 2006
705 (Admiralty)	Alfa (Lira)	4	81.4 m (267 ft)	9.5 m (31.2 ft)	2264 (surf) 3130 (sub)	1 x OK-550 LMR	40,000	41	1976 - 81	1990-93
705K (Severodvinsk)	Alfa (Lira)	3	79.6 m (261)	9.5 m (31.2 ft)	2280 (surf) 3610 (sub)	1 x BM-40 LMR	40,000	41	1977 - 81	1990-93
685	Mike (1-of-a-kind)	1	117.5 m (385.5 ft)	10.7 m (35.1 ft)	4400 (surf) 6400 (sub)	1 x OK-650B3	45,000	30	1984	1984-89 (sank)

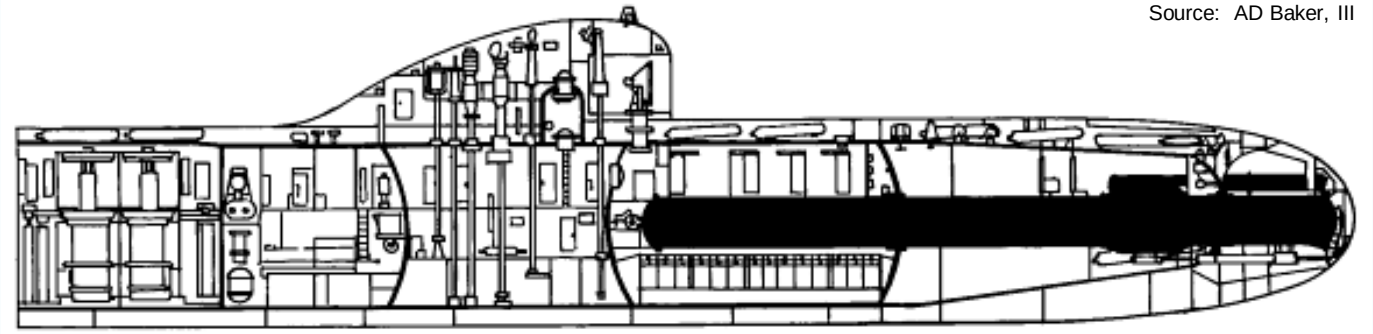
Russian SSNs

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
945	Sierra I (Barrakuda)	2	107 m (351 ft)	12.4 m (40.7 ft)	7500 (surf) 8600 (sub)	1 x OK-650B	36,500	34	1987	Laid up 1987 & 92, update started
945A	Sierra II (Kondor)	2	112 m (357.5 ft)	12.4 m (40.7 ft)	7630 (surf) 9500 (sub)	1 x OK-650B	36,500	32	1990 - 93	1990 - present
945AB	Sierra III (Mars)	5 (plan)	Not known	12.4 m (40.7 ft)	Not known	1 x OK-650B	36,500	12.4 m (40.7 ft)	Only one laid down in 1990, scrapped in 1993 before delivery	
971 & 971i	Akula I / Ii (Shchuka-B)	3 / 4	110.3 m (361.9 ft)	13.6 m (44.6 ft)	8140 (surf) 12770 (sub)	1 x OK-650B	36,500	35	1984-88 / 1991-17	1984 – present, some inactive
971U & 971 M	Akula II / III (Shchuka-B)	8 / 1	113.3 m (371.7 ft)	13.6 m (44.6 ft)	8450 (surf) 13400 (sub)	1 x OK-650B	36,500	35	1988 / 2001	1988 - present
885	Yasen (Graney)	1	111 m (364.2 ft)	12 m (39.4 ft)	8600 (surf) 13800 (sub)	1 x OK-650V	38,500	35	2013	2014 - present
885	Yasen-M (Graney)	9 (plan, 2015)	111 m (364.2 ft)	12 m (39.4 ft)	> 8600 (surf) > 13800 (sub)	1 x KPM-6	38,500 (est)	35 (est)	2015 - ongoing	

Project 627

Original concept for the November-class submarine

Source: AD Baker, III

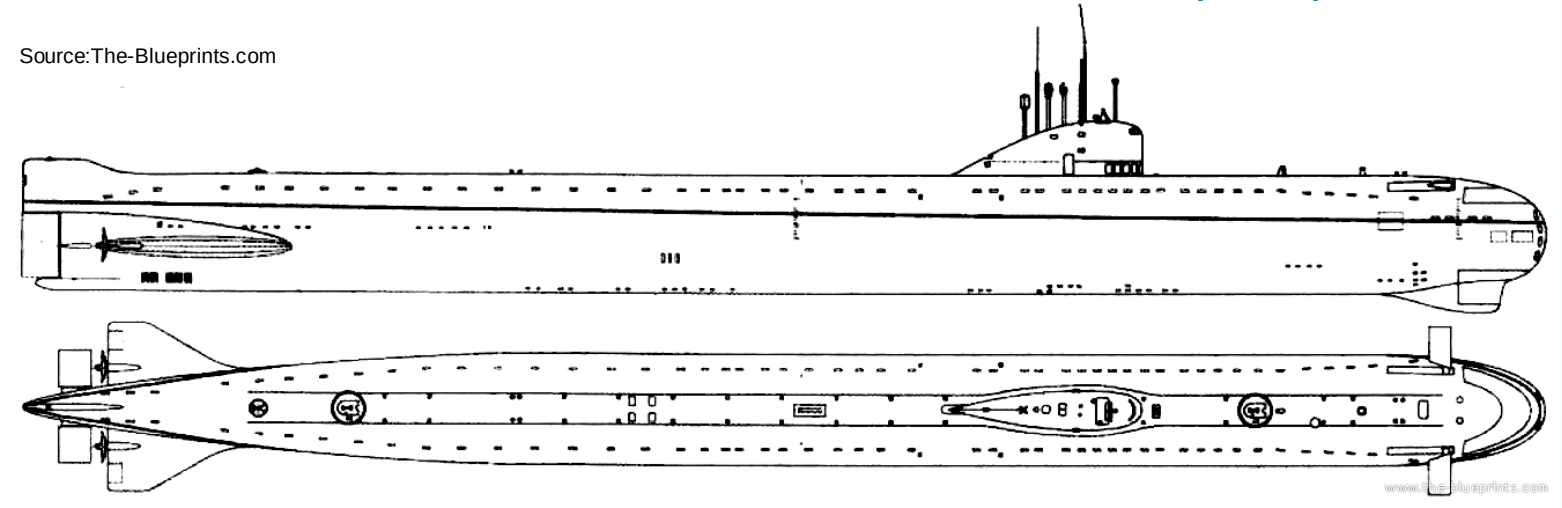


Note: Also refer to Polmar, Norman & Kenneth J. Moore; 2004; Cold War Submarine, The Design and Construction of U.S. and Soviet Submarines; Potomac Books, Inc.; Washington, D.C.; p. 74

- Stalin approved development of a nuclear submarine in 1952 and work on Project 627 began in Sep 1952.
  - The original mission of the Project 627 submarine was to destroy American naval bases and other selected coastal targets using a single, large, thermonuclear-armed torpedo.
  - Tactical and technical elements of the design were approved in Dec 1953.
- Original armament:
  - 1 x 1,550 mm (61 in) torpedo tube for one T-15 nuclear-armed torpedo
  - 2 x 533 mm (21 in) conventional torpedo tubes.
- The T-15 torpedo specifications:
  - Diameter: 1,550 mm (based on diameter of available Soviet nuclear weapons circa 1952 - 53); length: 23.5 m; weight: 40 tons, about 4 tons of which was reserved for the nuclear weapon
  - Power: battery; speed: 29 kts; planned range 30 - 40 km.
  - Nuclear yield: not specified, but likely in the megaton range
  - Fire control system "Tantalus" was intended to managed shooting a T-15 torpedo
- In March 1955, the above mission was cancelled. One concern was the ability of the submarine to get within range of the American coast to deploy the T-15. The Project 627 submarine mission was revised to a fast attack (SSN) mission.

Project 627, 627A

November-class fast attack submarines (SSN)

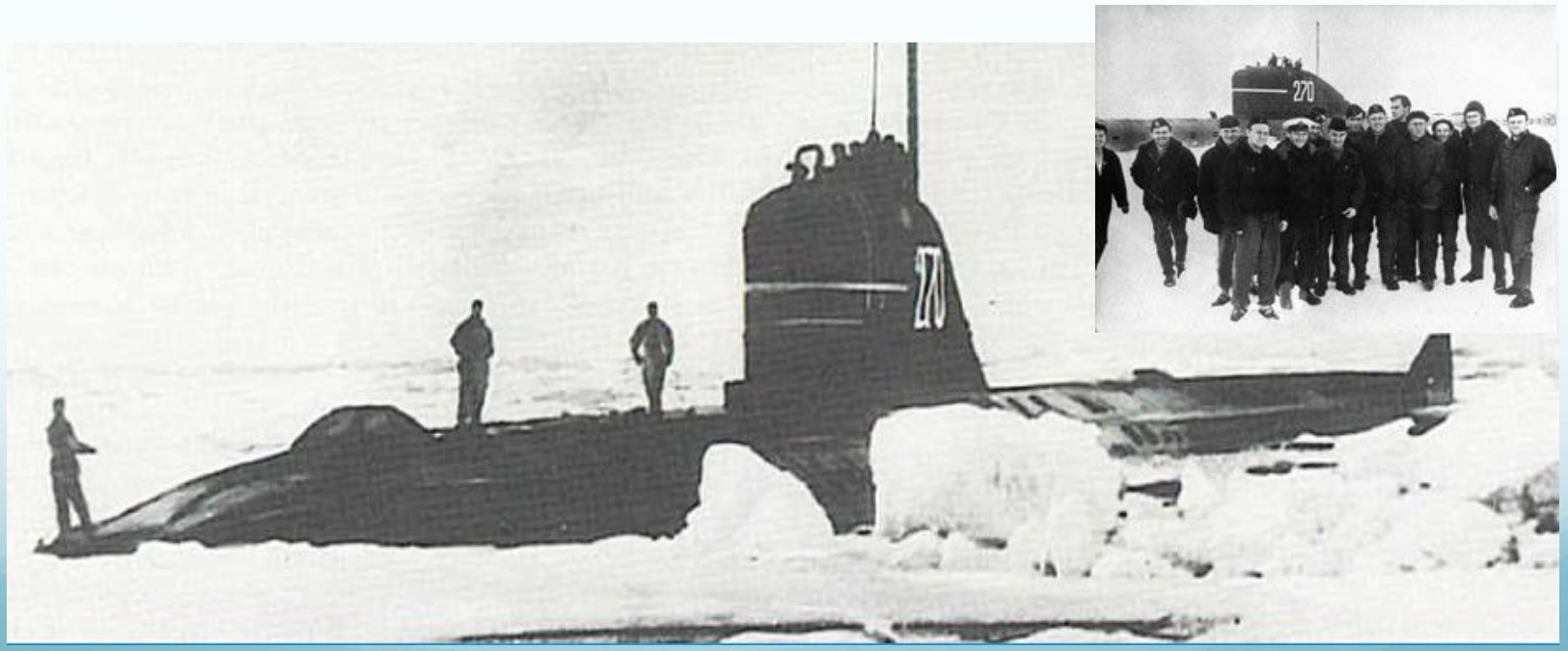


- 4 June 1958: November-class submarine K-3, *Leninsky Komsomol*, was the first Soviet vessel to be underway on nuclear power (almost 3-1/2 years after *USS Nautilus*).
  - K-3 was the only Project 627 boat. Other November-class boats were more combat-capable Project 627A boats equipped with the combat system of the Project 641 Foxtrot class diesel-electric attack submarines.
- Propulsion:
  - 2 x VM-A PWR reactors, each rated @ 70 MWt
  - 2 x steam turbines, combined rating of about @ 27,000 hp; driving 2 x shafts with variable-pitch propellers
- Armament: 8 x 533 mm bow torpedo tubes; storage for 20 torpedoes or a greater number of mines.

Leninsky Komsomol (K-3)

1st Russian sub to reach the North Pole

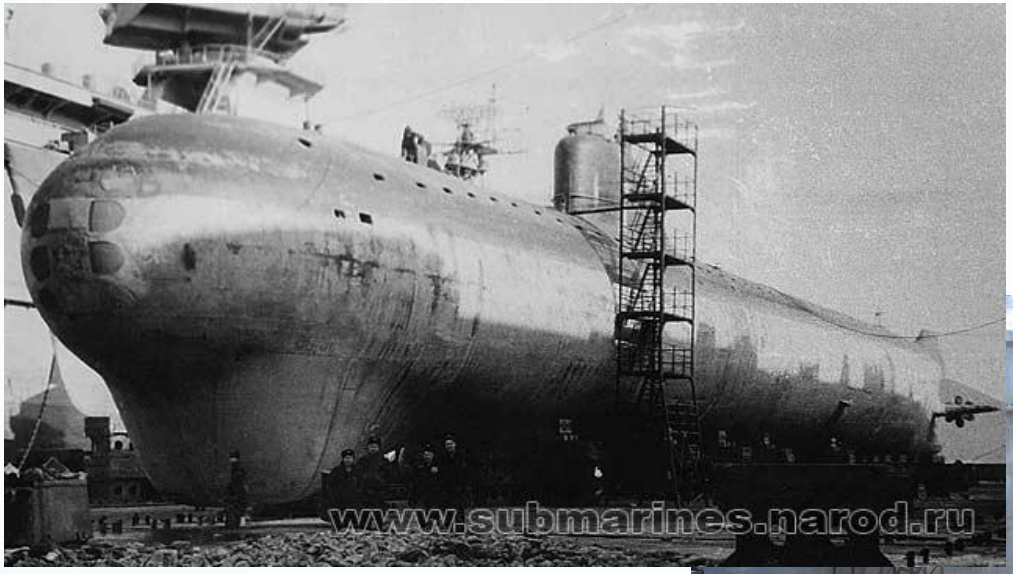
- November 1959: Initial Arctic under-ice voyage by November-class sub K-3 ended with a damaged periscope. K-3 did not reach the North Pole on this voyage.
  - The early mission showed that improvements were needed in ice monitoring instruments and training for Arctic operations. This was similar to 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.
- K-3 performed 14 long-range cruises and covered 128,443 miles over 30 years (1958–1988).
- In 2014, Rosatom and the Ministry of Defense finally agreed to make K-3 into a museum ship.

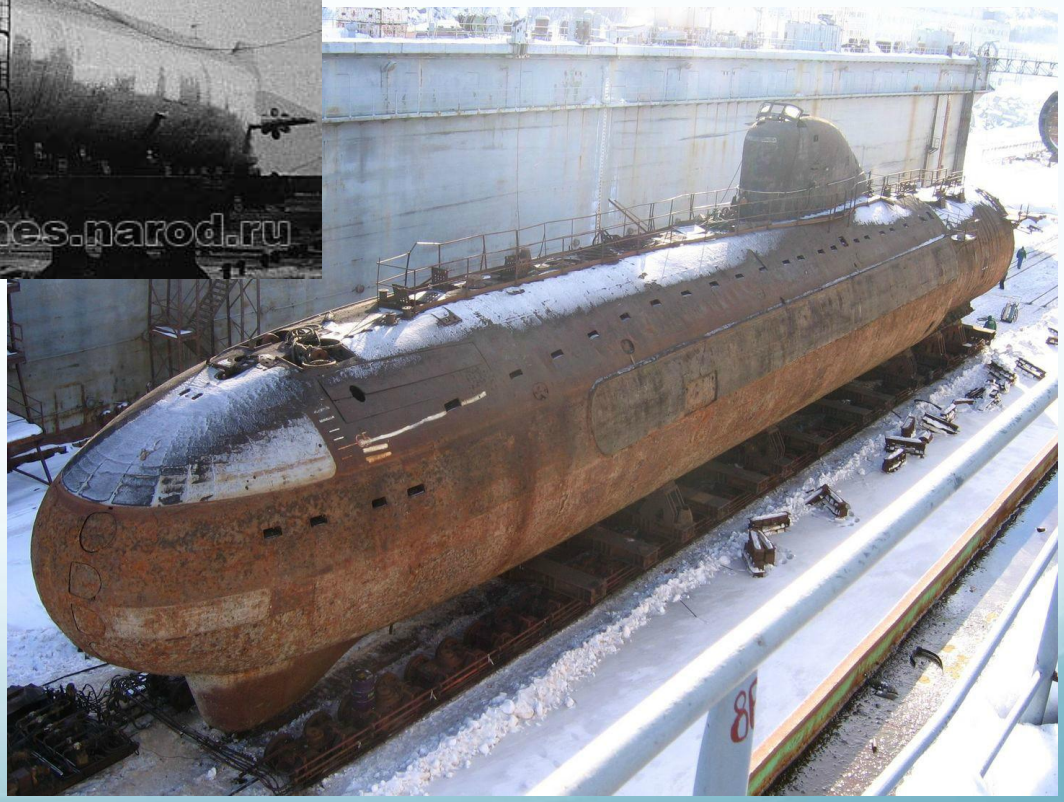


Source: rusnavy.com/history

Project 627, 627A

November-class fast attack submarines (SSN)





Operational matters:

- In 1968, the performance of a Soviet November-class sub surprised the U.S. Navy when it was able to keep pace with a high-speed carrier task force led by the nuclear-powered aircraft carrier *USS Enterprise* (CVN-65).
- November-class subs were much noisier than their U.S. counterparts.

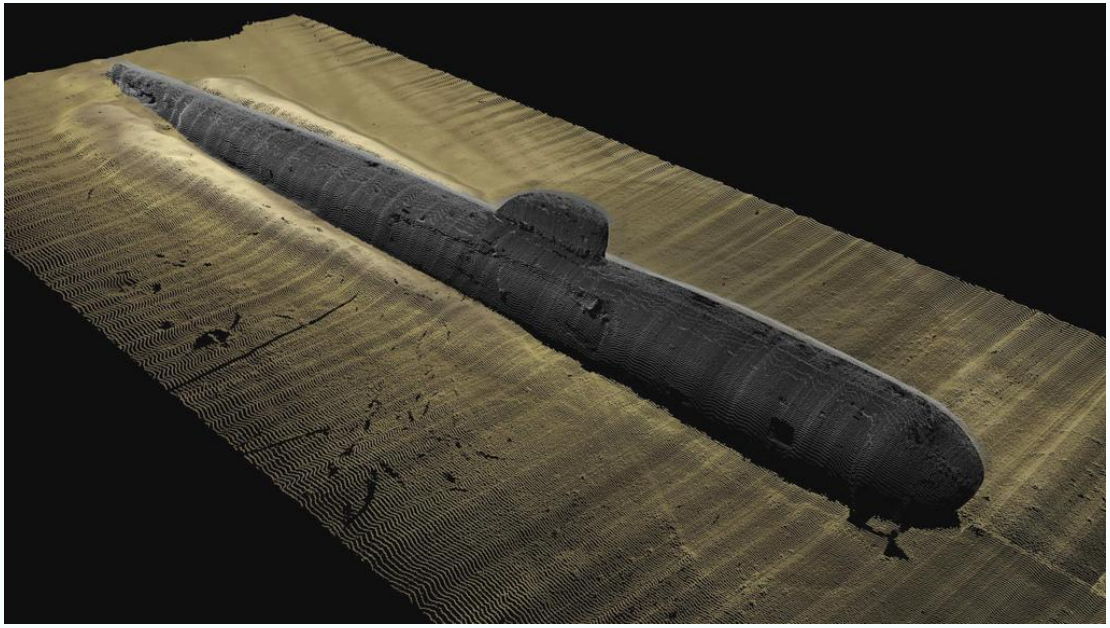
Source: www.reddit.com/r/WarshipPorn/

B-159 sinking in the Barents Sea

(former November-class K-159)

Source: bellona.ru

B-159 sinking in the Barents Sea



Visualization of multi-beam sonar data of B-159 from 2007 ADUS survey

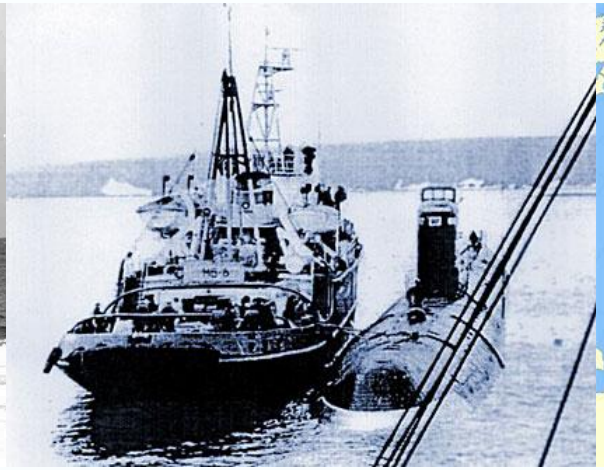
Source: *ADUS Deep Ocean and Salvage & Marine Operations (S&MO) of the UK MOD*

- November-class K-159 performed 9 missions, cruising 212,618 miles since commissioning in June 1963. K-159 was decommissioned in 1987 and renamed B-159 in 1989.
- 30 Aug 2003: B-159 was under tow from Gremikha to a shipyard in Murmansk to have its two fully-fueled reactors removed followed by scrapping the remaining vessel. During stormy weather, B-159 sank in a restricted military area in the Barents Sea, near Kildin Island.
- B-159 was found and investigated by Russian deep-sea vehicles the same day at a depth of 248 m (814 ft). The submarine sank stern first and stuck 12 m (39 ft) into the seabed. The hull then snapped at the aft end of the internal pressure hull and crashed to the seabed, leaving 8.5m (28 ft) of the outer casing, including the propellers, still buried vertically in the seabed.
- The 2007 survey by International Program for Arctic Military Environmental Cooperation (AMEC) found no indication of radioactive material leakage from into the environment.
- A joint Norwegian – Russian survey was conducted in Aug-Sep 2014. Results not yet available.

Project 645

K-27 fast attack submarine (SSN)

Source: http://theleansubmariner.com



Source: Vyacheslav Mazurenko

Source: bellona.ru

- One-of-a-kind submarine designed by SKB-143 for testing a liquid metal-cooled reactor installed in a Project 627A November-class hull; double hull with nine compartments;
- Propulsion:
  - 2 x VT-1 liquid metal-cooled (lead-bismuth eutectic) reactors, each rated @ 72 MWt
  - High-pressure steam would leak through the steam generators into the primary system, where it would oxidize the liquid metal coolant, requiring frequent cleaning of oxide particles from the coolant.
  - 2 x steam turbines with a combined rating of 35,000 hp; driving 2 x shafts
- Armament: 6 x 533 mm bow torpedo tubes
- Operations:
  - K-27 made deployments in 1964 & 1965 lasting 51 and 52 days, respectively.
  - A reactor accident occurred at sea on 24 May 1968. K-27 returned to port on one working reactor and never operated again.
  - The sub was scuttled on 6 Sep 1982 in shallow water in the Kara Sea.

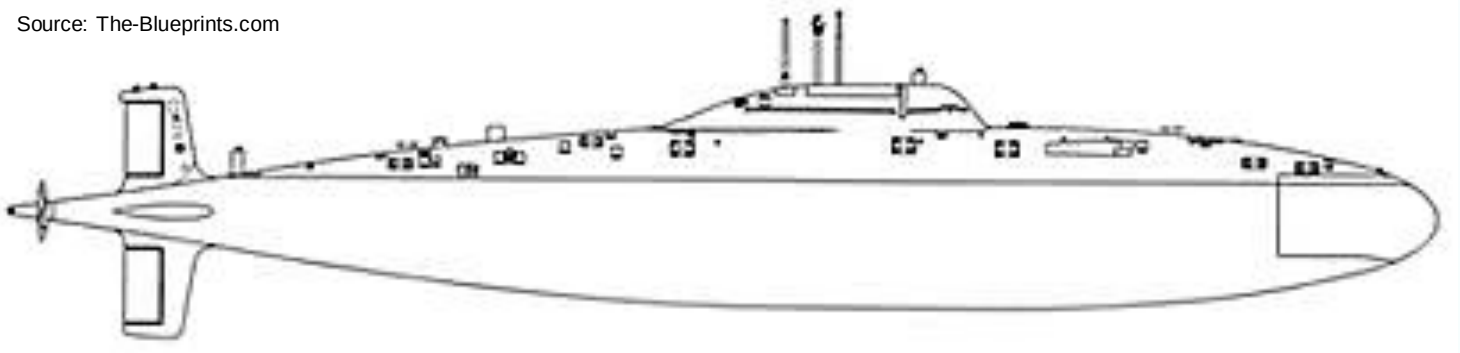
K-27 reactor accident at sea

- 24 May 1968 K-27 accident sequence:
  - With both VT-1 liquid metal cooled reactors initially at full power, the power level of one reactor dropped sharply (to about 7%) due to partial flow blockage.
  - Some fuel melted, fission products leaked into the reactor compartment and engineering spaces, and eventually to the rest of the submarine.
  - Maximum radiation levels reportedly reached about 150 Rem/hr (1.5 Grey/hr).
  - Apparently the Captain did not recognize that fuel failure had occurred in one reactor and delayed taking actions to protect the crew.
  - The remaining reactor continued operating, enabling K-27 to return to port.
  - Radiation alarms in the port were set off as K-27 approached.
  - Radiation exposures to the crew caused 9 deaths and 83 injuries, including 40 with acute radiation sickness.
- Approximately 20% of the fuel assemblies were found to be damaged
- Efforts to repair the submarine were unsuccessful. K-27 was officially decommissioned on 1 February 1979
- In summer 1981, its reactor compartment was filled with a special solidifying mixture to reduce ocean pollution prior to scuttling in shallow water (about 33 m, 108 ft) in Stepovogo Bay in the Kara Sea off Novaya Zemlya .
- In 2012, Russian and Norwegian scientists surveyed the K-27 site. No dangerous radioactive emissions where found on that mission.
- Experts believe that the sub will eventually have to be removed from its current location because of risk of radioactive contamination in shallow water.

Project 1710 Mackerel

Beluga diesel-electric experimental sub S-533

Source: The-Blueprints.com

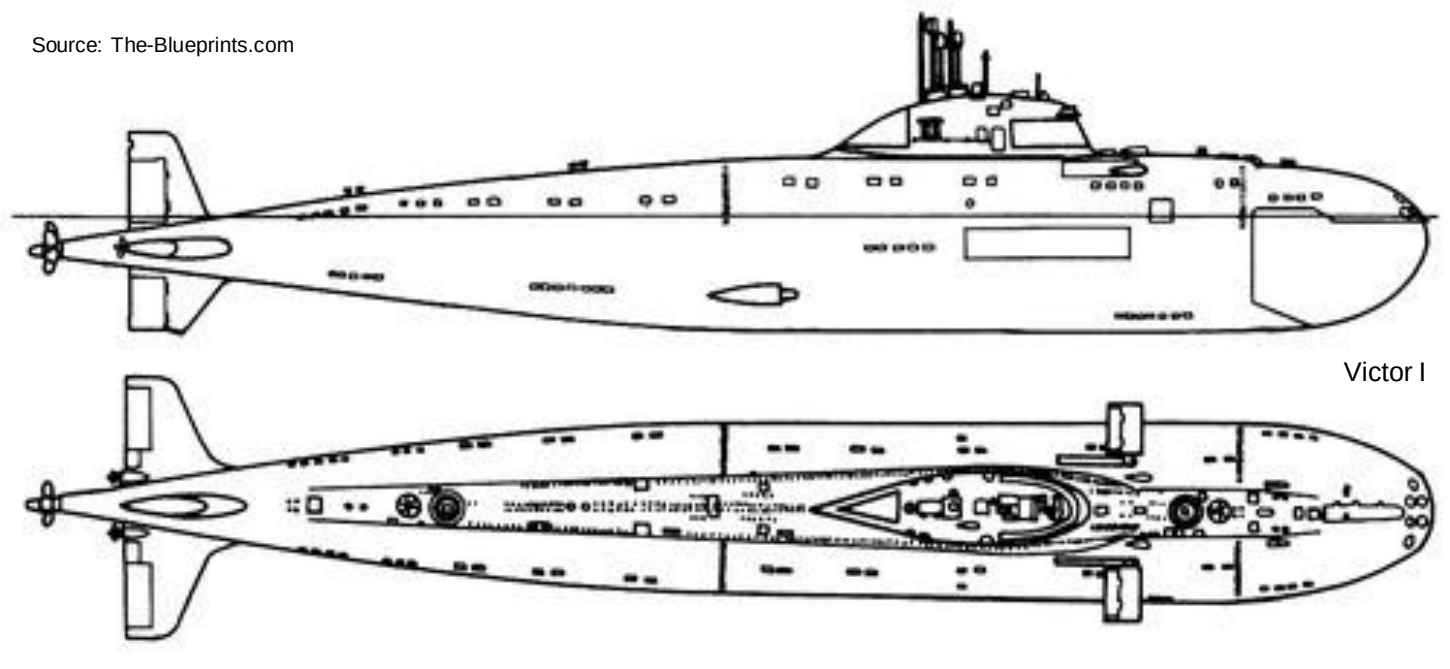


Project	Class	# in Class	Length	Beam	Displacement (tons)	Max speed	Years delivered	Years in service
1710	Beluga (Mackerel)	1	62-65.5 m (203.4-214.9 ft)	8.7 m (28.5 ft)	1400 (surf) 1900 (sub)	26.6 kts	1988	1987 – 97

- Experimental sub developed by Malakit Design Bureau. Commissioned in 1987.
- Built in Leningrad (St. Petersburg) and transferred via inland waterway for testing in the Black Sea. Testing focused on:
  - Streamlined hull form (7:1 length-to-beam ratio)
  - Propulsion system optimization, including propeller designs and distance between the prop and the hull,
  - Boundary-layer control via polymer injection into the flow stream around the hull and appendages
- Propulsion: 5,500 hp electric motor driving a single shaft and propeller.
- Beluga was an analog to the U.S. Albacore diesel-electric experimental sub, which entered service in 1953. Beluga was decommissioned and scrapped in 2002.
- This hull shape appeared on many later Russian nuclear subs.

Project 671(Yorsh), 671RT (Syomga) & 671RTM (Shchuka, aka 671 PTM)

Victor I, II & III-class fast attack submarines (SSN)



- 1st Russian nuclear sub with teardrop-shaped hull. Successor to the November-class SSNs
- Propulsion:
  - Victor I & II: OK-300: 2 x VM-4 PWRs, each rated @ 72 MWt
  - Victor III: OK-300A: 2 x VM-4A PWRs, each rated @ 75 MWt
  - 2 x steam turbines with a combined rating of 31,000 hp; driving 1 shaft
  - Two small, two-blade propellers are fitted on the stern planes for slow-speed operation

Project 671(Yorsh), 671RT (Syomga) & 671RTM (Shchuka, aka 671 PTM)

Victor I, II & III-class fast attack submarines (SSN)

- Armament:
  - Victor I: 6 x 533 mm (21”) bow torpedo tubes; stowage for 18 weapons; torpedoes, cruise missiles, mines
  - Victor II & III: 2 x 533 mm and 4 x 650 mm (25.6”) bow torpedo tubes; stowage for 18 weapons
  - Victor II introduced the 650 mm torpedo tubes and the Type 65 heavyweight torpedoes.
    - The Type 65 torpedo is a wire-guided torpedo with active/passive wake-homing sonar terminal guidance.
    - It has a range of 50,000 yards (28.5 mi) and was designed to be used against large enemy vessels (e.g. aircraft carriers) that would not be expected to sink if hit by one normal-sized (533 mm / 21”) torpedo.
    - The 650 mm torpedo tube can be fitted with a 533 mm converter to enable firing smaller size torpedoes and missiles.

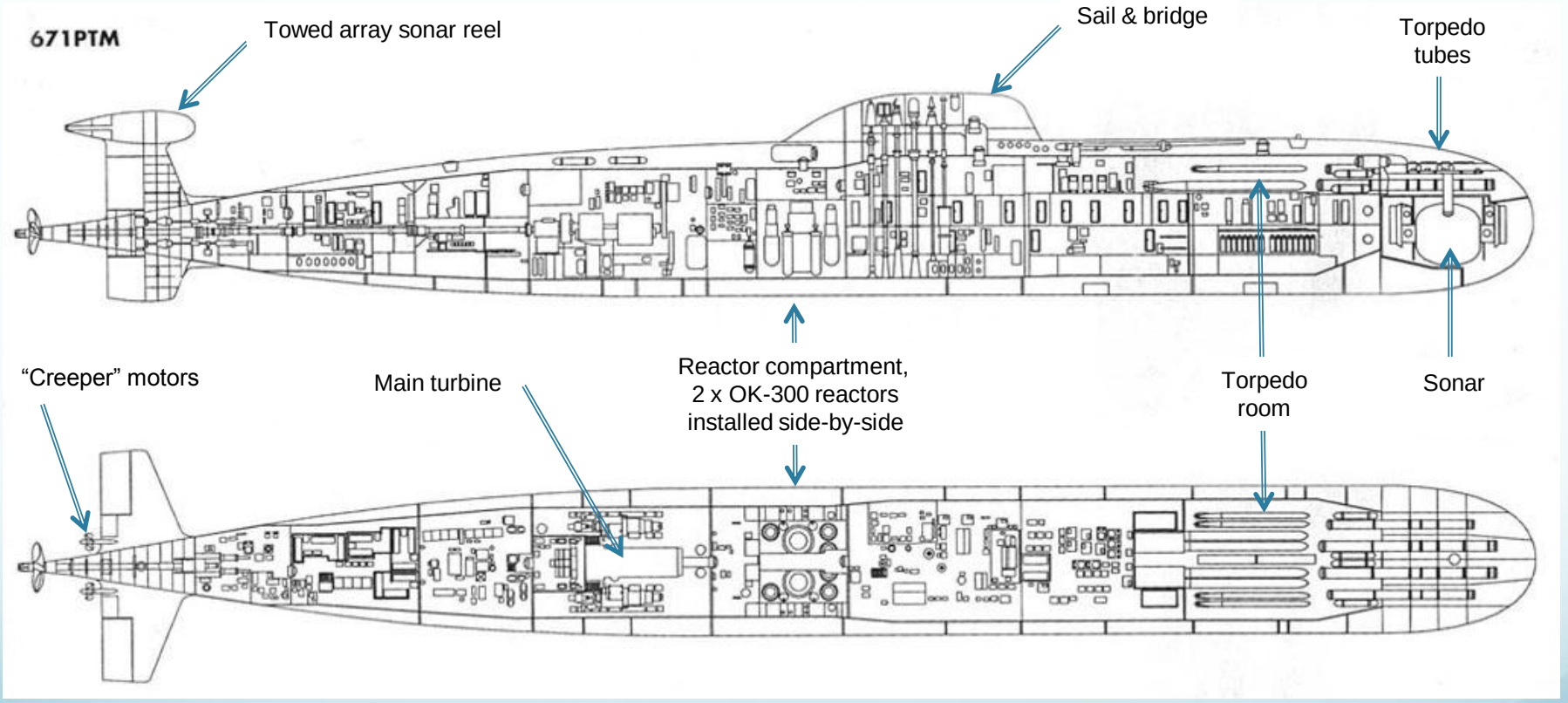
- Operational matters:
  - Victor-class subs were contemporary of the U.S. Sturgeon (637)-class SSN; faster, but the earlier Victor I and II models had greater radiated noise. Victor III was much quieter than the earlier versions.
  - Victor III hull was lengthened by nearly 20 feet to accommodate “rafting” and sound insulation for the turbine machinery.
  - Victor III also introduced a teardrop-shaped pod on top of the tail fin for handling a towed array sonar.

Victor III

Source: en.wikipedia.org

Project 671PTM

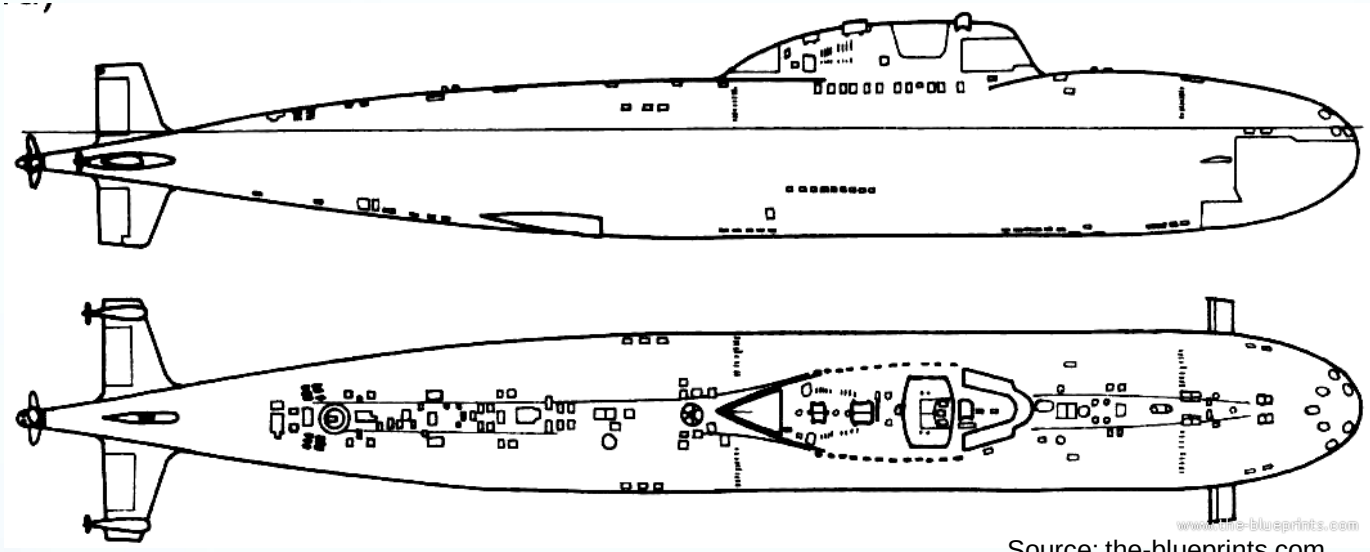
Victor III-class SSN notional arrangement

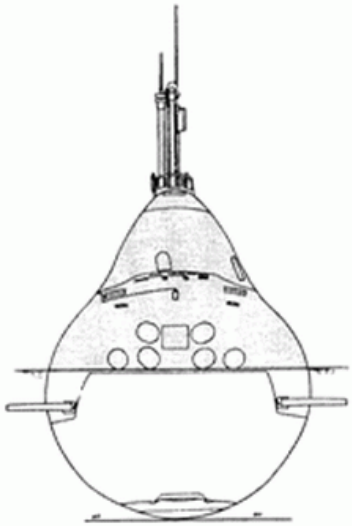


Source: warfare.be

Project 705 & 705K (Lira)

Alfa-class fast attack submarines (SSN)





Source: the-blueprints.com

- Four Project 705 subs built at the Admiralty Shipyard, St. Petersburg: K-377 (former K-64, 1st in class test ship), K-316, K-373 & K-463.
- Three Project 705K subs built at Sevmash Shipyard, Severodvinsk: K-123, K-432 & K-493.
- Propulsion:
  - Project 705 subs: 1 x OKBM Afrikantov OK-550 lead-bismuth cooled reactor rated @ 155 MWt
  - Project 705K subs: 1 x NIKIET BM-40A lead-bismuth cooled reactor rated @ 155 MWt
  - 2 x steam turbines with a combined rating of 40,000 hp driving a single shaft; also 2 x 75 hp “creeper” electric motors on horizontal fins for low-speed propulsion
  - Capable of a maximum speed of 41 kts.

