# Marine Nuclear Power: 1939 – 2018

## Part 3A: Russia

Peter Lobner
July 2018

# Foreword

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

In July 2018, I finished a complete update of the resource document and changed the title to, *"Marine Nuclear Power: 1939 – 2018."* What you have here is *Part 3A: Russia - Submarines*. The other parts are:

- *Part 1: Introduction*
- *Part 2A: United States - Submarines*
- *Part 2B: United States - Surface Ships*
- *Part 3B: Russia - Surface Ships & Non-propulsion Marine Nuclear Applications*
- *Part 4: Europe & Canada*
- *Part 5: China, India, Japan and Other Nations*
- *Part 6: Arctic Operations*

# Foreword

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

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

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

Best regards,

Peter Lobner
July 2018

# Marine Nuclear Power: 1939 – 2018
# Part 3A: Russia - Submarines

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# Marine Nuclear Power: 1939 – 2018

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# The beginning of the Soviet / Russian marine nuclear power program

# Timeline for the beginning of the Soviet / Russian marine nuclear power program

- **February 1943:** I. V. Kurchatov Institute of Atomic Energy (aka "Laboratory No. 2 of the USSR Academy of Sciences") was founded by Igor Kurchatov in Moscow
- **1945:** Work on nuclear propulsion began shortly after World War II. However, in 1945, Joseph Stalin's security chief, Lavrentiy Beria imposed a ban on the development of nuclear-powered ships, requiring instead that all resources be dedicated to development of the Soviet Union's atomic bomb and related nuclear infrastructure.
- **25 December 1946:** Russia's first nuclear reactor, F-1 (Physics-1), achieved initial criticality at the Kurchatov Institute. This natural uranium fueled, graphite-moderated reactor was similar in design to the Hanford 305 in the US
- **1947:** Noted Soviet submarine designer B. M. Malinin wrote, "A submarine must become an underwater boat in the full meaning of the word. This means that it must spend the grater and overwhelming time of its life underwater, appearing on the surface of the sea only in exceptional circumstances." While Malinin did not live to see the first Soviet nuclear submarine, one of his assistants, Vladimir Nikolayevich Peregudov, became the chief designer of the first Soviet nuclear submarine, K-3.
- **1948:** A. P. Alexandrov submitted a proposal to the Special Committee headed by Beria to start designing nuclear powered submarines. The proposal was declared untimely, because it distracted from creating the atomic bomb.
- **29 August 1949:** 1st Soviet nuclear device, RDS-1 (First Lightning), tested at Semipalatinsk, Kazakh SSR (now Kazakhstan).

# Timeline for the beginning of the Soviet / Russian marine nuclear power program

- **1951:** Construction started on the the APS-1 nuclear power plant (later named AM-1) at the Physics and Power Engineering Institute (PEI) in Obninsk.
- **August 1952:** A. P. Aleksandrov, I. V. Kurchatov, and N. A. Dollezhal submitted a memorandum to the Soviet government justifying the need to start developing nuclear submarines.
- **9 September 1952**: Stalin approved development of a nuclear submarine and signed a decree that appointed A. P. Alexandrov as the scientific supervisor for developing the USSR's first nuclear-powered submarine and its nuclear power unit.
- **September 1952:** Work on the Project 627 nuclear submarine began.
  - The original mission of the Project 627 submarine was to destroy American naval bases and other selected coastal targets using a single, large, nuclear-armed torpedo.
  - Tactical and technical elements of the design were approved in December 1953.
  - V. N. Peregudov was the chief designer for the nuclear power unit.
- **21 December 1952:** A resolution to develop and build nuclear submarines was adopted by the Supreme Soviet.
- **November 1953:** The Council of Ministers approved a project to build a powerful icebreaker that could open a northern sea route.
- **1954:** I. I. Afrikantov became the Chief Designer at Plant No. 92 (Gorky Machine Building Plant) Plant Design Bureau (OKB) and headed development of the OK-150 reactors for the first nuclear icebreaker, *Lenin*.

# Timeline for the beginning of the Soviet / Russian marine nuclear power program

- **5 May 1954:** Initial criticality of the world's 1st nuclear power plant, AM-1 (formerly APS-1), in Obninsk. Chief designer was N. A. Dollezhal. The AM-1 reactor design was based on a preliminary design developed by Dollezhal for use on a submarine, but rejected because of its large size.
- **27 June 1954:** AM-1 becomes the world's 1st grid-connected nuclear power plant, delivering 5 MWe to the electric power grid in Obninsk.
- **March 1955:** The original Project 627 mission was cancelled and the project was reoriented to develop a nuclear attack submarine that became the Project 627 / 627A November-class SSN.
- **June 1955:** Work on the 1st submarine land-based prototype reactor was underway.
- **25 August 1955:** The Soviet government decree approves the development of the R-13 ballistic missiles for strategic submarines
- **16 September 1955**: 1st Soviet launch of a ballistic missile from a submarine on the surface. The Project V-611 Zulu IV prototype SSB launched an R-11FM.
- **August 1957:** The Soviet Union's 1st nuclear-powered submarine, K-3, was launched.
  - The VM-A PWR reactor was designed by Scientific Research and Design Institute NIKIET, Moscow. A.P. Alexandrov was the Project research manager and N.A. Dollezhal was chief designer of nuclear power plant.
  - The submarine was designed by SKB-143, St. Petersburg (now Malakhit Central Design Bureau). V. N. Peregudov was the submarine chief designer.
  - K-3 was built by Soviet Shipyard - 402 Molotivsk (now SEVMASH Shipyard), Severodvinsk.

# Timeline for the beginning of the Soviet / Russian marine nuclear power program

- **5 December 1957:** The world's 1st nuclear-powered surface ship, the icebreaker *Lenin*, was launched.
  - OK-150 PWR reactor designed by Nizhny Novgorod Machine-Building Plant (OKB), Nizhniy Novgorod [later Special Design Bureau for Mechanical Engineering (OKBM) Afrikantov].
  - Built by Baltic Sea Shipyard (*Soviet Shipyard-189),* St. Petersburg.
- **4 July 1958:** 1st Soviet nuclear-powered submarine, Project 627 SSN K-3, *Leninskiy Komsomol*, was underway on nuclear power.
- **12 March 1959:** SSN K-3*, Leninskiy Komsomol, was* commissioned.
- **15 September 1959:** 1st voyage of the icebreaker *Lenin*, the world's first nuclear-powered surface ship*.*
- **11 October 1959:** 1st Soviet SSBN, Hotel I K-19, launched.
- **November 1959**: Initial Arctic under-ice voyage by SSN K-3.
- **12 May 1960:** 1st Soviet nuclear submarine launched in a Russian Far East shipyard: Echo I-class SSGN K-45 launched at Shipyard No. 199 in Komsomolsk-on-Amur.
- **20 October 1961:** 1st nuclear test involving an armed SLBM launched from a submerged submarine. In the test named *Raduga (Rainbow)*, a Golf-class SSB in the Barents Sea launched an R-13 SLBM at a target in the Novaya Zemlya nuclear test range.
- **17 July 1962**: K-3, under command of Captain III Rank Lev Zhiltsov, reached the North Pole and surfaced nearby.
- **February 1965:** 1st reactor accident on *Lenin*. One reactor core was severely damaged. It was removed and replaced.

# Igor Vasilyevich Kurchatov


Source, 2 images: Wikimedia Commons


- Born: January 1903; died February 1960
- Engaged in nuclear physics research at the Ioffe Institute in Moscow.
- Founded the I. V. Kurchatov Institute of Atomic Energy in 1943 with the initial purpose of developing nuclear weapons. Served as Director until his death in 1960.
- Kurchatov lead the teams responsible for several important nuclear milestones:
  - 25 December 1946: USSR's F-1 reactor initial criticality (1st reactor outside the US).
  - 29 August 1949: USSR's 1st nuclear device, *First Lightning* (aka RDS-1, *Joe 1*, 1st nuclear test other than by the US).
  - 27 June 1954: World's 1st nuclear power plant, AM-1, commissioned in Obninsk.
- From 1950 – 1957, he was a strong advocate for development of the USSR's nuclear-powered fleet.
- Awarded Hero of Socialist Labor three times and Orders of Lenin five times.

# Anatoly Petrovich Aleksandrov


Source, above: Wikimedia Commons

Source: http://www.niti.ru/

- Born: February 1903; died February 1994.
- Engaged in nuclear physics research at the Ioffe Institute in Moscow.
- In 1942, he was assigned to the Soviet Union's program to develop an atom bomb.
- In September 1952, Stalin appointed A. P. Aleksandrov as the scientific supervisor for developing the USSR's first nuclear-powered submarine and its nuclear power unit.
- Under his supervision, three generations of nuclear submarines and surface ships were developed, including :
  - K-3, November & Victor-class SSNs
  - Echo & Charlie-class SSGNs
  - Hotel, Yankee & Delta SSBNs
  - Lenin & Artika-class icebreakers
- A. P. Aleksandrov served as the Director of the Kurchatov Institute from 1960 to 1989.
- He was one of the most highly decorated nuclear scientists: Awarded Hero of Socialist Labor three times and Orders of Lenin nine times, Order of the October Revolution, and more.

# Nikolay Antonovich Dollezhal

Source: https://alchetron.com/Nikolay-Dollezhal

- Born: October 1988; died: November 2000
- Developed the natural uranium fueled, graphite-moderated reactors that produced the plutonium for the first Soviet nuclear test in 1949.
- After 1950, Dollezhal focused on nuclear marine propulsion. His first proposal, Type AM (a graphite moderated, channel type reactor design), was not practical for marine use because of its size. However, this core design was used in the USSR's first (and the world's first) nuclear power plant, AM-1, which was built in Obninsk between 1951 - 1954.
- In 1954, he produced a viable design of a light water cooled and moderated submarine pressurized water reactor (PWR).
  - He was the Chief Designer for several naval marine PWRs, including the first naval submarine reactor, VM-A, which used on the November-class SSNs, Hotel-class SSBNs and Echo-class SSGNs.
- He also designed the VVER PWR power reactors built by OKB Gidropress.
- In 1957, Dollezhal Institute introduced the dual-use (civilian energy and weapons-grade plutonium production) RBMK power plant. Seven years later, the first truly industrial-scale RBMK power plant, Beloyarsk unit 1, was commissioned.
- Highly decorated nuclear scientist: awarded Hero of Socialist Labor twice, Orders of Lenin six times, Order of the October Revolution, and more.

# Igor Ivanovich Afrikantov

Source: http://www.okbm.nnov.ru/

- At Plant No. 92 (Gorky Machine Building Plant, now, the Nizhny Novgorod Machine-Building Plant), Afrikantov served as the head of the Workshop Department, moving up to be the Chief Designer of the Plant Design Bureau (OKB).
- 1946 – 1951: Afrikantov took an active part in OKB's role in designing and launching production of gaseous diffusion machines for producing enriched uranium.
- He was Chief Designer (since 1959) and Director (1954 - 1969).
- From 1954, Afrikantov, as the Chief Designer, headed development of the reactors for the first nuclear icebreaker *Lenin*. For this work, he was honored with the title of the Hero of Socialist Labor, and the OKB was given the highest governmental award, the Order of Lenin.
- From 1 January 1964, the OKB became independent under his initiative, and was realigned under the USSR State Committee for Atomic Energy Application, and in 1967 the company has been named "OKBM" (OKB Mechanical Engineering).
- Later, Afrikantov headed the development of OK-900 modular PWR, which, in several variations, became the "workhorse" for the Russian icebreaker fleet and the naval surface and submarine fleets. He also developed the OK-550 liquid metal reactor (LMR) for the Alfa-class SSN as well as the land-based BN-350 and BN-600 liquid metal fast reactors.
- In 1985, the company was awarded the Order of the October Revolution for services in the field of nuclear technology development.
- In 2000 OKBM was re-named: "OAO I. I. Afrikantov OKB Mechanical Engineering."
- In 2004 the company was designated as a State research and production center.

# Russian current nuclear vessel fleet

As of mid-2018

# Russia’s current nuclear vessel fleet

## As of mid-2018

- The Russian nuclear fleet is comprised of 53 vessels.
- The Russian Navy operates a mixed fleet of conventional and nuclear submarines. The nuclear submarine fleet is comprised of 46 subs in the following classes:
  - SSNs: 18 total
    - 3 x Project 671RTM/RTMK Victor III SSNs (B-138, B-414 & B-448)
    - 4 x Project 945 Sierra I (B-239 & B-276) & Project 945A Sierra II (B-336 & B-534) SSNs
    - 10 x Project 971 Akula SSNs
    - 1 x Project 885 Yasen multi-purpose SSN (K-560)
  - SSBNs: 11 total
    - 1 x Project 667BRD Delta III SSBNs (K-44, *Ryazan*) returned to the fleet in 2017 after a major overhaul. It is armed with the R-29RKU-02 / RSM-50 SLBM and operates with the Pacific Fleet (Kamchatka).
    - 6 x Project 667BRDM Delta IV SSBNs (K-18, K-51, K-84, K-114, K-117 & K-403) SSBNs armed with the R-29RMU2 Sineva or newer R-29RMU2.1 Lainer SLBM all operate with the Northern Fleet (Kola Peninsula).
    - 1 x Project 941 Typhoon (TK-208, *Dimitry Donskoy).* Modified to test the RSM-56 Bulava, but current use and armament is unknown.
    - 3 x Project 995 Borei SSBNs (K-535, K-550 & K-551) SSBNs are armed with the RSM-56 Bulava SLBM. One is assigned to the Northern Fleet; two are assigned to the Pacific Fleet.
    - 0 x Project 995A improved Borei. Commissioning the 1$^{st}$ unit, *Kynaz Vladimir (Prince Vladimir)*, was expected in 2018, but now appears to have slipped into 2019.