Project 705 & 705K (Lira)

Alfa-class fast attack submarines (SSN)

- Titanium hull; maximum operating depth about 671 m (2,200 ft); first use of a crew rescue capsule in the sail.
- Armament: 6 x 533 mm torpedo tubes for torpedoes, mines, or SS-N-15 anti-submarine missiles (similar to U.S. SUBROC).
- Operational matters:
  - The Alfa class attack submarine had a crew of only about 30 due to the extensive use of automation
  - The Alfa sub reactors required a heater to prevent the liquid metal coolant from solidifying when the reactor was shutdown.
    - A special dockside facility was constructed at the Alfa sub base at Zapadnaya Litsa to supply steam to heat the reactors, but external heating proved to be generally unreliable.
    - Reactors were kept running even while the submarines were in port.
  - The reactors of the Alfa-class submarines were never refueled.
    - While the reactor core was intended to be loaded or unloaded as a “Removable Reactor Core Unit” (RRCU), in practice, it was not technically possible to remove the fuel assemblies without the metal coolant solidifying in the process.
    - When the reactor was shutdown in preparation for decommissioning, the liquid metal coolant solidified and the reactor control rods became fused with the coolant.
    - Conventional methods for disassembling the reactor could not be used. France’s CEA donated special equipment to remove and store the reactors.
    - All of the spent “removable reactor core units” (RRCUs) from Alfa-class submarines are stored at the Gremikha Naval Base in Murmansk

Project 705 & 705K (Lira)

Alfa-class fast attack submarines (SSN)

- Four of the seven Alfa-class subs were put out of service because of accidents involving their reactor plants:
  - 1974: K-377 suffered a equipment casualty during sea trials and the metal coolant "froze," damaging the OK-550 reactor; the reactor compartment was removed & sub decommissioned 1978.
  - 1982: K-123 BM-40A reactor accident caused by a leaking steam generator followed by a large amount of liquid metal coolant discharging into the reactor compartment.
    - 1983 – 1991 refit included reactor compartment replacement. Sub re-designated B-123 and was used for training; decommissioned 1995.
  - 1982: K-316 OK-550 reactor was damaged when the heating system was accidentally turned off while the sub was in port; decommissioned 1990
  - 1986: K-463 OK-550 unspecified reactor accident; decommissioned 1990.

Source: www.hollilla.com

Source: foxtrotalpha.jalopnik.com

Reactor removal from a decommissioned Alfa-class sub

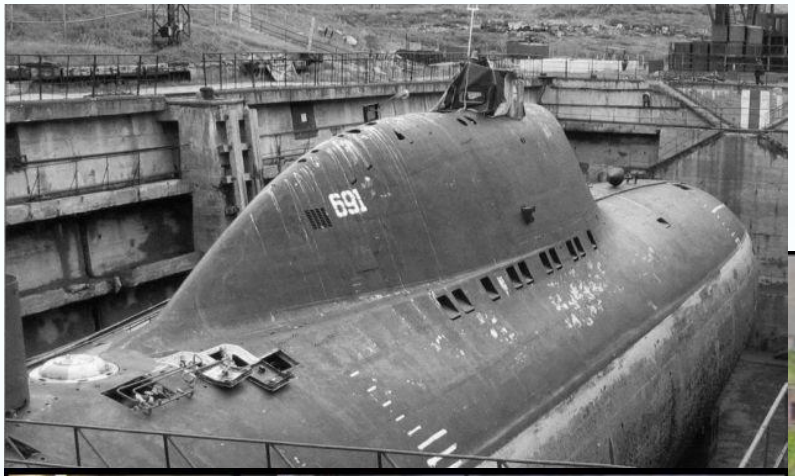
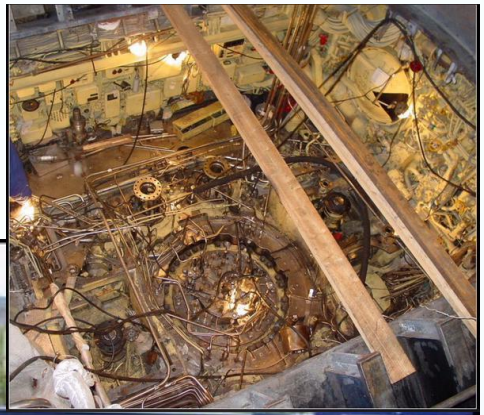


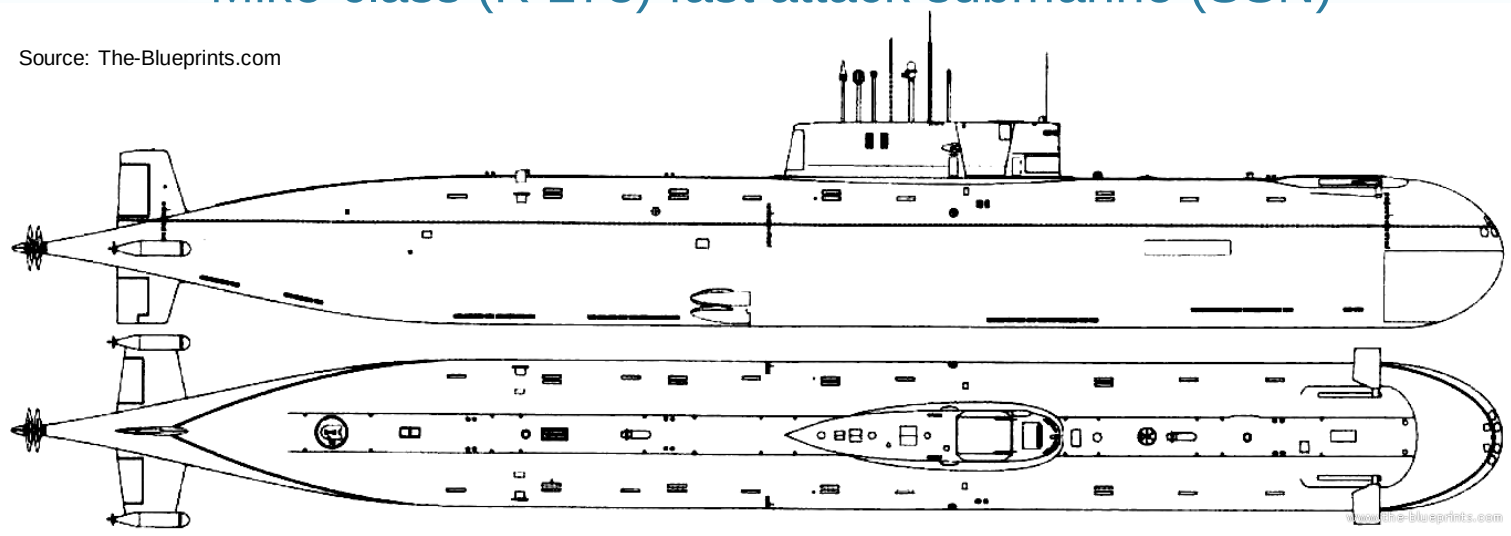
Photo left source:
http://foxtrotalpha.jalopnik.com

Other photos ource:
http://defence.pk/



Project 685 (Plavnik)

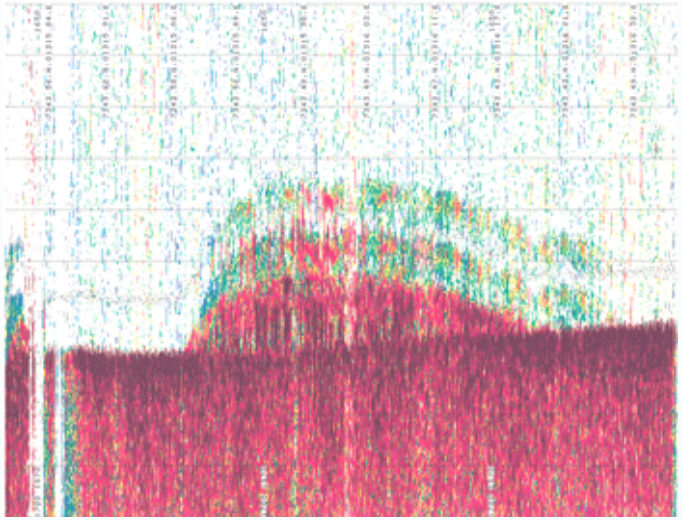
Mike-class (K-278) fast attack submarine (SSN)



- Double hull construction with a titanium inner hull comprised of 7 compartments.
  - Very deep-diving: 1,022 m (3,350 ft).
  - Emergency crew escape capsule in the sail.
  - Highly automated, enabling small crew (est. 64)
- Propulsion:
  - OK-650B3: 1 x PWR reactor rated @ 190 MWt
  - 2 x steam turbines with a combined rating of about 36,500; driving a single shaft
- Armament: 6 x 533 mm bow torpedo tubes
- Operational matters:
  - On 7 April 1989, K-278 had an accident at sea and sank to a depth of 1,680 meters (5,510 ft) in the Barents Sea.

Mike K-278 fire and sinking in the Barents Sea

- 7 April 1989 accident sequence:
  - *K-278 Komsomolets* had a fire in it's engineering compartment during the first operational patrol. Watertight doors were closed, ventilation shutdown, but fire spread by burning through bulkhead cable penetrations, and possibly from electrical short circuits.
  - Reactor shut down and propulsion lost.
  - Emergency ballast tank blow executed and *K-278* surfaced in the Barents Sea. Fire continued and the ship sank several hours later in 1,680 meters (5,510 ft) of water with two nuclear-armed torpedoes on board.
  - 42 crewmembers died, mostly from hypothermia before arrival of floating fish factory *Aleksey Khlobystov,* about 81 minutes after K-278 sank.
  - CO and four others exited the sinking sub via the escape capsule in the sail. Only one survived when the capsule sank in rough seas.
- Environmental assessments:
  - May 1992 Russian survey revealed cracks along the entire length of the titanium hull, some of which were of 30–40 cm (12–16 inches) wide, as well as possible breaches in the reactor coolant pipes.
  - Aug 1993 oceanographic survey of the area found that waters at the site were not mixing vertically, and thus the sea life in the area was not being rapidly contaminated. That survey also revealed a hole over six meters (20 feet) wide in the compartment 1 (torpedo room).
  - Mid-1994 survey detected some plutonium leakage.
  - Jun 1995 – Jul 1996: Russians made a series of visits to K-278 to "seal" the hull fractures in compartment 1 to limit further release from the nuclear warheads.
  - Aug 2008: Norwegian survey did not detected any significant radiation sources.



Sonar echogram of K-278 site
Source: Havforskningsinstitutte, Bergen

Artist concept of K-278 site. Note cracked hull & missing escape capsule (V-notch) in the sail

Project 945 Barrakuda, 945A (Kondor) & 945AB (Mars)

Sierra I, II and III-class fast attack submarine (SSN)

Source: The-Blueprints.com

- Designed by Lazurit Central Design Bureau with a titanium pressure hull, capable of operating at greater depth than it U.S. counterparts.
  - Emergency crew escape capsule in the sail.
- Propulsion:
  - OK-650B: 1 x PWR rated @ 190 MWt
  - 1 x steam turbine rated @ 36,500 hp; driving 1 shaft
- Armament:
  - 4 x 650 mm and 4 x 533 mm bow torpedo tubes for torpedoes, missiles and mines
- Operational matters:
  - Because of their titanium hulls, Sierra-class subs are being refurbished under Project 945M. The two Sierra I subs are expected to be back in service in 2016. There are plans to also refurbish the two Sierra II subs.

Examples of Russian submarine crew escape capsules

Sierra I SSN escape capsule in the sail

Source: forum.keypublishing.com

Typhoon SSBN escape capsule on the flanks of the sail

Source: forum.sub-driver.com

Innovative Russian torpedoes

Type 65 *Kit (Whale)* heavyweight torpedo

- Primary target: Aircraft carriers & other large vessels that may survive a standard torpedo hit
- Diameter: 650 mm (25.6 in)
- Length: 9.14m (30 ft)
- Weight 4,750 kg (10,472 lb)
- Warhead
  - 557 kg (1,268 lb) HE
  - Type 65-73 is an unguided, 20 kT nuclear variant introduced in 1973
- Max. speed: 50 kts (93 kph)

Source: https://www.pinterest.coom

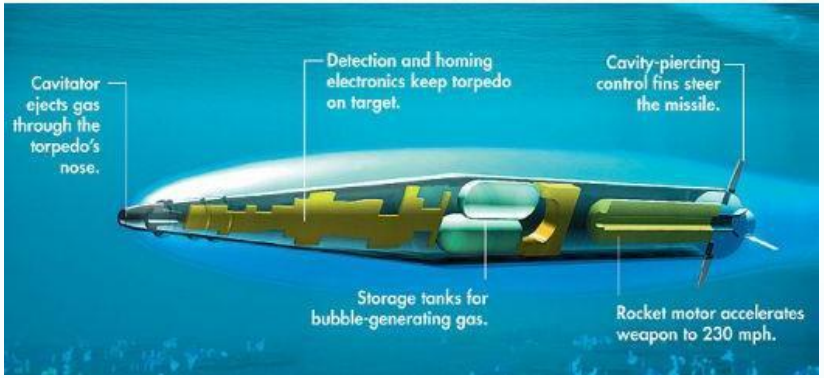
- High-test Hydrogen Peroxide (HTHP) fuel. An HTHP leak may have been the cause of the fire & explosions in the torpedo room that resulted in the sinking of the *Kursk* SSGN.
- Wire guided, wake homing, active/passive sonar
- Deployed only on subs with 650 mm torpedo tubes: Victor III, Sierra, Akula & Yasen SSNs, Oscar SSGNs.

Innovative Russian torpedoes

VA-111 *Shkval* (Squall) rocket-propelled torpedo

- Primary target: An attacking submarine or torpedo
- A stream of bubbles is generated inside *Shkval* and ejected through a special nozzle in the nose, creating a supercavitating bubble sheath that greatly decreases water drag.
- Max. speed: about 200 kts (372 kph)
- Diameter: 533 mm (21 in)
- Length: 8.2 m (26 ft 11 in)
- Weight: 2,700 kg (6,000 lb)
- Range: 11–15 km (6.8–9.3 mi)
- Guidance: Inertial + terminal guidance
- Warhead:
  - Initial version: Nuclear
  - Later versions: 210 kg (460 lb) conventional HE
- In service: 1977-present
- Widely deployed on Russian subs.

Notional Shkval cutaway drawing



Source: https://rwhiston.wordpress.com/2011/10/13/9/

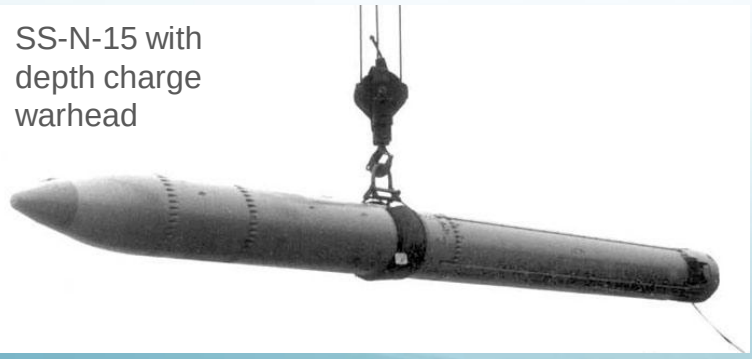
Gas ejection nozzle

Source: https://en.wikipedia.org/wiki/VA-111_Shkval#/

Russian submarine-launched anti-submarine missiles

Cruise missile	Years in service	Weight	Length	Diam (D) /Span (S)	Speed (mph)	Range	Guidance	Warhead
RPK-2 Viyoga (SS-N-15 Starfish) anti-sub missile	1969 - present Many submarines & surface ships	2,445 kg (5,390 lb)	8 m (est)(26.3 ft)	D = 533 mm (21 in)	Supersonic, ballistic	35-45 km (21.7-28.0 mi)	Inertial	Nuclear depth charge or 400 mm (15.75 in) light torpedo
RPK-7 Vodopei (SS-N-16 Stallion) anti-sub missile	1984 - present Many submarines & surface ships	Not known	8 m (est)(26.3 ft)	D = 533 mm (21 in) and D = 650 mm (25.6 in)	Supersonic, ballistic	100 km (62.1 mi)	Inertial	Nuclear depth charge or 400 mm (15.75 in) light torpedo
91RE1 & 91RE2 Kalibr /Klub anti-sub missile	2001 - present	2,050 kg (4,519 lb)	8 m (26.3 ft)	D = 533 mm (21 in)	Supersonic, ballistic	50 km (31 mi)	Inertial + homing torpedo	Light torpedo with 76 kg (168 lb) warhead

SS-N-15 with depth charge warhead



Source: http://topwar.ru/

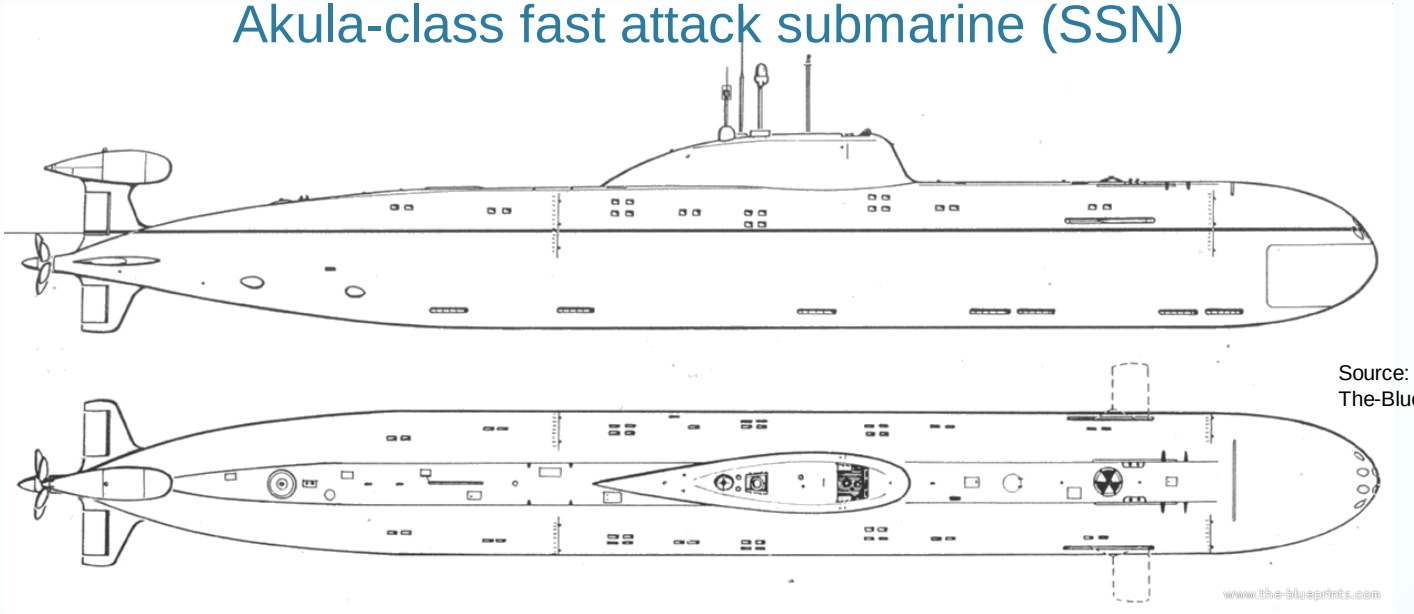
91RE1 & 91RE2 are expected to replace the SS-N-15 and SS-N-16 ASW missiles in the Russian Navy.

SS-N-16 with torpedo warhead

Source: http://militaryrussia.ru

Project 971 (Shchuka-B)

Akula-class fast attack submarine (SSN)



Source:
The-Blueprints.com

- Akula subs incorporated substantial improvements in sonar performance and radiated noise reduction.
- Extensive use of automation enables a small crew of about 50, which is less than one-half for the crew on a comparable U.S. SSN.
- Propulsion:
  - OK-650B: 1 x PWRs rated @ 190 MWt
  - 1 x steam turbine rated @ 36,500 hp (est.); driving 1 shaft
  - 2 x retractable electric motor-driven propulsors in the lower hull for slow speed propulsion.

Project 971 (Shchuka-B)

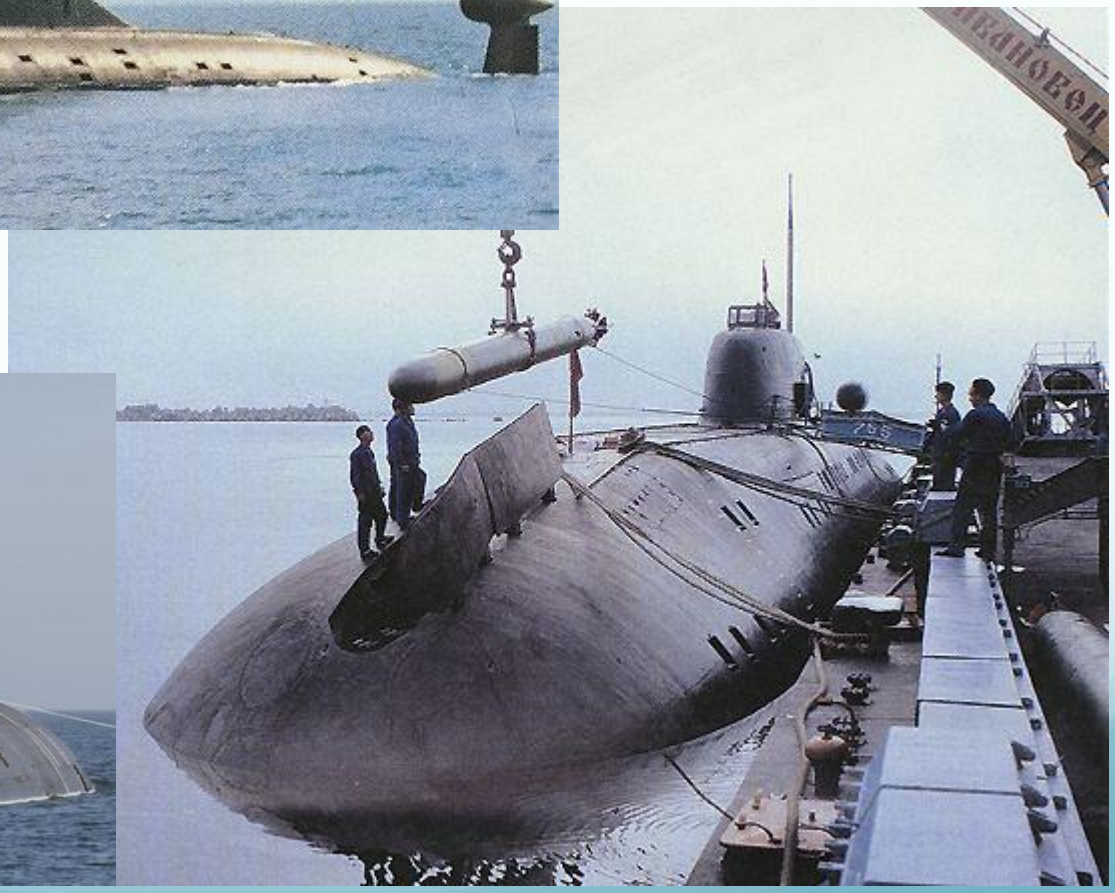
Akula-class fast attack submarine (SSN)

- Armament:
  - 4 x 533 mm bow torpedo tubes and stowage for 28 weapons
  - 4 x 650 mm bow torpedo tubes and stowage for 12 weapons
  - Improved Akula & Akula II have additional 533 mm bow torpedo tubes mounted external to the pressure hull, capable of launching decoys.
- Operational matters:
  - Three planned Akula II & III hulls were diverted for construction of the initial Borei-class SSBNs.
  - Two Akula II hulls were not completed and sold for scrap.
  - India has leased two Akula II subs from Russia.
    - Former Russian K-152, *Nerpa,* the longest and heaviest of the Akulas and likely to be among the quietest, was leased for 10 years, 2011 – 2021
    - In Dec 2014, India agreed to a 10-year lease for a second Akula II, K-322, *Kashalot*, to be delivered in 2018

Project 971 (Shchuka-B)

Akula-class fast attack submarine (SSN)

Source: www.subsim.com



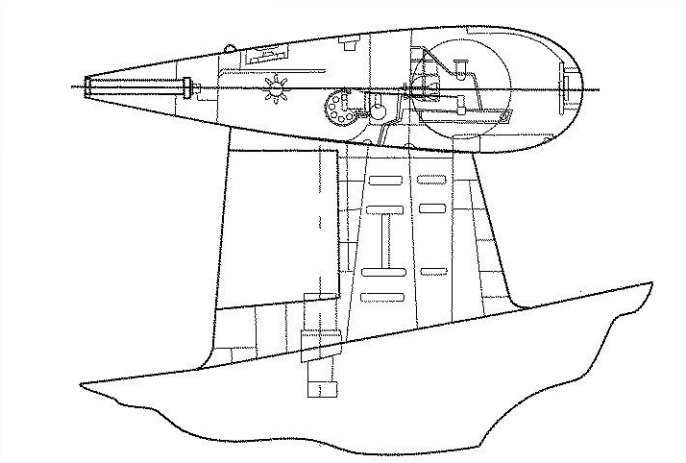
Source: www.china-sd.com

Akula special features

Akula in drydock, Rybachiy submarine base, Kamchatka.
Note the towed-array sonar pod on the top of the tail, and
the 7-bladed propeller with cruciform vortex diffuser at the tip.

Source: www.pinterest.com

Towed-array sonar pod

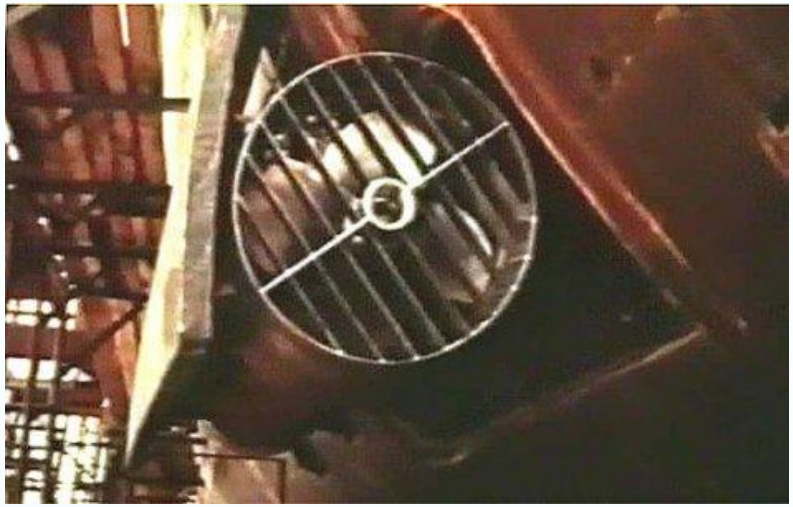


Source: http://www.shipmodels.info

Source: http://imgur.com/a/pZCb0

Akula special features

Retractable “creeper” low-speed propulsor



Source: https://battlemachines.wordpress.com/

SOKS

A wake may persist for several hours and wakes for different subs were different. Victors, Akulas and Sierras all have SOKS wake sensors. Russians claim to have trailed Ohio SSBNs for hours at a stretch by using SOKS, which allowed the training sub to stay beyond other sub’s sonar range while maintaining contact. Russians have wake homing torpedoes to kill subs without using sonar.

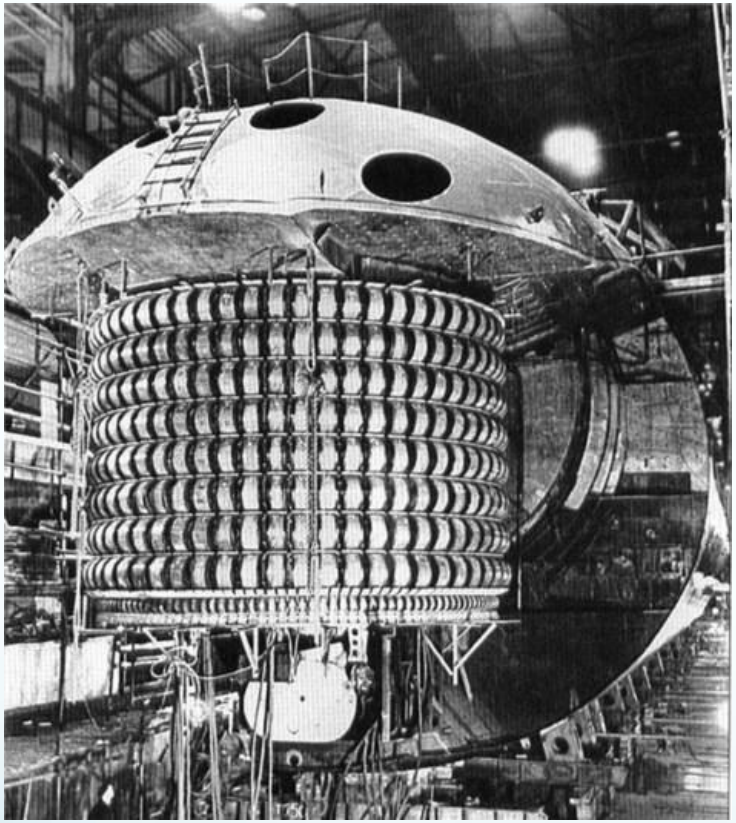
SOKS wake detection sensors on the leading edge of the sail

Source: https://battlemachines.wordpress.com/

SOKS sensors on the outer hull casing, forward of the sail

Source: https://battlemachines.wordpress.com/

Russian bow sonar arrays



Russian Victor cylindrical bow sonar array, torpedo tubes above

Akula SSNs & Oscars II SSGNs are fitted with the MGK-540 Skat-3 bow cylindrical bow sonar array. Torpedo tubes are above.

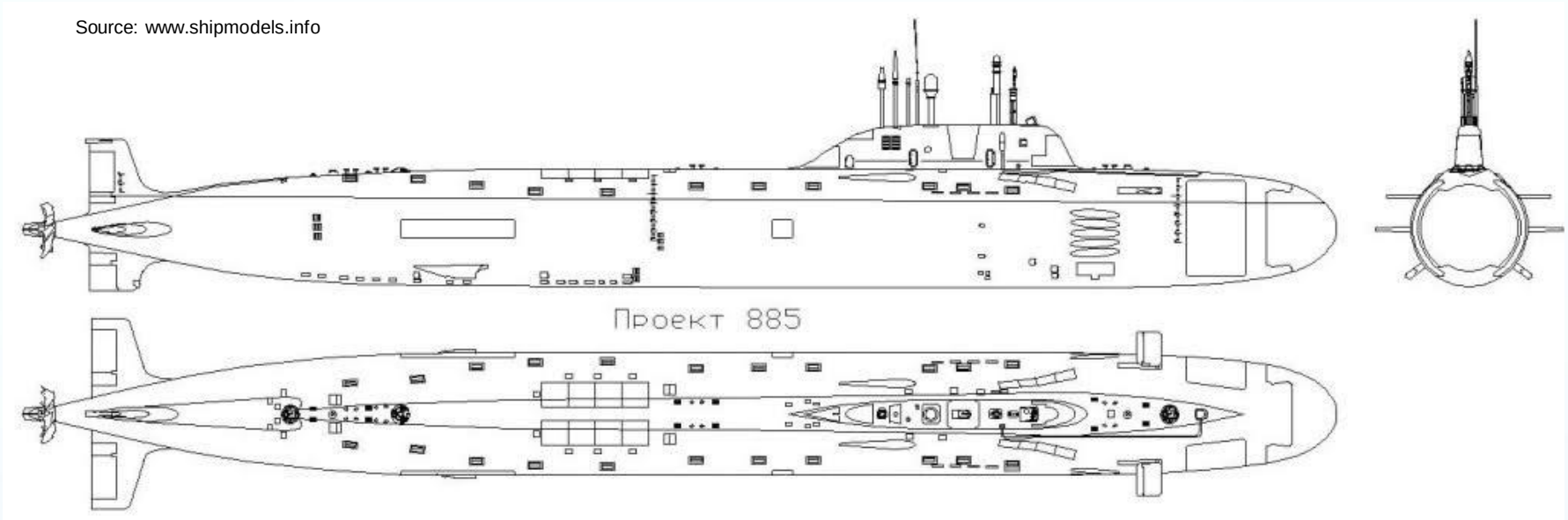
Source: http://31262.tumblr.com/

Russian Delta IV spherical bow sonar array, torpedo tubes are above

Source: https://twitter.com/russiannavyblog/status/

Project 885 (Yasen and Yasen-M)

Graney-class multi-purpose submarine



- Developed by Malakhit Central Design Bureau. Construction of the lead ship, *Severodvinsk*, started in 1993, was delayed due to funding, launched in 2010, and commissioned in 2013.
  - This is 1st Russian sub class with a spherical bow sonar array, similar to U.S. practice. The sonar suite also includes conformal flank arrays and a retractable towed-array sonar.
  - Expected to eventually replace Sierra & Akula SSNs and Oscar SSGNs.
  - Second ship in class, *Kazan*, keel laid 2009, will be first Yasen-M, which is expected to have improved electronics, new 4th generation nuclear plant with partial electric drive (for low speeds).
  - The keel for the the 4th Yasen-M boat, *Arkhangelsk*, was laid on 15 March 2015.

Project 885 (Yasen and Yasen-M)

Graney-class multi-purpose submarine

- Propulsion:
  - 1st in class Severodvinsk: OK-650V PWR rated @ 200 MWt, supplying steam to 2 x steam turbines with a combined rating of about 38,500 shp, driving one shaft
    - All OK-650 reactors operate on natural circulation at lower power, and requires pumps only at higher power.
  - Yasen M-class subs are expected to have a "4th-generation" nuclear reactor, which has been referred to as a KPM-6.
    - Reactor designer has not been identified
    - The new reactor is expected to have a 25-30 year core life. No refueling for the life of the sub.
  - 10 x amidships torpedo tubes [8 x 650mm (25.6 in) & 2 x 533mm (21 in)], storage for 30 weapons.
  - 8 large diameter Vertical Launch System (VLS) tubes located aft of the sail. The large diameter permits carrying a varied weapons load.
    - This is very similar to U.S. plans for the future Virginia-class Block V submarines.
  - VLS cruise missile options include:
    - 3 x P-800 (SS-N-26) Oniks cruise missiles per VLS tube.
    - 5 x Kalibr (SS-N-27 & SS-N-30A) cruise missiles per VLS tube. Kalibr is the Russian domestic version of the 3M-54 Klub (Club) export cruise missile, which is available in land-attack, anti-ship, and anti-submarine versions.
- Operational matters:
  - Crew size is about 90, which is much smaller than the 134 person crew for a comparable U.S. Virginia-class SSN.
  - Test depth is believed to be 600 m (2,000 ft), substantially greater than any U.S. SSN.
  - Yasen is expected to be the quietest Russian submarine built to date.

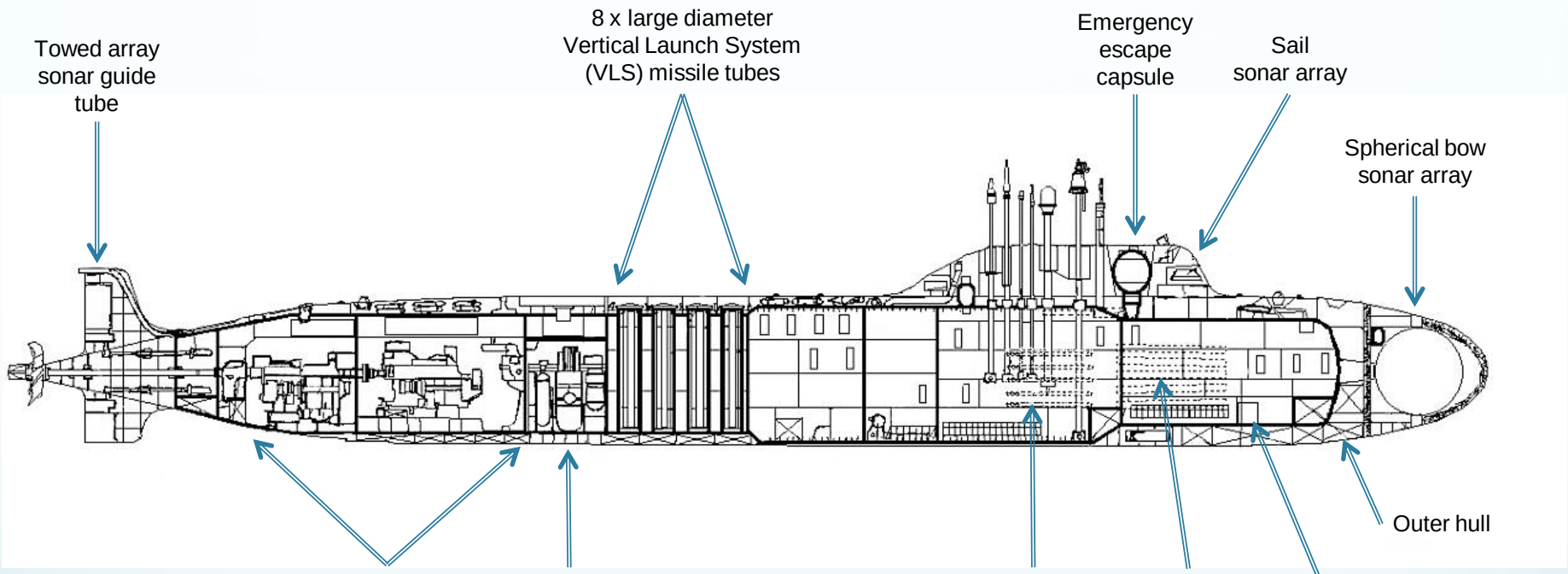
Project 885 (Yasen)

Graney-class multi-purpose submarine

Source: Vorkunkov Maxim, www.sevmash.ru

Project 885 (Yasen)

Notional arrangement of the Graney-class multi-purpose submarine



Source: adapted from dofiga.net

Project 885 (Yasen)

Graney-class multi-purpose submarine

Source: www.jeffhead.com/modelbuilds/RUS-k329.htm

Project 885 (Yasen)

Escape capsule test

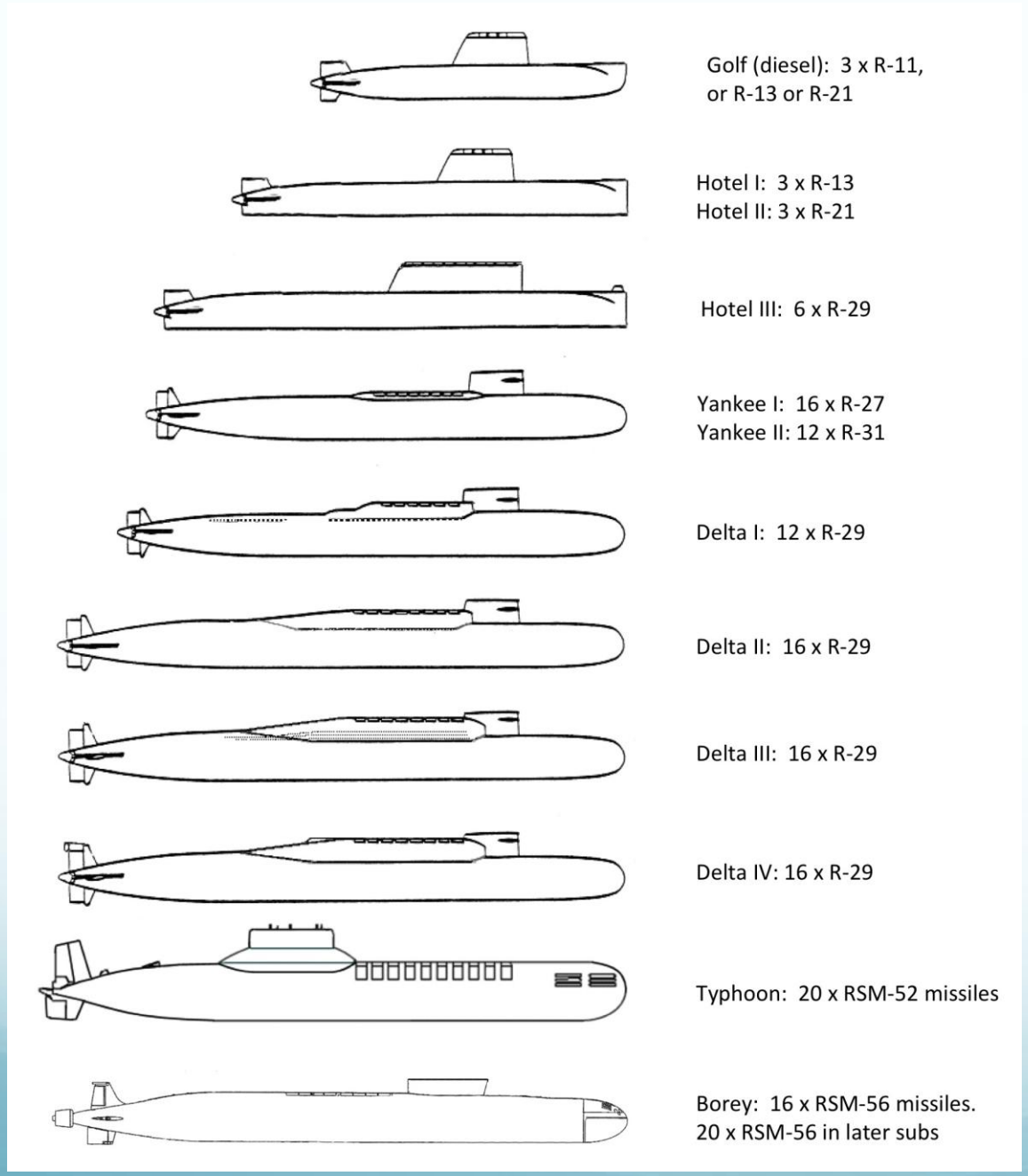
Source: englishrussia.com/2014/11/10

Russian 5th generation SSN concept

15 December 2014 press release from Malakhit Central Design Bureau, St. Petersburg

- The Malakhit Bureau had been developing the concept of fifth-generation (multi-purpose) attack subs on its own initiative as the Russian Defense Ministry had not yet provided the company with the list of design specification demands.
- Malakhit's Deputy General Director Nikolai Novoselov's described the expected characteristics of 5th generation nuclear-powered attack submarines.
- The subs will retain the Russian traditional double-hull submarine structure.
  - "We believe it is better than the single-hull design," which is traditionally used in U.S. subs.
- Displacement will be similar to that of the 4th generation Yasen-class attack subs, approximately 12,000 tons.
- The 5th generation (multi-purpose) subs will also be armed with torpedoes, missiles, mines, and unmanned underwater vehicles (UUVs).
  - UUVs will be able to detach from the submarine, power up on command, and be recovered if desired.
  - The submarine will be able to leave the area covertly, while the drone can remain to accomplish the submarine's mission in the area.

Russian strategic ballistic missile submarines (SSBN)



Evolution of Soviet /Russian strategic ballistic missile submarines

Russian SSBNs

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
658	Hotel I	8 *	114 m (374 ft)	9.2 m (30.2 ft)	4080 (surf) 5000 (sub)	2 x VM-A	27,000 (est)	26	1960 - 62	1960 - 69
658M	Hotel II	7 *	114 m (374 ft)	9.2 m (30.2 ft)	4660 (surf) 5588 (sub)	2 x VM-A	27,000 (est)	26	1963 - 67	1963 - 91
701	Hotel III	1 *	130 m (426.5 ft)	9.2 m (30.2 ft)	5500 (surf) 6400 (sub)	2 x VM-A	27,000 (est)	22	1970	1970 - 89
667A	Yankee I	34	132 m (433 ft)	11.6 m (38 ft)	7700 (surf) 9300 (sub)	OK-700: 2 x VM-4-2	34,500	27	1964-74	1967-83
667AU	Yankee I	Modified 667A	Same	Same	Same	OK-700: 2 x VM-4-2	34,500	Same	1972-83	1972-94
667AM	Yankee II	Modified 667A	Same	Same	Same	OK-700: 2 x VM-4-2	34,500	Same	1977-80	1980-90
667B	Delta I (Murena)	18	139 m (456 ft)	12 m (39.4 ft)	9000 (surf) 11000 (sub)	OK-700: 2 x VM-4B	52,000	25	1971 - 77	1973 - 98
667BD	Delta II (Murena-M)	4	155 m (508.5 ft)	12 m (39.4 ft)	10500 (surf) 13000 (sub)	OK-700: 2 x VM-4B	55,000	24	1973 - 75	1975 - 96
667 BDR	Delta III (Kalmar)	14	166 m (544.6 ft)	12 m (39.4 ft)	13500 (surf) 18200 (sub)	OK-700A: 2 x VM-4S	60,000	24	1976 - 82	1975 – present **

* All Hotel I converted, 7 to Hotel II; 1 converted to Hotel III.

Russian SSBNs

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
667 BDRM	Delta IV (Delfín)	7	166 m (544.6 ft)	12 m (39.4 ft)	13500 (surf) 18200 (sub)	OK-700A: 2 x VM-4SG	60,000	24	1984 - 90	1984 – present **
941	Typhoon (Akula)	6	175 m (574.1 ft)	23 m (75.5)	23200 (surf) 33800 (sub)	2 x OK-650	100,000	25	1981 - 89	1981 – present **
955	Borey (Borej)	3 (mid-2015)	170 m (557.7 ft)	13.5 m (44.3 ft)	14700 (surf) 24000 (sub)	2 x OK-650B	73,000	29	2012	2012 – present **
955	Improved Borey (Borej)	10 (planned)	Not known	13.5 m (44.3 ft)	Not known	2 x OK-650V	73,000	29	2016 – 17 expected	

** As of mid-2015, the following Russian SSBNs were in service:

- 2 x Delta III, armed with the R-29R / RSM-50 Vysota SLBM, operating with the Pacific Fleet (Kamchatka)
- 6 x Delta IV, armed with the R-29RMU Sineva or newer R-29RMU2 Layner SLBM, operating with the Northern Fleet (Kola Peninsula)
- 3 x Borei, armed with the RSM-56 Bulava SLBM*: Yuriy Dolgorukiy, Alexander Nevsky & Vladimir Monomakh; one assigned to Northern Fleet, two assigned to Pacific Fleet*.
- 1 x Typhoon, operating as a testbed for the RSM-56 Bulava SLBM. Not counted as an operational SSBN.

Russian SLBMs

SLBM	Years in service (platform)	Weight	Length	Diam	# of stages	Range	Warheads
R-13 (SS-N-4 Sark)	1961 - 75 (Golf I, Hotel I)	13,700 kg (33,203 lb)	11.8 m (38.7 ft)	1.3 m (4.26 ft)	1 liquid	560 km (348 mi)	1 x 1.0 – 2.0 MT
R-21/R21A (SS-N-5 Sark)	1963 - 91 (Golf II, Hotel II)	16,500 kg (36,376 lb)	13.0 m (42.7 ft)	1.2 m (3.94 ft)	1 liquid	R-21: 1,300 km (808 mi) R-21A: 1,650 km (1,025 mi)	1 x 800 kT
R-27 / RSM-25 (SS-N-6 Serb)	1968 (Yankee)	14,200 kg (31,306 lb)	8.89 m (29.2 ft)	1.5 m (4.92 ft)	1 liquid	Mod I: 2,400 km (1,491 mi) Mod II: 3,000 km (1,864)	Mods I & II: 1 x 1 MT Mod III: 3 x 200 kT
R-29 / RSM-40 (SS-N-8 Sawfly)	1973 - 94 (Hotel III, Delta I); 1977 - 96 (Delta II)	32,800 kg (72,312 lb)	13.0 m (42.7 ft)	1.8 m (5.90 ft)	2 liquid	Mod I: 7,700 km (4,785 mi); Mod II: 9,100 km (5,654 mi)	1 x 0.6 – 1.5 MT
R-29R / RSM-50 Vysota (SS-N-18 Stingray)	1983 - present (Delta III)	35,300 kg (77,823 lb)	14.4 m (47.2 ft)	1.8 m (5.90 ft)	2 liquid	Mod I: 6,500 km (4,098 mi) Mod II: 8,000 km (4,971 km) Mod III: 6,500 km (4,039 mi)	Mod I: 3 x 200 kT Mod II: 1 x 450 kT Mod III: 7 x 100 kT
R-29RM / RSM-54 (SS-N-23 Skif)	1986 - 2010 (Delta IV)	40,300 kg (88,846 lb)	14.8 m (48.6 ft)	1.9 m (6.23 ft)	3 liquid	8,500 km (5,282 mi)	4 x 100 kT
R-29RMU Sineva	2007 - present (Delta IV)	40,300 kg (88,846 lb)	14.8 m (48.6 ft)	1.9 m (6.23 ft)	3 liquid	11,500 km (7,146 mi)	4 or 10 x 100 kT
R-29RMU2 Layner	2014 - present (Delta IV)	35,400 kg (78,044 lb)	15.0 m (49.2 ft)	1.9 m (6.23 ft)	3 liquid	8,000 km (est) (4,971 mi)	Up to 12 low-yield

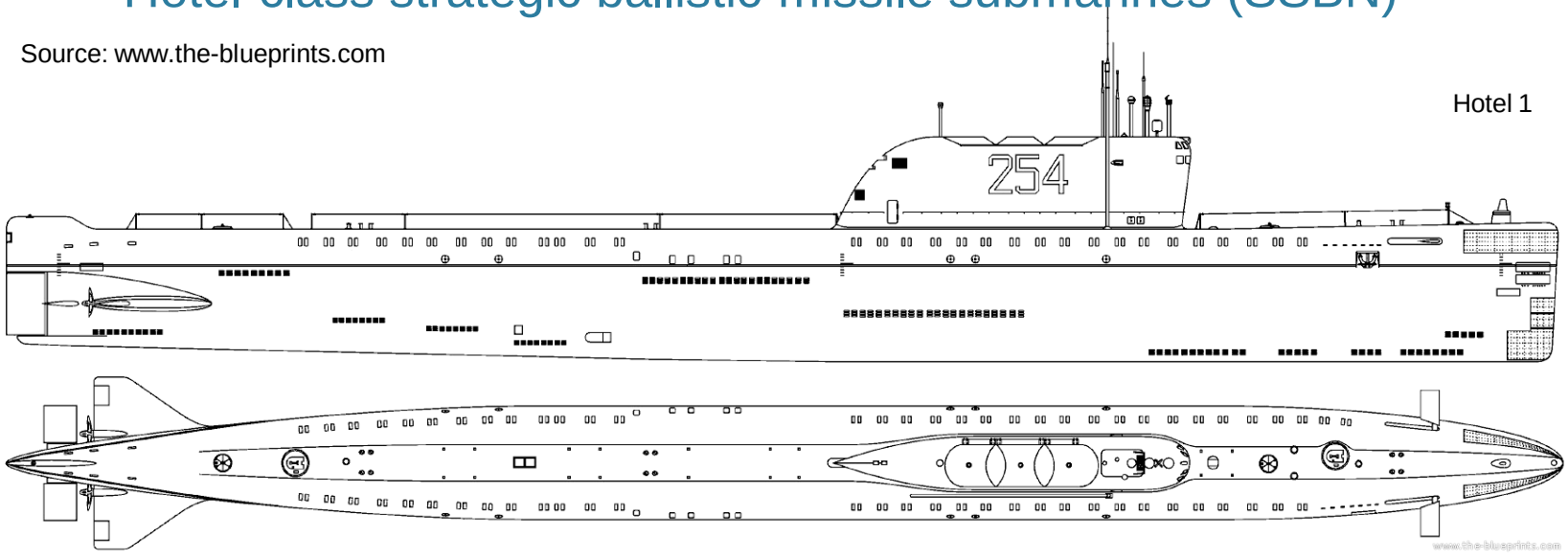
Russian SLBMs

SLBM	Years in service (platform)	Weight	Length	Diam	# of stages	Range	Warheads
R-31 / RSM-45 (SS-N-17 Snipe)	1980 - 91 (1 x Yankee II)	26,900 kg (59,304 lb)	10.6 m (34.8 ft)	1.54 m (5.05 ft)	2 solid	3,900 km (2,423 mi)	1 x 500 kT
R-39 / RSM-52 (SS-N-20 Sturgeon)	1983 - 2004 (Typhoon)	84,000 kg (185,188 lb)	16.0 m (52.5 ft)	2.4 m (7.87 ft)	3 solid	8,300 km (5,157 mi)	10 x 100 – 200 kT
RSM-56 Bulava (SS-NX-32)	2014 – present (Borei)	33,500 kg (73,855 lb)	11.5 m (37.7 ft)	2.0 m (6.56 ft)	2 solid + 1 liquid	10,000 km (6,214 mi)	Up to 10 x 100 -150 kT, maneuverable

658, 658M & 701 Project

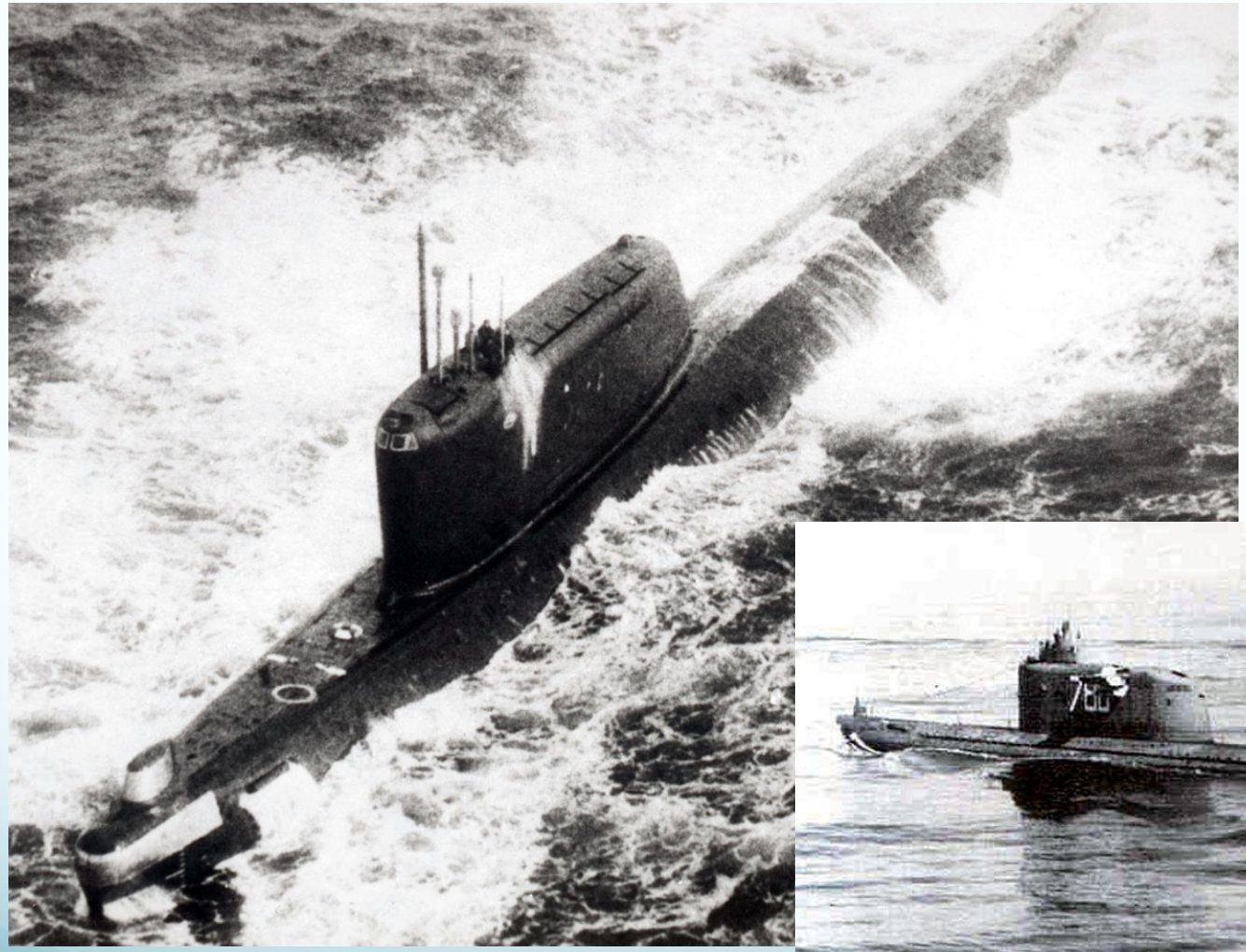
Hotel-class strategic ballistic missile submarines (SSBN)

Source: www.the-blueprints.com

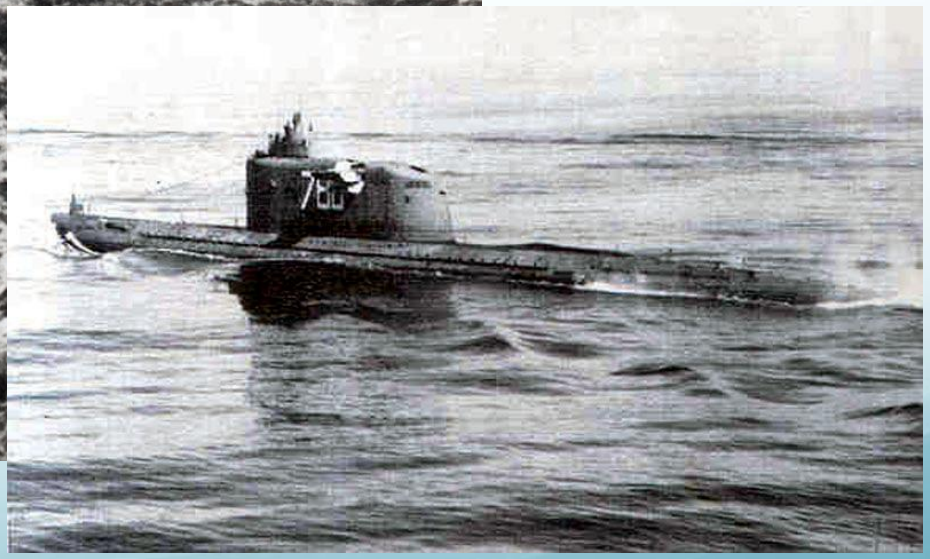


- Soviet Union's 1st SSBN; based on the design of the conventionally-powered Golf II SSB
- Propulsion:
  - 2 x VM-A PWRs rated @ 70 MWt
  - 2 x steam turbines with a combined rating of about 26,900 shaft horsepower; driving 2 x shafts
- Armament: 3 x strategic missile tubes in the sail, partially outside the pressure hull; also 4 x 533 mm and 4 x 400 mm torpedo tubes
  - Hotel I: D-2 launch system required launch when surfaced; 3 x R-13 missiles could be fired within 12 minutes after surfacing
  - Hotel II & III: D-4 launch system allowed submerged launch from a depth of 15 m (49 ft); Hotel II: 3 x R-21 missiles; Hotel III 6 x R-29 missiles

Hotel-class SSBN

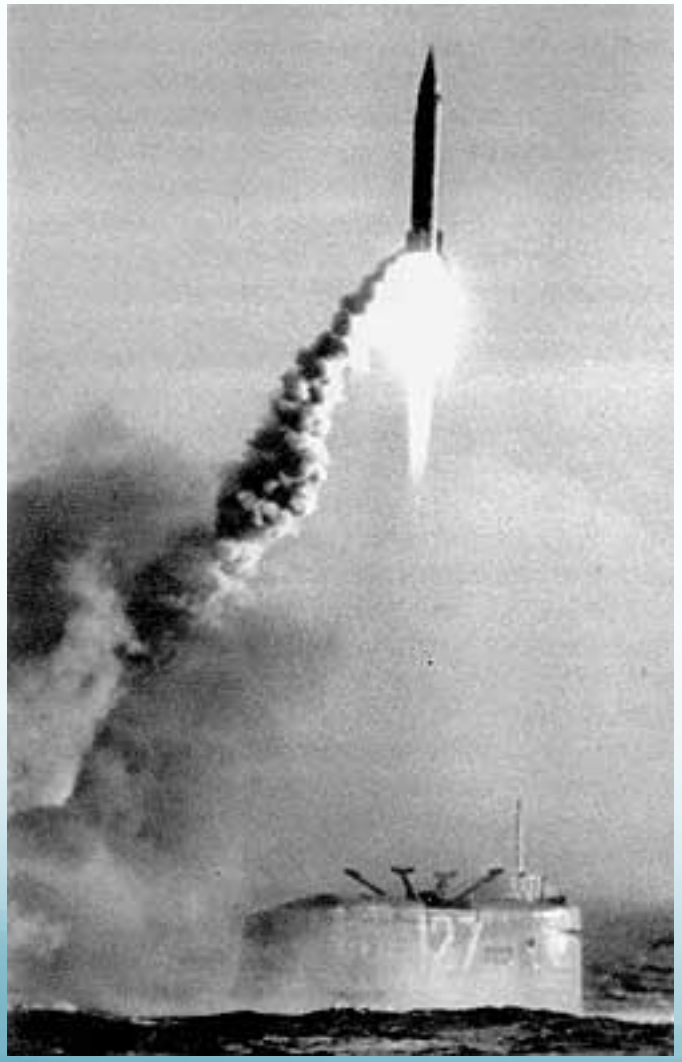


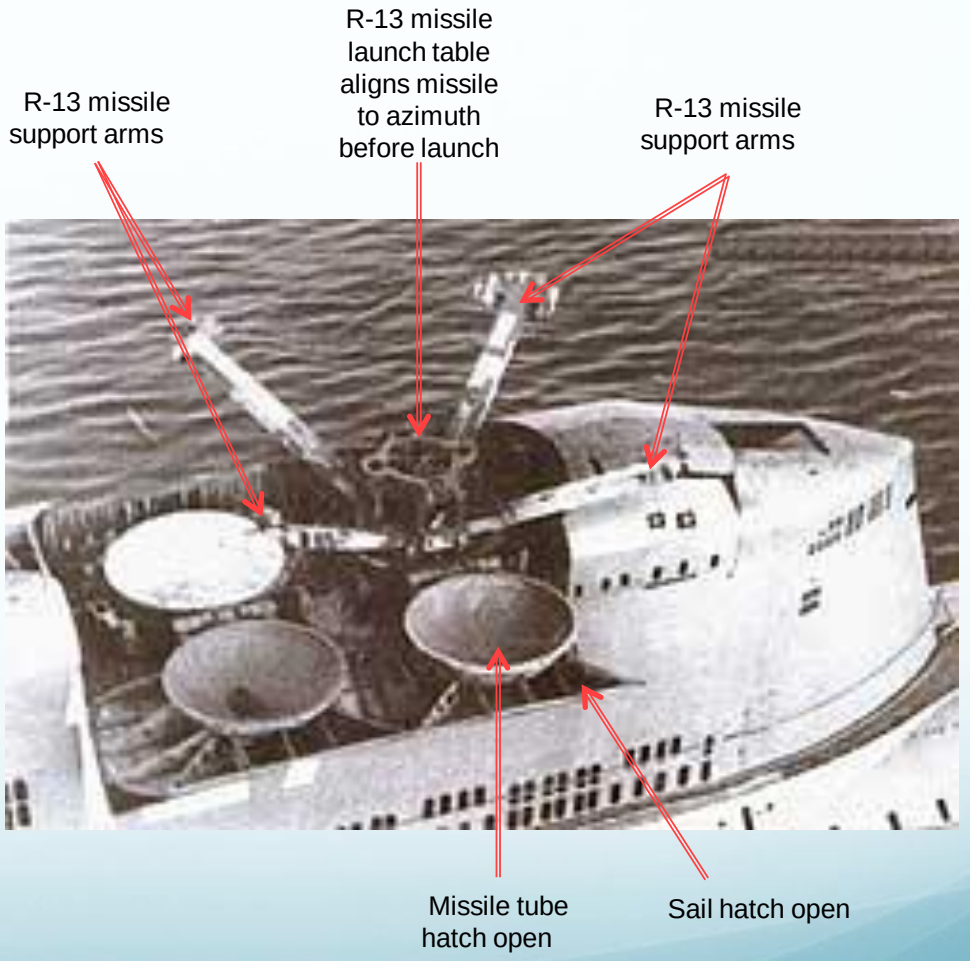
Source: en.wikipedia.org/wiki/Hotel-class_submarine



Source: forum.home.news.cn

R-13 missile launch from a Hotel I on the surface





Source: http://tonnel-ufo.ru/eanglish/weapon/missile-d-2-with-rsm-13-m-35-4.php

Example Russian SSBN deterrent patrol areas

Hotel I & II SSBNs, 1960s – 80s

Source: fas.org

Hotel K-19 series of accident

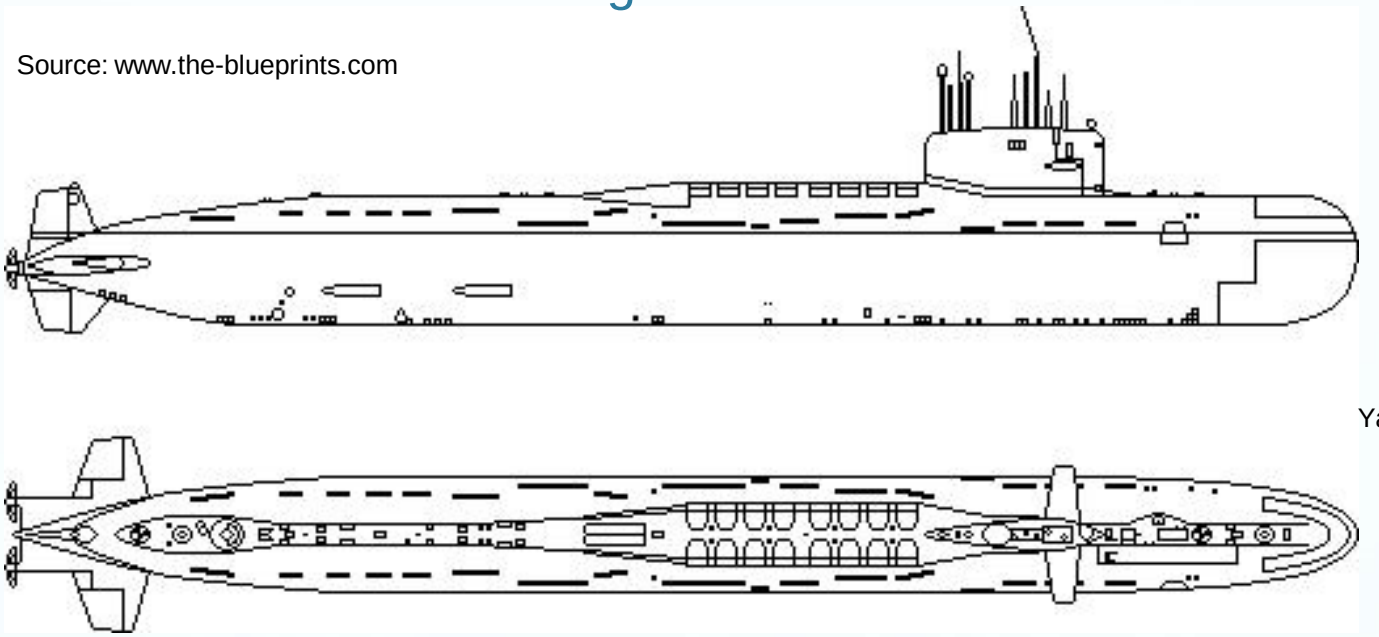
(Bad luck sub nicknamed “Hiroshima” and “Day of Judgment”)

- Before commissioning:
  - During a deep dive test, flooding occurred in the reactor compartment. The sub surfaced and heeled over to port due to the water taken on. It was determined that during construction workers had failed to replace a gasket important to watertight integrity.
  - October, 1960: improper operation of the trash disposal system led to flooding in aft compartment 9, which filled one-third full of water.
  - December 1960: a loss of primary coolant caused failure of a main circuit pump, which was repaired it at sea within a week.
- After commissioning, 30 April 1961:
  - 4 July 1961: a leak occurred in the primary cooling circuit of the starboard reactor, causing a sudden pressure drop and triggering emergency systems.
    - The ship was designed without an emergency coolant makeup system.
    - The crew improvised a system to supply coolant via a primary vent valve, but this requiring prolonged radiation exposure in the reactor compartment (compartment 6) while installing the fix.
    - Eight crew members received lethal doses of 5,000 to 6,000 rem; others received significant doses (at least 100 rem)
  - 1962-1967: The reactor compartment was completely removed and replaced. K-19 was converted to a Hotel II. The two damaged reactors were dumped in Abrosimova Bay in the Kara Sea
  - 15 November 1969: K-19 collided with the U.S. sub Gato (SSN-615), which was trailing the Soviet sub in the Barents Sea.
    - Bow sonar systems were completely destroyed and the covers of the torpedo tubes were damaged.
  - 24 February 1972: Fire broke out in a hydraulic system in aft engineering compartment 9 while submerged and returning from patrol about 1300 km northeast of Newfoundland.
    - The fire propagated forward into compartments 8 and 7.
    - Rescue operations, involving more than 30 ships of Soviet Navy, lasted more than 40 days and was hampered by storms.
    - In early April, K-19 was towed back to base. In Murmansk 28 crew members had died.

Project 667A, 667AU, 667AM (Navaga)

Yankee I & II-class strategic ballistic missile submarines

Source: www.the-blueprints.com

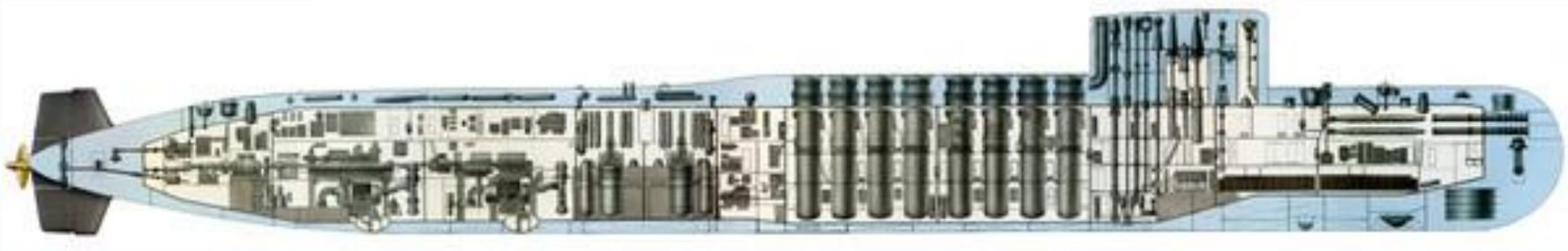


Yankee I

- Yankee SSBNs were counterparts to the U.S. Polaris SSBNs.
  - There were 34 Yankee SSBNs. The first entered service in 1964 and the last retired in 1994.
  - There were 41 U.S. Navy Polaris SSBNs. The first boats entered service in 1959 and the last SSBN retired in 1995.
- Propulsion:
  - OK-700: 2 x VM-4-2 PWRs, each rated @ 90 MWt
  - 4 x main turbines with a combined rating of about 34,500 shaft horsepower; driving 2 x shafts
- Armament:
  - Strategic missile tubes inside the pressure hull: Yankee I: 16 x R-27 or R-27U SLBMs; Yankee II: 12 x R-31 SLBMs
  - 6 x 533 mm bow torpedo tubes

Project 667A, 667AU, 667AM (Navaga)

Yankee I & II-class strategic ballistic missile submarines

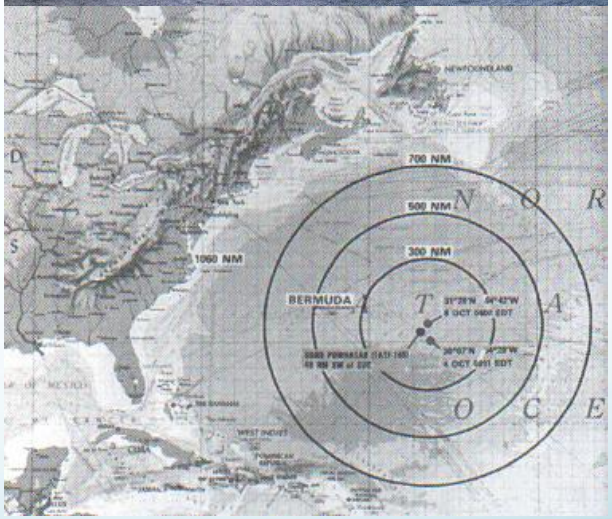


Source: Rubin Central Design Bureau for Marine Engineering

- Operation
  - Yankee-class SSBNs were capable of operating in ice-covered Arctic waters.
  - There was only one Yankee II conversion, K-140, that was converted to be the one-of-a-kind Yankee II used to test the R-31 (SS-N-17) SLBM.
    - Soviet Navy's 1st solid propellant SLBM
    - Also 1st cold-launched SLBM, which did not require flooding the launch tube before launching the missile.
  - Yankee I sub K-219 sank in the Atlantic in 1986 due to an accidental explosion in the missile compartment due to the interaction of hydrazine rocket fuel and seawater that was slowly leaking into a missile tube.
  - There were several Yankee variants modified for special roles:
    - 1 x Project 667M (Andromeda) Yankee Sidecar cruise missile test sub (SSGN)
    - 4 x Project 667AT (Grusza) 667M Yankee Notch cruise missile subs (SSGNs)
    - 1 x Project 09774 Yankee Stretch PLA-carrier ("mothership" for a small, nuclear-powered, special operations sub) "Orenburg" KS-411, former Yankee K-411
    - 1 x Project 667AK Akson-1 Yankee Pod and Project 09780 (Akson-2) Yankee Bignose test platform for advanced sonar systems

Yankee I K-219 sinking in Atlantic

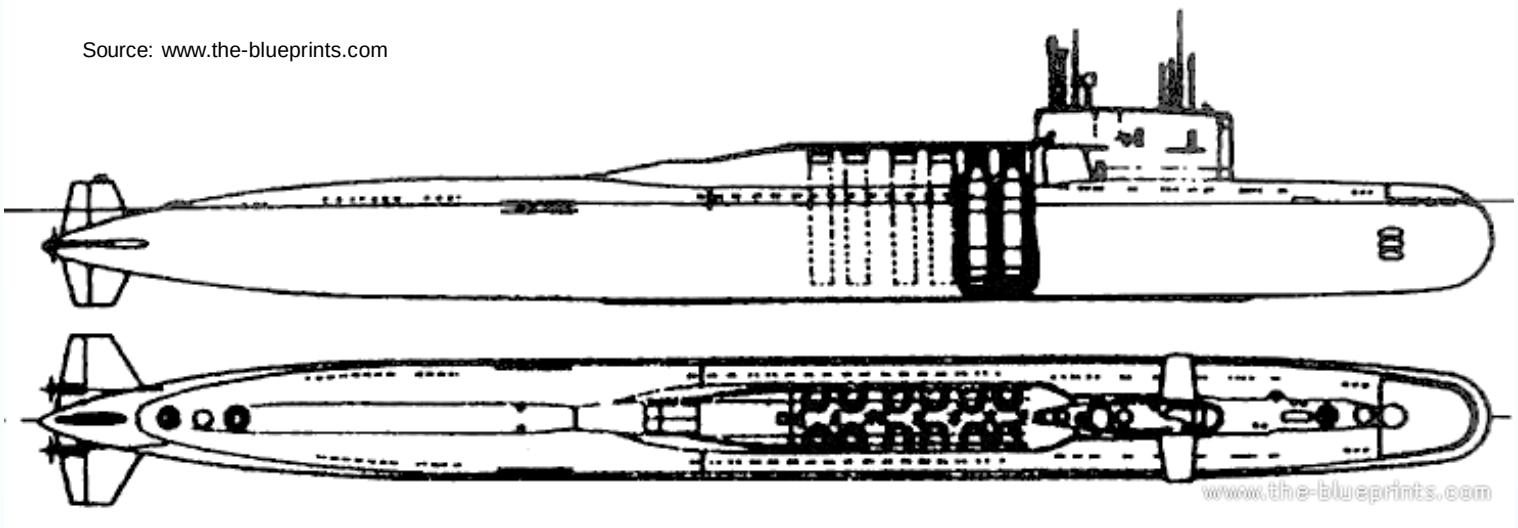
- 3 Oct 86: While on nuclear deterrent patrol in the N Atlantic, 680 miles NE of Bermuda, K-219 suffered an explosion and fire in missile tube while at a depth of about 39.6 m (130 ft).
  - Seawater was discovered leaking past the hatch cover seal for missile tube #6, allowing seawater to enter and react with residue from the missile's hypergolic (spontaneously igniting) liquid propellant; UDMH (hydrazine) and IRFNA (nitric acid).
  - Attempts to remedy the leak were not successful.
  - The explosion breached the hull and ejected the SS-N-6 missile and its two nuclear warheads into the sea.
  - Flooding occurred in the missile compartment (Compartment IV), the ship lost depth control and sank to 299 m (980 ft). before stabilizing, with all compartments isolated and damage control pumps running.
- The ship managed to surface on battery power alone. Damage control efforts were unsuccessful.
- Towing attempts by a Russian freighter were unsuccessful, the submarine continued to take on water, and the crew was evacuated to the freighter.
- 6 Oct 86: K-219 and it's 14 remaining nuclear-armed missiles sank in the Hatteras Abyssal Plain, to a depth of 6,000 m (18,000 ft).



- 1988: Soviet hydrographic research ship Keldysh visited the wreck of K-219 and found the submarine sitting upright on the sandy bottom. It had broken in two, aft of the conning tower. Several missile tube hatches were open, and the missiles, along with the nuclear warheads they contained, were gone.

Project 667B (Murena)

Delta I-class strategic ballistic missile submarine

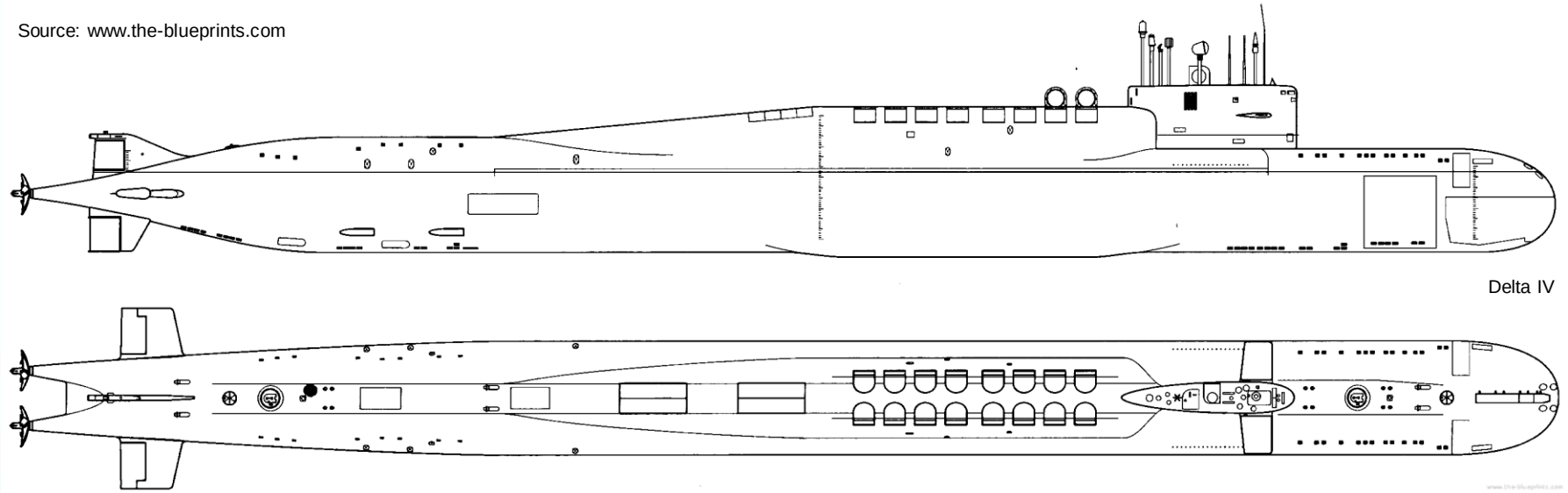


- Propulsion:
  - OK-700: 2 x VM-4B PWRs each rated @ 90 MWt
  - 2 x main turbines each with a combined rating of about 52,000 hp; driving 2 shafts
- Armament:
  - 12 x R-29 SLBMs in missile tubes inside the pressure hull
  - 6 x 533 mm bow torpedo tubes
- Operational matters:
  - The range of the R-29 SLBMs to reach the U.S targets from patrol areas in the Barents, Norwegian and Artic Seas. The Delta I no longer had to venture into waters monitored by the U.S. SOSUS sonar network.