Sources include: http://www.navalanalyses.com/2018/04/infographics-30-russian-navy-submarines.html

# Russia’s current nuclear vessel fleet

## As of mid-2018

- Submarines (continued)
  - SSGNs: 8 total
    - 8 x Project 949A Oscar II SSGNs, three in the Northern Fleet and five in the Pacific Fleet.
  - Special mission submarines: 9 total
    - 6 x small, deep-diving, special operations nuclear submarines in three classes:
      - 1 x Project 1851 Nelma / X-Ray: AS-23
      - 2 x Project 18511 Halibut / Paltus-class: AS-21 & AS-35
      - 2 x Project 1910 Kashalot / Uniform-class: AS-13 & AS-15
      - 1 x Project 10831 Losharik: AS-12
    - 1 x Project 20120 special operations sub, B-90 *Sarov*, with a conventional power plant and a small auxiliary nuclear power plant (ANPP).
    - 1 x Project 09786 Delta III special operations “mothership” BS-136 *Orenburg II* (converted from former SSBN K-129)
    - 1 x Project 09787 Delta IV special operations “mothership” BS-64 *Podmoskovye* (converted from former SSBN K-64)
- The Russian Navy operates a single nuclear-powered surface combatant.
  - 1 x Project 1144.2 Orlan (Kirov)-class guided missile cruiser (CGN), *Pyotr Velikiy*
- ROSATOMFLOT operates the Russian nuclear icebreaker fleet comprised of five ships in three classes: 5 total
  - 2 x Project 10520 Arktika-class deep-water icebreakers, *Yamal* & *50 let Pobedy*
  - 2 x Project 10580 Taymyr-class shallow-water icebreakers: *Taymyr* & Vaygach
  - 1 x Project 10081 *Sevmorput* ice-breaking cargo vessel

Sources include: http://www.navalanalyses.com/2018/04/infographics-30-russian-navy-submarines.html

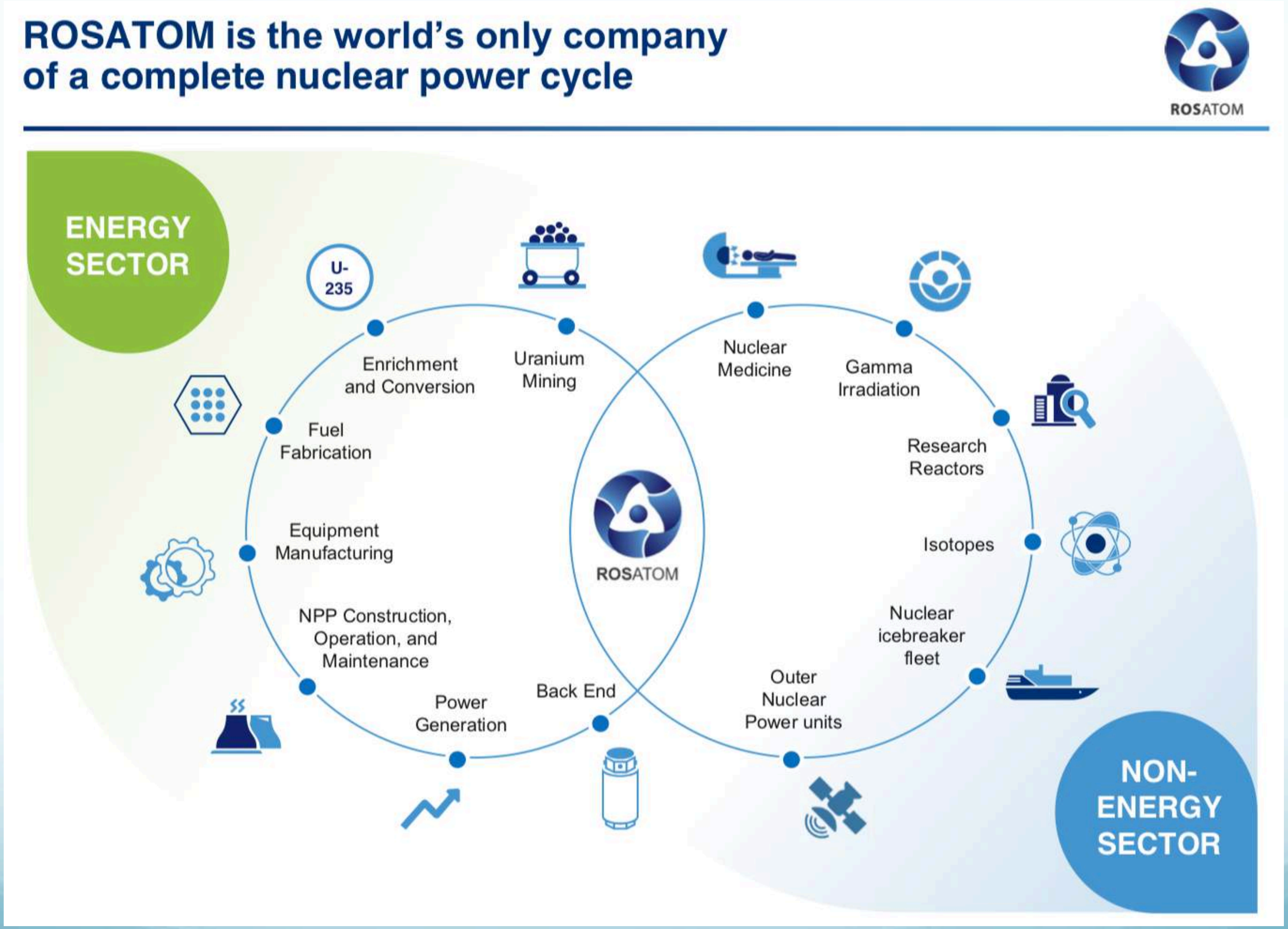
# Russian marine nuclear reactor & fuel cycle infrastructure

# Rosatom

- ROSATOM (aka State Energy Corporation Rosatom) was formed in 2007, with the mission to maintain national interests in defense, nuclear safety and nuclear power by achieving global leadership in advanced technologies, competencies and innovations.
- ROSATOM Group includes Russia's entire marine and energy sector nuclear fuel cycles:
  - Mechanical engineering division: Atomenergomash
  - Marine reactor design bureaus:
    - OKBM Afrikantov, NIKIET (Dollezhal Research and Development Institute of Power Engineering), and OKB Gidropress
  - Nuclear icebreaker fleet operator:
    - ROSATOMFLOT
  - Marine nuclear fuel manufacturing:
    - TVEL Fuel Company (uranium enrichment & conversion, non-military fuel)
    - Machine Building Plant (Elektrostal / Elemash) (naval fuel)
  - Marine nuclear waste management & naval vessel decommissioning
    - RosRAO - Moscow
    - SevRAO - Murmansk, Kola region
    - DalRAO - Vladivostok, Far East region
  - Marine spent fuel reprocessing:
    - Mayak Production Association, Ozersk (near Chelyabinsk)
  - ROSATOM Emergency Service, St. Petersburg

Logo sources: respective web home pages

# Rosatom




Source: Rosatom

# Four marine reactor design bureaus

- Special Design Bureau for Mechanical Engineering (OKBM) Afrikantov, Nizhniy Novgorod
  - Developed all Soviet / Russian surface ship reactors:
    - OK-150 (PWR): *Lenin* icebreaker (original reactors)
    - OK-900 / 900A (PWR): *Lenin* (replacement reactors), Arktika-class icebreakers, SSV-33 *Ural*
    - KN-3 (PWR), Orlan (Kirov)-class guided missile cruisers
    - KLT-40 / 40M / 40S (PWR): *Sevmorput* icebreaking cargo ship, Taymyr-class icebreakers, *Akademik Lomonosov* floating nuclear power plant (FNPP)
    - RITM-200 / 200M (PWR): LK-60Ya-class "universal" icebreakers, future FNPP
  - Developed many later-generation Soviet / Russian submarine reactors:
    - OK-550 (LMR): 2$^{rd}$-generation Project 705 Alfa subs
    - OK-650 (PWR): 3$^{rd}$-generation Mike, Oscar, Typhoon, Sierra and Akula subs, and 4$^{th}$-generation Borei & Yasen subs
  - Developed many small reactors for special applications:
    - Small PWR for *Losharik* special operations sub
    - ABV-6E (small PWR): Future transportable reactor unit (TRU), seabed-sited power module
    - VBER-300 (PWR): Future FNPP
    - Aisberg (small PWR): Seabed-sited power module
    - Autonomous HTGR: Seabed-sited power module

# Four marine reactor design bureaus

- N.A. Dollezhal Scientific Research and Design Institute of Energy Technologies (NIKIET), Moscow
  - Developed many earlier-generation Soviet / Russian submarine reactors:
    - VM-A (PWR): 1st-generation Hotel, Echo & November (HEN) subs
    - VM-4 (PWR): 2nd-generation Victor, Charlie, Yankee & Delta subs
    - VM-5 (PWR): 3rd-generation one-of-a-kind Papa sub
  - Developed many small reactors for special applications:
    - Small PWRs for Nelma / X-ray, Halibut / Paltus-class and possibly the Kashalot / Uniform-class special operations subs
    - VAU-6 Auxiliary Nuclear Power Plant (ANPP): *Sarov* special operations sub
    - SHELF (small PWR): Seabed-sited power module
- Experimental and Design Organization (EDO), OKB Gidropress, Moscow
  - Developed heavy liquid metal (lead-bismuth) cooled marine reactors:
    - VT-1 (LMR): 1st-generation November ZhMT sub
    - BM-40A (LMR): 2nd-generation Project 705K Alfa subs
    - SVBR-75/100 and SVBR-10 (LMR): Future TRU, future FNPP
- I. V. Kurchatov Institute of Atomic Energy, Moscow
  - Developing the ELENA small PWR with direct energy conversion

# OKBM Afrikantov

## Marine reactors for civil and naval application

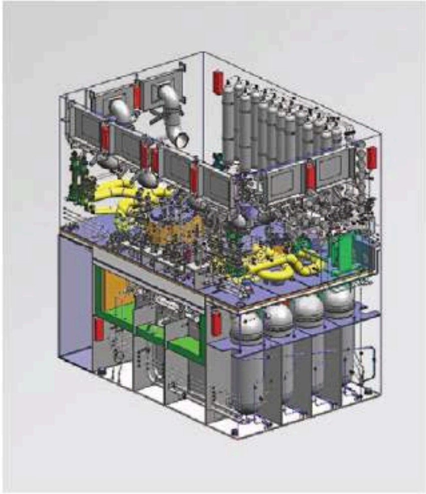
- OKBM Afrikantov traces its origins in the early 1950s to the Gorky Machine Building Plant, now, the Nizhny Novgorod Machine-Building Plant.
  - From 1954, I. I. Afrikantov, as the Chief Designer, headed development of the OK-150 loop-type PWRs for Russia's first nuclear icebreaker, *Lenin*, which also became the world's first nuclear powered surface ship.
- On 1 January 1964, the OKB became independent and was realigned under the USSR State Committee for Atomic Energy Application. Since 1967 the company has been named "OKBM" (OKB Mechanical Engineering) Afrikantov.
- OKBM Afrikantov is the major supplier of modern Russian marine and naval reactors:
  - All icebreaker reactors and all naval surface ship reactors
  - Almost all reactors for 3$^{rd}$-generation and 4$^{th}$-generation submarines
- OKBM Afrikantov operates two highly-enriched uranium (HEU) critical facilities:
  - ST-659 "cold" critical facility, since 1963
  - ST-1125 "hot" critical facility, since 1975. Capable of temperature to 325 °C (617 °F) and pressure to 17.6 MPa (2,553 psig).

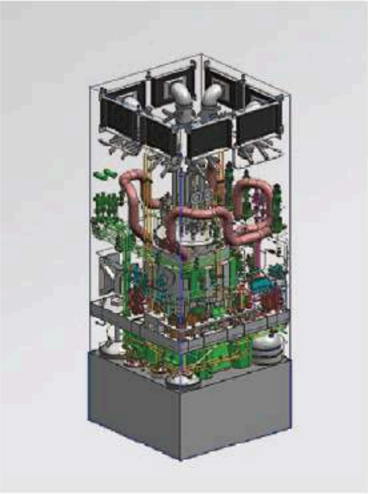
# OKBM Afrikantov

## Marine reactors for icebreakers and floating nuclear power plants (FNPP)

**Four generations of ship-based RPs**

1. OK-150 — 90 MWt — Loop RP
2. OK-900 (OK-900A) — 159 - 171 MWt — RP with the modularly arranged SGU
3. KLT-40 (KLT-40M, KLT-40S) — 135 - 171 MWt — RP with the modularly arranged SGU
4. RITM-200 — 175 - 209 MWt — RP with the integrally arranged SGU





Modular arrangement

Integrally arranged SGU

Source: OKBM Afrikantov

# Commonality among Afrikantov icebreaker and naval PWRs

- On the basis of Soviet Government Decree No. 546-177, "*Plans for Development of Nuclear Science and Technology Until 1990*," dated 17 June 1977, the Ministry of Medium-Machine Building and the Ministry of the Maritime Fleet issued joint order No. SR 588-80 on 20 March 1980. This joint order stipulated that all new reactor core designs intended for nuclear submarines should be tested aboard icebreakers.
- A 1983 CIA report* concluded that: "There is essentially one reactor design, although power levels may vary; this is the OK-900, which is the 'workhorse' of the Soviet Navy." The OK-900 is a modular PWR designed and built by OKBM Afrikantov.
  - The OK-900 was first deployed in 1970 as the replacement set of reactors installed on the icebreaker Lenin (after removal of the original OK-150 reactors).
  - Two improved OK-900A reactors were installed on each of the Arktika-class polar icebreakers, which entered service starting in 1975.
  - The OK-900A evolved into the very similar KLT-40 series of modular PWRs, versions of which was installed on the *Sevmorput* icebreaking cargo ship (KLT-40 entered service in 1988), Taymyr-class shallow water icebreakers (KLT-40M entered service in 1989), and the *Akademik Lomonosov* floating nuclear power plant (KLT-40S expected to enter service in 2019 - 2020).
  - The Orlan (Kirov)-class guided missile cruisers have a two-reactor nuclear plant designated KN-3, which uses an OK-900A variant capable of operating at significantly higher power.
  - The Titan (SSV-33) command ship had a two-reactor nuclear plant that has been confirmed to be very similar to the OK-900A on the Arktika-class polar icebreakers.
  - The submarine reactor designated OK-650 and used on almost all Russian 3rd-generation nuclear submarines, is believed to be a variant of the OK-900A modular PWR with support systems rearranged and modified to fit within the submarine hull.

* Source: CIA Intelligence Information Special Report, "Design and Performance of Soviet Naval Reactors," 11 January 1983, declassified and approved for release 16 June 2017.