Project 667BD, 667BDR & 667BDRM

Delta II to IV-class strategic ballistic missile submarines

Source: www.the-blueprints.com



Delta IV

- Delta II to IV were substantial upgrades over the initial Delta I subs.
- Propulsion:
  - Delta II: OK-700: 2 x VM-4B PWRs, each rated @ 90 MWt
  - Delta III & IV: OK-700A: 2 x VM-4 variants (4S/4SG) PWRs, each rated @ 90 MWt
  - 2 x main turbines with a combined ratings of 55,000 (Delta II) and 60,000 hp (Delta III & IV); driving 2 shafts
- Armament:
  - Delta III: 16 x R-29R / RSM-50 Vysota SLBMs
  - Delta IV: 16 x R-29RMU2 Layner SLBMs
  - 4 x 533 mm bow torpedo tubes; storage for 12 - 16 torpedoes or anti-ship missiles

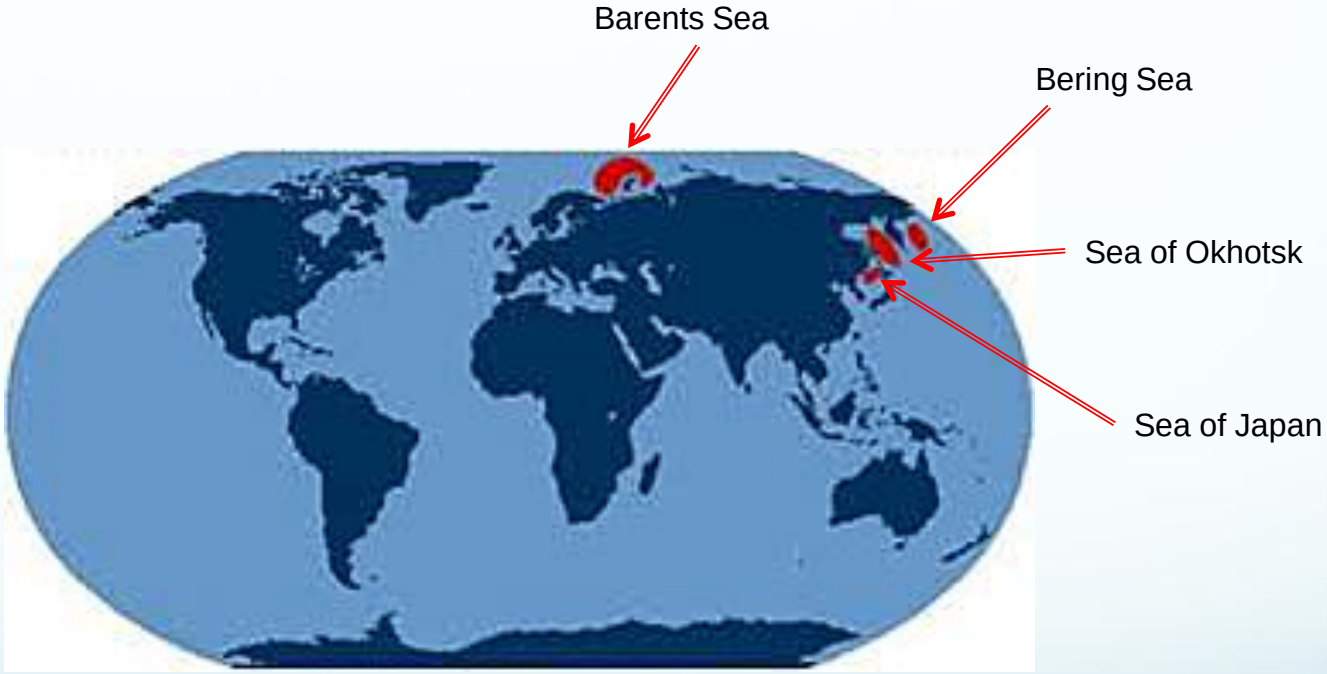
Project 667BD, 667BDR & 667 BDRM

Delta II to IV-class strategic ballistic missile submarines

- Operational matters:
  - All Delta-class subs are capable of operating under the Arctic ice, surfacing through the ice, and then launching their missiles.
  - In Operation Behemoth-2 on 6 August 1991, submerged Delta IV sub *Novomoskovsk* became the world's only submarine to fire an all-missile salvo, launching 16 R-29RM (RSM-54) ballistic missiles in 244 seconds.
    - The first and the last missiles hit their targets. All others were destroyed on command shortly after launch.
    - The previous record was a salvo of four Trident II missiles fired from a U.S. Ohio-class SSBN.
  - With the retirement of the R-39 SLBM and the Typhoon SSBNs by 2004, some Delta III's were reactivated as replacements.
  - In 2014, Delta IV subs became operational with the newer R-29RMU2 Layner SLBM, replacing the R-29RMU Sineva.
    - R-29RMU2 is expected to ensure the viability of the Delta IV class submarines until at least 2030.

Example Russian SSBN deterrent patrol areas

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



Source: fas.org

Delta IV (667 BDRM)

Delta IV (667 BDRM)

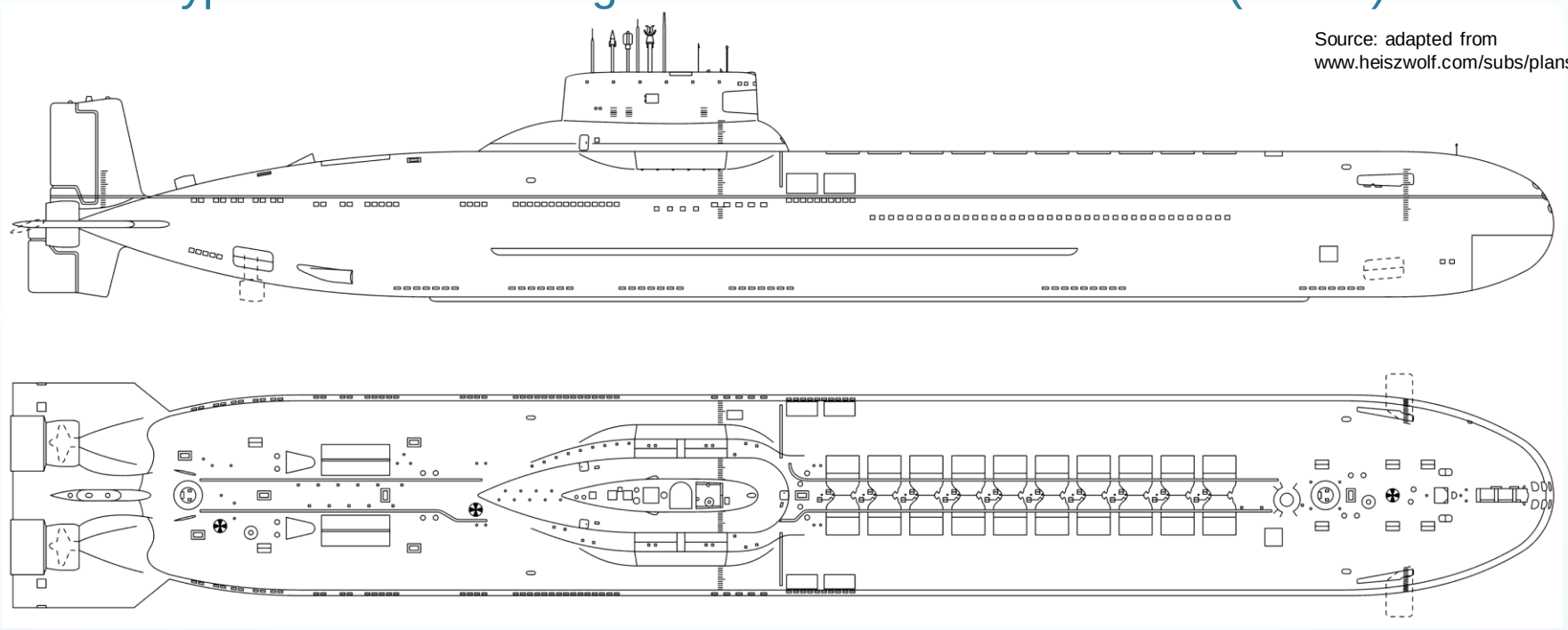
Source: forum.sub-driver.com

Depiction of Delta IV (667 BDRM) Arctic launch

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

Project 941 (Akula)

Typhoon-class strategic ballistic missile submarine (SSBN)



- Largest submarine ever built. Multi-hull design with five inner hulls with 19 compartments.
- Propulsion:
  - OK-650: 2 x PWRs each rated @ 190 MWt
  - 2 x main turbines with a combined rating of about 100,000 hp (37 MW); driving 2 shafts with shrouded propellers
- Armament:
  - 20 x R-39 (aka RSM-52 & SS-N-20) SLBMs in missile tubes between the pressure hulls.
  - 6 x 533 mm bow torpedo tubes

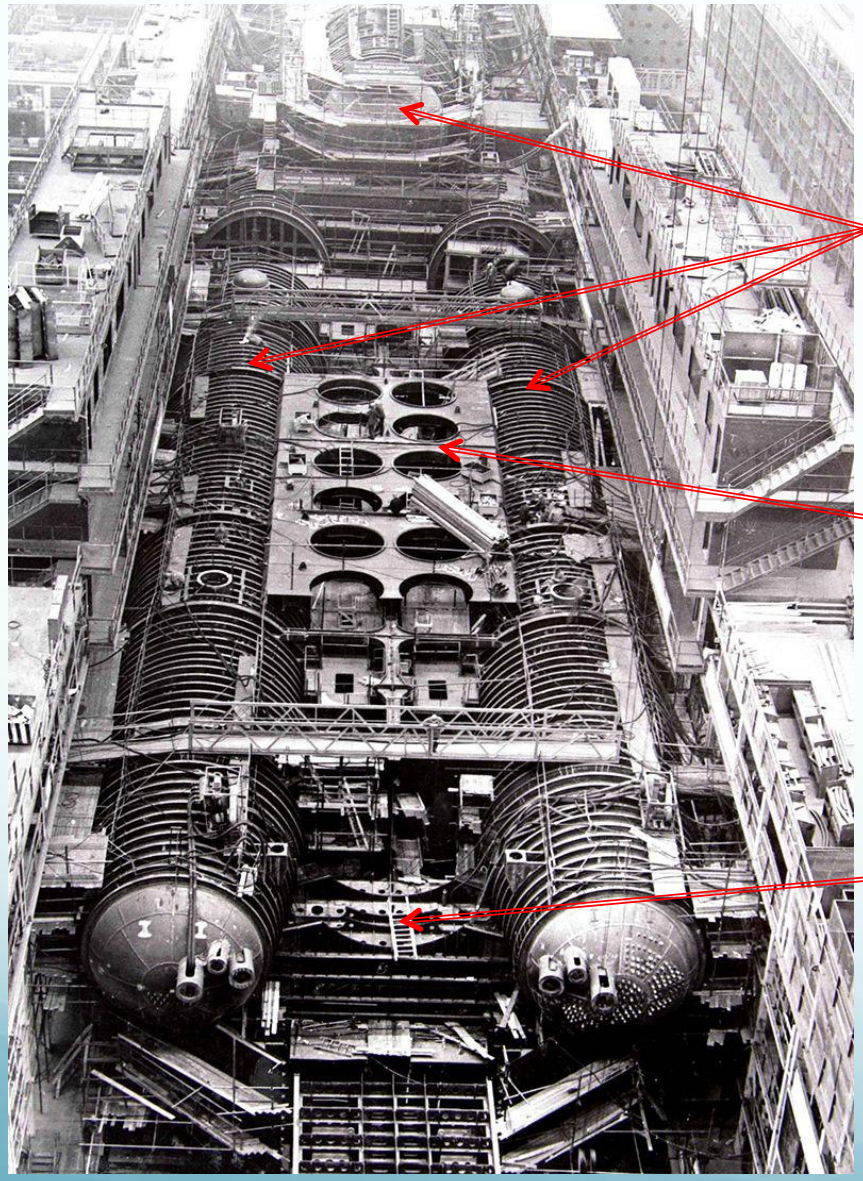
Project 941 (Akula)

Typhoon-class strategic ballistic missile submarine (SSBN)

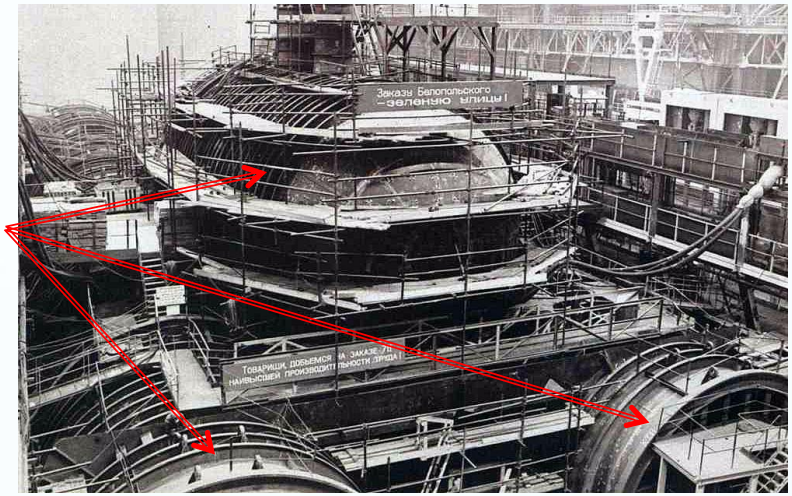
- Operational matters:
  - On 25 Aug 1995, a Typhoon SSBN surfaced at the North Pole, through 8 ft (2.5 m) of ice, and fired and R-39 SLBM.
  - Under the terms of the Start I and Start II treaties, R-39 missiles were removed from service starting in 1996 and the Typhoon-class subs were gradually retired.
    - All the R-39 missiles were decommissioned by 2004.
    - As of mid-2015, one Typhoon sub, *Dimitry Donskoy*, was configured for testing the RSM-56 Bulava SLBM used on Borei-class SSBNs; two Typhoons are in reserve; three have been scrapped + one was scrapped during construction.
  - The fate of the two Typhoon subs in reserve has not been finalized.

Source: www.naval-technology.com/projects/ssbn-typhoon-class

Typhoon during construction



Pressure hull

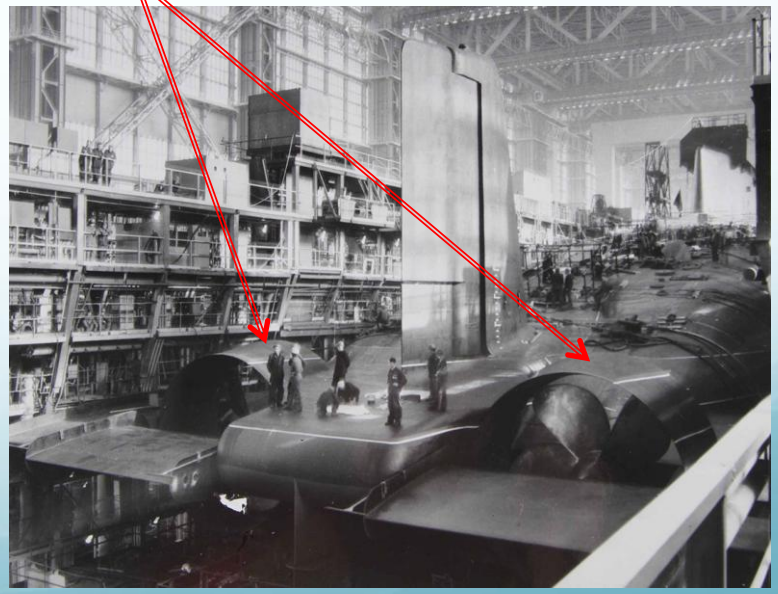


Missile tubes outside the pressure hull

Shrouded propellers

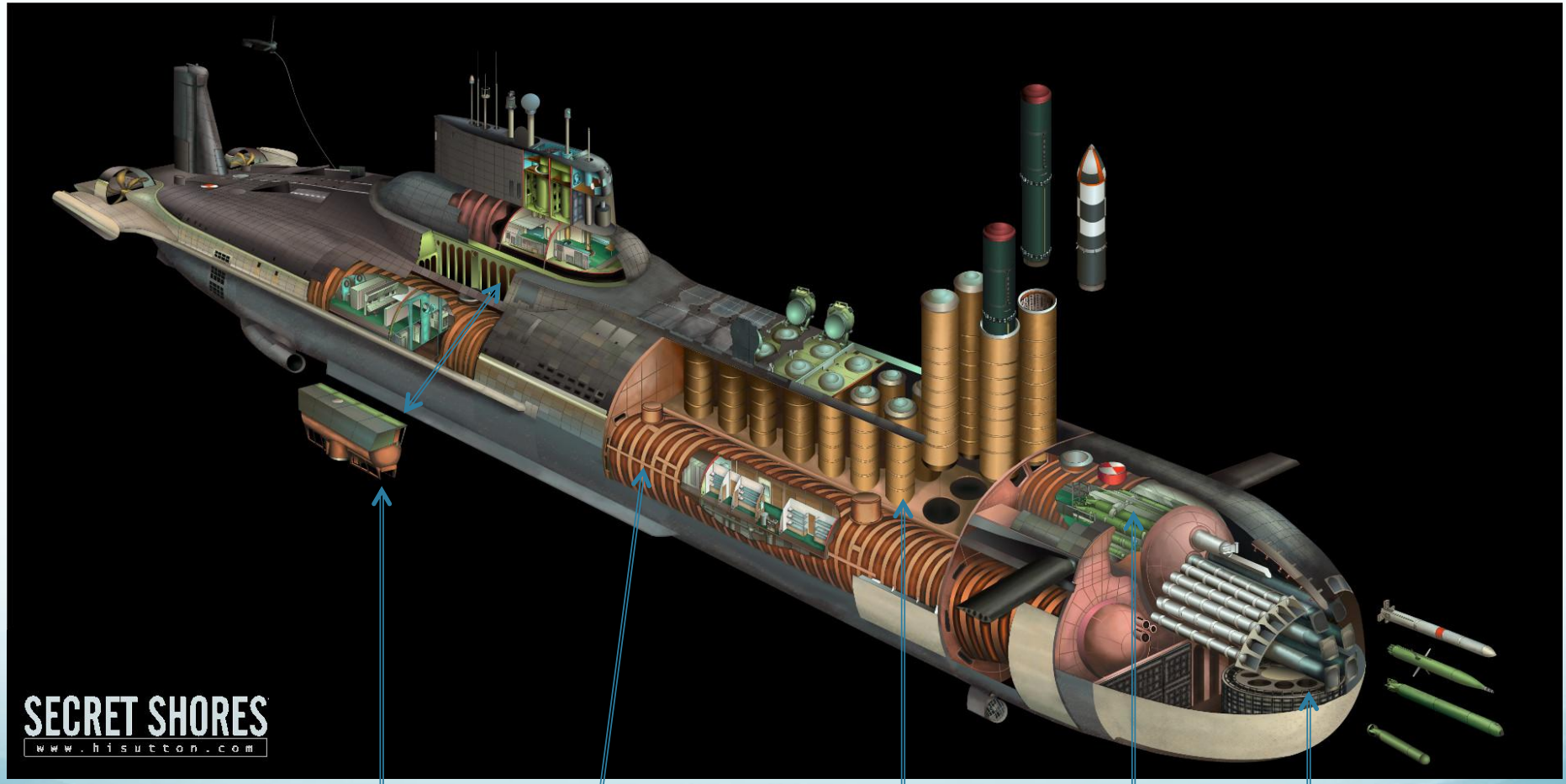
Source: http://warwall.ru/news/

Pressure hull for Torpedo Room not yet installed



Project 941 (Akula)

Typhoon-class strategic ballistic missile submarine (SSBN)

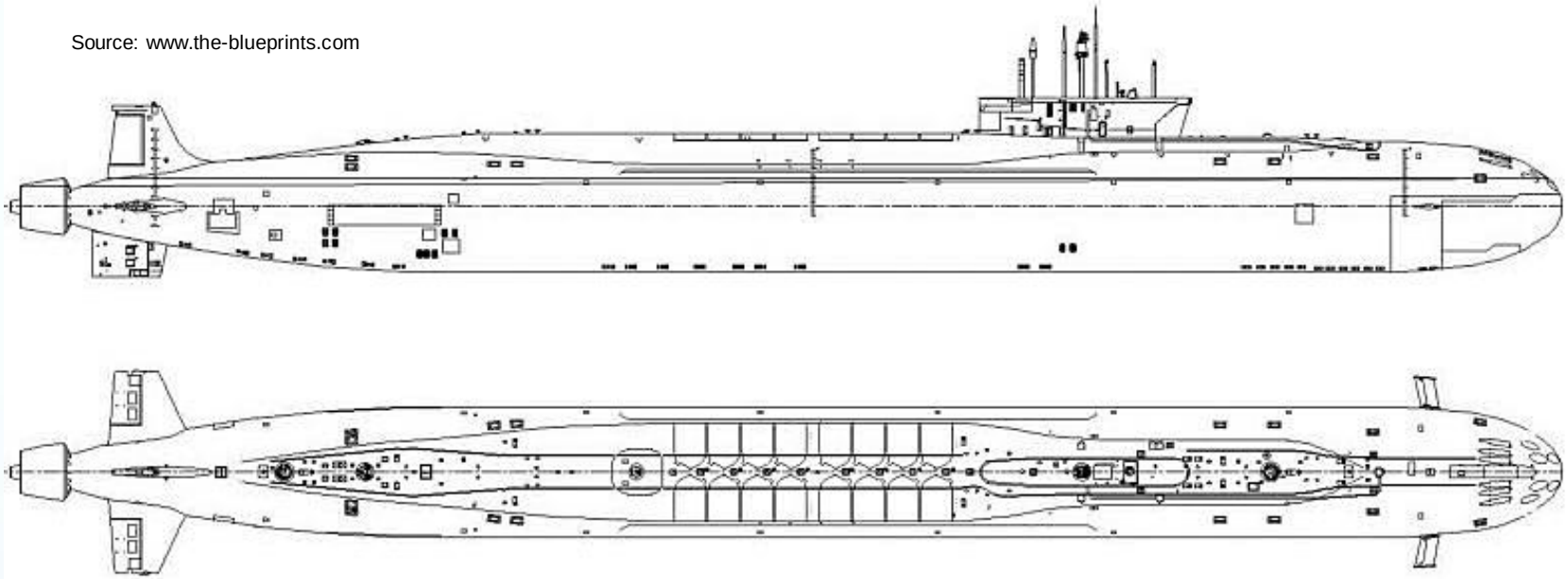


Source: www.hisutton.com

Project 955 & 955A (Borei)

Borey-class strategic missile submarine (SSBN)

Source: www.the-blueprints.com



- 4th generation SSBN.
  - Will replace Delta III & IV SSBNs.
  - Lead ship of this class, *Yuri Dolgoruky*, is the first submarine launched by Russia after the Soviet era. Keel laid in 1996, commissioned 2013.
  - The first three boats in this class (Project 09551) were built with hull sections originally procured for late-model Project 971 Akula SSNs. Later boats will be Project 955A improved Borei SSBNs.
- Propulsion:
  - OK-650V: 2 x PWRs each rated @ 190 MWt; core life expected to be 15 years. The PWR model is referred to as KPM-6 in some sources.
  - 2 x steam turbines with a combined rating of 73,000 hp; driving 1 x pump-jet

Project 955 & 955A (Borei)

Borey-class strategic missile submarine (SSBN)

- Armament:
  - Project 955: 16 x strategic missile tubes inside the pressure hull for RSM-56 Bulava SLBMs and 6 x 533 mm bow torpedo tubes
  - Project 955A: also expected to carry 16 x Bulava SLBMs, although there has been speculation that the 955A boats may carry 20 x SLBMs.
- Operational matters:
  - The lead ship, *Yuri Dolgorukiy*, joined the Northern Fleet in December 2013 and received its full complement of RSM-56 missiles in 2014.
  - As of January 2015, two more Project 955 subs have been accepted for service, *Alexander Nevskiy* & *Vladimir Monomakh*, both joining the Pacific Fleet.
  - Three more submarines are under construction. These are the first of the Project 955A improved Borei SSBNs: *Knyaz Vladimir* (laid down in Jul 2012), *Knyaz Oleg* (Jul 2014), and *Generalissimus Suvorov* (Dec 2014).
  - By 2020, the Defense Ministry plans to have eight Borei-class subs as the backbone of the naval component of the country's strategic nuclear deterrent.

Borei and Typhoon SSBNs

Borei & Typhoon SSBNs

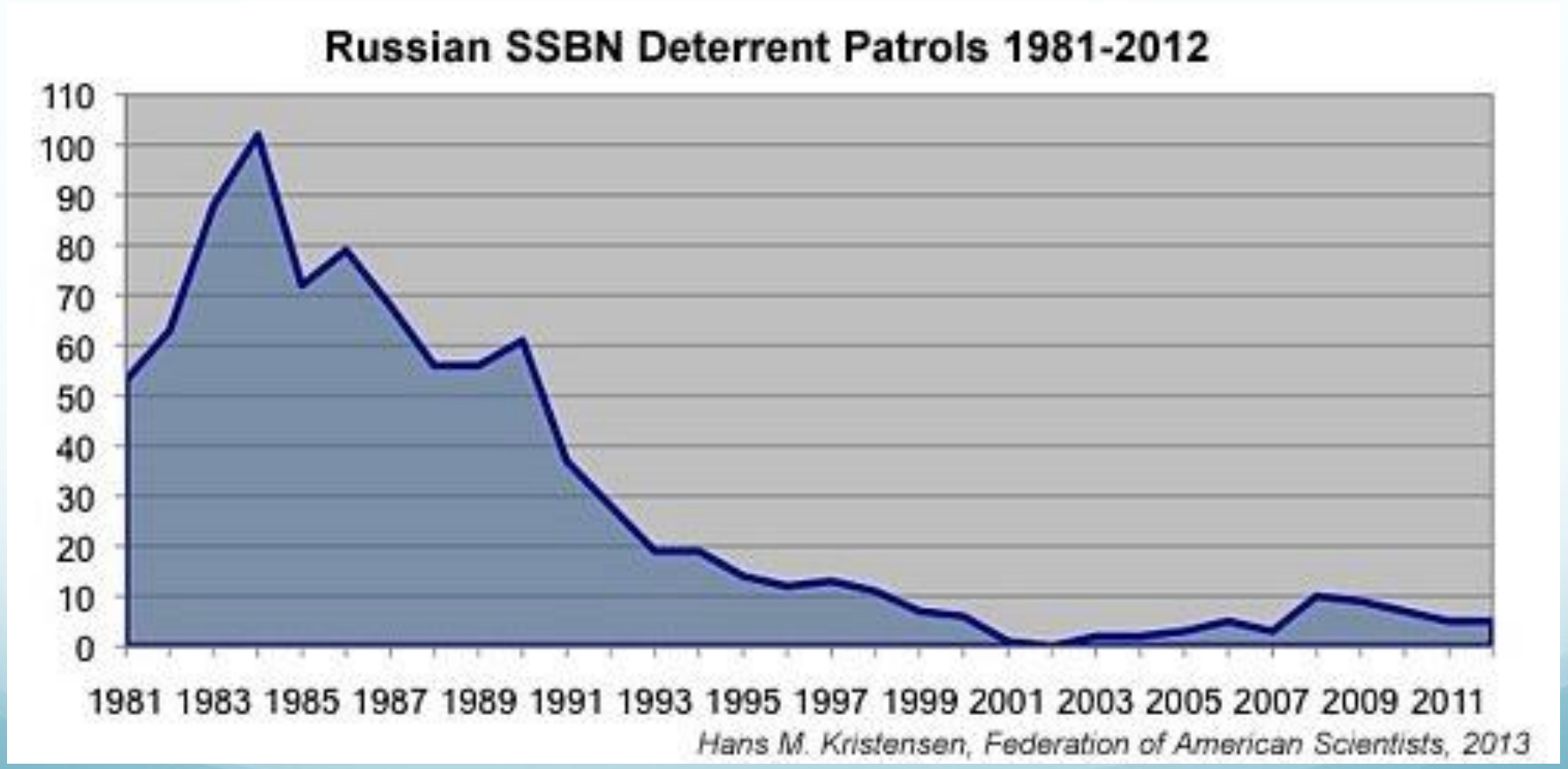
Source: failheap-challenge.com

Project 955 (Borei)

Borey-class strategic missile submarine (SSBN)

Source: www.shipmodels.info/

Trend in number of annual deterrent patrols by Russian SSBNs



Source: fas.org/blogs/security/2013/05/russianssbns/

Russian cruise missile submarines (SSGN)

Evolution of Soviet / Russian SSGs & SSGNs

Whiskey Twin Cylinder SSG

Whiskey Long Bin SSG

Echo I SSGN

Juliett SSG

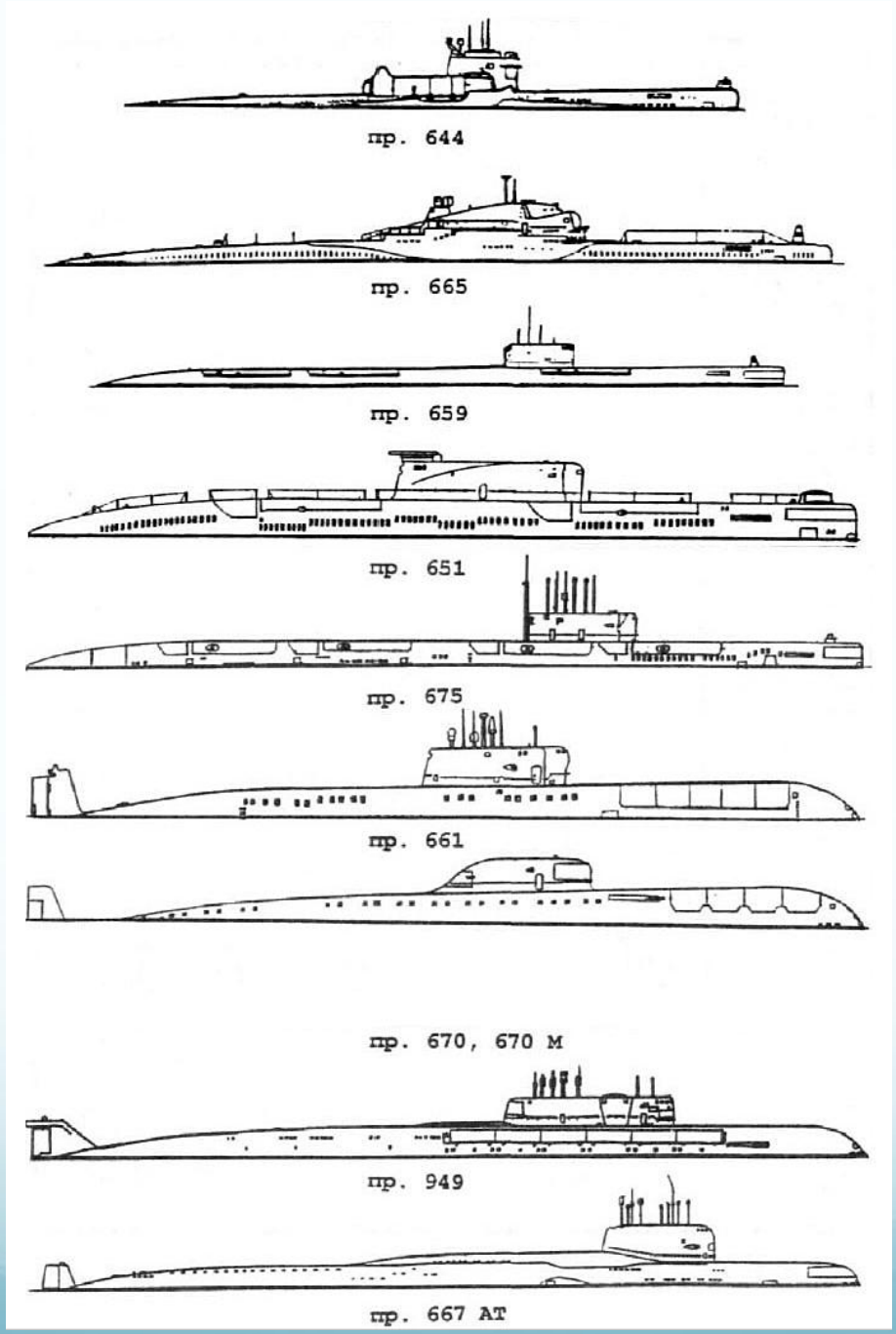
Echo II SSGN

Papa SSGN

Charlie I & II SSGN

Oscar I & II SSGN

Yankee Notch SSGN



Russian SSGNs

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
659	Echo I	5	111.0 m (364.2 ft)	9.2 m (30.2 ft)	3768 (surf) 4920 (sub)	2 x VM-A	30,000	24	1961 - 63	1961 - 89
675	Echo II	29	115.0 m (377.3 ft)	9.2 m (30.2 ft)	4415 (surf) 5760 (sub)	2 x VM-A	35,000	22	1963 - 68	1963 - 95
670	Charlie I	11	94.3 m (309.4 ft)	9.9 m (32.5 ft)	3574 (surf) 4980 (sub)	OK-350: 1 x VM-4-1	17,000	24	1968 - 73	1968 - 92
670M	Charlie II	6	104.9 m (344.2 ft)	9.9 m (32.5 ft)	4372 (surf) 5500 (sub)	OK-350: 1 x VM-4-1	17,000	24	1973 - 80	1973 - 94
667M	Yankee Sidecar (Andromeda)	1 Converted Yankee I	153 m (502 ft)	15 m (49.2 ft)	10500 (surf) 13650 (sub)	OK-700: 2 x VM-4-2	34,500	25	1982	1983 - ???
667AT	Yankee Notch (Grusza)	4 Converted Yankee I	141.5 m (464.2 ft)	12.8 m (42 ft)	8880 (surf) 11500 (sub)	OK-700: 2 x VM-4-2	34,500	25	1982 - 91	1983 – 94
661	Papa (Anchar)	1	106.9 m (350.7 ft)	11.6 m (38 ft)	5280 (surf) 7100 (sub)	2 x VM-5m	80,000	44.7	1969	1969 – 80
949	Oscar I (Granit)	2	143 m (469.2 ft)	18.2 m (59.7 ft)	12500 (surf) 15500 (sub)	2 x OK-650B	90,000	32	1982 - 83	1983 - 96
949A	Oscar II (Antei)	10 + 3 not complete	154 m (505.3 ft)	18.2 m (59.7 ft)	13400 (surf) 16400 (sub)	2 x OK-650B	90,000	30	1986 - 96	1986 - present

Russian submarine-launched cruise missiles

Cruise missile	Years in service	Weight	Length	Diam (D) /Span (S)	Speed	Range	Guidance	Warhead
Land attack P-5 Pyatyorka (SS-N-3 Shaddock)	1959 - ?? Whiskey SSG; 1961 - 69 Echo I SSGN	5,000 kg	11.75 m (38.5 ft)	D = 0.98 m (3.21 ft); S = 5.0 m (16.4 ft)	M = 0.9	750 km (466 mi)	Inertial	Nuclear, 930 kg (2,050 lb) RDS-4 warhead 200 - 350 kT
Anti-ship P-6 (SS-N-3A Shaddock)	1963 – 75 Juliett SSG & Echo II SSGN	5,000 kg	10.9 m (35.8 ft)	D = 0.98 m (3.21 ft); S = 5.0 m (16.4 ft)	M = 1.2	450 km (280 mi)	Inertial + command + active radar homing	2,200-lb Conventional or Nuclear warhead
Anti-ship P-500 Bazalt (4K-80) (SS-N-12 Sandbox)	1975 – 95 Juliett SSG & Echo II SSGN	4,800 kg (10,600 lb)	11.7 m (38.4 ft)	D = 0.88 m (2.89 ft); S = 2.6 m (8.5 ft)	M = 2.5	550 km (342 mi)	Inertial + command + active radar homing	Nuclear, 350 kT @ 1,000 kg (2,205 lb)
Anti-ship P-1000 Vulkan (3M-70) (SS-N-12 Mod 2 Sandbox)	1987 – 95 Echo II SSGN	May be lighter than P-500 due to use of titanium structures	Similar to P-500	Similar to P-500	M = 2.8	700 km (435 mi)	Inertial + command + active or passive radar homing	Nuclear, 350 kT @ 1,000 kg (2,205 lb)
Anti-ship P-70 Ametist (4K-66) (SS-N-7 Starbright)	1968 – 92 Charlie I & Papa SSGNs	3,650 kg	7.O m (23.0 ft)	D = 0.55 m	M = 0.9	65 km (40.4 mi)	Inertial + active radar homing	Conventional, 1,170 lb (530 kg) HE or Nuclear

Russian submarine-launched cruise missiles

Cruise missile	Years in service	Weight	Length	Diam (D) /Span (S)	Speed	Range	Guidance	Warhead
Anti-ship P-120 Malakhit (4K-85) (SS-N-9 Siren)	1973 - 94 Charlie II & Papa SSGNs	3,180 kg (7,010 lb)	8.84 m (29.0 ft)	D = 76.2 cm (30.0 in); S = 2.1 m (6.9 ft)	M = 0.9	70–110 km (43.5 – 68 mi)	Inertial + active radar homing + infrared homing	Nuclear, 200 kT, or Conventional, 500 kg (1,102 lb) HE
Land-attack Kh-90 Meteorit (3M-25) (SS-N-24 Scorpion)	Tested 1983 – 84 Yankee Sidecar Not operationally deployed	2,800 kg (6,173 lb)	10.5 m (34.4 ft)	D = 1.2 m (3.94 ft); S = 4.5 m (14.8 ft)	M = 2.5 to 3.0	3,000 km (1,900 mi)	Inertial + mid-course data link update	Nuclear, 2 x 90 kT
Anti-ship P-700 Granit (3K-45) (SS-N-19, Shipwreck)	1983 – present Oscar SSGN, Kirov CGN	7,000 kg (15,400 lb)	10 m (33 ft)	D = 0.85 m (33 in); S = 2.6 m	M = 1.6 (low-altitude); M = 2.5 (high-altitude)	625 km (388 mi)	Inertial, active radar homing	Conventional 750 kg (1,650 lb) HE, or Nuclear 500 kT
Anti-ship P-800 Oniks (3M-55) (SS-N-26, Strobile)	2002 – present; 2013 – present on Yasen SSN	3,000 kg (6,614 lb)	8.9 m (29.2 ft)	D = 0.7 m (2.3 ft); S = 1.7 m (5.6 ft)	M 2.0 (low altitude); M 2.6 (high-altitude)	600 km (373 mi)	Inertial + active radar homing	Conventional, 250 kg (551 lb) HE