# Evolution of the OK-900 and its relationship to naval reactors

### OK-900
- IOC 1970
- 159 MWt
- *Lenin* icebreaker (2nd set of reactors)

### OK-900A
- IOC 1975
- 171 MWt
- Arktika-class icebreakers

### KLT-40
- IOC 1988
- 135 MWt
- *Sevmorput* icebreaking cargo ship

### KLT-40M
- IOC 1989
- 171 MWt
- Taymyr-class icebreakers

### KLT-40S
- IOC 2019 - 2020
- 150 MWt
- *Akademik Lomonosov* floating nuclear plant

Icebreaker reactors

Naval reactors

IOC = Initial operating capability

### KN-3
- IOC 1980
- 300 MWt (est)
- Orlan (Kirov)-class guided missile cruisers

### OK-900A variant
- IOC 1989
- 171 MWt
- SSV-33 *Ural* command ship

### OK-650
- IOC 1981
- 190 MWt
- Most 3rd-gen subs: Typhoon, Oscar, Sierra, Mike, Akula

### OK-650V
- IOC 2012 - 2013
- 190 MWt
- Initial 4th-gen Yasen & Borei-class subs

* Based on numerous sources, including: CIA Intelligence Information Special Report, “Design and Performance of Soviet Naval Reactors,” 11 January 1983, declassified and approved for release 16 June 2017.

# OKBM Afrikantov

## Marine reactors for naval application

- OK-550 LMR, liquid metal cooled reactor, rated @ 155 MWt
  - Employed on four Project 705 Alfa SSNs, as an alternate to the Gidropress BM-40A LMR.
  - All Alfa-class subs were decommissioned between 1990 – 1996.
- OK-650 modular PWR, rated @ 190 – 200 MWt, is believed to be similar to the OK-900A, repackaged to fit in a submarine.
  - Widely used in 3rd-generation Russian submarines:
    - SSNs: Project 945 Sierra, Project 971 Akula, Project 685 Mike, and Project 885 Yasen
    - SSBNs: Project 941 Typhoon and Project 955 Borei SSBNs
    - SSGNs: Project 949 Oscar SSGNs
- KN-3 modular PWR surface ship propulsion plant
  - 2 x PWRs, each with a VM-14-5/03 reactor core rated at about 300 MWt, in a Combined Nuclear and Steam (CONAS) propulsion plant. The VM-14-5/03 is believed to be an OK-900A variant with longer fuel elements.
  - 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 (aka Phoenix KTP-7I)
  - OKBM Afrikantov has been attributed as the designer of a small PWR used on the *Losharik* special operations sub. With propulsion power for *Losharik* cited at about 10,000 shaft horsepower, reactor power of about 50 MWt would be required.

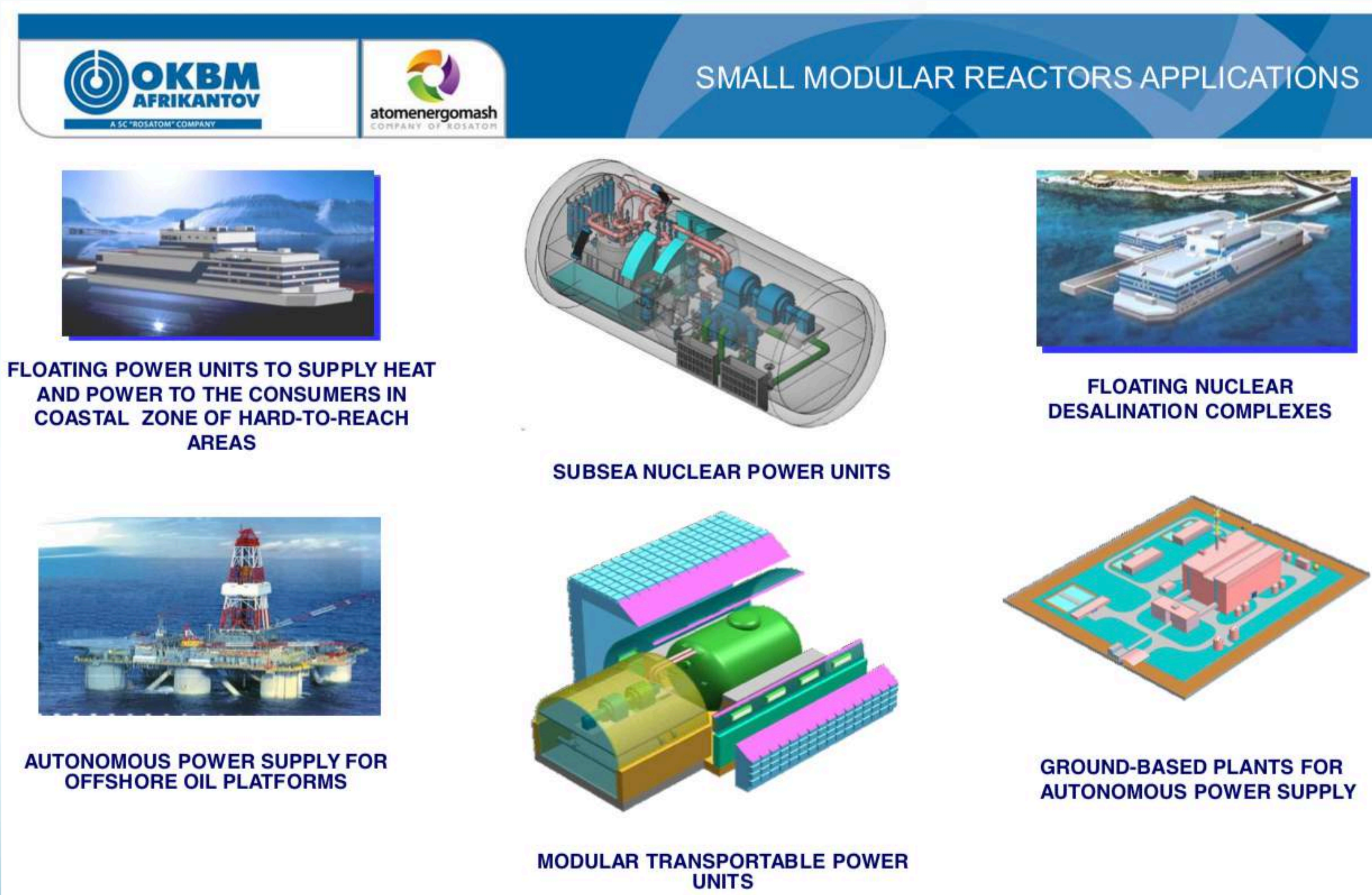
# OKBM Afrikantov
## Liquid metal reactor experience


Source: adapted from Afrikantov, http://www.okbm.nnov.ru/english/npp

- Initial operation of the first Project 705 Alfa-class sub with a lead-bismuth cooled Afrikantov OK-550 LMR was in 1976. This places OK-550 naval reactor development between the BN-350 (1973) and the BN-600 (1980) land-based, sodium-cooled LMRs.
- OKBM Afrikantov reported: "A fundamental decision was made in the design of BN-600 reactor related to transition from primary circuit looped layout to integrated layout where the entire equipment of the primary circuit is arranged in the reactor vessel. This allowed enhancing the reactor safety and operation reliability."
- The OK-550 is believed to have had an integral primary system.

# OKBM Afrikantov

## Marine reactors for non-propulsion applications




Source: OKBM Afrikantov & Atomenergomash presentation at the OECD/NEA Workshop on Innovations in Water-cooled Reactor Technologies, Issy-les-Moulineaux, France, 11 – 12 February 2015

# NIKIET

## Marine reactors for naval applications

- The N.A. Dollezhal Scientific Research and Design Institute of Energy Technologies (also known as NIKIET) was founded in Moscow in 1952 by Academician Nikolay Antonovich Dollezhal.
- Since the early 1950s, NIKIET has been one of leading organizations responsible for developing and manufacturing nuclear steam supply systems (NSSS) for Russian submarines, as well as operating and repairing these systems.
  - NIKIET also designed the RBMK-series of early Soviet-era power reactors.
- N. A. Dollezhal was the Chief Designer of the VM-A loop-type 70 MWt PWR NSSS used in the 1st Russian nuclear submarine, the November-class K-3 SSN.
  - Also used on 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 developed the VM-5 compact 177 MWt PWR NSSS.
  - Used in the one-of-a-kind Project 661 Papa SSGN, which was the fastest Russian sub.

# 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 Nelma / X-Ray and Project 18511 Halibut / Paltus
  - Project 1910 Kashalot / Uniform
- NIKIET designed the VAU-6, a small, "hermitic" auxiliary nuclear power plant (ANPP) that can serve as an auxiliary electric power source for diesel-electric submarines.
  - Used on Juliett-class diesel-electric sub B-68, *Nerka*; delivered 600 kWe (net). This would require a reactor with a gross power level of about 2 MWt.
  - ANPP likely used on modern diesel-electric sub B-90, *Sarov.*
- NIKIET continues to design reactors for land and marine applications and conduct research on reactor materials and reactor physics.
  - The SHELF PWR is designed for autonomous operation in remote locations, and can be used in seabed site in the Arctic.
- Today, NIKIET is the chief contractor in the areas of nuclear and radiation safety for disposal of nuclear submarines and surface vessels retired from the Russian Navy, and environmental rehabilitation of former nuclear facilities, including the current cleanup of the former naval nuclear maintenance base at Andreyeva Bay (near Murmansk) with SevRAO.

# OKB Gidropress

## Experimental & Design Organization (EDO) Gidropress

- Designer and builder of liquid metal (lead-bismuth) cooled reactors (LMR) for naval applications:
  - 27/VT LMR submarine prototype reactor
    - Lead-bismuth cooled fast reactor, prototype of the VT-1 LMR
    - This submarine prototype LMR was constructed at I.I. Leypunsky Institute of Physics and Power Engineering (IPPE), Obninsk
  - VT-1 LMR
    - This was the first Russian LMR employed on an operational sub; the Project 645 K-27 SSN.
    - K-27 entered service in 1963. After several years of successful service, K-27 experienced a reactor accident at sea on 24 May 1968.
    - Summer 1982: K-27 and its two fueled VT-1 reactors were intentionally scuttled in the Kara Sea
  - BM-40A LMR
    - Employed on three Project 705K Alpha SSNs, as an alternate to the OKBM Afrikantov OK-550.
    - First Alfa sub with a BM-40A entered service in 1978. All Alfa-class subs were decommissioned between 1990 – 1996, the last one being K-123, which operated with a BM-40A reactor.
- LMRs currently are not used in Russian naval vessels, but a new LMR prototype is planned at the A.P. Aleksandrov Scientific Research Technological Institute (NITI).

# OKB Gidropress

## Experimental & Design Organization (EDO) Gidropress

- Gidropress currently is developing civil reactor applications of submarine "heavy" (lead-bismuth) LMR technology:
  - LMR technology developed on the BM-40A has been leveraged by Gidropress in the development of the lead-bismuth-cooled SVBR-75/100 and the smaller SVBR-10, both of which have land-based and marine applications. "SVBR" is the Russian acronym for "lead-bismuth fast reactor."
  - Potential marine SVBR applications include:
    - Transportable Reactor Unit (TRU)
      - A TRU is a nuclear steam supply system (NSSS) module that can be transported by barge and delivered to a powerplant site on the shore of a navigable body of water, installed as a unit to complete the powerplant, replaced with another TRU after many years of operation, and removed at the end of the powerplant life cycle.
      - Example applications include coastal power generation, co-generation with process heat, and/or water desalination facility
      - Both the SVBR-75/100 and the SVBR-10 are candidates for use in a TRU.
    - Floating Nuclear Power Plant (FNPP)
      - The smaller SVBR-10 is a candidate for use in a floating nuclear power plant, likely in a smaller package than the first Russian floating nuclear power plant, *Akademik Lomonosov*, which uses 2 x KLT-40S PWRs.
  - No SVBRs have been built.

# Other nuclear technical support organizations

- I.I. Leypunsky Institute of Physics and Power Engineering (IPPE), Obninsk
  - IPPE provides liquid metal reactor (LMR) design support for OKB Gidropress & OKBM Afrikantov
  - Russia's first LMR naval prototype reactor was built at IPPE, the 27/VT.
  - 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), Sosnovy Bor
  - Established in 1962 as a subsidiary of the Kurchatov Institute, NITI has operated independently since 1979.
  - Responsible for designing, testing, and supporting nuclear power and naval propulsion reactors as well as their systems and parts.
  - NITI has operated three full-scale naval reactor prototypes / training facilities: the KM-1 LMR prototype and the KV-1 and KV-2 PWR prototypes. Only KV-1 is operational.
  - NITI also develops and produces simulators and modeling systems for training naval reactor operators.

# Marine nuclear fuel cycle facilities

- Uranium enrichment:
  - Russia produces enriched uranium at four facilities:
    - Urals Electrochemical Combine in Novouralsk (Sverdlovsk-44)
    - Isotope Separation Plant at the Siberian Chemical Combine in Seversk (Tomsk-7)
    - Electrochemical Plant (EKhZ) in Zelenogorsk (Krasnoyarsk-45)
    - Angarsk Electrochemical Combine (aka Angarsk Electrolytic Chemical Combine, AEKhK), in Angarsk, Irkutsk Oblast
  - The IPFM (International Panel on Fissile Materials) reported in February 2018 that all four of these facilities were operational, producing LEU for power reactor; with one centrifuge cascade in the Zelenogorsk Electrochemical Plant producing HEU. IPFM stated that Russia restarted HEU production in 2012, after temporarily ending HEU production in the mid-2000s.
- Marine reactor fuel manufacturing:
  - TVEL Fuel Company, Moscow
    - Produces 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.
  - Elektrostal Machine-Building Plant, [aka Public Joint Stock Company "Mashinostroitelny Zavod" (PJSC MSZ) and ELEMASH], Elektrostal
    - One of the leading global manufacturers and suppliers of nuclear fuel for nuclear power plants, with more than 50 years of experience in manufacturing fuel rods and fuel assemblies. Affiliated with TVEL Fuel Company.
    - PJSC MSZ manufactures research and marine reactor fuel and produces all naval reactor fuel.
    - Also manufactures special containers for nuclear fuel transportation as well as special handling equipment.

Logo sources: respective web home pages

# Marine nuclear fuel cycle facilities

- Spent fuel reprocessing:
  - Mayak Production Association, Ozersk, Chelyabinsk Region (Siberia), is operational
    - Naval and icebreaker spent nuclear fuel is transported by rail to Mayak for storage / reprocessing.
    - The RT-1 reprocessing plant at Mayak can reprocess spent fuel of power reactors as well as HEU fuel from production reactors and fuel from naval and research reactors.
  - IPFM reported that the reprocessing plants in Seversk (Tomsk-7) and Zheleznogorsk (Krasnoyarsk-45) were shut down in 2010 and 2012 respectively.

ПРОИЗВОДСТВЕННОЕ ОБЪЕДИНЕНИЕ МАЯК

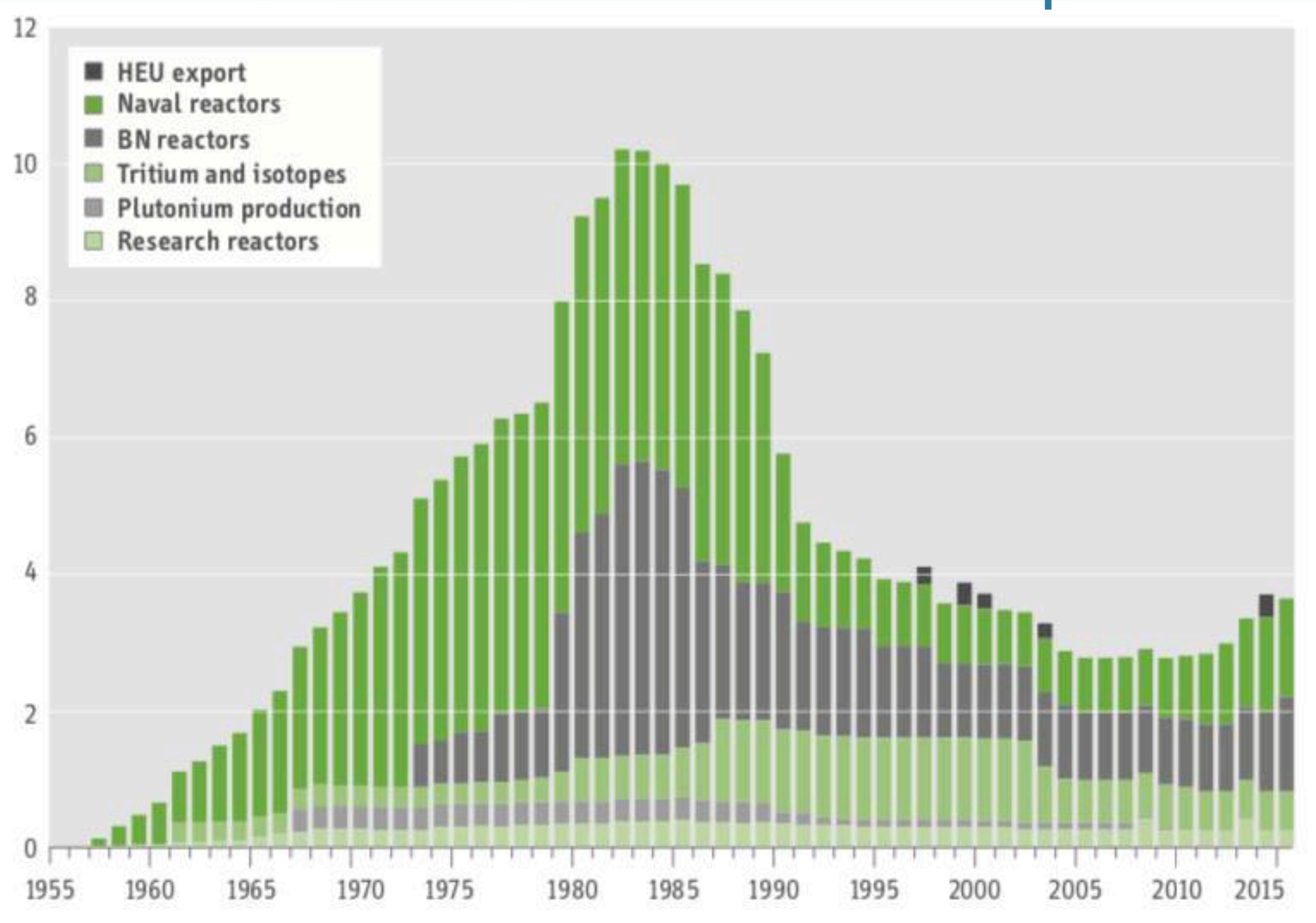
Logo sources: respective web home pages

# Russia’s HEU inventory

- All of the marine reactors operating in Russian vessels today use highly-enriched uranium (HEU, > 20% U-235) fuel with initial fuel enrichments typically in the range from 30 – 45%. This is very different than in the US, where all naval reactors use HEU fuel enriched to 93 – 97% U-235.
- Two new Russian marine reactors from OKBM Afrikantov are expected to begin operation in 2018 or 2019 using low-enriched uranium (LEU, ≤ 20% U-235) fuel. These are the KLT-40S PWRs on the floating nuclear power plant *Akademik Lomonosov*, and the RITM-200 PWRs on the lead ship *Arktika*, in the new LK-60Ya class of “universal” icebreakers.
- The their February 2018 status update *, the IPFM (International Panel on Fissile Materials) summarized Russia’s HEU inventory as follows:
  - As of the end of 2016, Russia had an estimated 679 tons of HEU. Of this amount, about 650 tons was military material. Unlike the US, there is no HEU stockpile that is declared or obligated as a naval fuel reserve or non-military uses.
    - Russia has an additional estimated 20 tons of HEU (8 tons, 90% HEU equivalent) in the cores of operational submarines and military and civilian surface ships.
    - The material in discharged naval cores is not included in the current stock since the enrichment of uranium in these cores is believed to be less than 20 percent uranium-235, so it is no longer classified as HEU.
    - There is another 9 tons of HEU (6 tons, 90% HEU equivalent) in various research facilities, which is considered civilian use.
    - In Russia, stored spent naval fuel, as well as stored spent research reactor fuel, is reprocessed.
  - Under an agreement with the US, Russia eliminated 500 tonnes (500,000 kg) of its HEU. The material was blended down and the resulting LEU was sold to the US to produce fuel for power reactors. The program was completed in 2013. Another program, the Material Conversion and Consolidation (MCC) project, has blended down 16.8 tonnes (16,800 kg) of HEU by the end of 2014, when the program ended.

* Source: http://fissilematerials.org/countries/russia.html

# Russia's HEU consumption




Estimated amount of highly-enriched uranium (in tons/year 90% HEU equivalent) consumed by various programs.
Source: Figure 1.1 from "The Use of Highly-Enriched Uranium as Fuel in Russia," Research Report No. 16, International Panel on Fissile Materials, 2017, https://wws.princeton.edu/system/files/research/documents/HEU.pdf

# Russian nuclear vessel design, construction & life-cycle infrastructure

# United Shipbuilding Corporation

- USC has consolidated most of the Russian domestic shipbuilding industry and currently includes about 40 shipbuilding companies and organizations, including main shipbuilding and ship repair yards and leading marine design bureaus.
- USC includes the following organizations that are responsible for Russian nuclear vessels:
  - Nuclear submarine design bureaus: Rubin & Malachite
  - Nuclear naval surface ship design bureaus: Severnoye & Nevskoe
  - Nuclear icebreaker design bureaus: Iceberg OJSC & Vympel
  - Nuclear-capable shipyards: Sevmash, Baltic Sea Shipyard, Admiralty Shipyard, Krasnoye Sormovo Shipyard, Amur Shipbuilding Plant & Zvezdochka Shipyard
  - Shipbuilding research & development: Onega

Logo sources: respective web home pages

# Submarine design bureaus

- Malachite (Malakhit) Central Design Bureau (previously SKB-143, merged with SKB-193 and SKB-16), St. Petersburg
  - Project 627A November-class SSN (SKB-143)
  - Project 645 November ZhMT-class (one-of-a-kind) SSN (SKB-143)
  - Project 1710 Beluga (one-of-a-kind, diesel-electric, experimental teardrop-shaped hull)
  - Project 671 Victor-class SSN (SKB-143 )
  - Project 705 & 705K Alfa-class SSN (SKB-143)
  - Project 661 Papa-class (one-of-a-kind) SSN (OKB-16)
  - Project 971 Akula-class SSN
  - Project 885 Yasen-class multi-role SSN
- Lazurite Central Design Bureau (previously STB-122), Nizhniy Novgorod
  - Project 651E “Nerka” Juliett-class (one-of-a-kind) SSG with auxiliary nuclear power plant (ANPP)
  - Project 670 Charlie-class SSGN
  - Project 945 Sierra-class SSN
  - Project 1855 Priz-class deep-submergence rescue vehicle (non-nuclear)
  - Arctic nuclear submarine drillship concept

Logo sources: respective web home pages

# Submarine design bureaus

- Rubin Central Design Bureau for Marine Engineering (previously SKB-18), St. Petersburg
  - Project 658 Hotel-class SSBN
  - Projects 659 & 675 Echo-class SSGN
  - Project 667 Yankee and Delta-class SSBN
  - Project 667AT (Grusza) Yankee Notch SSGN
  - Project 667M (Andromeda) Yankee Sidecar SSGN
  - Project 667AK Akson-1 Yankee Pod (sonar test platform)
  - Project 09780 Akson-2 Yankee Bignose (sonar test platform)
  - Project 949 Oscar-class SSGN
  - Project 685 Mike-class SSN
  - Project 941 Typhoon-class SSBN
  - Project 955 Borei-class SSBN
  - Project 20120 Sarov special operations sub with auxiliary nuclear power plant (ANPP)
  - Project 09851 Khabarovsk special operations sub
  - Harpsichord-1P and -2P autonomous underwater vehicles (non-nuclear)
  - Status-6 nuclear-powered, nuclear-armed strategic torpedo

Logo sources: respective web home pages

# Nuclear naval surface ship design bureaus

- Severnoye Design Bureau, St. Petersburg
  - Leading company designing surface ships in Russia; founded in 1946.
  - Project 1144.2 Orlan (Kirov-Class) nuclear guided missile cruiser
  - Project 2195.6 (or 23560) – Lider (Leader)-class nuclear multi-purpose destroyer
- Nevskoe Design Bureau, St. Petersburg
  - A leading planning and design bureau of shipbuilding industry in Russia
  - Responsible for designing and producing documentation for building, operational service, refitting and modernizing the largest warships, including aircraft carriers.
- State Unitary Enterprise “Krylov Shipbuilding Research Institute,” St. Petersburg
  - Responsibilities cover the full scope of ship qualities including seaworthiness, strength, powering, acoustics, electromagnetic signatures, nuclear & radiation safety and definition of ship concepts meeting these requirements.
  - Also developing advanced composite materials intended for use in ship and submarine construction in the 2020s.
  - Project 23000E (Shtorm) aircraft carrier concept.

Logo sources: respective web home pages

# Nuclear icebreaker design and operation

- Nuclear icebreaker design bureaus
  - 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
  - “Vympel” Joint-stock company design office for shipbuilding, Nizhny Novgorod
    - Specialized in design of ships and floating facilities, including ice-breakers, other Arctic vessels and floating facilities for Arctic shelf development
    - Also designs nuclear maintenance ships
- Nuclear Icebreaker Operating Organization
  - ROSATOMFLOT (Atomflot), St. Petersburg
    - Operator of all Project 10520 Arktika-class and Project 10580 Taymyr-class icebreakers and the Project 10081 *Sevmorput* LASH (lighter aboard ship) carrier and container ship
    - Will be the operator for future nuclear icebreakers currently being built or planned.
      - Project 22220 LK-60-class “universal” icebreakers; initial operating capability (IOC) in 2019.
      - Project 10510 LK-110Ya heavy polar icebreakers, with IOC not likely before 2025.
      - Project 10570 multi-function offshore icebreakers, with IOC not likely before 2025.

ROSATOM FLOT

Logo sources: respective web home pages

# Nuclear shipyards

- Production Association Sevmash, Severodvinsk (abbreviation of *Severnoye Mashinostroitelnoye Predpriyatie*, "Northern Machine-Building Enterprise"; previously named Soviet Shipyard-402)
  - Largest shipbuilding enterprise in Russia, and currently the only shipyard producing new nuclear submarines
  - 38 x 1st-gen nuclear-powered subs (November, Hotel & Echo II classes & Project 645 November ZhMT)
  - 63 x 2nd-gen nuclear-powered subs (Yankee, Delta, Papa, Project 705K Alfa)
  - 27 x 3rd-gen nuclear-powered subs (Oscar, Typhoon, Mike, Akula)
  - 6 x 4th-gen nuclear-powered subs (Borei, Yasen)
  - Project 09852: Converting KC-139 *Belgorod* (former Oscar II SSGN K-139 )
- Baltic Sea Shipyard (previously named Soviet Shipyard-189), St. Petersburg
  - Project 92M – *Lenin* nuclear icebreaker
  - Project 10520 Arktika & Project 10580 Taymyr-class nuclear icebreakers
  - Project 1144.2 Orlan (Kirov)-class nuclear guided missile cruisers
  - Project 1941 *Ural* nuclear command ship
  - Project 22220 LK-60-class nuclear icebreakers
  - Project 20870 floating nuclear power plant (FNPP) *Akademik Lomonozov*

Logo sources: respective web home pages

# Nuclear shipyards (cont'd)

- Admiralty Shipyard (previously named Soviet Shipyard-194), St. Petersburg (Sudomekh, Shipyard No. 196, merged with Admiralty in 1972)
  - From 1973 to 1998, built 298 submarines, including:
    - 41 x 2nd-gen nuclear submarines (Victor I, II, III & Project 705 Alfa SSNs)
    - Naval special operations submersibles: Lima, Uniform, X-ray, Beluga & Paltus classes
- Amur Shipbuilding Plant (previously named Leninskiy Komsomol Shipyard and Soviet Shipyard-199), Komsomolsk-on-Amur (Far East)
  - 18 x 1st-gen nuclear submarines (Echo I & II class SSGNs)
  - Nuclear submarine overhauls (Akula SSNs, Oscar II SSGNs)
- Krasnoye Sormovo Shipyard (previously named Factory-112), Nizhny Novgorod
  - Over 75 years more than three hundred submarines and rescue vehicles (25 of them are nuclear) have been built and modernized, including:
    - 17 x 2nd-gen nuclear submarines (Charlie I & II classes)
    - Special operations submersibles

Logo sources: respective web home pages

# Nuclear shipyards (cont'd)

- Ship Repair Center "*Zvezdochka*," Severodvinsk, Arkhangelsk region
  - Zvezdochka is Russia's largest ship repair facility, managing production subsidiaries in the Barents, White, Black, Caspian Seas, and the Sea of Azov.
    - Repair, retrofitting, and modernization of submarines and surface ships, including those powered by nuclear propulsion plants
    - Complete marine equipment recycling, including nuclear-powered ships
  - Converted and modernized Delta III and Delta IV subs to serve as "motherships" for small special operations submarines:
    - Project 09786: BS-136 "Orenburg II" (former Delta III SSBN K-129)
    - Project 09787: BS-64 *Podmoskovye* (former Delta IV SSBN K-64)
- Shipyard "*Nerpa*" (previously Navy Yard 85), Murmansk region, Snezhnogorsk
  - A branch of Ship Repair Center Zvezdochka specializing on repair, modernization, dismantling of nuclear-powered submarines, surface ships and vessels, shipbuilding and large-size offshore objects building.
    - This is the main shipyard for repair and maintenance of nuclear subs of the Northern Fleet.
    - From 1994 to 2009, dismantled 40 nuclear submarines
    - Will dismantle all of Atomflot's retired nuclear icebreakers

Logo sources: respective web home pages

# Nuclear shipyards (cont'd)

- Far Eastern Shipbuilding and Ship Repair Center (FESRC, JSC)
  - Part of the Rosneft Oil Company PJSC Group; comprises the key ship repair and ship construction businesses inside the Far Eastern Federal District. Key roles are:
    - Managing FESRC-controlled companies that repair, retrofit, and maintain the Pacific Fleet surface ships and submarines or build commercial ships
    - Coordinating the operation and expansion of the Zvezda Shipbuilding Complex
- Zvezda Shipbuilding Complex, Far East, Bolshoi Kamen (Part of FESRC)
  - Services and modernizes nuclear-powered submarines.
  - Capacity expansion works of the yard are being executed without interrupting operations of the existing yard. Construction works started in 2012 and are expected to be completed by 2019.
  - Upon completion, the Zvezda Shipbuilding Complex will be the biggest shipbuilding complex in Russia, fitted to build all types of naval and merchant ships, up to 350,000 ton tankers.
- Northeast Repair Center "Vilyuchinsk", Far East, near Petropavlovsk (Part of FESRC)
  - The company specializes in repairs and disposal of the Russian Navy's weapons and equipment in the Russian North East. The shipyard performs repairs of nuclear-powered and diesel-electric submarines, surface ships and support vessels
  - Also recycles retired nuclear-powered submarines.