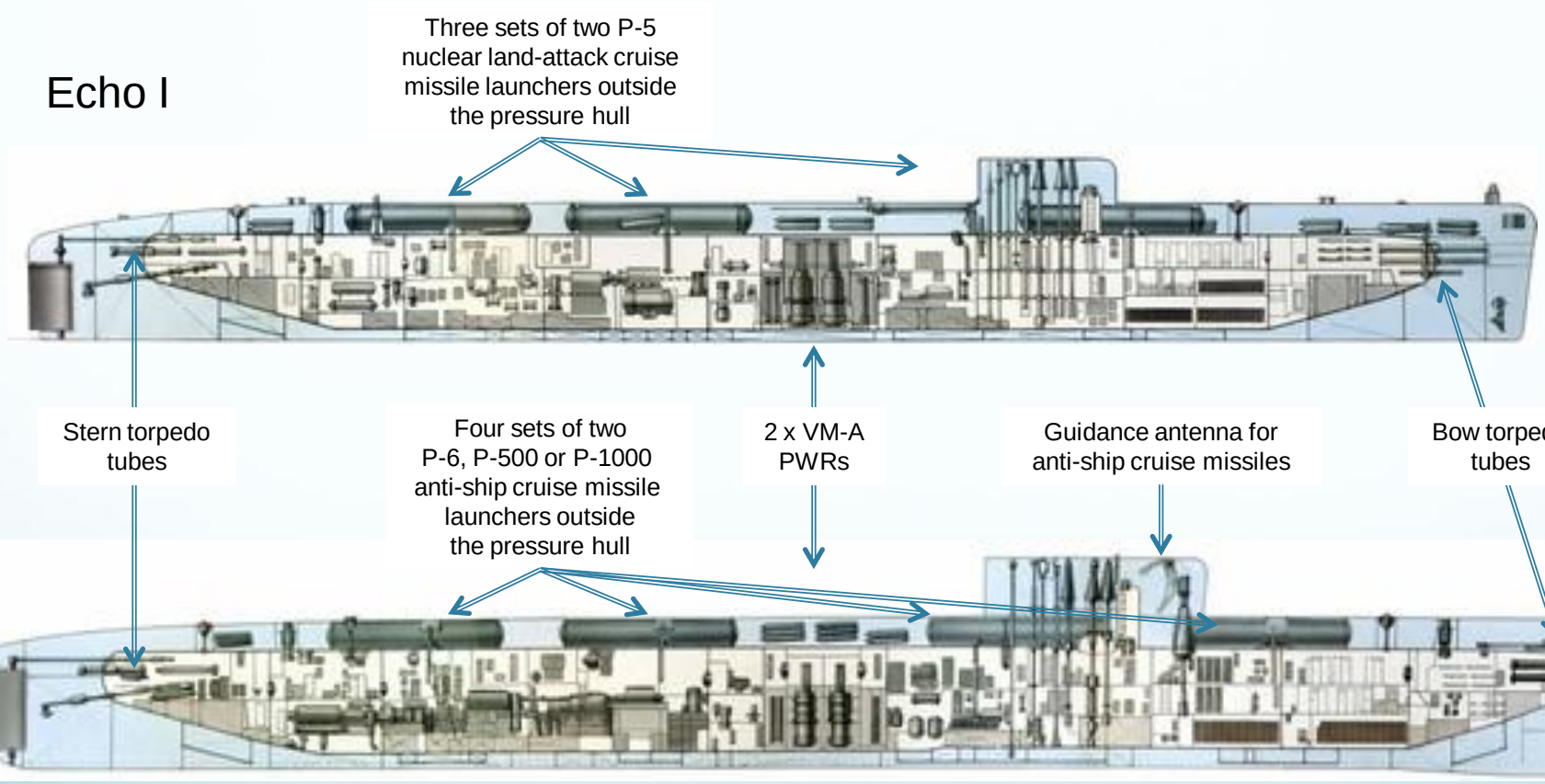
Russian submarine-launched cruise missiles

Cruise missile	Years in service	Weight	Length	Diam (D) /Span (S)	Speed	Range	Guidance	Warhead
Land-attack RK-55 Granat (3M-10) (SS-N-21 Sampson)	1976 – present Victor III, Sierra, Akula & Yasen SSNs; Yankee Notch SSGNs	1,700 kg (3,750 lb)	8.1 m (26.6 ft)	D = 51 cm (20.1 in) S = 3.1 m (10.1 ft)	720 kph (447 mph)	3,000 km (1,864 mi)	Inertial + Glonass+ TERCOM	Nuclear, 200 kT (believed to have been retired) Converted to conventional 410 kg (904 lb) HE warheads (present)
Anti-ship Kalibr (domestic version of 3M-54 Klub) (SS-N-27 Sizzler)	2001 Akula & Yasen SSNs; Kilo and Lada SS	1,780 kg (3,924 lb)	Klub S: 6.2 m (20 ft)	D = 53 cm (21 in)	Subsonic cruise + M = 2.5 - 2.9 terminal "sprint"	220 km (137 mi)	Inertial + active radar homing	Conventional, 200 kg (440 lb) HE
Land-attack Kalibr (domestic version of 3M-14 Klub) (SS-N-30A Sizzler)	2001 Akula & Yasen SSNs; Kilo and Lada SS	1,770 kg (3,924 lb)	Klub S: 6.2 m (20 ft)	D = 53 cm (21 in)	Subsonic cruise & terminal phase	1,500 – 2,500 km (930– 1,550 mi)	Inertial + TERCOM + active radar homing	Conventional, 450 kg (990 lb) HE

Projects 659 & 675

Echo I & II cruise missile subs (SSGN)

Echo I



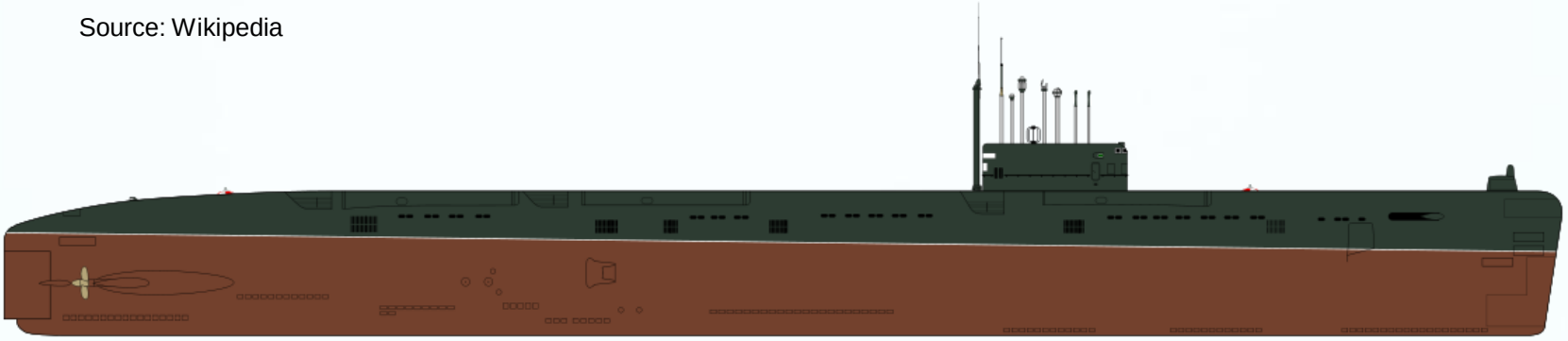
Echo II

Source: Rubin Central Design Bureau for Marine Engineering

Project 659

Echo I cruise missile submarines (SSGN)

Source: Wikipedia



- Soviet Union's 1st SSGN, designed for strategic nuclear land-attack missions by Rubin Central Design Bureau for Marine Engineering.
  - All Echo I boats were built in the Russian Far East at the Komsomolsk-on-Amur Shipyard, and all were deployed in the Far East. Five boats in this class. The 1st boat entered service in 1961.
- Propulsion:
  - 2 x VM-A PWRs each rated @ 70 MWt. 2 x steam turbines with a combined output of about 30,000 hp; driving 2 x shafts
- Armament:
  - 6 x P-5 Pyatyorka (SS-N-3C Shaddock) nuclear-armed, land-attack cruise missiles in launch tubes outside the pressure hull. The cruise missiles could be launched only while surfaced.
  - 4 x 533 mm and 2 x 406 mm torpedo tubes in the bow + 2 x 406 mm torpedo tubes in the stern.

Project 659T

Echo I conversion to attack sub (SSN) role

- During the period 1965 – 69, all Echo I boats had their P-5 (SS-N-3C) nuclear land-attack cruise missiles removed to comply with the SALT I treaty.
- Under Project 659T, these subs were converted to SSNs.
  - Missile launchers were plated over and the hull was streamlined to reduce underwater noise.
  - The same sonar system as in the November-class SSNs was installed.

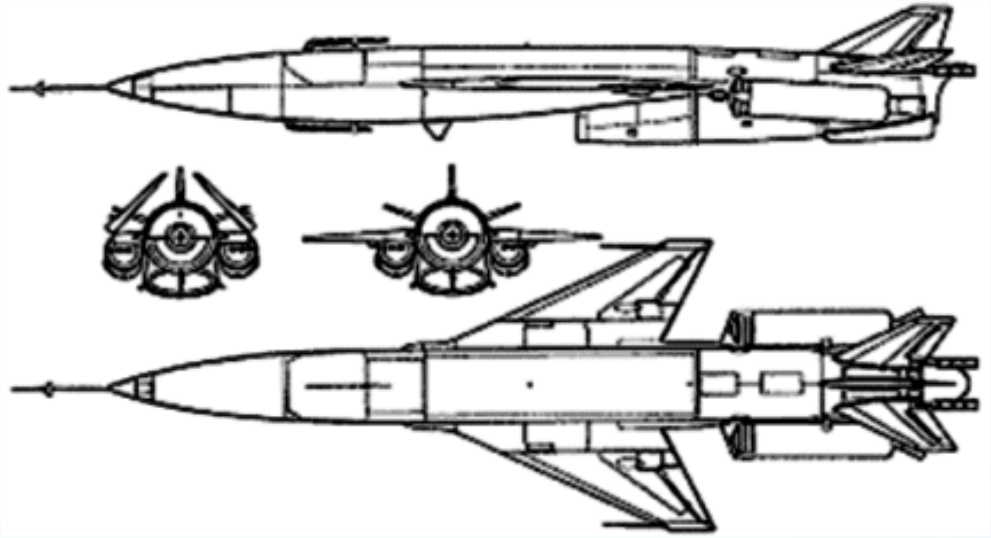
Source: http://wordforge.net/index.php

- 21 Aug 1981: While on SSN patrol in the Pacific near Okinawa, Echo I K-122 was disabled by a fire in an engineering compartment (compartment VII) and had to be towed back to Vladivostok. Apparently the reactor plant was not involved in this accident.
- All Echo I subs were decommissioned by 1989.

P-5 / SS-N-3C Shaddock

Subsonic land attack cruise missile

- 1st naval version of the SS-N-3 family of cruise missiles
  - Rocket booster + turbojet sustainer engine
  - Inertially guided
  - Range: 750 km (466 mi) at an altitude of 100 - 400 meters (328 – 1,312 ft) and a speed of Mach 0.9
  - All SS-N-3 variants have a similar airframe with folding wings for storage prior to launch
- Deployed on the following Soviet submarines:
  - Diesel-electric Whiskey-conversion SSGs (1 x “Single-Cylinder”; 6 x “Twin-Cylinder”; and 6 x “Long Bin”); entered service in the late 1950s.
  - Echo I SSGNs; five boats; 1st entered service in 1961
  - Diesel-electric Juliet SSGs; 16 boats; 1st entered service in 1963



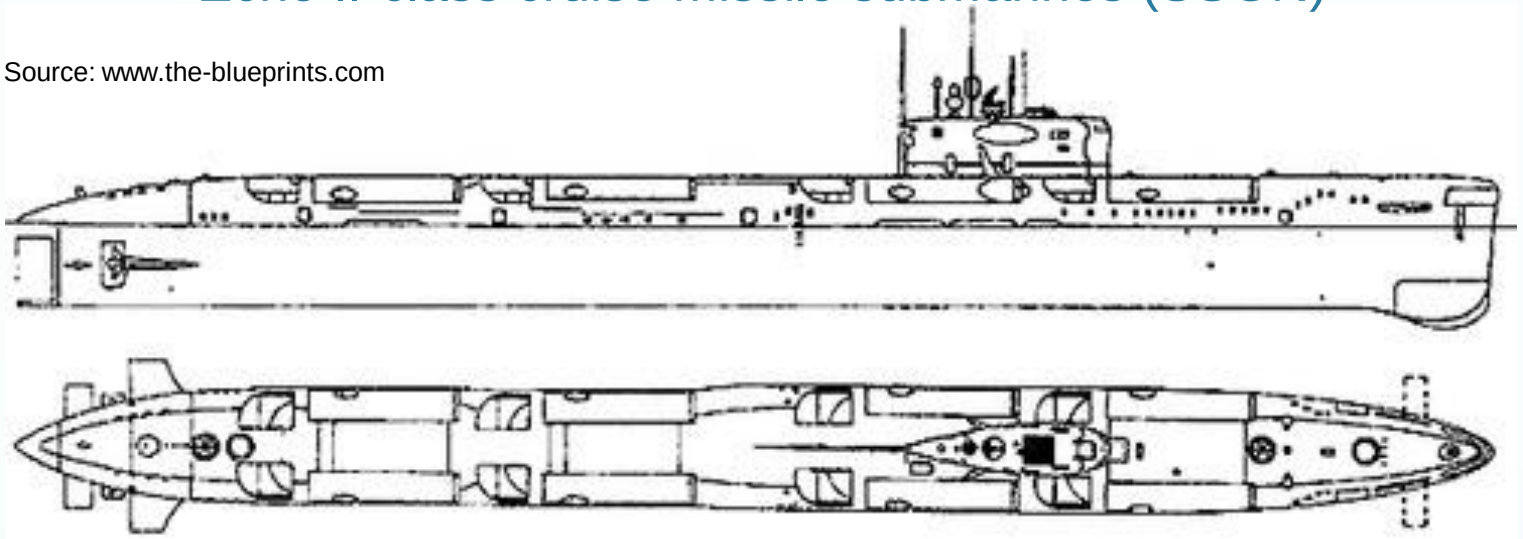
Source: http://www.globalsecurity.org/military//world/russia/ss-n-3-specs.htm

- For Echo I and Juliett subs, the first P-5 missile could be launched in about five minutes after surfacing. Subsequent missiles could be launched at approximate ten second intervals.
- P-5 removed from service in 1956 – 59 time period to comply with SALT I treaty.
- The P-5 was the Soviet counterpart to the U.S. Regulus 1 nuclear-armed cruise missile.

Project 675

Echo II-class cruise missile submarines (SSGN)

Source: www.the-blueprints.com



- Enlarged version of the Echo I SSGN designed for anti-shipping missions by Rubin Central Design Bureau for Marine Engineering. 29 subs in this class; 1st boat entered service in 1963.
  - Hull lengthen 5 m (16.4 ft) to accommodate an extra pair of missile launchers
  - Anti-ship cruise missile guidance radar is in a housing at the front of the sail (same as Juliett-class SSG).
- Propulsion:
  - 2 x VM-A PWRs each rated @ 70 MWt. 2 x steam turbines with a combined output of about 35,000 hp; driving 2 x shafts
- Armament:
  - 8 x anti-ship cruise missiles in launch tubes outside the pressure hull. The missiles were launched only while surfaced.
    - Original armament was 8 x P-6 cruise missiles
    - Some Echo II boats were modified to carry 8 x P-500 or P-1000 cruise missiles.
  - 4 x 533 mm torpedo tubes in the bow + 2 x 406 mm torpedo tubes in the stern.

Project 675

Echo II-class cruise missile submarines (SSGN)

- Operational matters:
  - To attack a surface vessel, the submarine surfaced, deployed the missile guidance radar, elevated the missile launcher(s), launched the missile(s), and remained on the surface to guide the high altitude cruise missile in flight via a datalink, providing guidance commands based on the submarine's radar tracking data.
    - It took about 20 minutes to launch all eight missiles. The submarine was highly vulnerable to attack while on the surface operating its radar.
  - In the mid-1980s, Echo II subs were updated with the P-500 cruise missile. In 1987, four Northern Fleet Echo II boats were updated to use the P-1000 cruise missile.
  - Under Project 06754, Echo II K-170 / K-86 was converted into the PLA-carrier ("mothership") KS-86, which was equipped to carry one small Project 1851 / 18511 Nelma / Paltus special operations submarine
- Reactor accidents in Echo II SSGNs:
  - K-431 (formerly K-31), 10 Aug 1985, in port, Chazhma Bay naval facility, Vladivostok
    - Reactor refueling accident with prompt criticality of a new core; steam explosion ejected the core; 10 fatalities from the steam explosion; significant radiation doses to many workers and significant release of radioactivity to the environment. Sub never operated again.
  - K-116: 18 Aug 1978, at sea, in the Bay of Vladimir, Sea of Japan
    - Primary coolant leak from the port reactor. Some of the crew received a large radiation dose, but there were no fatalities. Sub decommissioned in 1985.
  - K-192 (formerly K-131), 25 Jun 1989, at sea, in the Barents Sea.
    - Primary coolant leak from one reactor, which was severely damaged before the cooling water supply could be restored. Returned to port by never operated again.

P-6 / SS-N-3A Shaddock

Supersonic anti-ship cruise missile

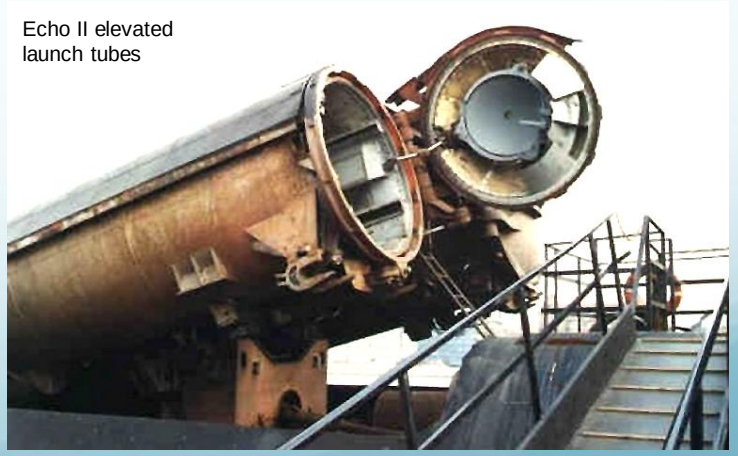
Source: http://www.navalofficer.com.au

Elevated P-6 launcher & guidance radar in front of sail of a Juliett SS

Source: https://en.wikipedia.org/wiki/Juliett-class_submarine

Source: moremhod.info/index.php/library-menu/16-morskaya-tematika/188-pf7

Echo II elevated launch tubes



Source: http://www.ausairpower.net/APA-Rus-Cruise-Missiles.html

P-500 & P-1000 / SS-N-12

Supersonic anti-ship cruise missile

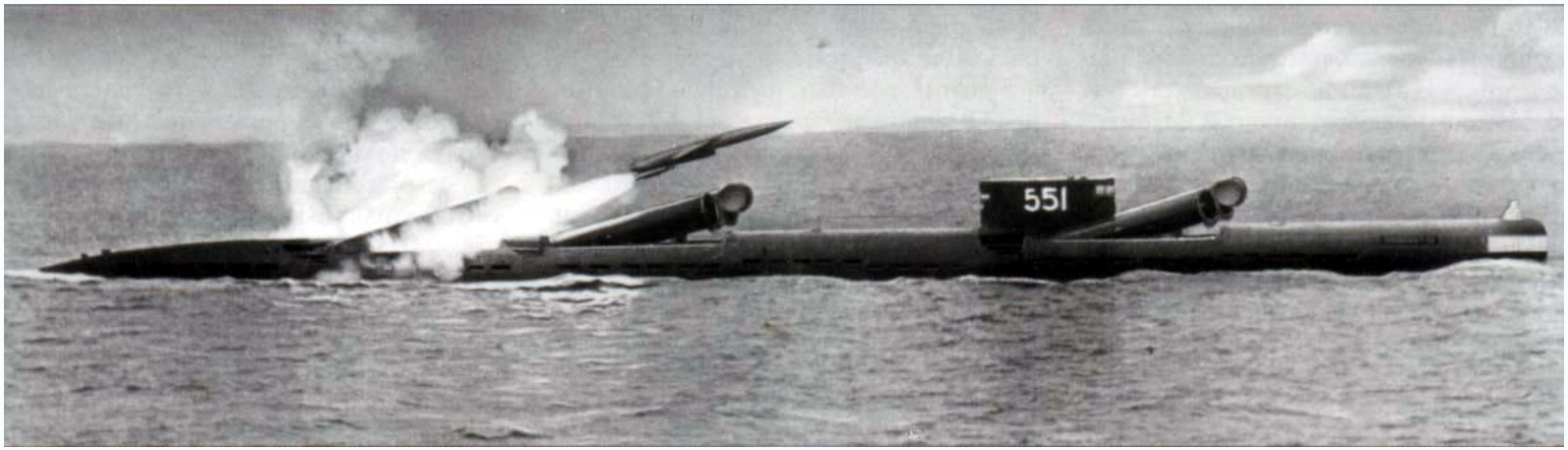
Source for three photos: http://www.ausairpower.net/APA-Rus-Cruise-Missiles

- P-500 & P-1000 have similar size and planform; fit into the same launchers.
- P-500 introduced an active electronic countermeasures package not found on earlier Russian cruise missiles.
- P-1000 made extensive use of titanium structures, had reduced weight & longer range than P-500.
- P-500 deployed on Echo II SSGNs & one Juliett SSG. P-1000 deployed on four Echo II SSGNs.
- Subs must surface to launch these missiles.
- Rocket boosters + turbojet sustainer engine

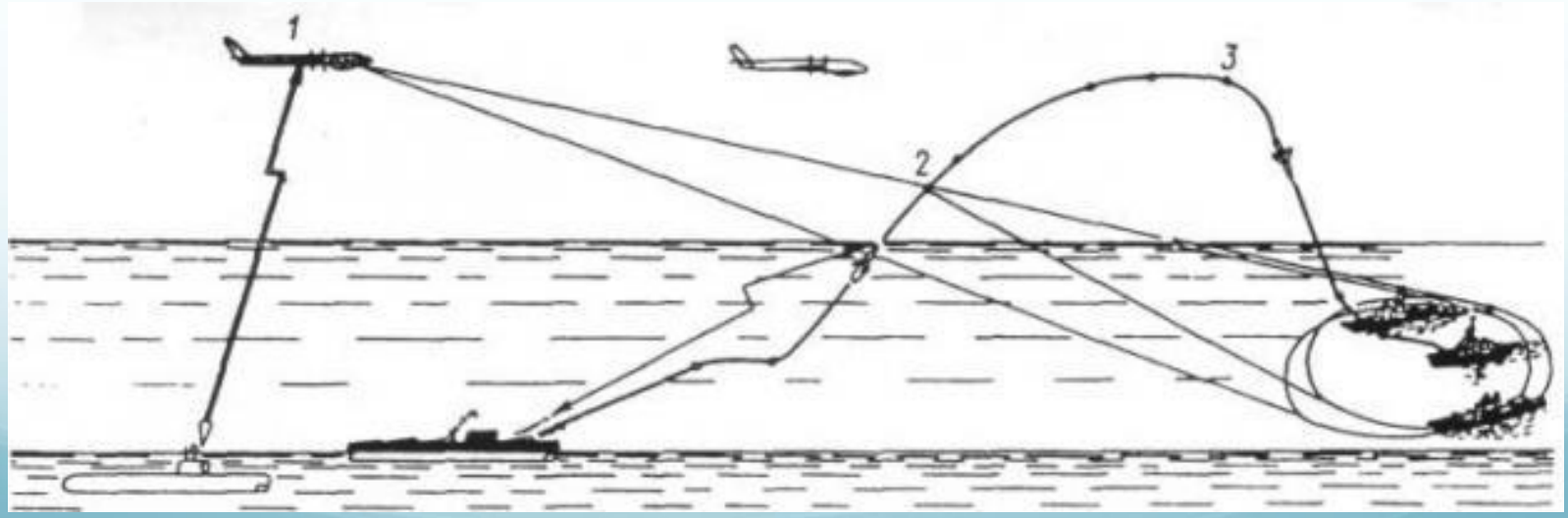
Project 675

Echo II launching an anti-ship cruise missile

Echo II must launch the anti-ship missile while surfaced



Echo II cruise missile mission profile. Missile could be controlled from an aircraft after launch.

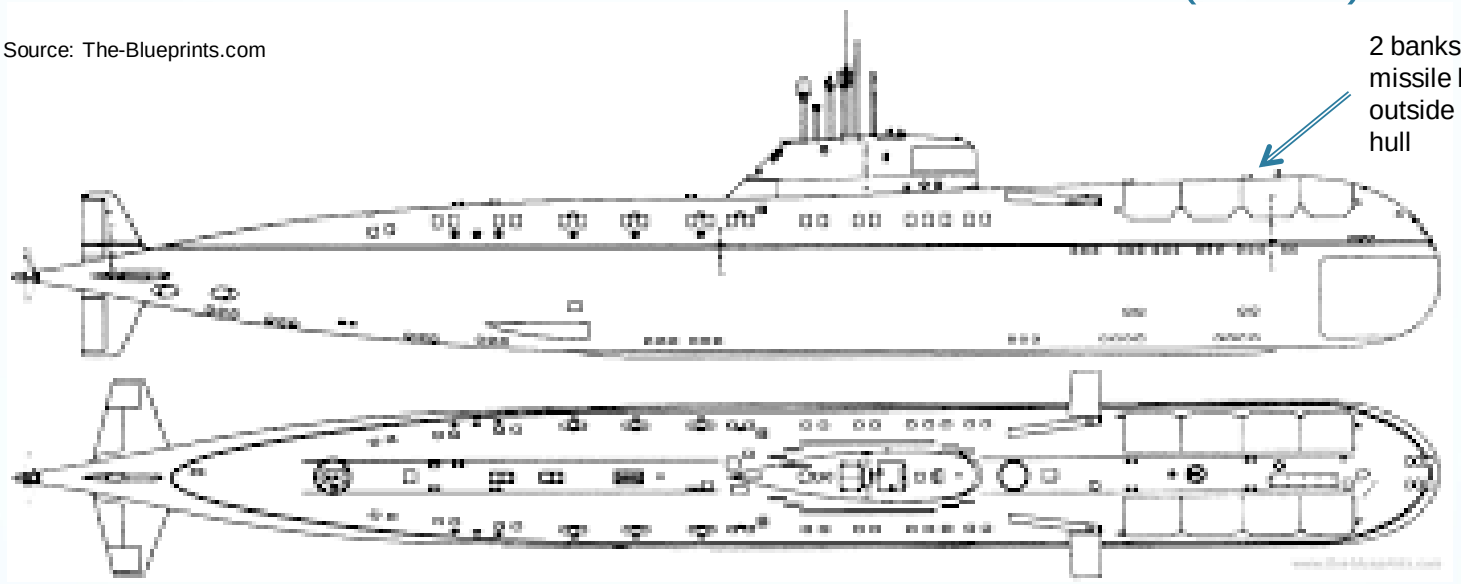


1 = sub alerted; 2 = missile launched, guidance via data link; 3 = terminal radar homing

Source for photo & diagram: http://moremhod.info/index.php/

Project 670 (Skat) & 670M (Čajka)

Charlie I & II-class cruise missile submarines (SSGN)



- Counterparts of the Victor-class SSN
- Propulsion:
  - OK-350: 1 x VM-4-1 PWR rated @ 89 MWt
  - 2 x steam turbines delivering a total of about 17,000 hp; driving 1 x shaft
- Armament:
  - 2 banks of 4 cruise missile launchers in the bow angled up outside the pressure hull (Charlie I: 8 x P-70 missiles; Charlie II: 8 x P-120 missiles)
  - 6 x 533 mm bow torpedo tubes and stowage for 12 weapons
- Operational matters:
  - Charlie I K-43 was leased to the Indian Navy as the *Chakra* from 1988 – 92.
  - Charlie I K-429 sank in the Pacific off the Kamchatka Peninsula in 1983 with 16 fatalities. The ship was recovered.

P-70 / SS-N-7 Amethist

Subsonic anti-ship cruise missiles

- First Russian cruise missile designed for submerged launch; launch depth 30 - 40 m (98 – 131 ft)
- Deployed on Charlie I & Papa SSGNs. Launched from large-diameter inclined launch tubes in the free-flood area outside the submarine pressure hull.
- Solid rocket propelled
- Range: 65 km (40.4 mi) at Mach 0.9. No mid-course guidance required and, hence, no guidance radar on the submarine as with P-6 missile.
- Active radar homing; also may have had an anti-radiation seeker to target defending radars

Source: http://moremhod.info/index.php/library-menu/16-morskaya-tematika/188-pf7

P-120 / SS-N-9 Malakhit

Subsonic anti-ship cruise missiles

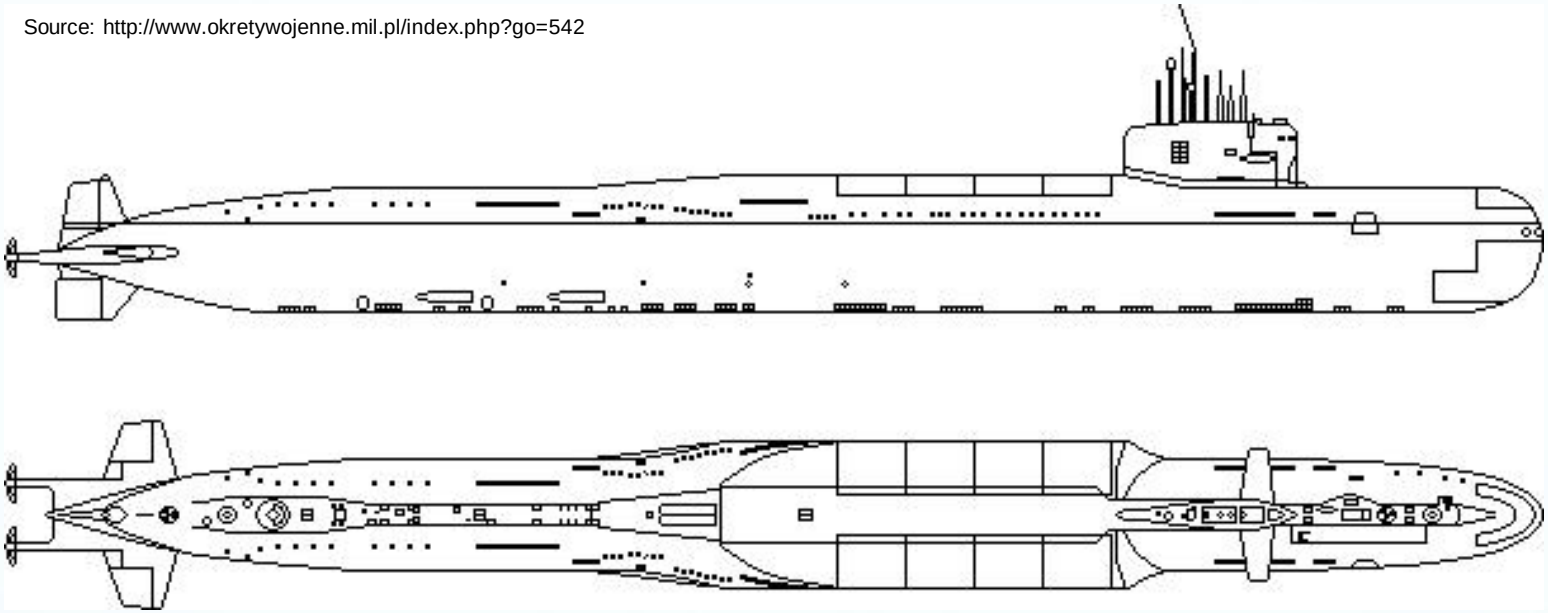
Source: http://www.ausairpower.net/APA-Rus-Cruise-Missiles

- Designed for submerged launch at 30 - 40 m (98 – 131 ft)
- Deployed on Charlie II & Papa SSGNs. Launched from large-diameter inclined launch tubes in the free-flood area outside the submarine pressure hull.
- Launched with solid propellant boosters and then used a turbojet engine for the remainder of the flight.
- Range: 70 – 110 km (43.5 – 68 mi) at Mach 0.9.
- Active radar homing; also infrared seeker in pod under fuselage to improve resistance to countermeasures
- The P-120 missile was later used as the basis for the SS-N-14 anti-submarine rocket-propelled torpedo

Project 667M (Andromeda)

Yankee Sidecar SSGN

Source: http://www.okretywojenne.mil.pl/index.php?go=542



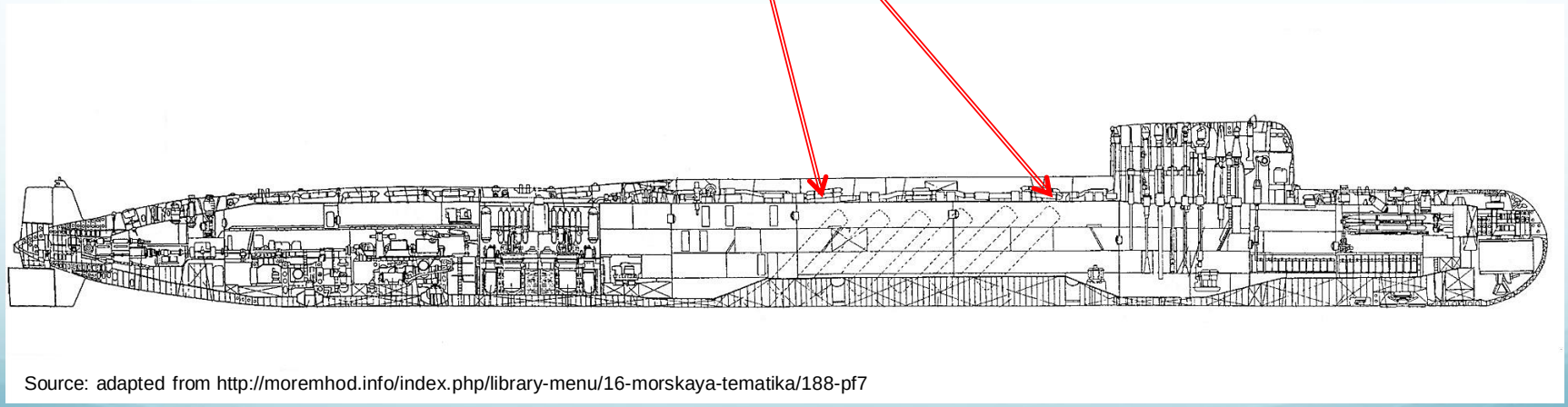
- One Yankee Sidecar SSGN was a conversion of a former Yankee I SSBN.
  - Established the basic cruise missile launcher arrangement used in the larger Project 949 (Granit) & 949A (Antei) Oscar I & II SSGNs.
- Propulsion, same as Yankee I:
  - OK-700: 2 x VM-4-2 PWRs, each rated @ 90 MWt
  - 4 x main turbines with a combined rating of about 34,500 shp; driving 2 x shafts
- Armament:
  - 12 x launchers for the SS-N-24 cruise missile installed amidships, on the flanks of the submarine, outside the pressure hull.
  - 4 x 533 mm and 2 x 406 mm torpedo tubes in the bow

Project 667M (Andromeda)

Yankee Sidecar SSGN

"Sidecar" for mid-ships SS-N-24 cruise missile launchers outside the pressure hull

Source: www.shipmodels.info



Source: adapted from http://moremhod.info/index.php/library-menu/16-morskaya-tematika/188-pf7

Kh-90 Meteorit / SS-N-24

Supersonic land-attack cruise missile

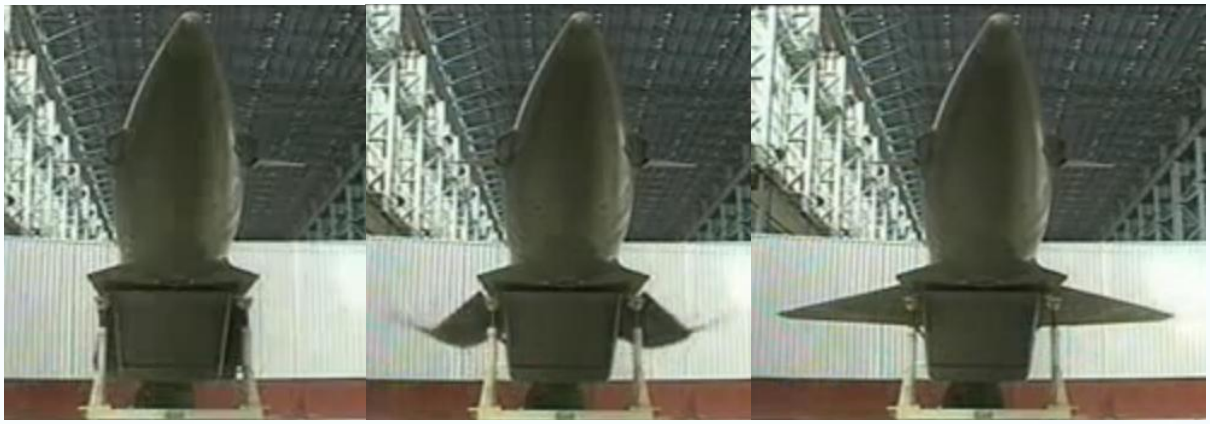
- Russia was developing the Meteorit-M long-range, nuclear-armed, strategic land-attack cruise missile in the mid 1980s.
- Land-, sub-, and air-launched versions were planned.
- Intended to carry 2 x 90 kT nuclear weapons and attack two targets up to 100 km (62 mi) apart.
- Naval deployment was planned on Project 667M Yankee Sidecar submarines with 12 launchers per boat.
- 1st launch from a 667M sub took place on 26 Dec 1983 in the Barents Sea.
- All variants were canceled in 1988 as a result of the INF Treaty.

Mockup of a Meteorit A

Source: http://missilethreat.com/missiles/meteorit/

Kh-90 Meteorit / SS-N-24

Supersonic land-attack cruise missile



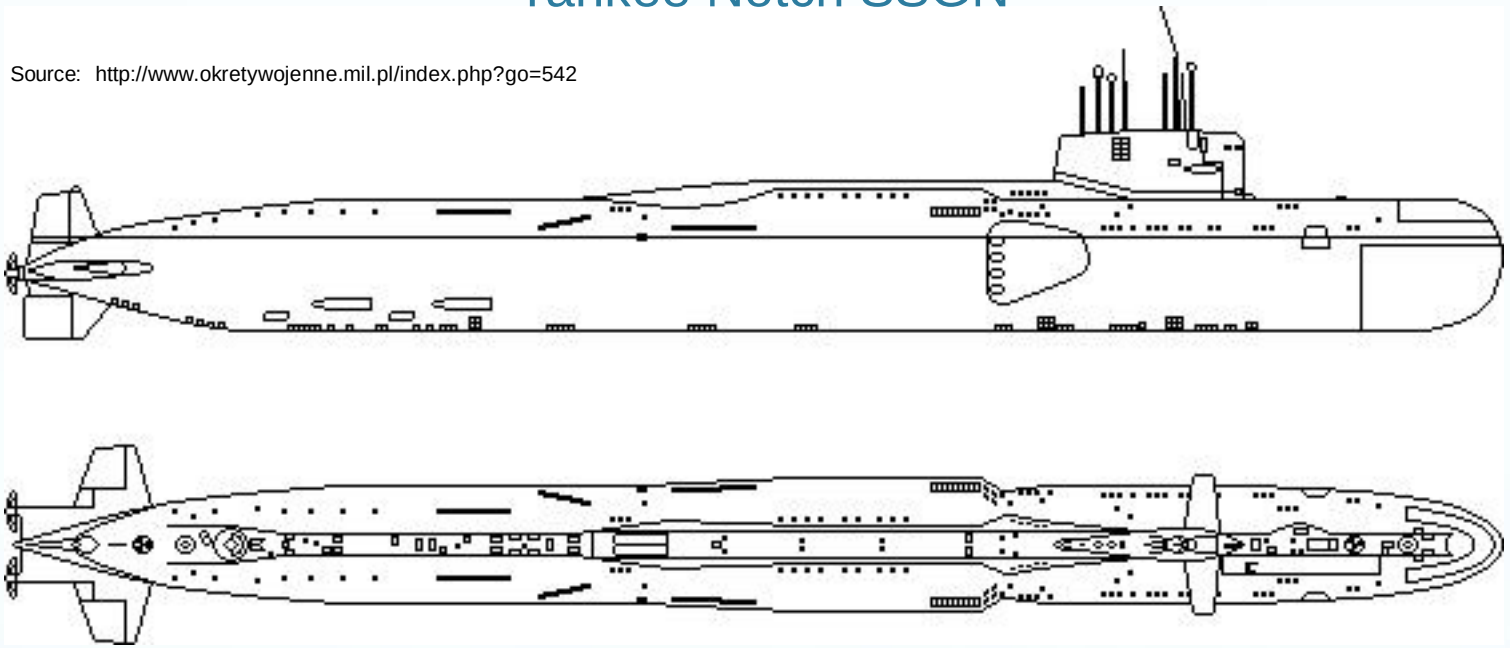
Meteorit A mockup demonstrating the wing deployment sequence following launch.