Logo sources: respective web home pages

# Nuclear shipyards (cont'd)

- Black Sea Shipyard (aka *Nikolayev South Shipyard* or *Soviet Shipyard No. 444),* Mykolaiv, Ukraine
  - Project 1143.7 Ulyanovsk-class aircraft carrier. 1st unit of the class was laid down in late 1988. Project cancelled, hull salvaged.
  - Since the breakup of the Soviet Union, and until the Zvezda Shipbuilding Complex expansion is completed in 2019, Russia has not had its own shipyard capable of building a vessel as large as the the Project 1143.7 aircraft carrier.

УКРОБОРОНПРОМ
Державний концерн

Logo sources: respective web home pages

# Nuclear ship decommissioning organizations & facilities

- Management of nuclear vessel decommissioning and storage and nuclear site cleanup:
  - Russian Federal State Unitary Enterprise Radioactive Waste Management Enterprise, RosRAO (Moscow)
  - Northern Federal Enterprise for Radioactive Waste Management, SevRAO, (Gremikha, Murmansk Region)
  - Far Eastern Center, DalRAO (Vladivostok Far East region)
- Ship Dismantling:
  - Zvezdochka Shipyard, Severodvinsk
  - Nerpa Shipyard, Kola Peninsula,
  - Sevmash Shipyard, Severodvinsk (Alfa-class subs)
  - Zvezda Shipyard (Bolshoi Kamen), near Vladivostok
- Technical support organizations:
  - Research and Development Technological Bureau "Onega," Severodvinsk, Archangelsk Region (part of USC)
    - Provides engineering and design support for decommissioning of civil and naval atomic energy utilization facilities.

# Nuclear ship decommissioning organizations & facilities

- 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

# Other nuclear marine facilities

## Kola peninsula

- Icebreaker support vessels and facilities, Murmansk
  - Existing support vessels:
    - Fuel transports *Imandra* & *Lotta* are used for refueling and spent fuel handling
    - *Serebryanka* is a tanker used for liquid waste
  - Future support vessels:
    - In October 2017, Iceberg Design Bureau was contracted by Russia's Ministry of Industry & Trade for a multi-functional nuclear maintenance ship (MNMS) to replace *Imandra.*
      - The floating service base will be designed for maintenance of ships and sea structures (floating nuclear power plants) powered by reactor plants KLT-40S, RITM-200 and the prospective RITM-400. In particular, the MNMS will be capable to recharge, store, and carry new and spent nuclear fuel.
  - Spent Nuclear Fuel (SNF) Building 5
    - Intended to store SNF in 50 TUK-120 dry-storage containers for up to 50 years.
    - The ferrocement TUK-120 cask originally was developed to transport and store SNF from nuclear submarines.

*Imandra.* Source: http://mil.today/2017/22763/

Spent Nuclear Fuel Building 5 at Atomflot.
Source: Nils Bøhmer, https://web.archive.org/

# Other nuclear marine facilities

## Far East

- 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.
  - Facility connects to the Trans-Siberian Railroad, allowing it to receive fresh fuel from the Machine Building Plant (MSZ) in Elektrostal and return spent fuel assemblies for storage or reprocessing at the Mayak Chemical Combine (in Chelyabinsk)
- Nuclear support vessels, Far East
  - Project 326 floating technical base PTB-4 (formerly technical tanker TNT-4) & *Pinega*
    - Other Project 326 floating technical bases are believed to have been retired: PTB-16 (formerly TNT-16) in 1994, PTB-8 (formerly TNT-49) in 2011, and PTB-24 (formerly TNT-50) in 2009.
  - Floating workshop PM-74
  - Floating radiation monitoring vessel PKDS-12

# Russian naval nuclear infrastructure

# Russian military organization


Source. Adapted from Ministry of Defense of the Russian Federation, http://eng.mil.ru/en/index.htm

# Russian naval fleets

- Two Russian fleets are characterized as operational-strategic associations of the Navy of Russia. These fleets operate nuclear-powered vessels and share responsibility for operating and maintaining naval strategic nuclear forces.
  - **The Northern Fleet (NF)** provides military security for Russia in northern European and Atlantic regions. NF is composed of nuclear-powered strategic missile, cruise missile and attack submarines, a nuclear-powered guided missile cruiser, a non-nuclear aircraft carrier, missile-carrying and anti-submarine naval aviation, anti-submarine ships and other vessels. NF has 2/3 of all Russian naval vessels.
  - **The Pacific Fleet (PF)** provides military security for Russia in Asia Pacific regions. PF is composed of nuclear-powered strategic missile, cruise missile and attack submarines and diesel-electric submarines, surface ships for operations in oceanic and near-sea areas, naval missile-carrying aviation, anti-submarine and fighter aviation, and units of coastal troops.
- Two smaller Russian fleets are characterized as operational strategic large unit of the Navy. They do not operate nuclear-powered vessels, but do operate advanced conventional submarines.
  - **The Baltic Fleet (BF)** is organized with a division of surface ships, a brigade of diesel-electric submarines, units of auxiliary and search & rescue vessels, naval aviation, units of coastal troops, combat service support and special support units.
  - **The Black Sea Fleet (BSF)** is responsible for providing military security of Russia in the South. The BSF consists of diesel-electric submarines, surface ships that can operate in ocean and close sea zones, sea-based missile-carrying aviation as well as anti-submarine warfare aviation and fighters, and coastal troops.
- One small unit, the **Caspian Flotilla,** is responsible for protecting Russian national interests in the Caspian Sea region. It does not operate nuclear-powered vessels or submarines.

# Main Directorate of Deep-Sea Research

## (GUGI, Military Unit 40056)

- The Main Directorate of Deep-Sea Research (GUGI), in the Russian Ministry of Defense, is an organizational structure that is separate from the Russian Navy.
  - The Head of GUGI is Vice-Admiral Aleksei Burilichev, Hero of Russia
- GUGI is responsible for fielding specialized submarines, oceanographic research ships, undersea drones and autonomous vehicles, sensor systems, and other undersea systems.
- GUGI operates the world's largest fleet of covert manned deep-sea vessels. In mid-2018, that fleet consisted of:
  - Six nuclear-powered, deep-diving, small submarines ("nuclear deep-sea stations")
  - Two nuclear-powered "motherships" (PLA carriers) for the nuclear deep-sea stations
- These nuclear submarines are operated by the 29th Special Submarine Squadron, which is based along with other GUGI vessels at Olenya Bay, in the Kola Peninsula on the coast of the Barents Sea.
- GUGI also is responsible for the development of the Poseidon (formerly Status-6 / Kanyon) strategic nuclear torpedo and the associated "carrier" submarines.

Vice-Admiral Aleksei Burilichev at the commissioning of GUGI oceanographic research vessel Yantar. Source: http://eng.mil.ru/

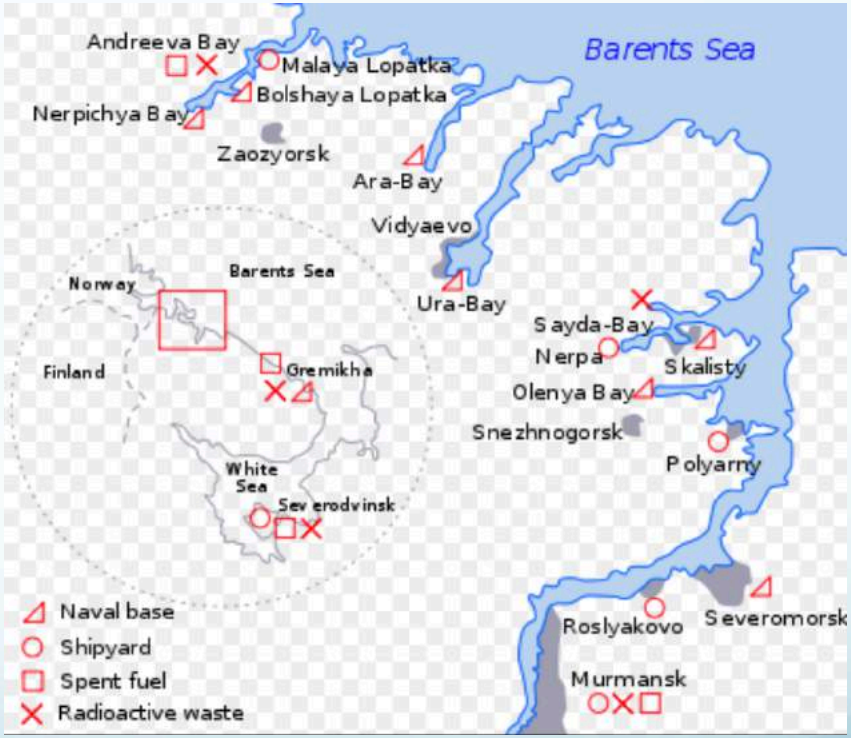
# Main Directorate of Deep-Sea Research
## (GUGI, Military Unit 40056)

- The GUGI fleet provides deep ocean and Arctic operating capabilities that greatly exceed those of any other nation. Potential missions include:
  - Conducting subsea surveys, mapping and sampling (i.e., to help validate Russia's extended continental shelf claims in the Arctic; to map potential future targets such as seafloor cables)
  - Placing and/or retrieving items on the sea floor (i.e., retrieving military hardware, placing subsea power sources, power distribution systems and sonar arrays)
  - Maintaining military subsea equipment and systems
  - Conducting covert surveillance
  - Developing an operational capability to deploy the Poseidon strategic nuclear torpedo.
  - In time of war, attacking the subsea infrastructure of other nations in the open ocean or in the Arctic (i.e., cutting subsea internet cables, power cables or oil / gas pipelines)
- Since about 2015, NATO has observed Russian vessels stepping up activities around undersea data cables in the North Atlantic. None are known to have been tapped or cut.
- For more information on GUGI, Russian special operations submarines and other covert underwater projects, refer to the *Covert Shores* website created by naval analyst H. I. Sutton: http://www.hisutton.com

# Russian naval bases for nuclear vessels

- Northern Fleet (mid-2018):
  - 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
    - 2 x Sierra II SSNs and 1 x Victor III SSN.
    - One Sierra I SSNs modernized, expected to return to service in 2017. One more awaiting modernization.
  - Oscar-class SSGNs are based at Ara Bay
    - 3 x Oscar-class subs are believed to be based here
  - Typhoon-class SSBN *Dimitry Donskoy* and two reserve Typhoon SSBNs are at Nerpichya Bay
  - The Orlan (Kirov)-class guided missile cruiser (CGN) *Pyotr Velikiy* is based at Severomorsk, which is the Northern Fleet's main administrative base.
- Main Directorate of Deep-Sea Research (GUGI)
  - Special operations subs (Kashalot & Losharik) & PLA-carriers (motherships) are based at Olenya Bay.

Northern Fleet and GUGI naval bases & nuclear facilities




Source: https://commons.wikimedia.org

# Russian naval bases for nuclear vessels

- Pacific Fleet (mid-2018):
  - Kamchatka Rybachiy Nuclear Submarine Base (Krasheninnikov Bay, south of Petropavlovsk)
    - SSBNs are in the 16th Squadron:
      - 2 x Borei SSBNs
      - 1 x Delta III SSBN
    - 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.

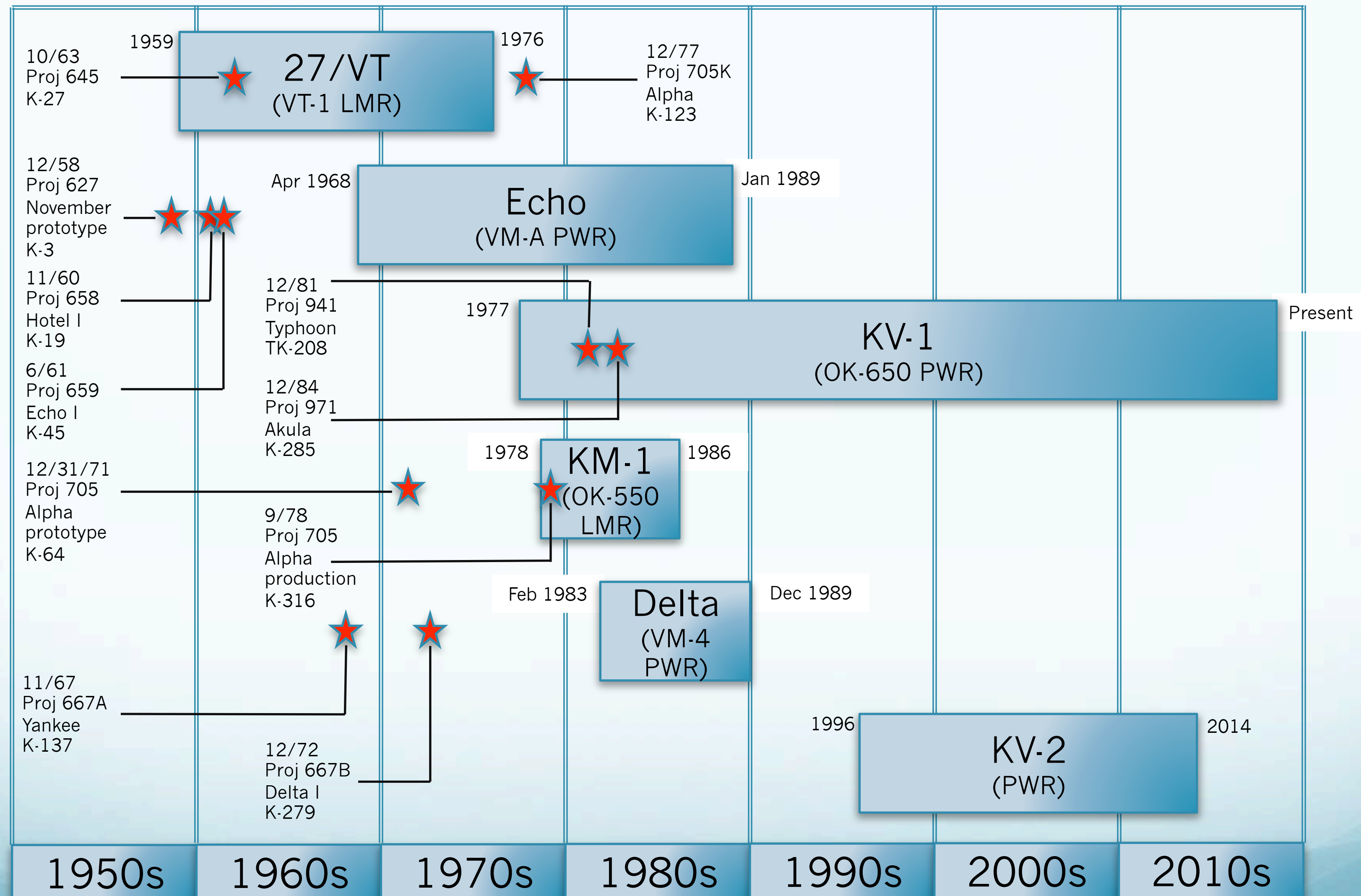
Pacific Fleet naval bases & nuclear facilities


Source: Center for Nonproliferation Studies

# Naval reactor training centers & reactor prototypes

- Russia has operated naval nuclear training centers at the following sites, some of which had submarine reactor prototypes for operational testing and crew training:
  - I.I. Leypunsky Institute of Physics and Power Engineering (IPPE), Obninsk
    - 27/VT LMR prototype reactor was the prototype for the Gidropress VT-1 LMR. Decommissioned.
  - A.P. Aleksandrov Scientific Research Technological Institute (NITI), Sosnovyy Bor
    - KM-1 LMR prototype reactor was the prototype for the Afrikantov OK-550 LMR. Decommissioned.
    - KV-1 PWR prototype reactor. Operational.
    - KV-2 PWR prototype reactor. Decommissioned.
  - Nuclear submarine training center, Paldiski, Estonia
    - Echo-class naval training facility housed a VM-A reactor prototype. Decommissioned.
    - Delta-class naval training facility housed a VM-4 (OK-700-series) reactor prototype. Decommissioned.
  - Nuclear training center, Sevastopol, Ukraine
    - This training center was the largest in the Soviet Union and operated advanced computer-based reactor simulators; turning out 500 submarine officers a year. There were no reactor prototypes at this facility.
    - Since Ukraine's independence in 1991, the Russian Navy has not used this facility.
  - Dzerzhinsky Naval College, St. Petersburg
    - All training of crews and service personnel for nuclear submarines now takes place here
- In addition, Rubin Central Design Bureau reported that they took part in the production of "a test facility with a single-block boiling water reactor with natural circulation. The plant was intended as an auxiliary power source onboard diesel electric submarines."
  - This likely was a prototype for the Nikiet VAU-6 Auxiliary Nuclear Power Plant (ANPP). Location of this prototype is not known.

# Naval reactor prototype timeline




The star denotes the date the lead sub in each class using each reactor type was commissioned. In several cases, the reactor was used on an operational submarine before the land-based “prototype” reactor facility was available. The VAU-6 ANPP prototype not shown on this chart.

# Nuclear submarine prototype 27/VT at IPPE

- The liquid metal (lead-bismuth) cooled 27/VT LMR submarine prototype reactor was constructed at IPPE. This was a prototype of the VT-1 reactor design developed by Gidropress and IPPE to be installed on submarine K-27.
- Construction started in 1953, one year after the start of the submarine PWR project. The nuclear steam supply system (NSSS) equipment was manufactured by Podolsk Machine Building Plant. The prototype was commissioned in January 1959.
- The 27/VT prototype consisted of the NSSS and a full-scale submarine engineering section, including reactor, steam generator, pumps, primary and secondary pipelines, turbine plant, control systems and other service systems.
  - The reactor was rated at 70 MWt.
  - Primary pressure was about 20 kg/cm$^2$ (284 psig).
  - Secondary steam parameters were: pressure 42 kg/cm$^2$ (597 psig), temperature 440 °C (824 °F).
  - The propulsion plant delivered 17,500 shp.
- The prototype was used to support engineering development of NSSS equipment and systems, refinement of reactor plant operational conditions and control, and for submarine crew training.
- The prototype operated for 17 years, between 1959 – 1976, with two different cores.
  - Experience with the 27/VT second core likely supported development of the 2nd-generation LMR core used in the Gidropress BM-40A reactor for the Project 705K Alpha submarines.

# Nuclear submarine training center & prototypes at NITI

- Submarine officer training center
  - The training center includes classroom and training simulators.
  - On 2005, the training center expanded to include training facilities and simulators for nuclear submarine crews from India

Source: http://www.greenworld.org.ru/

- KM-1 LMR prototype: Operational from 1978 to 1986. Decommissioning complete in 2016.
  - Russia's 2nd-generation full-scale liquid metal reactor (LMR) submarine prototype was comprised of an Afrikantov OK-550 nuclear steam supply system (NSSS) and an Alfa-class submarine engineering plant.
  - Before the KM-1 land-based prototype was built, the first OK-550 reactor was operationally tested in the Alfa submarine prototype K-64, which was commissioned on 31 December 1971.
  - The land-based KM-1 operated between 1978 – 1987. It was not refueled.
  - The core was unloaded and stored at Gremikha, near Murmansk.
  - In their 2015 annual report, NITI reported that the main purpose for the current decommissioning work at KM-1 was to "ensure the possibility of using the production areas of Building 101, after its reconstruction, for placement and testing of a promising nuclear power plant with a heavy liquid-metal carrier. Works on the reconstruction of the KM-1 stand are conducted on the basis of a joint decision of the Navy and the State Corporation Rosatom."

# Nuclear submarine training center & prototypes at NITI

- KV-1 PWR prototype: Operational from 1975 to the present.
  - Rubin Central Design Bureau reported* that it took part in the production of "a test facility with a pressurized water reactor. The plant tested at the facility became (the) default for all third generation SSNs. Some design solutions for the fourth generation nuclear submarine plants were also tried there."
    - This is likely KV-1, which would be an Afrikantov OK-650 PWR.
  - The 2015 NITI annual report noted that one objective of the current testing program was to investigate KV-1 operations with natural circulation at higher power.
- KV-2 PWR prototype: Operational from 1996 to 2014. Now decommissioned.
  - Rubin Central Design Bureau also reported* taking part in the production of "a test facility with a single block reactor with natural coolant circulation within the entire output range. The facility was used for numerous tests at a selection of regimes. Also the studies were done for neutronic and thermohydraulic processes and for water-chemical regimes, and plant regimes and control algorithms were improved."
    - This may have been the KV-2 prototype.
    - No operational naval nuclear plant has been associated with this prototype.
  - Fuel unloading began in 2014 and was completed in February 2015. Spent fuel transfer to the Mayak reprocessing plant was completed in February 2017.
  - In their 2015 annual report, NITI stated that decommissioning was complete and that "the goal of decommissioning the KV-2 nuclear power plant is to use the production facilities of Building 103 to accommodate a new prospective unified nuclear power unit of the new generation."

* Source: http://ckb-rubin.ru/en/projects/naval_engineering/test_facilities/

# Nuclear submarine prototypes at NITI

KV-2 prototype control center

One of the reactor prototypes at NITI. Source, two photos:
http://ckb-rubin.ru/en/projects/naval_engineering/test_facilities/

# Nuclear submarine training center at Paldiski, Estonia

- Paldiski, which is situated 50 km (31 miles) west of Tallinn, Estonia, was an important Soviet-era military base and submarine harbor. The Nuclear Submarine Training Center was constructed in the early 1960s as a closed military town, with about 16,000 military employees.
- The training center included two large submarine reactor training facilities in the Main Technological Building, each with an operating reactor and a corresponding submarine propulsion system installed in a full-scale replica of a submarine hull. At the time, this was the largest such training facility in the Soviet Union.

| Parameter | Unit 1 | Unit 2 |
|---|---|---|
| Project no / NATO Class | 658 / Echo II | 667 / Delta I-IV |
| Reactor type | PWR / VM-A | PWR / VM-4 |
| Thermal Power | 70 MW | 90 MW |
| Enrichment of fuel in U-235 | 21 % | 21 % |
| Approx. qty of Uranium / U-235 [kg][62] | 250 / 50 | 350 / 70 |
| Encasement (submarine hull segment) | diam. 7.5 m<br>length about 50 m | diam. 9.5 m<br>length about 50 m |
| First criticality | April 1968 | February 1983 |
| Last criticality | January 1989 | December 1989 |
| Refuel and maintenance | 1980-81 | never |
| Operating time | first load 13 781 h<br>second load 7 040 h | 5333 h |

Sources:
(1) http://coldwarsites.net/country/estonia/soviet-nuclear-submarine-training-center-paldiski
(2) http://www.nuclear-heritage.net/index.php/Soviet_Nuclear_Submarine_Training_Center
(3) https://www.keskkonnaamet.ee/sites/default/public/kiirgus/Nonpro_est.pdf

# Nuclear submarine training center at Paldiski, Estonia


Paldisksi site circa 1995. Source: http://www.wmsym.org/archives/1998/html/sess27/27-14/27-14.htm

# Nuclear submarine training center at Paldiski, Estonia

- The reactors were shut down in 1989; unit 1 in January and unit 2 in December. Classroom training continued until 1993. Shipment of nuclear material back to Russia was completed in October 1994. Russia relinquished control of the reactor facilities in September 1995.
  - The Russians removed all classified equipment, including the submarine hulls, but not the sections containing the nuclear reactors. They were left in place and encapsulated in concrete sarcophagi.
  - The Russians did not clean up the site.
- When Estonia took over the facility they had two main tasks:
  - To clean up the whole area and buildings for radioactive contamination and other kinds of pollution, and
  - To build new and safer sarcophagi around the nuclear reactors and renew the old building.
- Most of the old Soviet-era buildings have been torn down and a new building exterior has been built around the encapsulated reactors.

Sources: (1) http://coldwarsites.net/country/estonia/soviet-nuclear-submarine-training-center-paldiski
(2) http://www.nuclear-heritage.net/index.php/Soviet_Nuclear_Submarine_Training_Center

# Nuclear submarine training center at Paldiski, Estonia

Top left: Paldiski site today. Yellow indicates removed buildings.

Top right: One of the reactor prototypes inside the Main Technical Building before retirement

Bottom right: The remains of the two reactor prototypes enclosed in concrete sarcophagi.

Bottom left: One reactor prototype shell.

Source, top left photo: http://commondatastorage.googleapis.com/static.panoramio.com/photos/original/27488123.jpg
Source, top right photo: http://spb.org.ru/bellona/ehome/russia/nfl/nfl1.htm
Source, bottom left photo: http://coldwarsites.net/country/estonia/soviet-nuclear-submarine-training-center-paldiski
Source, bottom right photo: Liis Treimann, https://news.postimees.ee/2896047/paldiski-to-get-cleansed-of-radioactive-waste

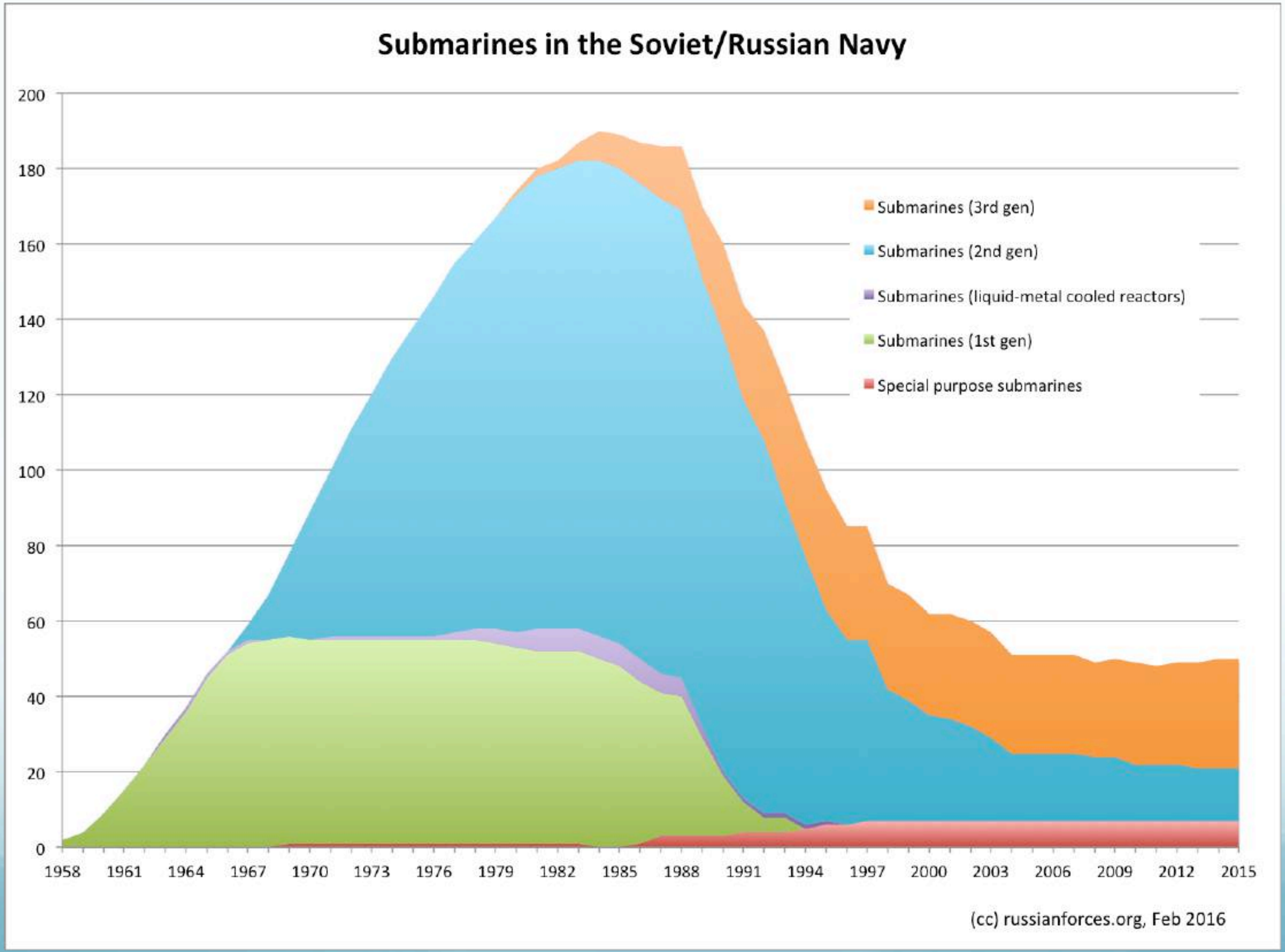
# Russian nuclear-powered submarines

- Submarine reactors
- Nuclear-powered fast attack submarines (SSN)
- Strategic ballistic missile submarines (SSB & SSBN)
- Cruise missile submarines (SSG & SSGN)
- Nuclear-powered special operations subs & strategic torpedoes
- Other special-purpose nuclear-powered subs
- Examples of unbuilt nuclear submarine projects