Source: https://www.youtube.com/watch?v=yylJaJDM3aU

Project 667AT (Grusza)

Yankee Notch SSGN

Source: http://www.okretywojenne.mil.pl/index.php?go=542

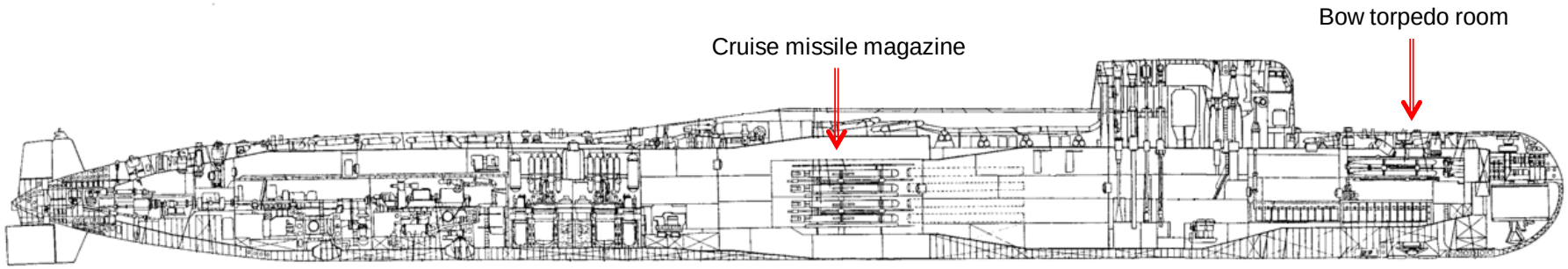


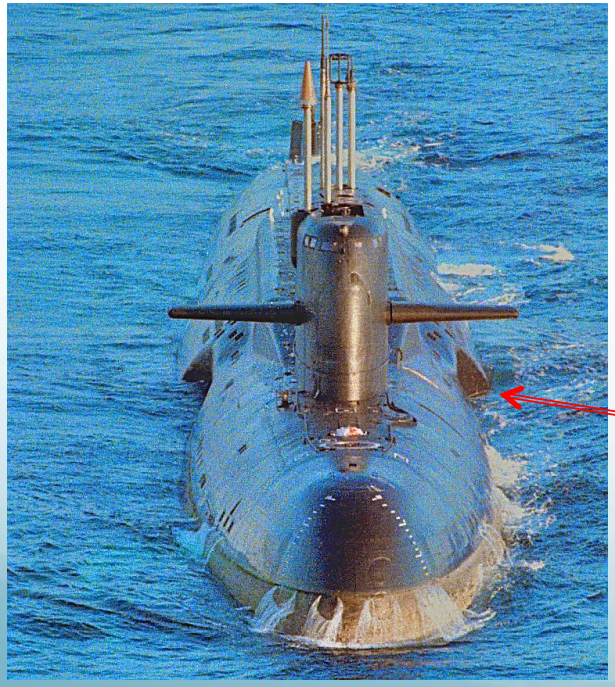
- Four 667AT Yankee Notch subs were converted of former Yankee I SSBNs. The conversion increased the overall length by 12 m (39.4 feet) to 141.5 m (464.2 feet), with a displacement of up to 11,500 tons submerged.
- Propulsion, same as Yankee I:
  - OK-700: 2 x VM-4-2 PWRs, each rated @ 90 MWt
  - 4 x main turbines with a combined rating of about 34,500 shp; driving 2 x shafts
- Armament:
  - 4 x 533 mm and 2 x 406 mm torpedo tubes in the bow
  - 8 x additional 533 mm torpedo tubes installed mid-ships for launching SS-N-21 Sampson (RK-55 Granat / S-10) cruise missiles. Storage was provided for 32 - 40 missiles. The new tubes and missile magazine were in the space previously occupied by strategic missiles.

Project 667AT (Grusza)

Yankee Notch SSGN

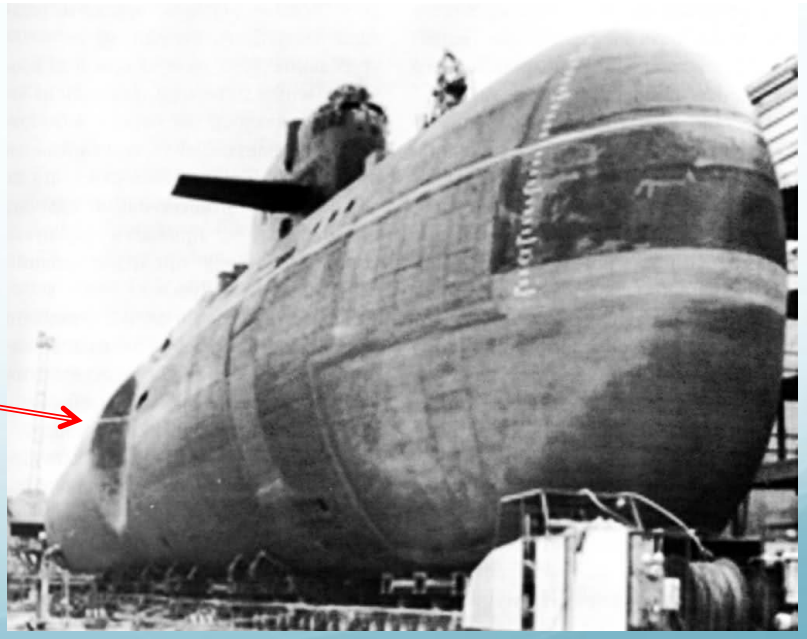
Source: adapted from http://moremhod.info/index.php/library-menu/16-morskaya-tematika/188-pf7





Source: http://www.ausairpower.net/APA-Rus-Cruise-Missiles.html

Notch in hull for mid-ships 533 mm (21 in) torpedo tubes is apparent in these photos

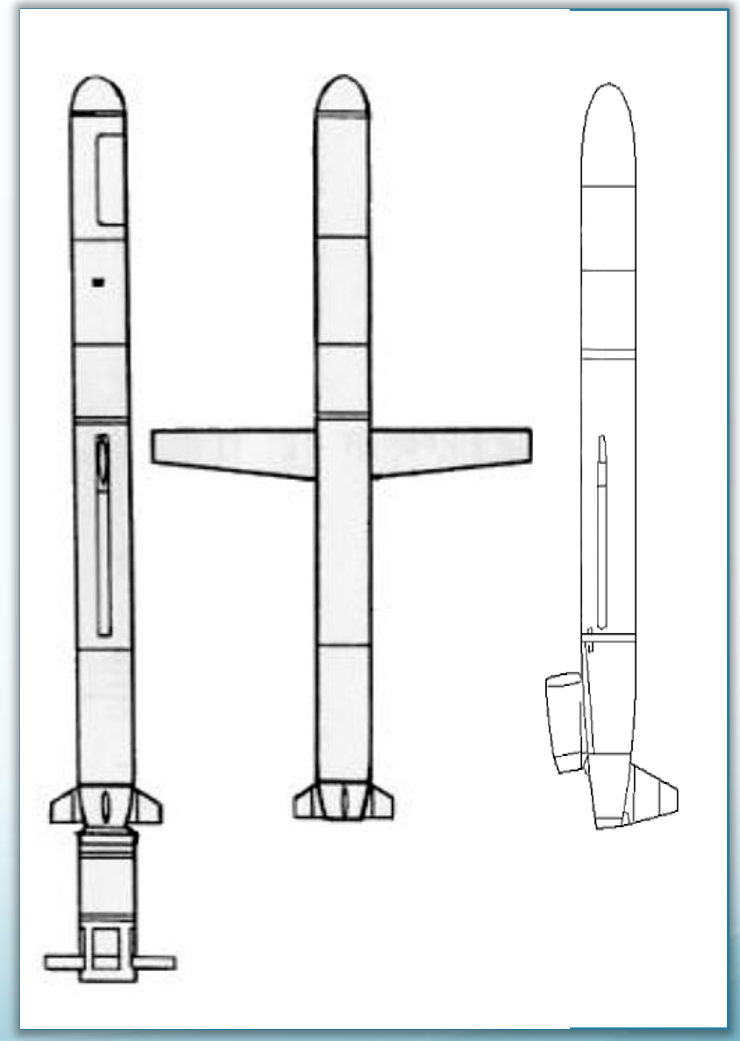


Source: www.shipmodels.info

RK-55 Granat / SS-N-21 Sampson

Subsonic land attack cruise missile

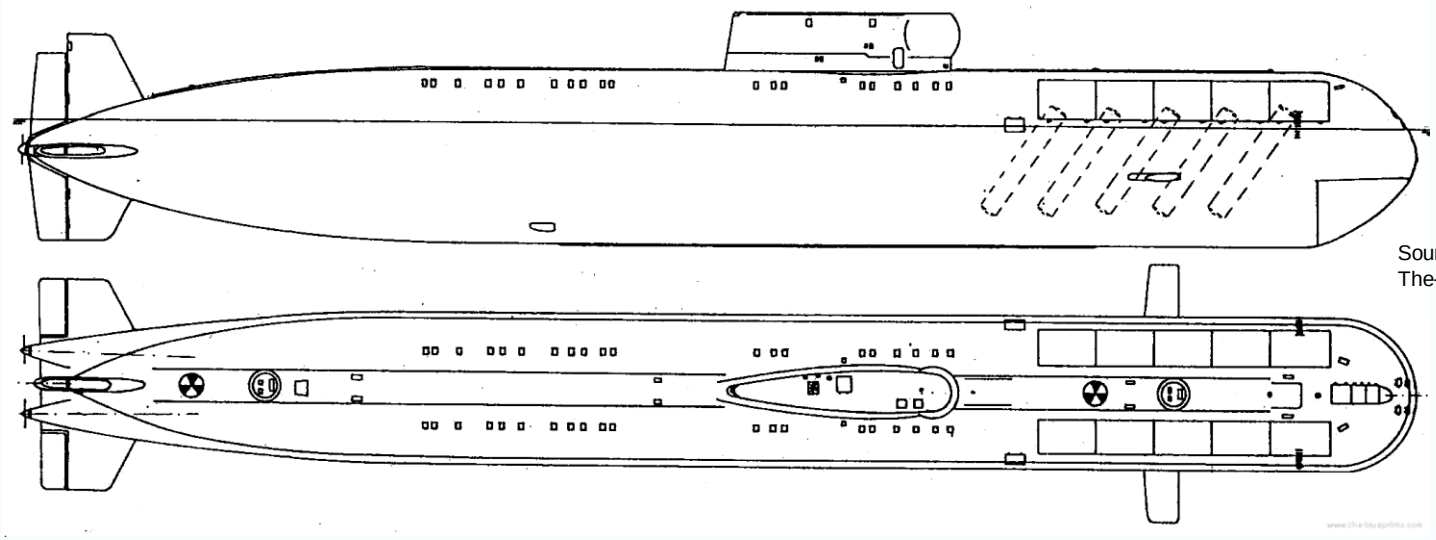
- Originally nuclear-armed.
- All are likely to have been retired or converted to conventionally-armed missiles.
- Analog to the U.S. nuclear-armed Tomahawk cruise missiles.
- Can be launched from a standard 533 mm (21 in) torpedo tube.
- About 150 submarine-launched missiles were produced.
- Deployed on Victor III, Sierra and Akula SSNs and Yankee Notch SSGNs.



Sources: adapted from http://fas.org/nuke

Project 661 (Anchar)

Papa-class (K-222) cruise missile submarine (SSGN)



Source:
The-Blueprints.com

- First submarine with a titanium hull (inner and outer hulls, 5 compartments).
  - Considered to be the predecessor to the titanium hull Alfa and Sierra-class SSNs.
- Propulsion:
  - 2 x VM-5M NIKIET PWRs each rated @ 177 MWt
  - 2 x steam turbines with a combined rating of 80,000 hp driving 2 x shafts.
  - World's fastest submarine at 44.7 kts.
- Armament:
  - 10 x P-70 Ametist (SS-N-7) or P-120 Malakhit (SS-N-9) cruise missiles in two rows of bow launchers outside the pressure hull
  - 4 x 533 mm bow torpedo tubes, with storage for 12 torpedoes

Project 661 (Anchar)

Papa-class (K-222) cruise missile submarine (SSGN)

Source: www.storvik.com

Angled cruise missile launchers in the bow free-flood area

Source: http://moremhod.info/index.php/

Source: en.wikipedia.org

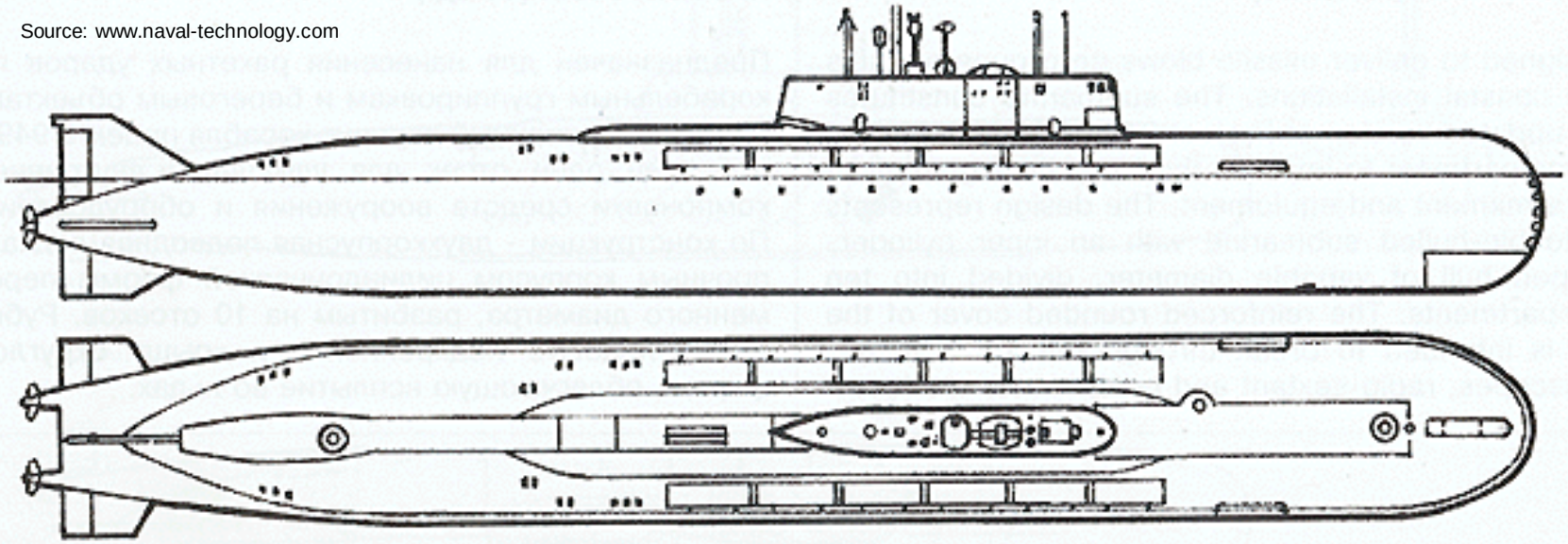
Operational matters:

- Commissioned 31 Dec 69.
- On 30 Sep 1980, one of K-222's nuclear reactors was damaged during maintenance in the shipyard and not repaired. By 1984, she was placed in reserve.
- Beginning on 5 March 2010, K-222 was dismantled at Sevmash shipyard, which was capable of dismantling the titanium hull. The scrapping of the reactor section was performed with the reactors and nuclear fuel still on board.

Project 949 (Granit) & 949A (Antei)

Oscar-class cruise missile submarines (SSGN)

Source: www.naval-technology.com



- Largest Russian cruise missile sub built. Double hull with nine compartments.
  - The “VSK” crew escape capsule in the sail can accommodate 110 people
- Propulsion:
  - OK-650B: 2 x PWRs, each rated @ 190 MWt
  - 2 x steam turbines with a combined rating of 90,000 hp; driving 2 x shafts
- Armament:
  - Mid-ship cruise missile tubes outside the pressure hull for 24 x P-700 Granit (SS-N-19)
  - 4 x 533 mm and 2 x 650 mm torpedo tubes for torpedoes, mines or missiles (SS-N-15 or SS-N-16 anti-submarine missiles)

Project 949 (Granit) & 949A (Antei)

Oscar-class cruise missile submarines (SSGN)

- Operational matters:
  - Like the Kirov-class CGNs, Oscar-class SSGNs originally were designed to defeat an American aircraft carrier battle group by firing a salvo of many supersonic P-700 cruise missiles, which may overwhelm the battle group's defenses.
  - K-141, *Kursk*, sank on 12 Aug 2000. The majority of the sub was salvaged in 2001.
  - Under Project 949AM, Rubin Design Bureau developed in 2011 a plan to modernize Oscar-class SSGNs. On 5 April 2013, the Ministry of Defense and Shipyard "Zvezda" signed a contract for modernization of the first Oscar-class SSGN.
    - Modernization is expected to include conversion of each missile launch tube to carry three P-800 Oniks cruise missiles or similar-sized weapons, for a total of 72 missiles.
    - This contract runs through Nov 2017. The modernized SSGN may be named Oscar III.

Oscar II-class SSGN Omsk with flank cruise missile hatches & bow torpedo loading hatch open

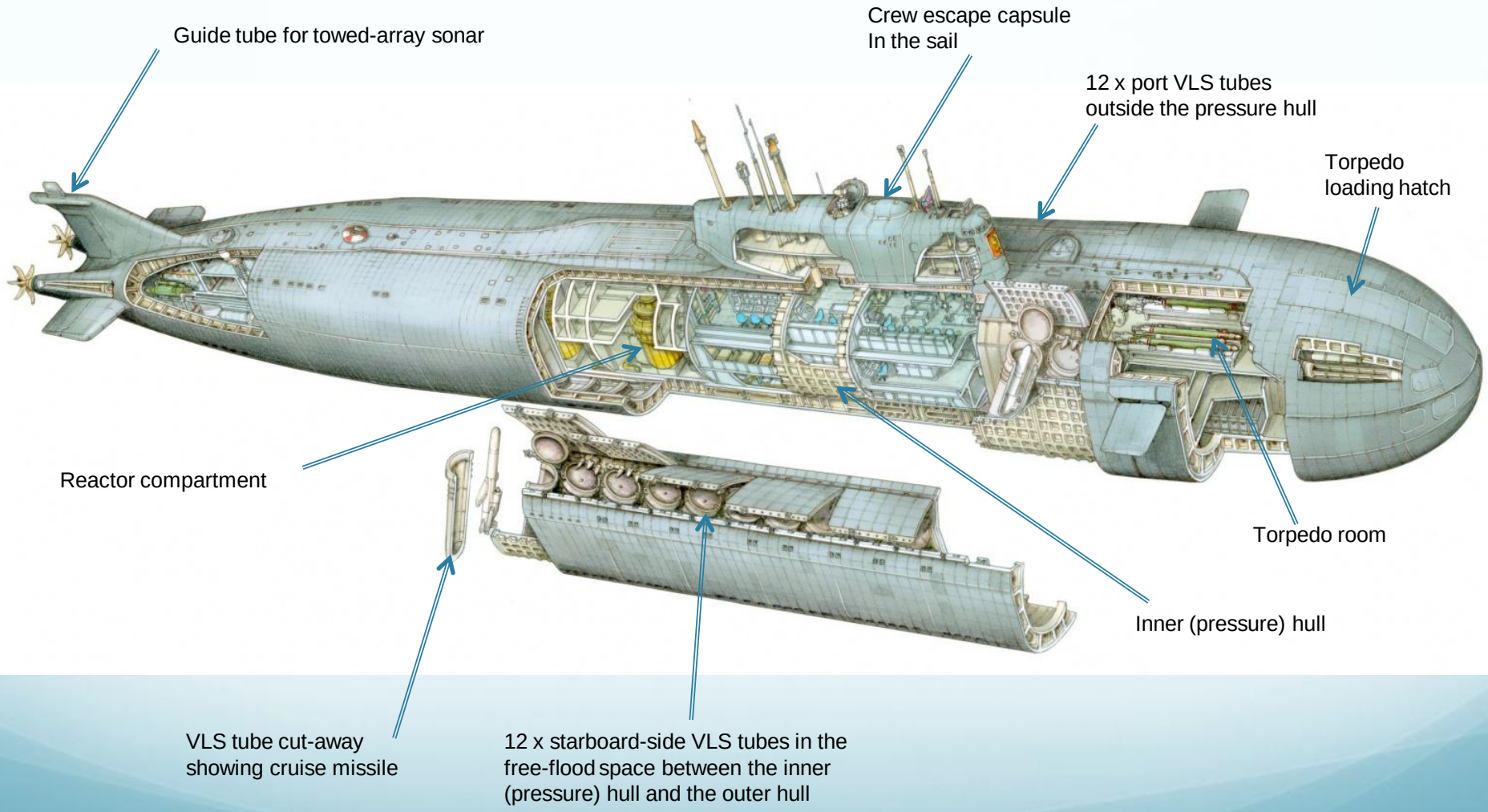
Source: http://chrisjnugent.com/

Oscar II-class SSGN Omsk in dry dock with bow torpedo loading hatch & torpedo tube doors open

Source: www.obramba.com

Project 949 (Granit) & 949A (Antei)

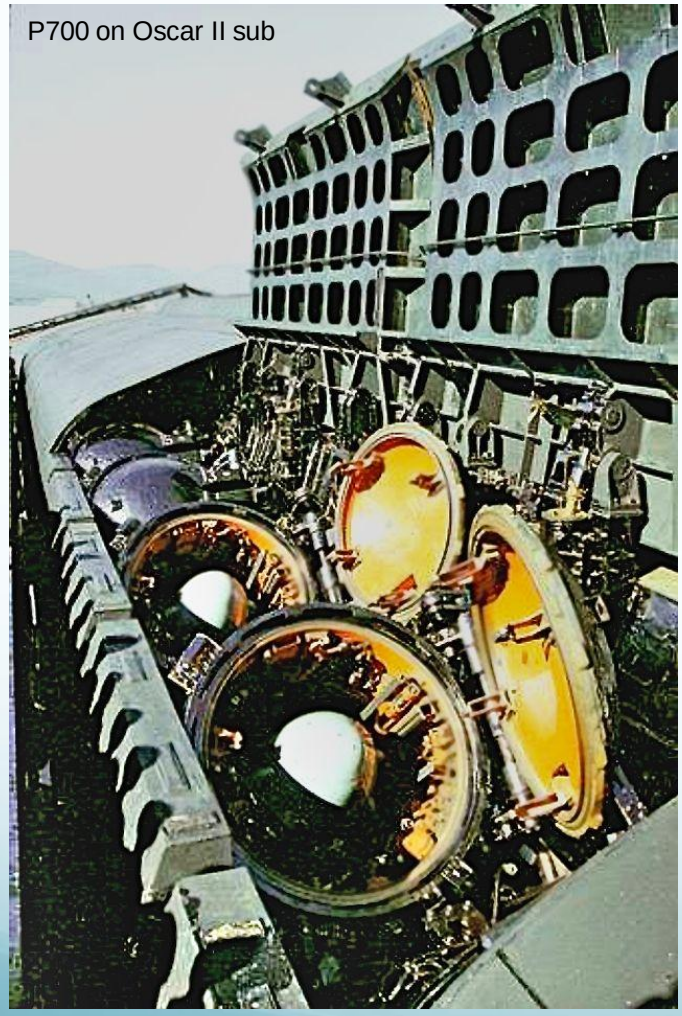
Oscar-class SSGN notional cut-away drawing



Source: adapted from sinodefenceforum.com

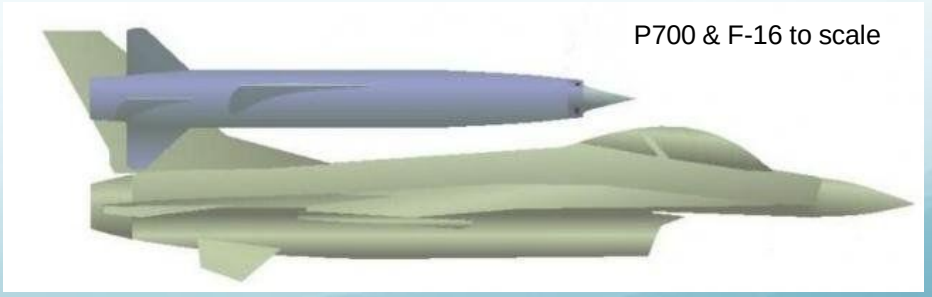
P-700 Granit / SS-N-19

Supersonic anti-ship cruise missile



Source: https://www.pinterest.com/

Source: www.navalofficer.com.au/category/s9-articles1/c42-missiles/



Source: http://survincity.com/2012/08/

P-700 Granit / SS-N-19

supersonic anti-ship cruise missile

Source: http://moremhod.info/index.php/

- Designed to be fired in salvos of multiple missiles against a carrier battle group.
  - One missile in the salvo climbs to high altitude, uses its radar to locate the target, and then generates guidance commands for the other missiles, which remain at low altitude.
  - If the high altitude missile is shot down, then another missile in the salvo automatically climbs to take its place and guide the others closer to the targets.
  - At close range, each missile uses its own active radar to home in on its assigned target.
- Deployed on Oscar-class SSGNs, Kirov-class CGNs, and the Type 1143.5 Kuznetsov-class conventionally-powered aircraft carrier in large diameter vertical or inclined launch tubes.
- Rocket booster; turbojet engine powers the remainder of the flight.
- Range: 625 km (388 mi) at Mach = 1.6 at low- altitude, Mach = 2.5 at high-altitude
- Being replaced by the P-800 Oniks cruise missile.

P-800 Oniks / SS-N-26

Supersonic anti-ship cruise missile

- Like the P-700, P-800 is designed to be fired in salvos of multiple missiles against a carrier battle group.
- Developed in land-, sea-, submarine- and air-launched versions. Land-, sea-, submarine versions are designed to be launched from a vertical or inclined launch tube.
- Export version is the Yakohnt. Also served as the basis for the BrahMos supersonic cruise missile being jointly developed by Russia and India.

Source: http://forums.hexus.net/

- Rocket booster & ramjet sustainer; maximum speed about Mach 2.0 (low altitude), Mach 2.6 (high-altitude); range 600 km (373 mi)
- At close range, each missile uses its own active radar to home in on its assigned target.
- Deployed on Project 885 Yasen multi-purpose SSNs in large diameter Vertical Launch System (VLS) tubes, each capable of holding 3 x P-800 Oniks cruise missiles.
- Modernization of Oscar-class SSGNs and the Kirov-class *Admiral Nakhimov* is expected to include conversion of each P-700 missile launch tube to carry three P-800 Oniks cruise missiles or similar-sized weapons.

Kursk K-141 sinking in Barents Sea

- During military training exercises on 12 Aug 2000, an explosion equivalent to 110 – 250 kg of TNT and fire occurred in the torpedo room. Source is believed to be a fault in a high-test hydrogen peroxide (HTP)-fueled torpedo and the subsequent reaction of HTP with a catalyst. The resulting blast killed everyone in the torpedo room and likely incapacitated crew in the next two compartments.
- A second, much larger explosion, equivalent to 2 – 3 tons of TNT, occurred 135 seconds later from the explosion of torpedo warheads. This ruptured the hull and collapsed the first three compartments in the bow.
- Kursk sank in 108 m (354 ft) of water.

Visualization of the Kursk wreck site

Source: SubArt.net

- All but 24 of the crew of 118 were killed or incapacitated by the effects of the explosions. The remaining crew survived the sinking in an aft engineering compartment. They died when the potassium superoxide canisters in a chemical O_2 generator / CO_2 removal system came in contact and reacted with sea water, causing a flash fire.

Kursk K-141 salvage

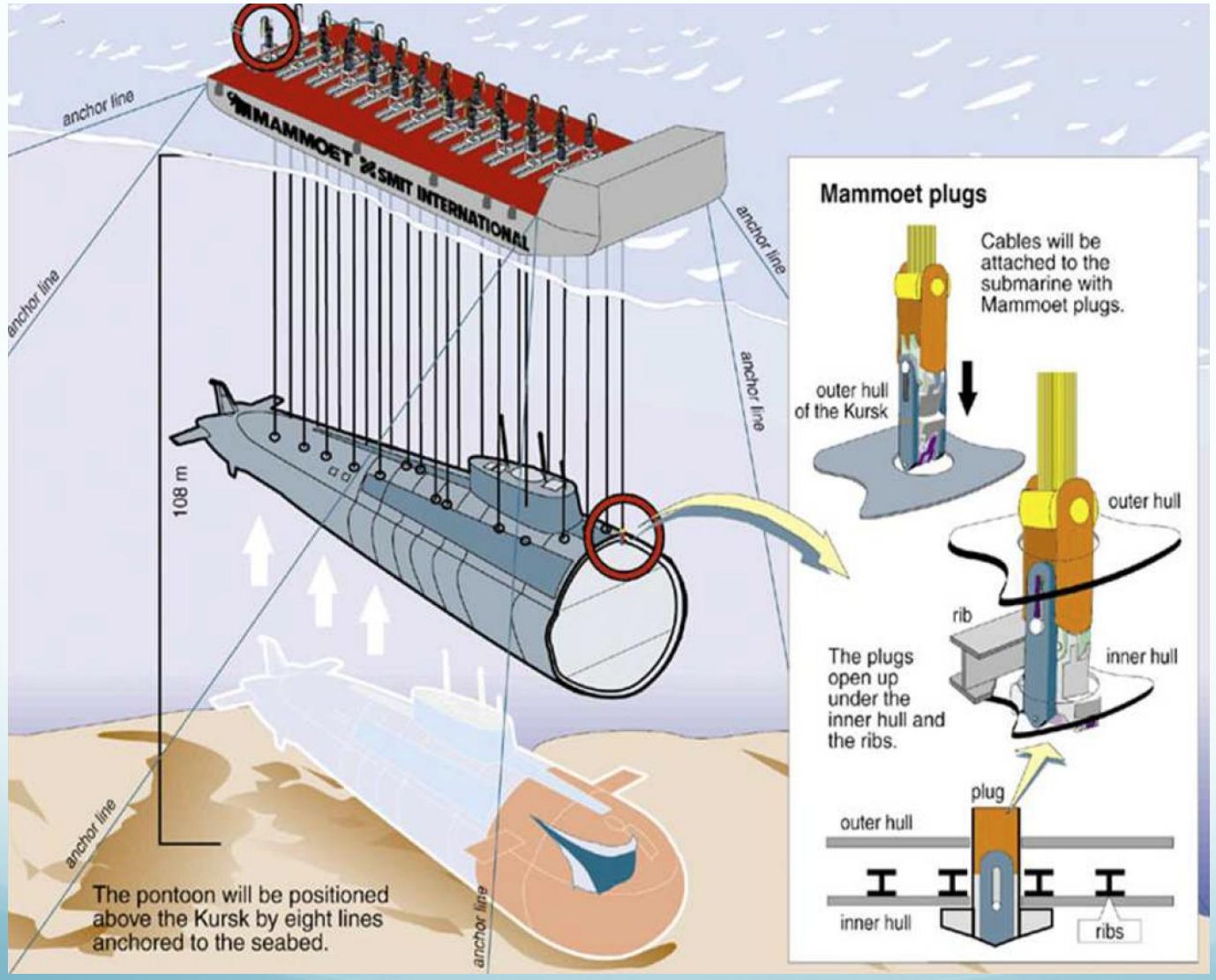


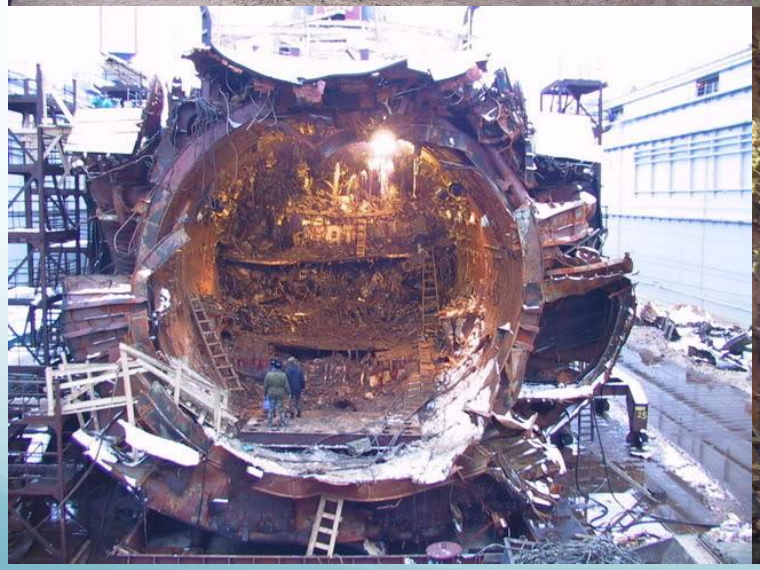
Diagram source: Mammoet Smit International

- Bow section cut away prior to lifting in 2001
- Recovered portion was placed in a floating dry dock
- Reactors de-fuelled in 2003, reactor compartment removed to Kola Peninsula storage site, and remainder of the ship was scrapped
- Bow section not recovered; destroyed in 2002 by explosives

Kursk K-141 salvage

Source: www.tagzania.com

Source: en.wikipedia.org



Source: 02varvara.wordpress.com

Source: io9.com

Kalibr /SS-N-30A Sizzler

Subsonic land-attack cruise missile

- Sub-, surface ship-, air-, and land-launched versions.
- Generally comparable to RK-55 Granat / SS-N-21 Sampson and the U.S. Tomahawk cruise missile.
- Can be launched from a standard 533 mm (21 in) torpedo tube at a launch depth of 30-40 m (98–131 ft)

- Conventional, 450 kg (990 lb) HE warhead
- Deployed in large diameter VLS tubes each capable of holding 5 x Kalibr cruise missiles on Project 885 Yasen multi-purpose SSNs,
- Export version is the 3M-14 Klub (Club)

Source: http://www.ausairpower.net/APA-Rus-Cruise-Missile

Kaliber / SS-N-24 Sizzler

Subsonic + terminal supersonic anti-ship cruise missile

- Sub-, surface ship-, and air-launched versions, including export versions
- Small rocket booster launches the weapon, then a turbojet engine powers the missile at subsonic speed until in the vicinity of the target. Then, a small, rocket-propelled “second stage” warhead separates from the subsonic airframe, accelerates to about Mach 2.5 - 2.9, and uses active radar to home in on the designated target.

- Can be launched from a standard 533 mm (21 in) torpedo tube. Launch depth of 30 - 40 m (98 – 131 ft)
- Penetrating high-explosive warhead.
- Range about 220 km (137 mi).
- Export version is the 3M-54 Klub (Club)

Source: http://www.ausairpower.net/APA-Rus-Cruise-Missile

Russian naval nuclear special submarines

- “Deep diving nuclear power stations”
- PLA-carriers (“Motherships”)
- Other special subs

Russian small special operations submarines

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
1851 / 18510	X-ray (Nelma)	1	44 m (144.4 ft)	3.5 m (11.5 ft)	Not known (surf) 529 (sub)	Possible NIKIET 10 MWt (est.)	1,900 (est.)	6	1986	1986 - present
18511	X-ray (Paltus)	3	55 m (180.4 ft)	3.8 m (12.5 ft)	Not known (surf) 730 (sub)	Possible NIKIET 10 MWt (est.)	1,900 (est.)	6	1994 - 95	1994 - present
1910	Uniform (Kashalot)	3	69 m (226.4 ft)	7 m (23 ft)	1390 (surf) 1580 (sub)	Possible NIKIET 52 MWt (est.)	10,000 (est.)	25-30 (est.)	1986 - 91	1986 - present
10831	Losharik (NORSUB-5)	1	74 m (242.8 ft)	7 m (23 ft)	1600 (surf) 2100 (sub)	Possible Afrikantov E-17 52 MWt (est.)	10,000 (est.)	25-30 (est.)	2003	2003 - present
09851	Khabarovsk (Wicket-SMP)	Not known	Not known	Not known	Not known	Not known	Not known	Not known	2015 -16 (est)	

Project 1851/18511 Nelma / Paltus

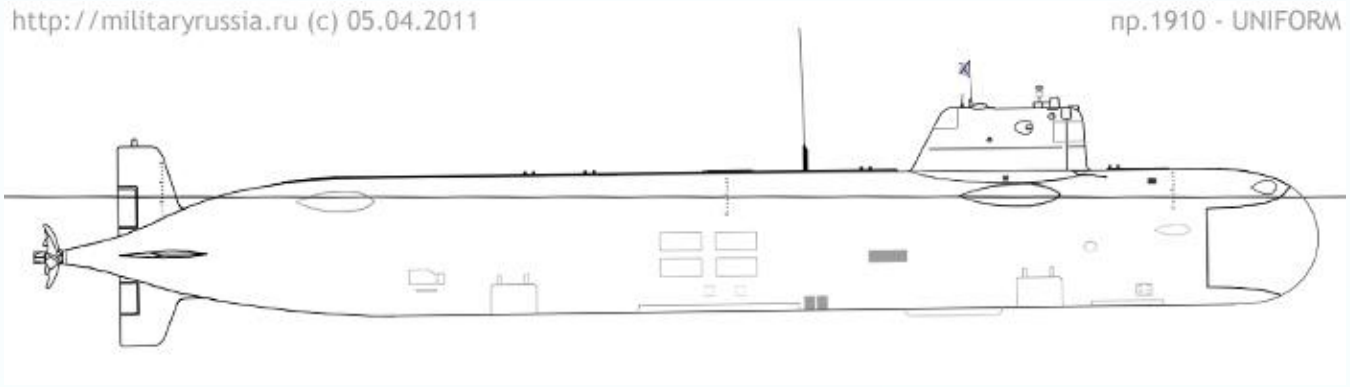
"Deep diving nuclear power station" (aka Project 678)
X-Ray-class research & special operations submarines

Source: www.hisutton.com

- The design is roughly comparable to the U.S. NR-1 small nuclear submarine, but differs in: (a) being double hull, (b) having a diver lock-out capability, and (c) being carried by a "mother submarine."
- Sub is designed for operation at great depth and is equipped with various devices for underwater work.
- No armament. Crew complement: est. 14
- Propulsion: 1 x PWR rated @ 10 MWt attributed to NIKIET; may have turbo-electric drive for single shrouded propeller; small auxiliary propulsors (thrusters) for precise underwater positioning. Propulsion power about 1,900 hp.
- The sole Project 1851 Nelma submarine, AS-23, was launched at the Admiralty Shipyard, St. Petersburg, in Sep 83 and joined the Northern Fleet in Dec 86. AS-23 may have been modernized in 2011 – 12 under Project 18510M.
- First Project 18511 Paltus submarine, AS-21, was launched in Apr 91 & joined fleet in Dec 91. The second sub, AS-35, was launched in Sep 94; joined the fleet in Oct 95; and was modernized 2012. There may be a fourth unfinished hull.