# Five generations of Soviet/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 / 705K (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 / SSGN: Project 885 / 885M (Yasen / Yasen-M)
  - SSBN: Project 955 / 955A (Borei / Borei A)
- 5th generation (future new construction):
  - SSN: Husky (interceptor)
  - SSGN: Husky with a hull insert for cruise missiles
  - SSBN: Borei-II or Husky with a hull insert for SLBMs

# Nuclear submarines in the Soviet/Russian Navy



# Key differences between Russian & US nuclear submarines

| Russia | USA |
|---|---|
| Double hull: the pressure hull is enclosed in a streamlined outer hull. | Single hull: most of the pressure hull is the outside of the boat. |
| Greater reserve buoyancy. More space is available for ballast tanks between the pressure hull and the outer hull. | Less reserve buoyancy. Relatively small double-hull sections and free-flood areas for and aft house the ballast tanks. |
| Mostly steel hulls, but several titanium hulls. | All high-strength steel hulls. |
| Many sub classes are powered by two reactors. | All but one sub have been powered by a single reactor. |
| Many sub classes have two propellers. | Except for the earliest subs, all have had single propellers. |
| Until new Yasen class, all subs had cylindrical sonar arrays and bow torpedo tubes | Since Permit-class, most SSNs have had large, bow spherical array sonars and mid-ships torpedo tubes. |
| Greater number of compartments inside the pressure hull. Sub can survive flooding of the single largest compartment and adjacent ballast tank. | Few compartments inside the pressure hull. Sub is not designed to withstand flooding of the largest compartment. Interior bulkheads not designed to same "test depth" as hull. |
| Most subs have crew escape capsules. | No crew escape capsules. Individuals or small groups escape via an escape trunk (airlock). |
| Greater automation, smaller crews. | Larger, well-trained crews. |

# Submarine reactors

# Four generations of Russian submarine reactor plants

- **1st generation; initial operations in 1958**
  - NIKIET VM-A PWR: All "HEN" (Hotel-Echo-November) 1st-generation nuclear subs
  - Gidropress VT-1 LMR: 1-of-a-kind Project 645 sub K-27
- **2nd generation; initial operations in 1967**
  - NIKIET OK-300 (VM-4 series) PWR: All Victor SSNs
  - NIKIET OK-350 (VM-4 series) PWR: All Charlie SSGNs
  - NIKIET OK-700 (VM-4 series) PWR: All Yankee & Delta SSBNs
  - Afrikantov OK-550 LMR: All Project 705 Alfa SSNs
  - Gidropress BM-40A LMR: All Project 705K Alfa SSNs
- **3rd generation; initial operations in 1976 (VM-5), 1981 (OK-650), 2012 (OK-650V)**
  - NIKIET VM-5 PWR: 1-of-a-kind Project 661 Papa SSGN
  - Afrikantov OK-650 PWR: All Sierra, Mike & Akula SSNs, Oscar SSGN and Typhoon SSBN.
  - Afrikantov OK-650V PWR for the single Project 885 Yasen SSN and at least the initial Project 885M Yasen-M SSN. Also the three Project 955 Borei SSBNs and at least the initial Project 955A improved Borei SSBNs.
- **4th generation; not yet operational**
  - The specific 4th-generation reactor and design bureau have not been identified. However, some sources claim this is a PWR named KPM-6 or CTS-6.
  - The following submarines have been identified as potential users:
    - Originally the Project 885M Yasen-M (improved Yasen) SSNs and the Project 955A improved Borei SSBNs were expected to have a 4th-generation reactor.
    - The Husky SSN expected in the mid-2020s

# Russian submarine reactors

| Reactor system | Reactors | Design bureau | Power (MWt) | Initial ops | Application |
|---|---|---|---|---|---|
| --- | 2 x VM-A PWRs | NIKIET | 70 | 1958 | • VM-A prototype at Echo training center, Paldiski, Estonia<br>• 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 | • 27/VT LMR prototype at IPPE, Obninsk<br>• 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<br>• Planned Project 664 amphibious assault sub |
| 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 | • OK-700 prototype at Delta training center, Paldiski, Estonia<br>• 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 | • KM-1 LMR prototype at NITI, Sosnovy Bor<br>• Project 705 Alfa SSNs |
| BM-40A | 1 x BM-40A LMR | Gidropress | 155 | 1977 | Project 705K Alfa SSNs |

# Russian submarine reactors

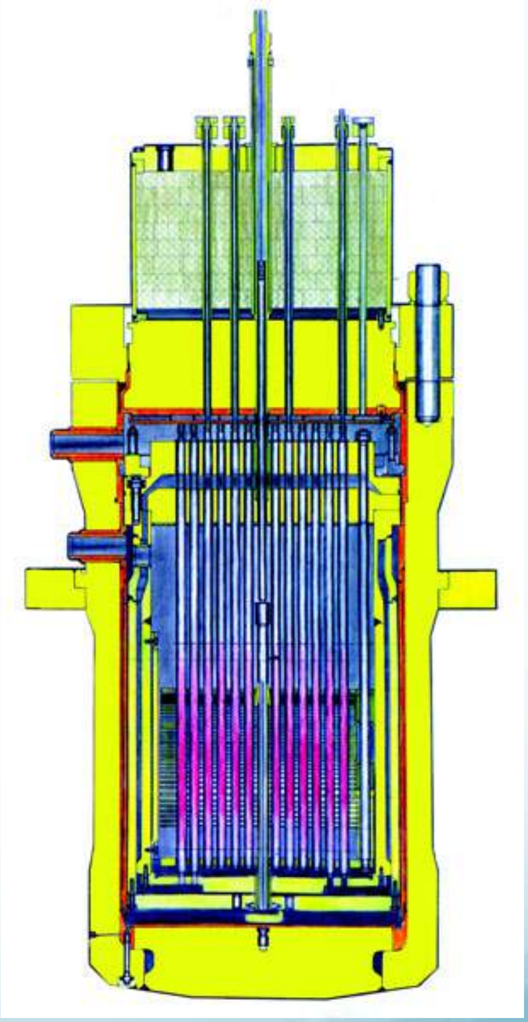
| Reactor system | Reactors | Design bureau | Power (MWt) | Initial ops | Application |
|---|---|---|---|---|---|
| --- | 2 x VM-5M PWRs | NIKIET | 177 | 1976 | 1-of-a-kind Project 661 Papa SSGN, fastest Russian sub |
| OK-650 | 2 x PWRs | Afrikantov | 190 | 1981 | • KV-2 prototype reactor facility at NITI, Sosnovy Bor<br>• Project 941 Typhoon SSBN |
| OK-650B | 1 x PWR | Afrikantov | 190 | 1987 | • Project 945 & 945A Sierra I & II titanium hull SSNs;<br>• Project 971, 971i, 971U & 971M Akula I, Ii, II & III SSNs |
| OK-650B | 2 x PWRs | Afrikantov | 190 | 1982 | Project 949 & 949A Oscar I & II SSGNs |
| OK-650B3 | 1 x PWR | Afrikantov | 190 | 1984 | 1-of-a-kind Project 685 Mike titanium hull SSN |
| OK-650V | 1 x PWR | Afrikantov | 190 | 2013 | Project 885 Yasen & Project 955A Borei SSBNs;<br>3rd generation nuclear plant |
| --- | Small PWR | Attributed to NIKIET | 10 MWt (est.) | 1986 | Project 1851/18511 Nelma / X-Ray & Halibut / Paltus-class small special operations subs |
| --- | Small PWR | Attributed to NIKIET | 50 MWt (est.) | 1986 | Project 1910 Kashalot / Uniform-class special operations subs |
| E-17 or KTP-71 Phoenix | Small PWR | Attributed to Afrikantov | 50 MWt (est) | 2003 | Project 10831 Losharik special operations sub |
| VAU-6 | Small BWR integrated with a turbo-generator | Attributed to NIKIET | 2 MWt (est) | 1971 | • Auxiliary Nuclear Power Plant (ANPP) prototype facility built by Rubin Central Design Bureau<br>• "Hermitic" ANPP used on diesel-electric subs B-68 (late 1980s) and B-90 (late 2000s - present) |

# Russian submarine reactors

| Reactor system | Reactors | Design bureau | Power (MWt) | Initial ops | Application |
|---|---|---|---|---|---|
| KPM-6 (CTS-6) | PWR | Likely Afrikantov | 200 (est) | TBD | • 4th generation nuclear plant.<br>• Initial deployment appears to have been delayed. Possibly intended for Project 885M Yasen-M SSNs & Project 955A improved Borei SSBNs. |
| ABM-8 | LMR | Possibly Gidropress | TBD | TBD | • 4th generation nuclear plant.<br>• New LMR prototype reactor facility that may be built in place of KM-1 at NITI, Sosnovy Bor. |
| --- | TBD | Possibly Afrikantov | TBD | TBD | • 4th generation nuclear plant.<br>• New water-cooled prototype reactor facility that may be built in place of KV-2 at NITI, Sosnovy Bor. |

# VM-A
## Loop-type PWR

- 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
- Key plant parameters:
  - Primary pressure:  200 kg/cm$^2$ (2,845 psig)
  - Secondary saturated steam pressure: 36 kg/cm$^2$ (512 psig)
  - Secondary saturated steam temperature: 245 °C (472 °F)
- Design features:
  - There are no piping connections below the upper edge of the core. The core cannot be accidentally drained, as happened to an OK-150 reactor on the icebreaker *Lenin* in 1966.
  - Short service life of the steam generators caused radioactive primary coolant leakage into the secondary (steam) system.
  - The control rod system had an unusual design feature: apparently it was not possible or at least not easy to lift the lid of the reactor vessel without also lifting the control rods. This resulted in two criticality accidents with 1$^{st}$-generation submarines



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

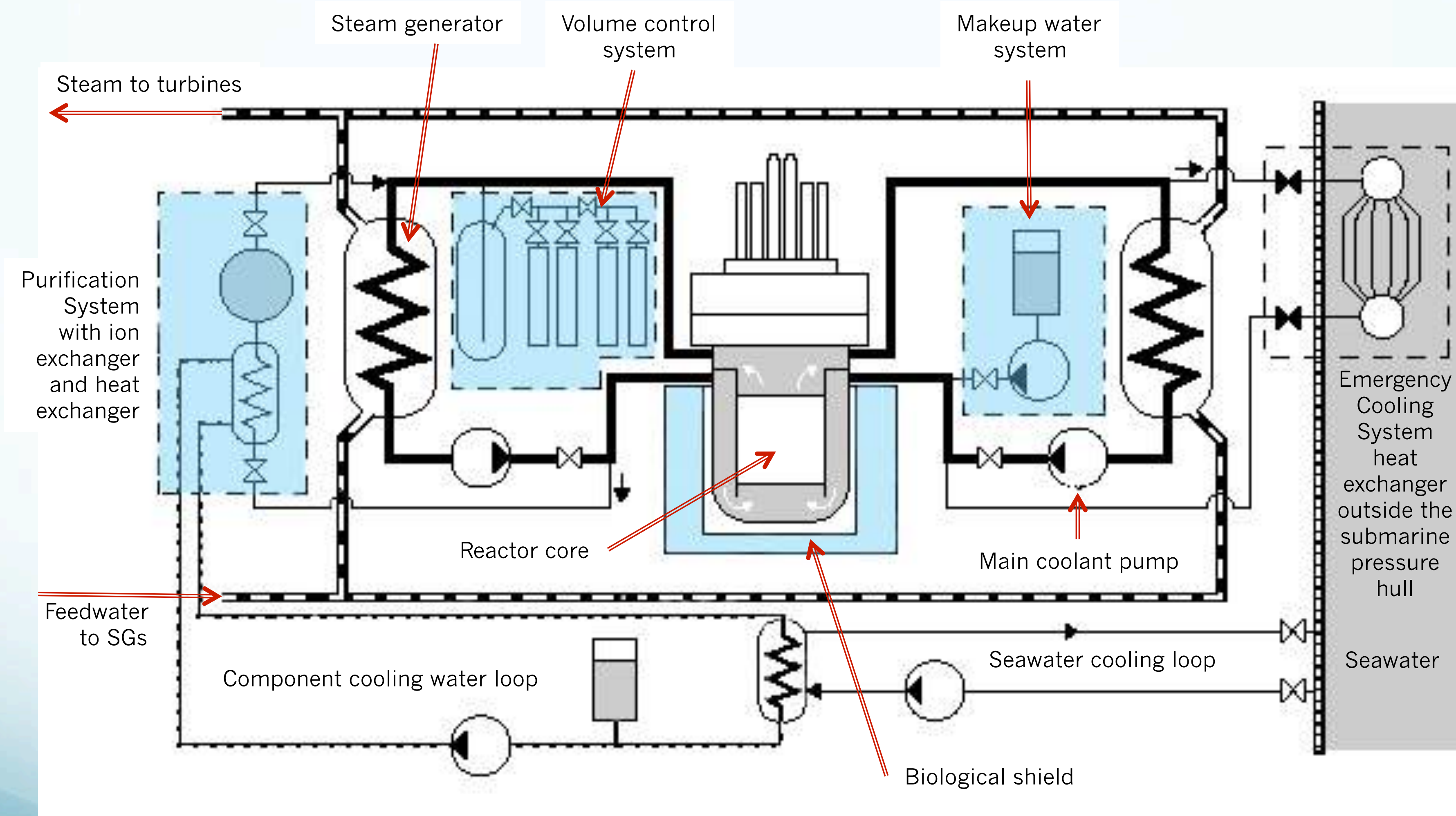
# VM-A
## Loop-type PWR

- Training application: 1 x VM-A reactor was installed in the “Echo” land-based nuclear submarine training prototype in Paldiski, Estonia.
- Operational applications: 2 x VM-A reactors on each of the following submarines:
  - Project 627 / 627A November-class attack subs
    - Submarine K-3 made the first Soviet underway on nuclear power on 4 June 1958.
  - Project 659 & 675 Echo I and Echo II-class cruise missile subs
  - Project 658, 658M & 701 Hotel-class ballistic missile subs
- VM-A core performance improved significantly over several fuel design iterations*:
  - VM-AB: 750 equivalent full-power hours (EFPH)
  - VM-1A: 2,000 EFPH (1961 – 1963)
  - VM-1AM: 2,500 (1964)
  - VM-2A: 4,000 EFPH
  - VM-2AG: 5,000 EFPH (1969)