Project 1910 Kashalot

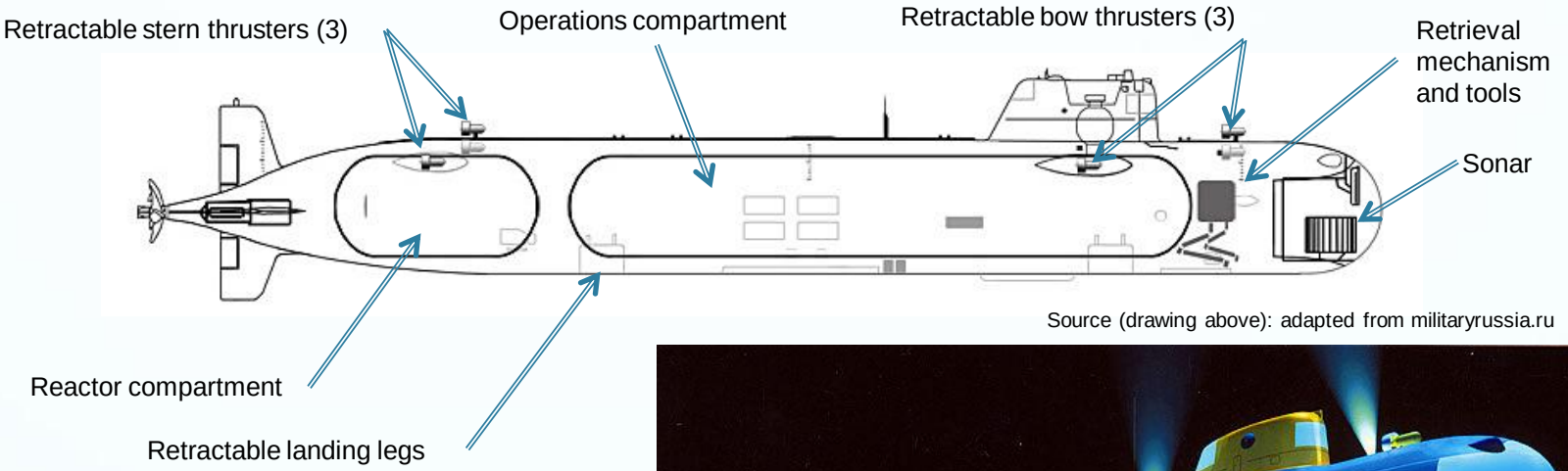
“Deep diving nuclear power station”
Uniform-class research & special operations submarines



- Titanium hull. Sub is designed for operation at great depth (1000s of meters) and is equipped with various devices for underwater work. Can be carried by a “mothership”
- 1st keel laid in 1977, completed as AS-13 in 1986.
  - 2nd keel laid in 1983, completed as AS-15 in 1991.
  - 3rd boat in class, AS-33, keel laid in 1988 and completed in 1994.
- No armament. Crew complement: est. 36
- Propulsion: 1 x PWR @ about 50 MWt attributed to NIKIET; 2 x turbo-generators providing about 10,000 hp (7.46 MW) for propulsion power; single, variable-pitch main propeller and six small, retractable auxiliary thrusters for precise underwater positioning.
- Under Project 19102, AS-15 was modernized in 2009 - 2013.

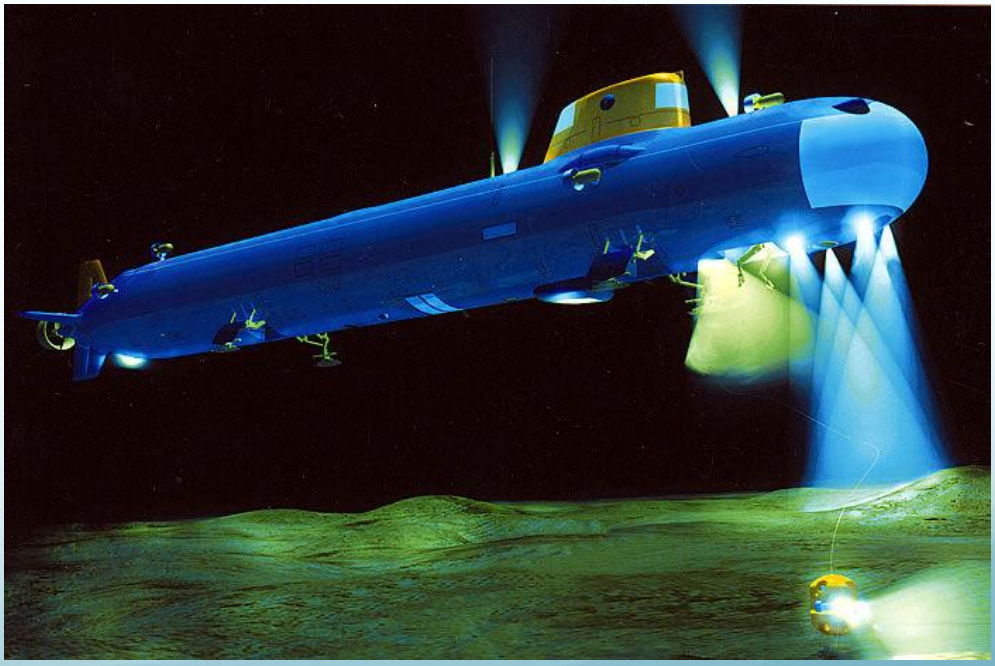
Project 1910 Kashalot

"Deep diving nuclear power station"
Uniform-class research & special operations submarines



Source (drawing above): adapted from militaryrussia.ru

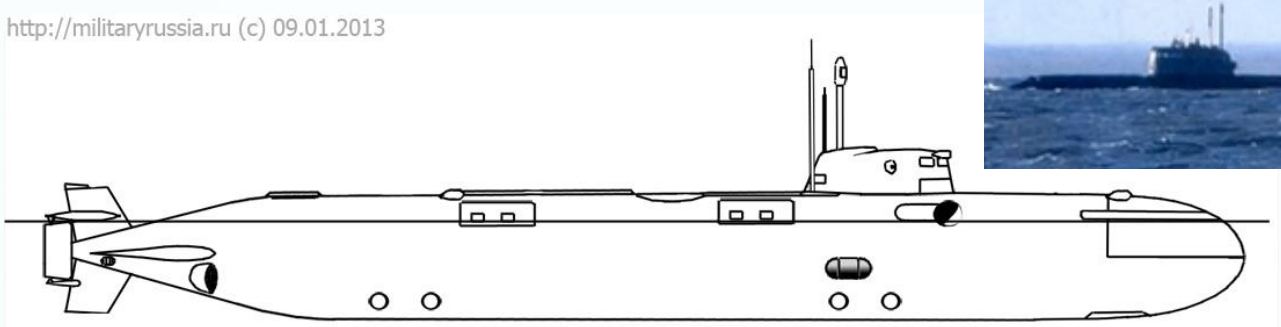
- The reactor compartment may not be accessible at sea. Servicing in port may required.
- Landing legs, thrusters, and retrieval mechanisms all deploy for work on the ocean bottom.



Source: militaryrussia.ru

Project 10831 Losharik

“Deep diving nuclear power station”
(aka Kalitka, AC-12, AS-31, NORSUB-5, Project 201)

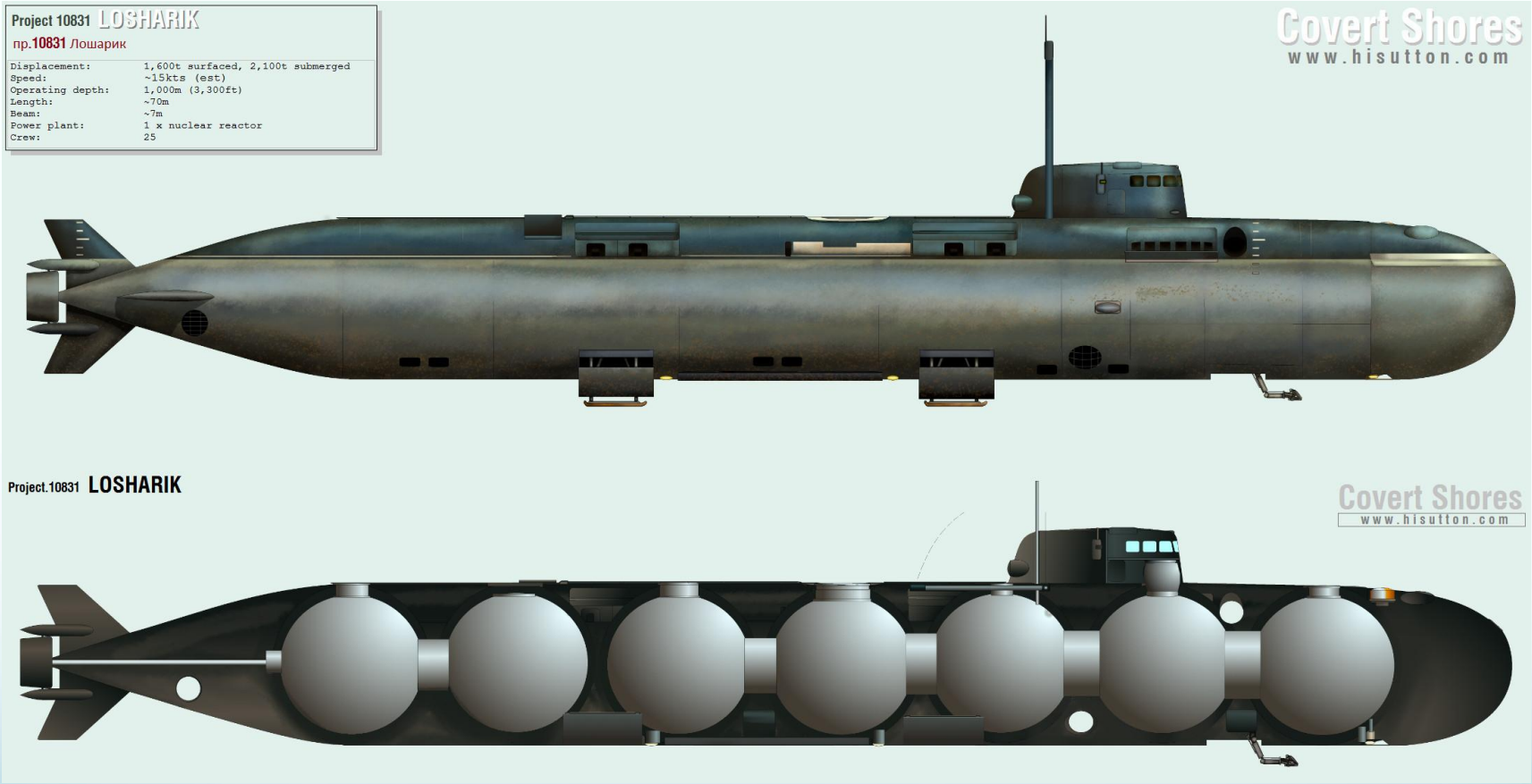


Source: TopGear

- Sub designed by Malakhit Design Bureau. Keel laid in 1988, but not completed until 15 years later, in 2003 as hull number BN-220. A second unit is believed to exist, but apparently has not been completed.
- Inner hull rumored to be comprised of several spherical titanium hull elements within a more conventional outer hull.
  - Sub can be carried by a PLA “mothership” to a distant operating area.
  - Sub designed for operation at great depth (1000s of meters) and is equipped with various devices for underwater work.
  - As part of Arctic-2012 expedition, this sub operated in the Arctic collecting samples at depths of 2500 – 3000 m.
- No armament. Crew complement: est. 25 - 36
- Propulsion:
  - 1 x E-17 PWR rated at 78 MWt (est.) assuming total propulsion power of about 10,000 hp delivered to a single shrouded propeller plus an array of small auxiliary propulsors (thrusters) for precise underwater positioning.
  - Reactor attributed in some sources to OKB Afrikantov (Nizhny Novgorod). The nuclear power plant is probably in one or more of the stern spherical hull blocks.

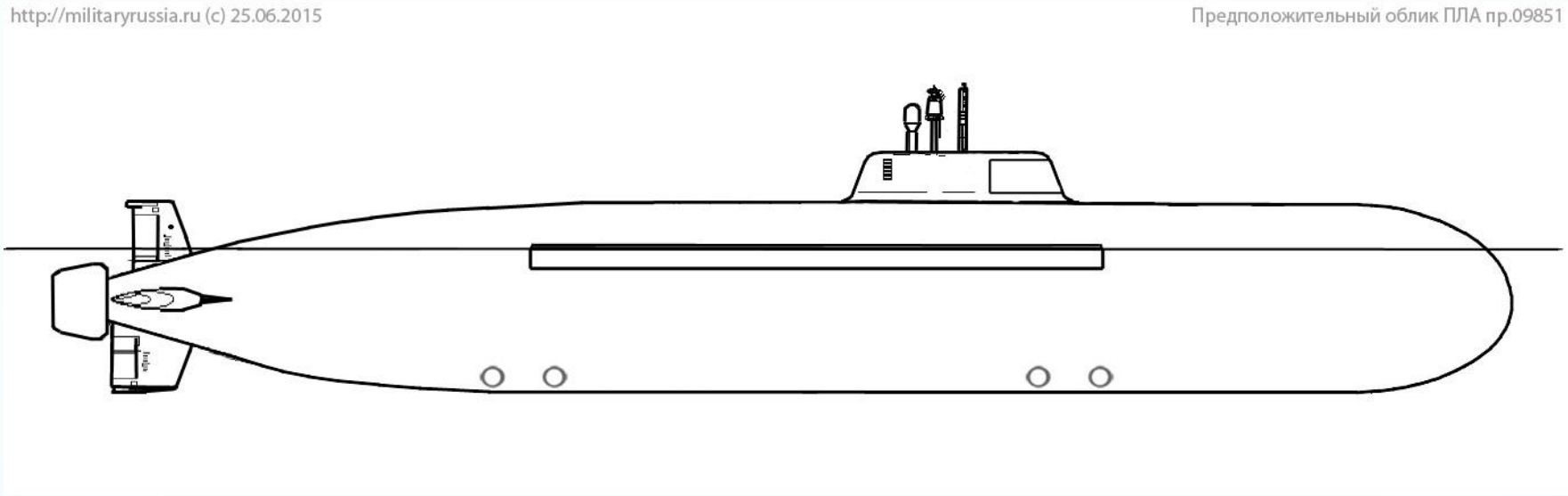
Project 10831 Losharik

“Deep diving nuclear power station” notional arrangement



Project 09851, Khabarovsk

(aka Wicket-SMP)



- Sub design attributed to Rubin Design Bureau. The notional design, above, is speculative.
- A 2014 contract between shipyard Sevmash and the Rubin Design Bureau is reported to cover construction of the Project 09851 submarine.
- The purpose of the Project 09851 sub is not known. Speculation includes:
  - New generation of small, “deep diving nuclear power station,” similar in function to the nuclear-powered Project 10831 Losharik and Project 1910 Kashalot subs.
  - First production vehicle of a new weapons system that was developed and tested on the Project 21020 Sarov sub, which was diesel-electric-powered, supplemented with an auxiliary nuclear power plant (ANPP)
- Crew complement: not known
- Propulsion not known

Small nuclear reactors for Russian special operations subs

- Project 1851/18511 Nelma / Paltus: 1 x 10 MWt PWR attributed to NIKIET
  - Modest propulsion power, estimated to be about 2000 hp (1.5 MW); max. speed reported to be about 6 kts.
- Project 1910 Kashalot: 1 x PWR attributed to NIKIET; max power not specified
  - Propulsion power reported to be about 10,000 hp, with a max. submerged speed of about 30 kts.
  - This would require a reactor with a power level of about 52 MWt.
- Project 10831 Losharik: 1 x E-17 PWR attributed to OKB Afrikantov; max power not specified
  - Propulsion power reported to be about 15,000 hp, with a max. submerged speed of about 30 kts.
  - This would require a reactor with a power level of about 78 MWt.
  - Information was reported in 2012 on the manufacture of a new, small reactor in Obninsk for a new type of special operations sub (ACS).
    - First mentioned in Feb 2012 in an issue of *Nizhegorodoskaya delovaya gazeta* (Nizhny Novgorod Business Newspaper) dedicated to the anniversary of the Afrikantov Experimental Heavy Equipment Design Bureau, the leading developer of nuclear reactors for submarines.
    - It said in an article that the bureau in 2011, "developed a project for the new atomic submarine *Kalitka*, on which a principally new steam generating system, the Phoenix KTP-7I, is being installed."
- Project 651E Nerka and Project 21020 Sarov: Auxiliary Nuclear Power Plants (ANPPs)
  - VAU-6 ANPP designed by NIKIET as a small, hermitic module that can be added to conventional (diesel-powered) subs as an electric power source.
  - Reactor configuration is not known, but likely to be a single loop PWR + turbo-generator producing about 600 kWe net output.

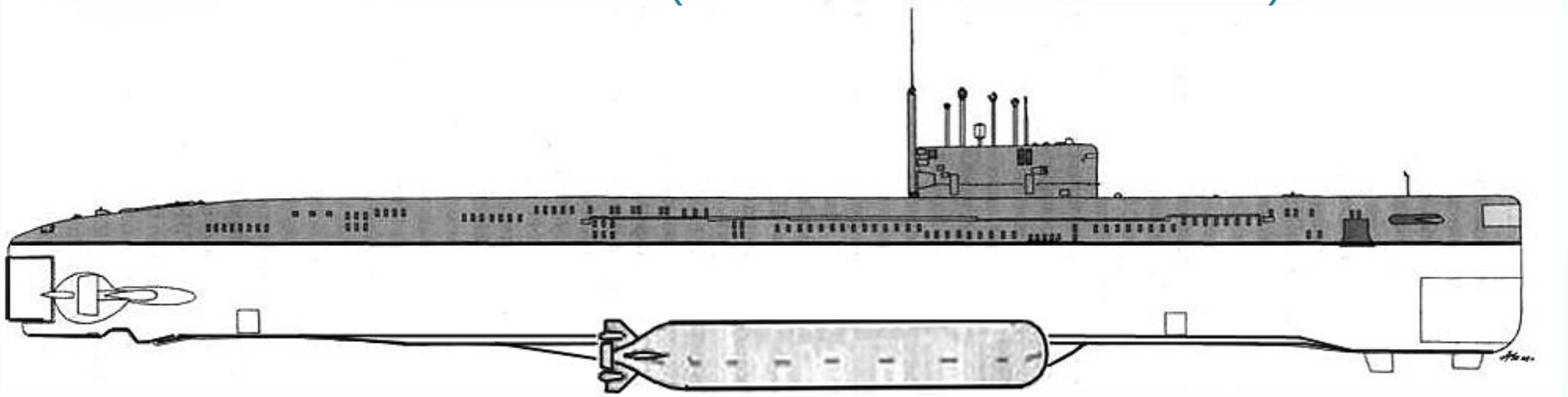
Russian PLA-carriers

("Motherships" for small special ops subs)

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
06754 (675N)	PLA-carrier KS-86	1 x modified Echo II	Not known	9.2 m (30.2 ft)	Not known	2 x VM-A	35,000	Not known	1985	1985 - ???
09774	PLA-carrier "Orenburg" KS-411	1 x modified Yankee Stretch	160 m	11.6 m (38 ft)	Not known	OK-700: 2 x VM-4-2	34,500	Not known	1990	1990 - 2009
09786	PLA-carrier BS-136	1 x modified Delta III	164 m	12 m (39.4 ft)	Not known	OK-700A: 2 x VM-4	60,000	Not known	2002	2002 - present
09787	PLA-carrier KS-64	1 x modified Delta IV	175 m	12 m (39.4 ft)	Not known	OK-700A: 2 x VM-4	60,000	Not known	Expected 2015	
09852	PLA-carrier	1 x possible modified Oscar II	Not known	Not known	Not known	2 x OK-650b	90,000	Not known	Not known	

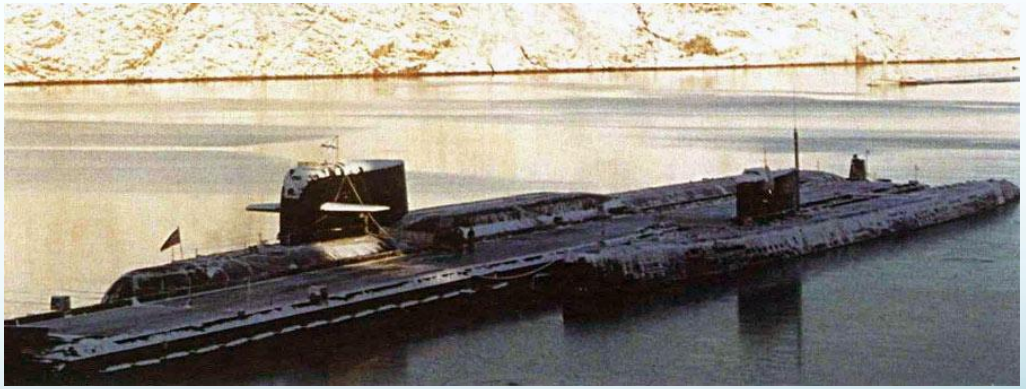
Project 06754 (675N)

PLA-carrier KS-86 (former Echo II K-170 / K-86)



Source: oosif.ru

- Echo II K-170, originally launched in Aug 1963.
- Converted to serve as a “mothership” for a Project 1851 / 18511 Nelma / Paltus special operations submarine and renamed KS-86 in Apr 1985.
- Mission believed to be a combination of oceanographic research, search and rescue, and underwater intelligence-gathering.
- Decommissioned in 1991.

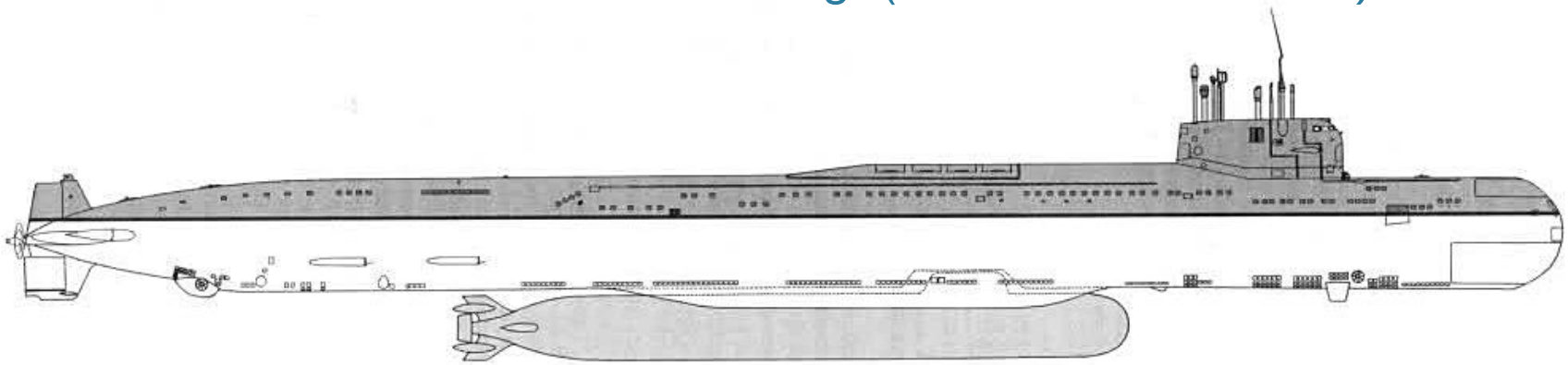


PLA-carriers KS-411 (Yankee Stretch) and KS-86 (Echo II)

Source: oosif.ru

Project 09774

PLA-carrier KS-411 “Orenburg” (former Yankee K-411)



Source: GlobalSecurity.org

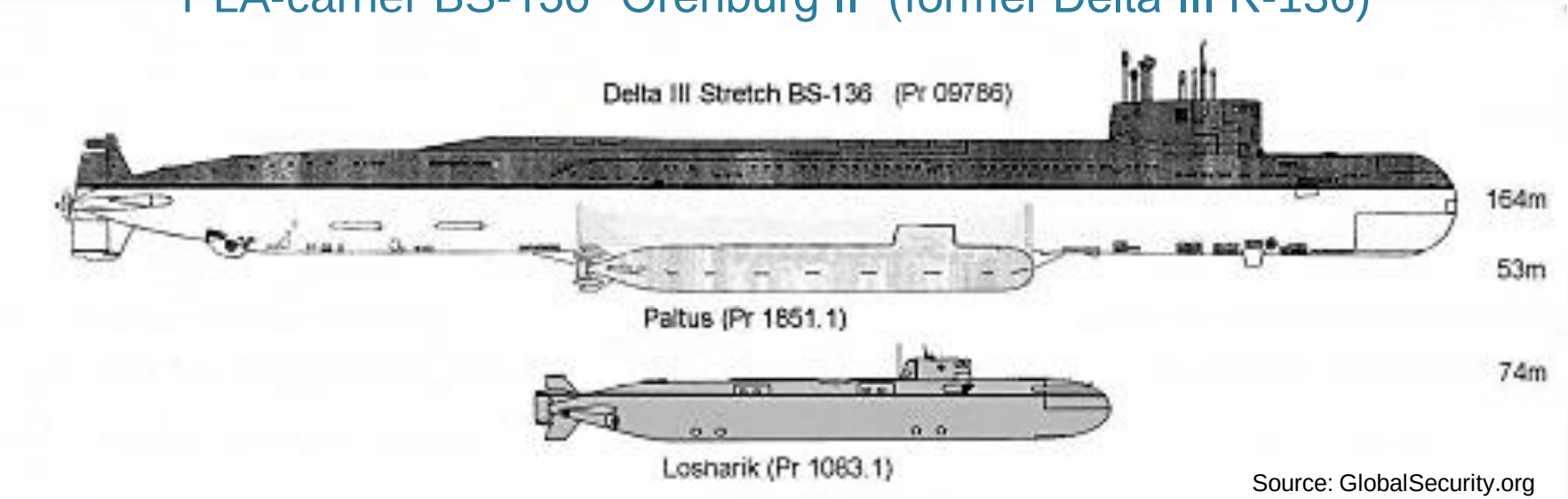
KS-411 + Paltus

Source: military.tomsk.ru

- “Yankee Stretch” conversion in 1983 - 90 with missile compartment replaced by an extended hull section. Length 160 m, displacement 11,600 tons submerged.
- Serves as “mother ship” to support a small special operations submarine.
- Mission believed to be a combination of oceanographic research, search and rescue, and underwater intelligence-gathering.
- Decommissioned in 2009 and special operations mid-section removed for re-use on Delta IV Stretch K-64.

Project 09786

PLA-carrier BS-136 “Orenburg II” (former Delta III K-136)

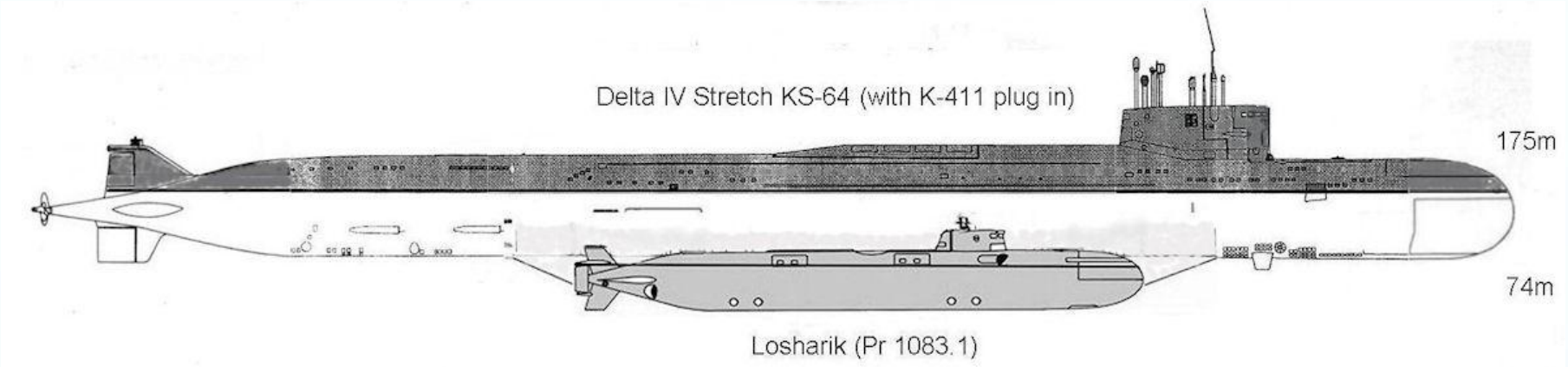


Source: GlobalSecurity.org

- “Delta III Stretch” conversion 1994 – 2002 with missile compartment replaced by an extended hull section. OA length 164 m.
- Serves as “mother ship” to support a small special operations submarine.
- Assigned to Northern Fleet

Project 09787

PLA-carrier KS-64 (former Delta IV K-64)

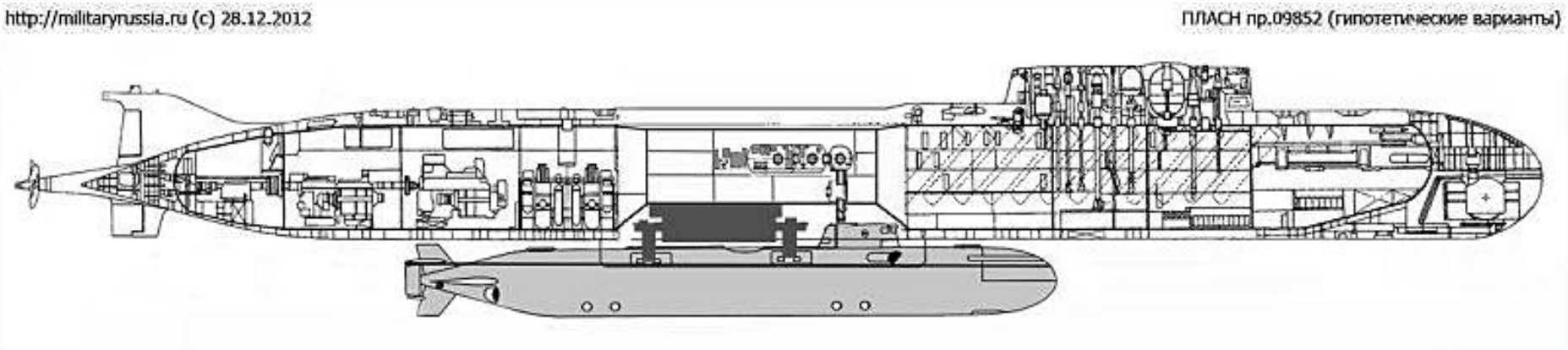


Source: GlobalSecurity.org

- "Delta IV Stretch" conversion started in 1999. Missile compartment removed & replaced by an extended hull section taken from retired "Yankee Stretch" KS-411. OA length now 175 m.
- Serves as "mother ship" to support a small special operations submarine.
- Expected to be assigned to Northern Fleet, based in Olenya Bay, replacing KS-411.
- Scheduled to be completed in December 2015.

Project 09852

PLA-carrier (former Oscar II)



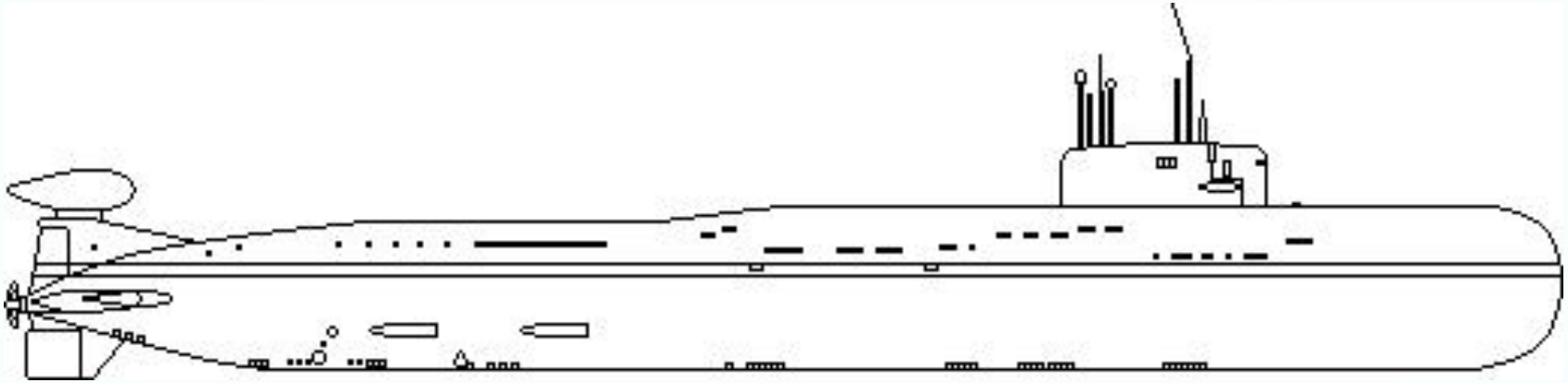
- In December 2012, construction began at the Sevmash shipyard on the Project 09852 submarine, allegedly based on a Project 949A (Oscar II class) submarine.
  - The submarine is likely being modified to serve as a “mothership” to carry a smaller submarine.
  - Some sources speculated that the boat being built /modified is actually the incomplete Oscar II K-139, *Belgorod*.
- A speculative view of K-139 configured to carry a small submarine similar to AC-12 (AS-31) *Losharik* is shown above.

Russian other special subs

Project #	Class	# in Class	Length	Beam	Displacement (tons)	Reactor	Shaft hp	Max speed (kts)	Years delivered	Years in service
667AK	Akson-I Yankee Pod	1	Not known	Not known	Not known	OK-700: 2 x VM-4-2	34,500	Not known	1985	1983 - 1993
09780	Akson-2 Yankee Bignose	1	Not known	Not known	Not known	OK-700: 2 x VM-4-2	34,500	Not known	1995	1996 - 2009
651E	Nerka	1	90 m	10 m	3225 (surf) 4200 (sub)	VAU-6 hermitic ANPP	600 kWe (800 hp) from ANPP	18 kts	1985	1985 - 1990
20120	Sarov	1	72.6 m	9.9 m	2300 (surf) 3950 (sub)	VAU-6 hermitic ANPP	600 kWe (800 hp) from ANPP	17 kts	2008	2008 - present

Project 667AK Akson-1

Yankee-Pod

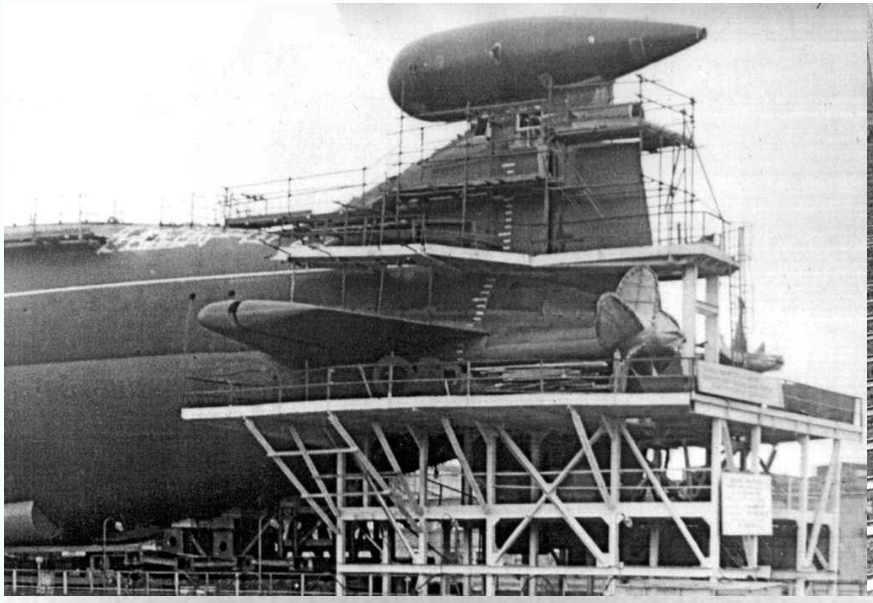


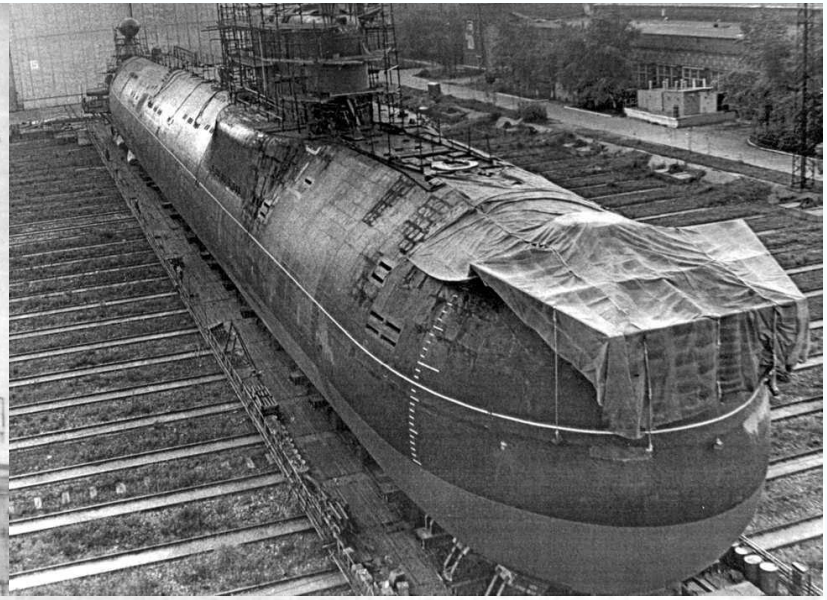
Source: http://www.okretywojenne.mil.pl/index.php?go=542

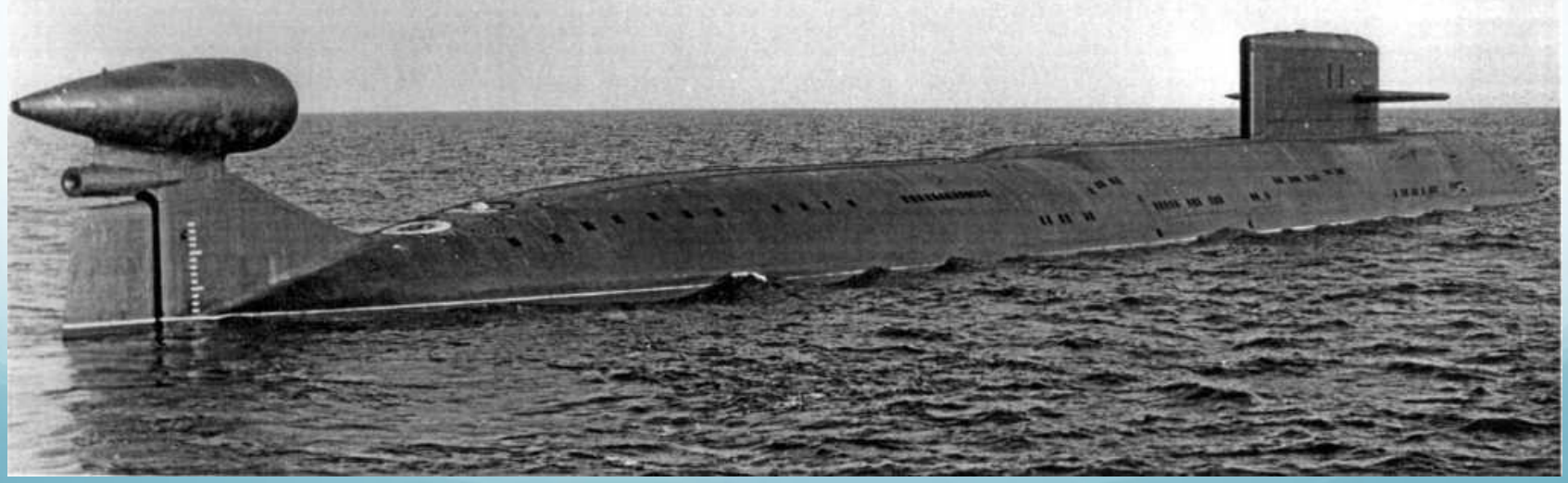
- Yankee Pod was a Yankee I conversion used for field trials of advanced sonar sensor and signal processing equipment.
- The conversion was designed by the Rubin Central Design Bureau for Marine Engineering
- In 1984, the prototype Pod towed array sonar was fitted at the stern, on top of the vertical fin, and associated sonar signal processing equipment was installed.
- Yankee Pod was refit in 1993 – 94 and emerged from the refit as Yankee Bignose.
- Propulsion, same as Yankee I:
  - OK-700: 2 x VM-4-2 PWRs, each rated @ 90 MWt
  - 4 x main turbines with a combined rating of about 34,500 shp; driving 2 x shafts

Project 667AK Akson-1

Yankee-Pod



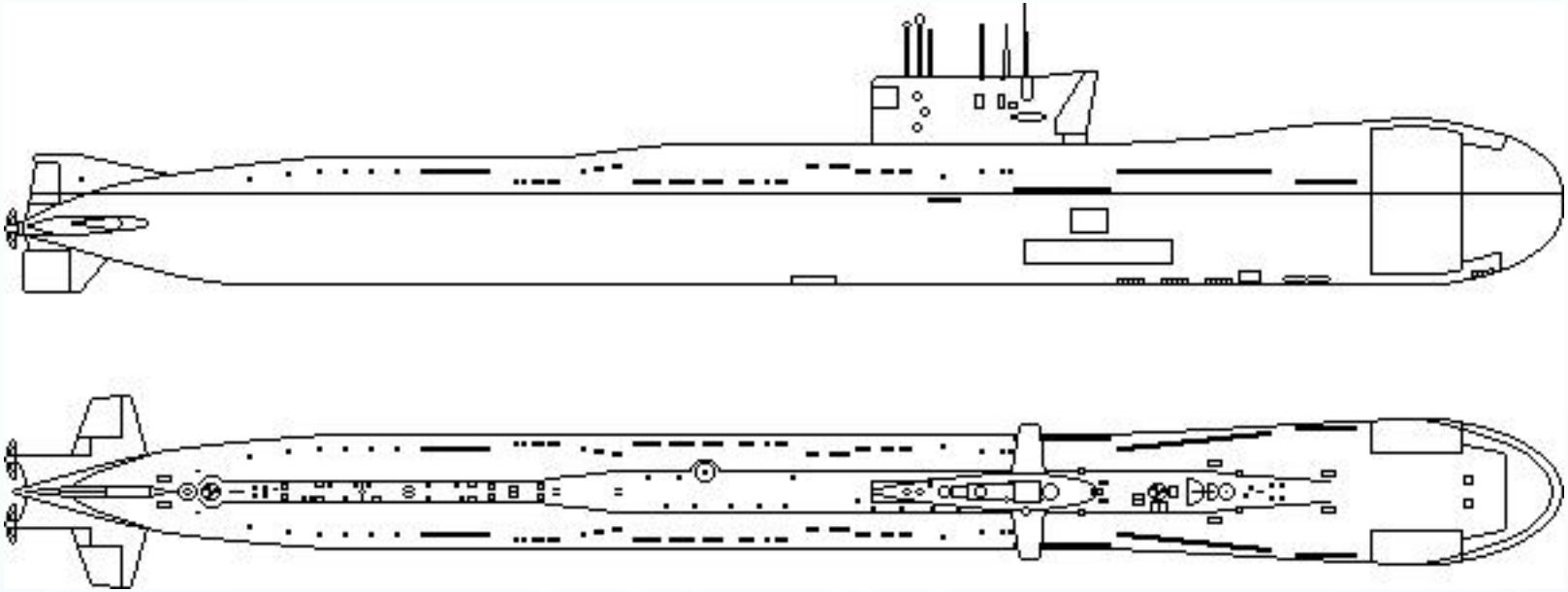




Source: http://www.shipmodels.info/

Project 09780 Akson-2

Yankee Bignose



Source: http://www.okretywojenne.mil.pl/index.php?go=542

- Yankee Bignose (KS-403) is the result of a 1993 - 94 conversion of the former Project 667AK Akson-1 Yankee Pod.
  - Refit design was the responsibility of Rubin Central Design Bureau for Marine Engineering.
  - Refit was completed in August 1995 and the boat was re-commissioned in 1996.
- Propulsion, same as Yankee I:
  - OK-700: 2 x VM-4-2 PWRs, each rated @ 90 MWt
  - 4 x main turbines with a combined rating of about 34,500 shp; driving 2 x shafts

Project 09780 Akson-2

Yankee Bignose

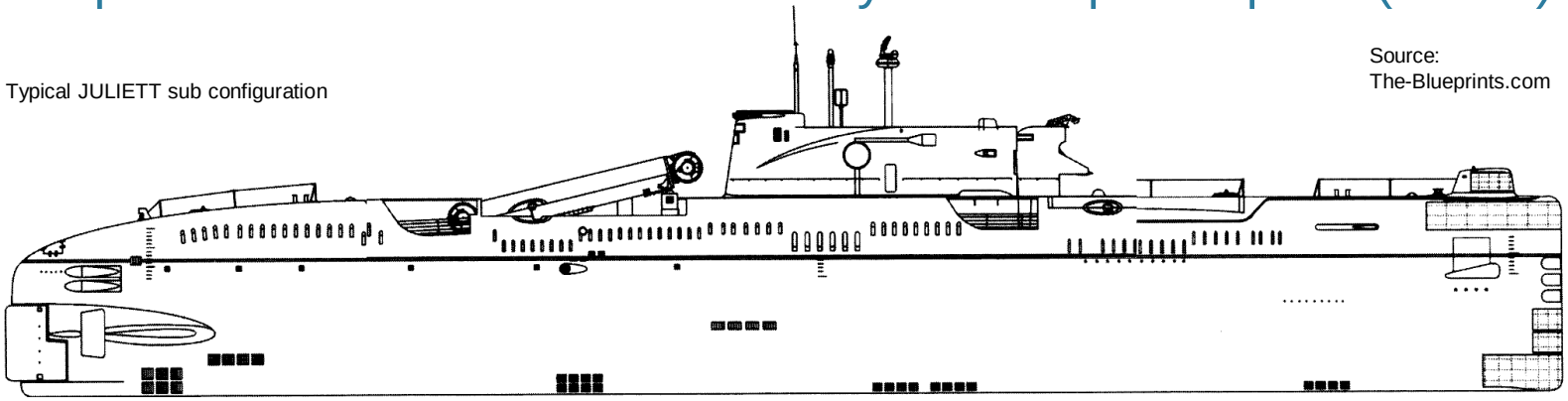
- Yankee Bignose tested the *Irtysh/Amfora* spherical sonar array, flank arrays, and associated sonar signal processing system originally intended for the Sierra III (Mars-B) project, five of which were under construction back in 1991 before all were scrapped.
- Now, the Yasen-class SSN is the first Russian submarine class to use this spherical sonar array instead of the cylindrical array historically used on most earlier Russian subs.
- Yankee Bignose sail appears similar to that on the Borei-class SSBN.

Source: www.shipmodels.info

Project 651E Nerka

Experimental sub B-68 with auxiliary nuclear power plant (ANPP)

Typical JULIETT sub configuration

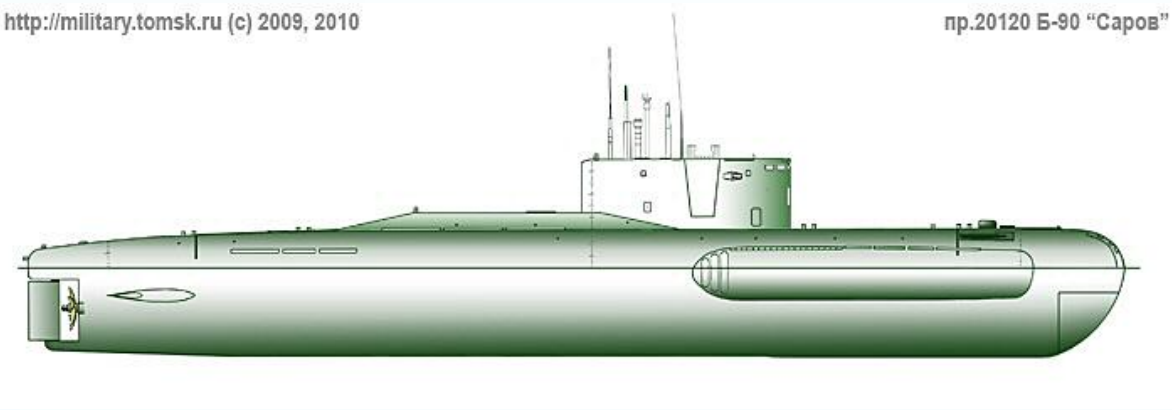


Source:
The-Blueprints.com

- B-68 sub, designed by Lazurite Central Design Bureau, was the former K-68 Project 651 Juliett-class diesel-electric sub that was modified in 1985 with the addition of a small auxiliary nuclear power plant (ANPP) installed under the aft compartment (compartment 8)
- Propulsion: Standard Juliett-class diesel-electric (2 x 3000 kW and 1 x 1300 kW diesel generators + 2 x 3000 hp propulsion motors and 2 x 500 hp “creeper” motors) supplemented by electric power generated by a NIKIET VAU-6 hermitic ANPP.
  - VAU-6 reactor type is unknown, but likely to be a single loop PWR + turbo-generator producing about 600 kWe
  - A prototype VAU-6 was built in 1971 and a second was built in 1986.
  - The continuous submerged range of B-68 increased from 350 miles at an economic speed of 2.8 knots using storage batteries alone to almost 7,000 miles at an economic speed of 4 knots using the ANPP.
- Armament: If standard Juliett armament was retained, then: 6 x 533 mm bow torpedo tubes for torpedoes, missiles and mines + 4 x 400 mm stern torpedo tubes + 4 x missile launchers recessed on the top deck, outside the pressure hull, for SS-N-3 or SS-N-12 cruise missiles. These cruise missiles are launched from the surface.

Project 20120 Sarov

Experimental sub B-90 with auxiliary nuclear power plant (ANPP)

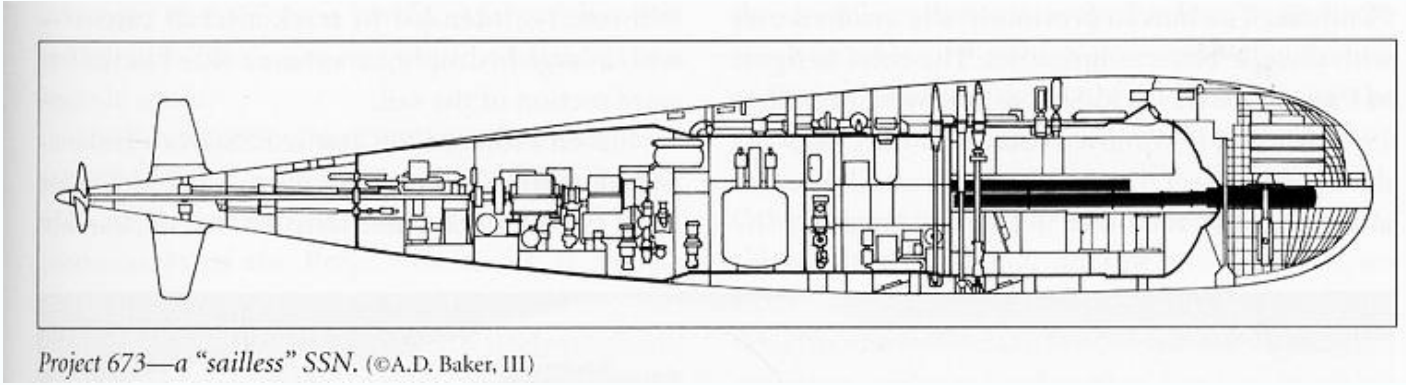


Source: www.hisutton.com

- Designed by Rubin, may be based on a Project 877 Kilo-class diesel-electric sub with the addition an ANPP.
  - Stated mission: test and develop new technologies and new weaponry.
- Propulsion: Assume standard Kilo-class diesel-electric (2 x 1000 kW diesel generators + 1 x 5,500 hp propulsion motor) supplemented by a NIKIET VAU-6 hermitic ANPP.
  - VAU-6 reactor type unknown, but likely to be a single loop PWR + turbo-generator producing about 600 kWe (800 shp)
  - Power generated by the reactor greatly extends the underwater endurance of the submarine and gives a diesel sub the capability to operate independently under the Arctic ice.
- Armament: Believed to be 2 x torpedo tubes + 1 x larger size launcher. Sizes not known

Unbuilt nuclear submarine projects

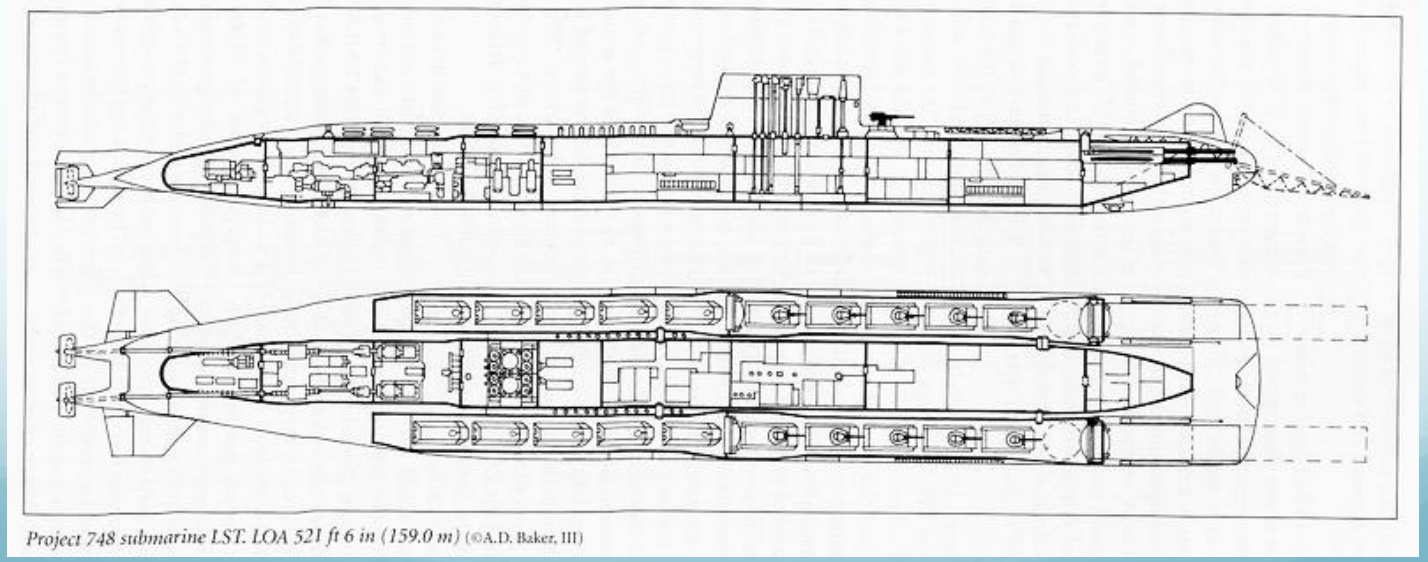
Sail-less SSN: Project 673 (circa 1960)



Project 673—a "sailless" SSN. (©A.D. Baker, III)

Note: These figures are from Polmar, Norman & Kenneth J. Moore; 2004; Cold War Submarine, The Design and Construction of U.S. and Soviet Submarines; Potomac Books, Inc.; Washington, D.C.; p. 161

Nuclear amphibious assault sub: Projects 664, 717 (circa 1970) & 748:

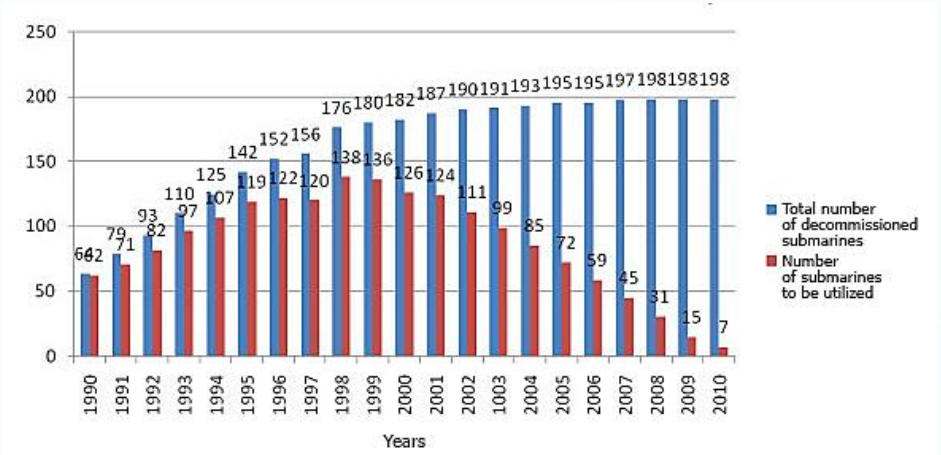


Project 748 submarine LST. LOA 521 ft 6 in (159.0 m) (©A.D. Baker, III)

Russian nuclear vessel decommissioning and environmental cleanup status

Russian decommissioned nuclear submarine status

- In June 2015, Sergei Kiryenko, head of Rosatom, reported that a total of 201 nuclear submarines have been retired, 195 have been dismantled, and 6 are in process.
  - Kiryenko noted that, “when (Rosatom) was put in charge of this function in 1999, 120 submarines were waiting for dismantlement”
- Dismantling takes place at the Nerpa Shipyard, in the Kola Peninsula, Zvyozdochka Shipyard in Severodvinsk, Sevmash Shipyard, in Severodvinsk (Alfa-class subs), and Zvezda Shipyard (Bolshoi Kamen) near Vladivostok.
- Spent nuclear fuel is transported by ship and railway to Mayak reprocessing facility near Chelyabinsk, in Siberia, for storage and reprocessing.
- The reactor section of each submarine is cut off and sealed.
- For Northern Fleet, reactor sections are transported for storage at the Regional Centre for Radioactive Waste Conditioning and Long Term Storage at Sayda Bay, near Murmansk.
- For Pacific Fleet, hull sections are placed in “afloat storage” near Chazhma Ship Repair Facility, Vladivostok, awaiting completion of the on-shore storage facility at Cape Ustrichny, near Vladivostok.

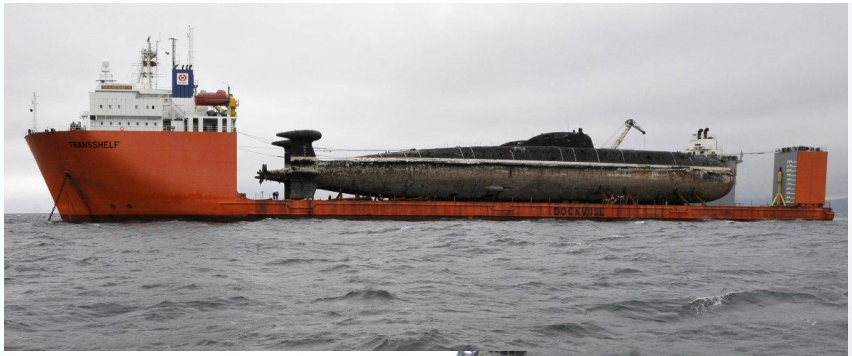


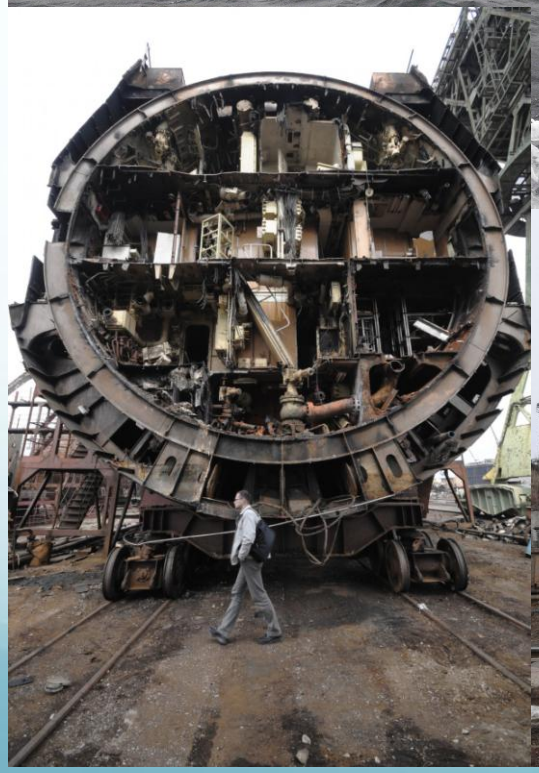
Sealed reactor compartments at Sayda Bay

Source: NIKIET

Source: Bellona Foundation

Decommissioning a Northern Fleet Victor III sub





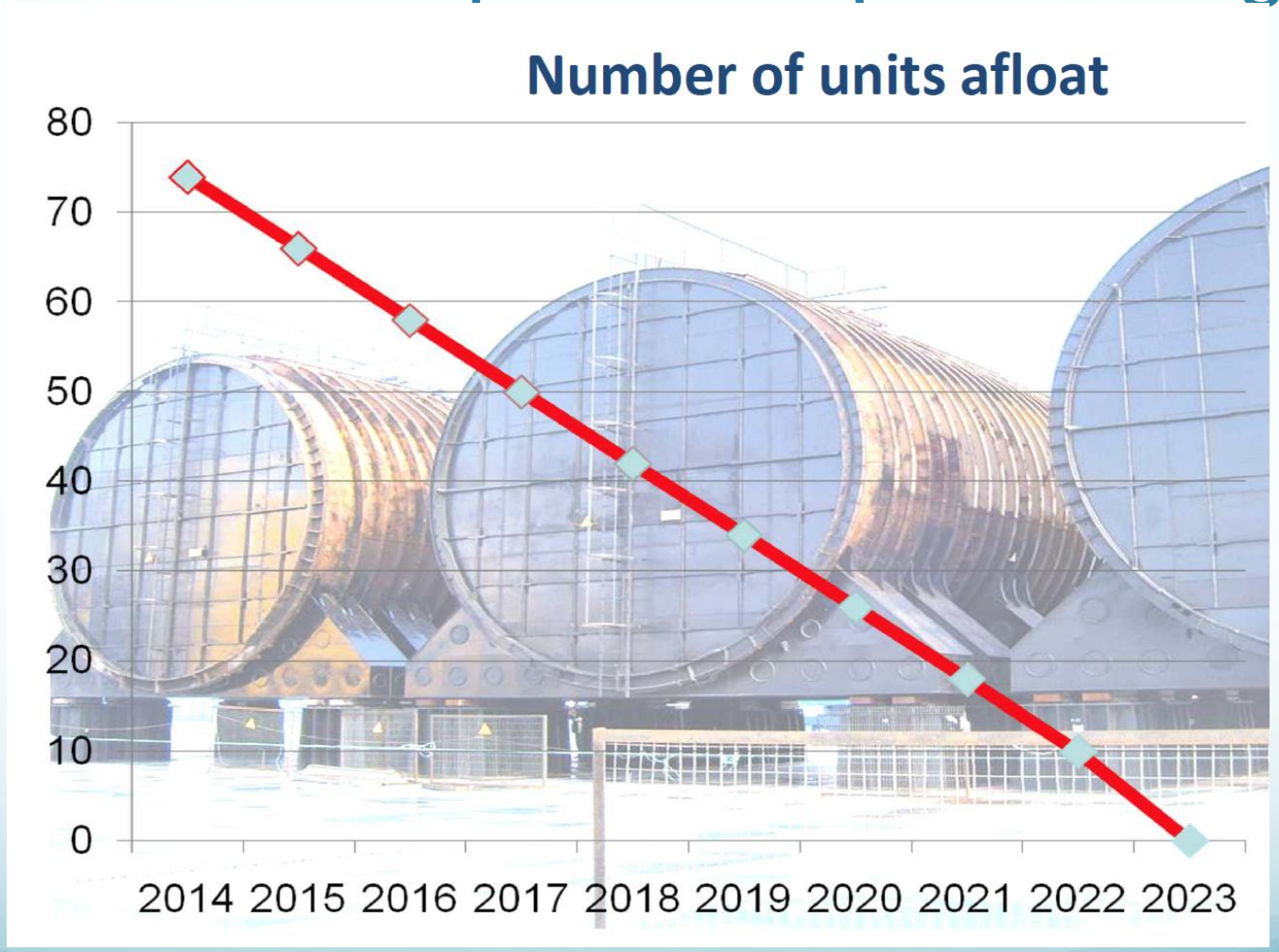
Source: Yuri Maltsev / Reuters

Afloat storage of Pacific Fleet submarine reactor compartments

For the Pacific Fleet reactor compartments are removed and sealed along with adjacent compartments that provide the necessary buoyancy for “afloat storage”. These multi-compartment packages are stored afloat in Razboynik Bay, awaiting completion of the Pacific Fleet on-shore storage facility at Cape Ustrichny.

Source: http://bellona.org/

Schedule for Pacific Fleet floating reactor compartment processing



Source: DalRAO: Plans for the Dismantling of Reactor Units of Nuclear Submarines, Nuclear Maintenance Vessels and Nuclear Powered Surface Ships

Isolation building for Pacific Fleet subs not suitable for afloat storage

In 2011-2012 the isolation facility for damaged nuclear submarines was built, and 2 three-compartment units of damaged submarines were placed there.

Source: DalRAO: Plans for the Dismantling of Reactor Units of Nuclear Submarines, Nuclear Maintenance Vessels and Nuclear Powered Surface Ships

Long-term storage facility for nuclear vessel reactor compartments

Cape Ustrichny

- This Pacific Fleet facility will be similar to the Northern Fleet's on-shore storage facility at Sayda Bay, near Murmansk.
- Russian-Japanese cooperation in nuclear vessel disposal is supporting completion of the on-shore facility.
  - May 2012: Japanese equipment for placing nuclear submarine reactor compartments on the long-term shore-based storage pad was handed over to FEC DalRAO.
    - The equipment includes a towboat, two gantry cranes of 10- and 32-ton capacity, and a floating dry dock.
  - Japan also funded a reactor compartment (RC) preparation and coating shop.
- The facility also will provide on-shore storage for the two reactor that will be removed by 2017 from the large naval surface ship SSV-33 *Ural*.

Russian nuclear service ship decommissioning & cleanup status

- In June 2015, Sergei Kiryenko, head Rosatom, said that the 16 remaining decommissioned nuclear service ships that served the Navy and the nuclear icebreaker fleet will be brought into drydock and dismantled by 2020.
  - Nuclear service ships, also called floating technical bases, perform refueling operations for nuclear vessels at sea, and carry away their spent nuclear fuel, contaminated items, and radioactive waste.
  - Some of these service vessels contain large inventories of spent nuclear fuel and/or radioactive waste and represent significant risk.
- Northern Fleet nuclear service ships are being processed at the Nerpa Shipyard, on the Kola Peninsula.
  - The first two ships are: *Volodarsky* (completed in 2014) and *Lepse* (started in mid-2015).
- Pacific Fleet nuclear service ships are being processed by Far Eastern Center "DalRAO" in Shipyard "Zvezda," near Vladivostok.
  - Nuclear service ship TNT-4 started the dismantling process in mid-2015.

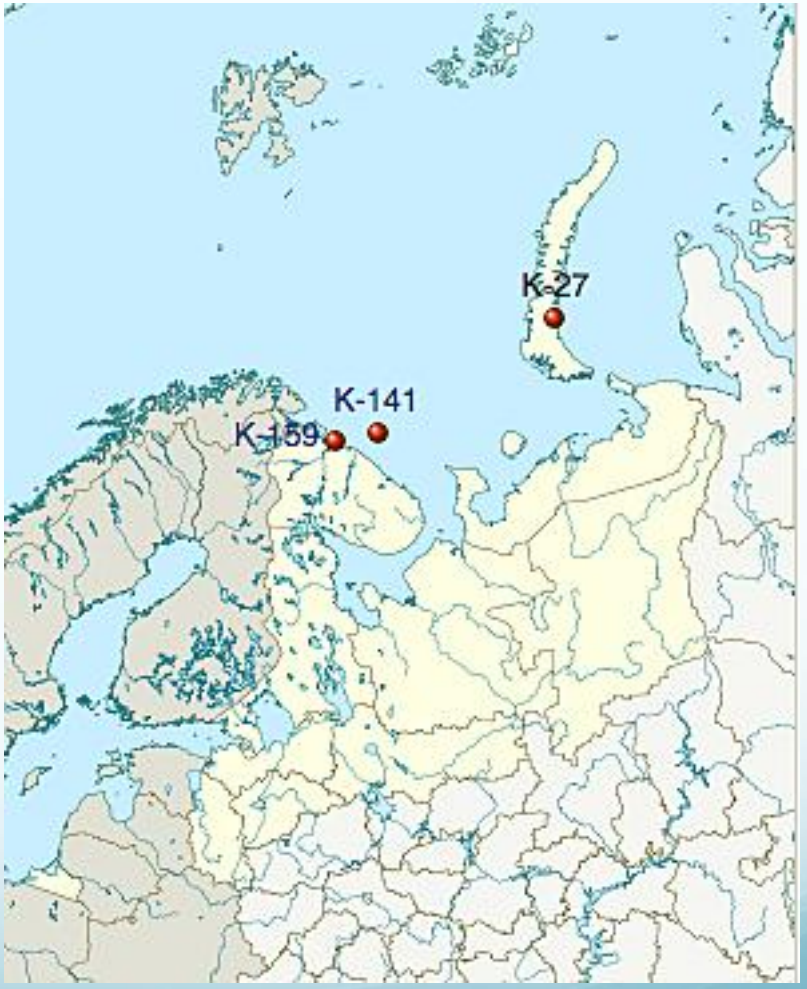
Source: http://bellona.org/

Source: http://balkanist.net/

Sunken nuclear submarines

Above:
Sunken nuclear submarines in the Atlantic

Map source: Wikipedia



Right:
Sunken nuclear submarines in the Arctic.

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

Sunken Russian nuclear submarines

- Kara Sea:
  - Sunken submarine K-27, at a depth of 33 m (108 ft)
    - Hull integrity judged to be good, but shallow site and inadequately sealed HEU liquid-metal cooled reactor cores make this the highest risk sunken sub site.
- Barents Sea:
  - Two sunken submarines; currently no indication of significant radioactive contamination of the ocean environment.
    - November-class K-159, at a depth of 248 m (814 ft)
      - Hull integrity was poor prior to sinking
    - Mike-class K-278, at a depth of 1,680 meters (5,510 ft)
      - Hull is cracked in several locations.
      - Sub carried two nuclear-armed torpedoes.
      - Site is in a high-marine traffic area
- Atlantic Ocean:
  - Two sunken Russian submarines in deep water; currently no indication of significant radioactive contamination of the ocean environment:
    - November-class K-8, Bay of Biscay, at a depth of 4,680 m (15,350 ft)
      - Sub carried four nuclear-armed torpedoes
    - Yankee-class K-219, mid-Atlantic, at a depth of 6,000 m (18,000 ft)
      - K-219's full complement of 16 nuclear-armed SS-N-6 ballistic missiles was lost along with the vessel. Some missiles were not accounted for in the wreckage.

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.

Other radioactive contamination from marine nuclear power operations

- Kara Sea (Arctic Ocean):
  - 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
    - Sunken submarine K-27
- Pacific Ocean
  - Two Russian naval nuclear reactors without fuel were dumped in the Sea of Japan off Vladivostok
  - Various naval marine nuclear system components (i.e., steam generators, pumps) were dumped off Kamchatka

Russia
marine nuclear power
current trends

Russia current trends

- Increasing tempo of new-build nuclear powered vessels:
  - Project 885 Yasen-M multi-purpose SSNs
    - On 26 July, the Russian Navy command announced that starting in 2011, one multi-purpose submarine would be laid down every year.
    - As of mid-2015, only the lead ship, *Severodvinsk*, is operational and four Yasen-M subs are under construction.
  - Project 955A Borei II SSBNs
    - As of mid-2015, three Project 955 Borei subs are operational and three Project 955A Borei II subs are under construction.
  - Project 2195.6 - Leader-class destroyer
    - Lead ship expected to enter service in the 2023 – 25 timeframe
  - LK-60-class “universal” icebreaker
    - The lead ship, *Arktika*, is scheduled for launch in Dec 2017.
    - Next two ships are scheduled to be completed in 2019 and 2020.
  - *Akademik Lomonosov* floating nuclear power station (PEB)
    - This PEB is scheduled to be completed in 2016 and deployed in 2017.
  - Project 09851, *Khabarovsk*, special operations submarine
    - A 2014 contract between shipyard Sevmash and the Rubin Design Bureau is reported to cover construction of the Project 09851 submarine.

Russia current trends

- Refurbishment / modifications:
  - Some Project 1144.2 Kirov (Orlan)-class guided missile cruisers
    - Only one CGN is in service (*Pyotr Veliky)*, one is being modernized for return to service in 2018 (*Admiral Nakhimov*), and two are in reserve storage and have not yet been funded for modernization (*Admiral Ushakov & Admiral Lazarev*).
      - The poor physical condition of *Admiral Ushakov & Admiral Lazarev* may preclude their modernization. The alternative is scrapping.
    - Plans have been proposed to convert these CGNs to carry SS-N-26 (P-800 Oniks) and SS-N-27 (Kalibr) cruise missiles.
  - Some Project 945 Sierra-class SSNs
    - Sierra-class subs are being refurbished under Project 945M. The two Sierra I subs are expected to be back in service in 2016. There are plans to also refurbish the two Sierra II subs.
    - Justified by the unique value of their titanium hulls and deep-diving capabilities.
  - Some Project 971 Akula-class SSNs
    - Update electronics and sonar systems, add ability to handle SS-N-27 (Kalibr) cruise missiles.
  - Some Project 949A Oscar-class SSGNs
    - Plans have been proposed to convert these SSGNs to carry non-nuclear SS-N-26 (P-800 Oniks) and SS-N-27 (Kalibr) cruise missiles.
  - Project 09787 PLA carrier (former Delta IV SSBN)
    - Expected completion in December 2015.
  - Project 09852 PLA carrier (former Oscar II SSGN)
    - Modification schedule not known.

Russia current trends

- Phase-out / replacement of aging vessels:
  - Some Project 671RTM Victor III SSNs, Project 971 Akula SSNs, and Project 649 / 649A Oscar SSGNs
    - To be replaced by the multi-purpose Yasen-M
  - Project 667 Delta III SSBN, and later Delta IV SSBNs
    - To be replaced by Borei / Borei II.
    - New R-29RMU2 Layner SLBM, introduced to the Delta IV fleet in 2014, is expected to ensure the viability of the Delta IV SSBNs until at least 2030
  - Arktika-class and Taimyr-class icebreakers
    - To be replaced by LK-60 icebreakers starting in 2017
- Operations:
  - Increased worldwide SSN & SSBN patrols after a significant decline of patrol activity during the past two decades
  - Increased use of specially-equipped nuclear submarines to support Arctic exploration, particularly to support Russian claims to an extended continental shelf in the Arctic Ocean
  - Increased commercial utilization of the Northern Sea Route
  - Increased use of floating nuclear power plants (PEBs) to support industrial development along the north coast and in the Arctic Ocean.

Russia current trends

- New marine reactor development:
  - OKBM Afrikantov RITM-200 for LK-60-class icebreakers & future PEBs
    - First deployment will be in the LK-60 lead ship, *Arktika*, in 2017
  - A 4th generation reactor is expected to be used in the Yasen-M submarines
  - World Nuclear Association claims that a Russian 5th generation naval reactor will be a supercritical water reactor (SCWR) with a single supercritical water/steam circuit that is expected to run 30 years without refueling.
    - Reactor designer not identified
    - WNO claims a full-scale prototype was being tested early in 2013
- New nuclear vessel development:
  - 5th generation multi-purpose nuclear submarine design & development is in progress
  - Project 2195.6 - Leader-class destroyer
    - In design stage. Lead ship expected no earlier than 2023-2025
  - Next-generation floating nuclear power plant (PEB) design & development in progress, using the RITM-200 reactor.

Russia current trends

- New weapons system development / deployment:
  - RSM-56 Bulava SLBM:
    - New class of strategic missile with independently targeted warheads capable of maneuvering during hypersonic flight enroute to the target.
    - First deployed on Borei-class SSBNs in 2014. Will not be used on Delta IV SSBNs.
  - Non-nuclear cruise missiles:
    - Plans have been made to convert the Oscar-class SSGNs and Kirov-class guided-missile cruisers from carrying large SS-N-19 cruise missiles to non-nuclear SS-N-26 (P-800 Oniks) and SS-N-27 (3M-54 Klub) cruise missiles
- Final disposition of retired nuclear vessels:
  - The existing program managers, SevRAO (Northern Fleet) and DalRAO (Pacific Fleet), will continue managing the disposition of retired naval vessels.
  - Japan continues to support Russian efforts to dismantle decommissioned Pacific Fleet nuclear vessels and nuclear support ships and provide equipment and funding for completion of the future Long-Term Storage Facility for nuclear vessel reactor compartments at Cape Ustrichny, near Vladivostok
  - After completion of the Pacific Fleet's future Long-Term Storage Facility, sealed reactor compartments currently in "afloat storage" will be moved to more secure storage sites on land.
  - Retired icebreaker *Arktika* likely will become a museum ship in St. Petersburg.
  - Russia's first nuclear-powered vessel, submarine K-3 likely will become a museum ship.

Russia current trends

- Cleanup of radioactive contamination from marine nuclear activities:
  - International pressure is mounting on Russia to deal with the radioactive contamination it created in the Arctic region from oceanic dumping of radioactive waste, reactor cores, and other radioactive items, and from three sunken nuclear submarines:
    - K-27, at a depth of 33 m (108 ft)
    - 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)
  - In addition, Japan continues to demand cleanup of Pacific Fleet radioactive waste and items dumped in the Sea of Japan.
- On-going infrequent monitoring of other Russian sunken nuclear submarines in deep-water sites; currently with no indication of significant radioactive contamination of the ocean environment:
  - November-class K-8, Bay of Biscay, at a depth of 4,680 m (15,350 ft)
  - Yankee-class K-219, mid-Atlantic, at a depth of 6,000 m (18,000 ft)
- Leases to other nations:
  - Negotiations for an additional Akula-class SSN lease to India have been concluded in early 2015, with the expected of the transfer of the former *Iribis* to the Indian Navy in 2018
  - In July 2015, Russia and India were reported to be in discussions regarding a lease of a current-production Yasen-class multi-purpose SSN.
- Technical support to other nations:
  - Likely support to India for continuing development of the reactor and submarine systems for their Arihant-class SSBN.