* Source:Reistad, O., & Ølgaard, P. L., “Russian nuclear power plants for marine application,” NKS-138, 2006

# VM-A

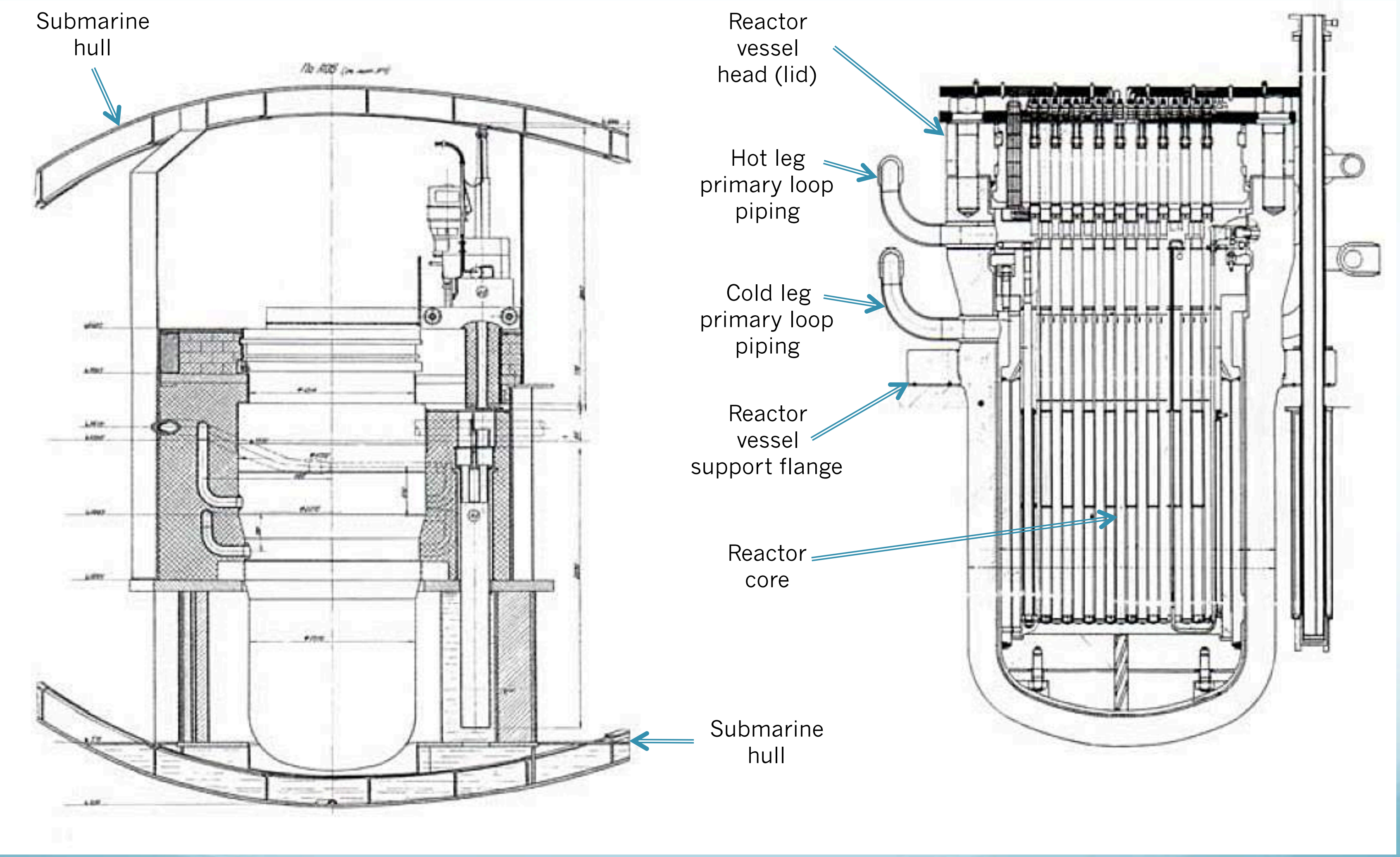
## Process flow diagram for one reactor




Source: adapted from spb.org.ru/bellona

# VM-A

## Installation on a 1st-generation nuclear submarine




Source: adapted from Reistad, O., & Ølgaard, P. L., "Russian nuclear power plants for marine application," NKS-138, 2006

# 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 50 mSv (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 40 mSv (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.
  - The 27/VT prototype reactor used to validate the VT-1 reactor design was constructed at IPPE, and was 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). 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).

# VT-1

## (aka VT RM-1, 627/VT)

- Applications:
  - The 27/VT prototype reactor operated for 17 years from 1959 to 1976.
  - 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.
    - A reactor accident aboard K-27 occurred on 24 May 68, severely damaging one VT-1 reactor. The damaged reactor never operated again.
- Operational issues with lead-bismuth reactors:
  - “Slag” buildup (oxidation products from high-pressure steam leaking into the primary coolant system) in the reactor was noted during inspections of the 27/VT prototype at IPEE. Operating procedures were developed to periodically remove the slag.
  - 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.
- The undamaged VT-1 reactor on K-27 was allowed to freeze and was kept in that state for two years. Then the primary system was warmed up, unfrozen, and the reactor was successfully operated at high power.

# VM-4

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

- Pressurized water reactor for 2nd generation Russian submarines.
  - Developed by NIKIET
  - Compact, modular primary coolant system, with reduced physical volume through use of pipe-within-pipe (co-axial) “loop” connections between the reactor vessel, the steam generators and primary coolant pumps.
- Reactor:
  - Rated at 72 – 90 MWt
  - 20% enriched Uranium
- Training application:
  - 1 x VM-4 reactor was installed in the land-based “Delta” nuclear submarine training prototype in Paldiski, Estonia.
- Operational 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 after the original OK-550 lead-bismuth cooled reactor was removed.
  - 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

# VM-4

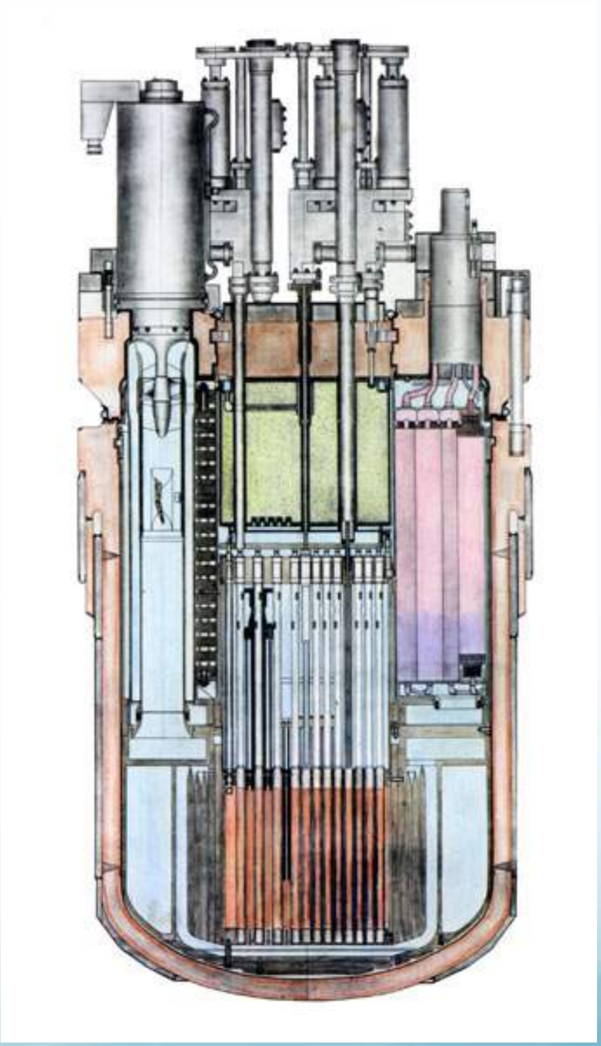
## Accidents in which a VM-4 was irreparably damaged

- K-140, Yankee SSBBN, August 1968, in the naval yard at Severodvinsk for repairs
  - One of the reactors started up automatically when the control rods were raised to a higher position. Power increased to 18 times its normal amount, while pressure and temperature levels in the reactor increased to four times the normal amount. The automatic start-up of the reactor was caused by the incorrect installation of control rod electrical cables and by operator error.
- 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 the 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.

# 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 was rated @ 177 MWt:
    - One-of-a-kind Project 661 Papa-class cruise missile sub K-222 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.

Integral PWR identified by NIKIET as a naval "steam generating unit," perhaps a VM-5



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

# OK-550 and BM-40A
## Liquid metal reactors (LMRs)

- 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, the Afrikantov OK-550 & Gidropress 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.
  - Both used highly-enriched uranium (HEU) 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.
  - An LMR core operates at a higher power density and thermal efficiency than a PWR, with a low-pressure primary system.
  - Both reactors were rated @ 155 MWt and were expected to have a long-life core, possibly up to 7 years.
  - The lead/bismuth eutectic solidifies at 125 °C (257 °F). If the coolant ever solidified, the control rods would be frozen in place in the core, precluding a subsequent reactor startup. Whenever the reactor is shut down, the primary system must be heated by steam from an external source to maintain the coolant in a liquid state.

# OK-550 and BM-40A

## Liquid metal reactors (LMRs)

- I.I. Leypunsky Institute of Physics and Power Engineering (IPPE), Obninsk supported both reactor developers and operated the 27/VT full-scale LMR prototype used to validate the Gidropress VT-1 reactor design. The 17 years of 27/VT operating experience with two cores likely contributed to the design of the Gidropress BM-40A.
- A.P. Aleksandrov Scientific Research Technological Institute (NITI) operated the KM-1 full-scale LMR prototype of the Afrikantov OK-550 reactor.
- 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.

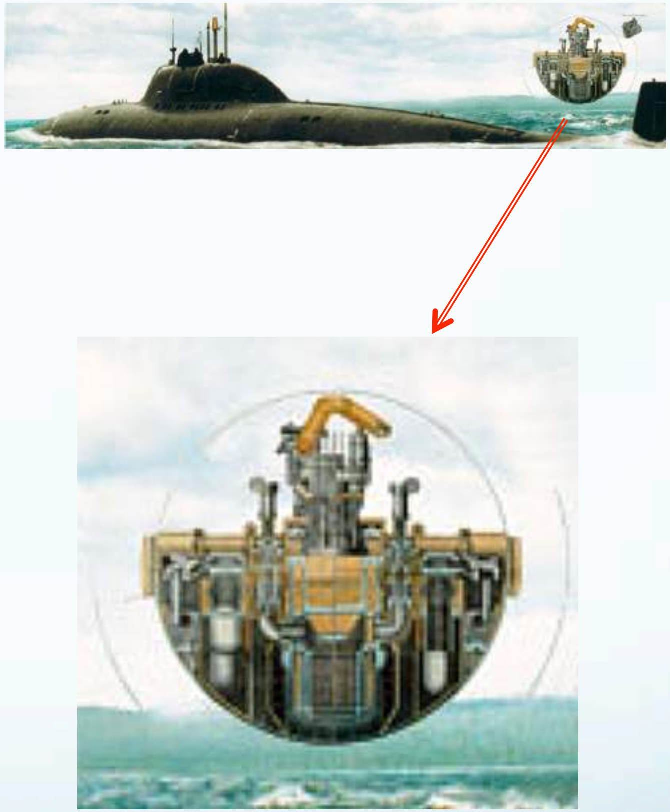
# OK-550

## Afrikantov liquid metal reactor (LMR)

- OK-550 was developed by OKBM Afrikantov, Nizhniy Novgorod.
  - Primary system design is not known, but it likely was an integral primary system, comparable in principle to the similar-vintage land-based BN-600 also designed by Afrikantov. The relevant BN-600 features include:
    - The reactor and primary pumps are submerged in a large pool of liquid metal.
    - Three secondary (steam-side) loops.
    - Each steam generator is comprised of multiple steam generating modules, each with evaporator, superheater and reheater sections. The output of the multiple modules is manifolded together.
  - Operational application: 1 x OK-550 reactor on four Project 705 Alfa-class submarines built in Severodvinsk.
    - The first Alfa submarine, K-64, was an operational prototype with an OK-550 reactor. It was commissioned on 31 December 1971.
    - The first production Project 705 Alfa submarine, K-316, was commissioned almost seven years later, on 30 September 1978.

# BM-40A
## Gidropress liquid metal reactor (LMR)

- The BM-40A was developed by OKB Gidropress, St. Petersburg.
  - Gidropress, together with IPPE, the Central Research Institute for Structural Materials (CNII KM) "Prometey", the Podolsk Machine Building Plant in Ordzhonikidze, and other enterprises, developed and manufactured the more advanced, modular BM-40A LMR nuclear steam supply system (NSSS) for the Project 705K Alpha submarines.
- The BM-40A NSSS had an integrated primary system ("monoblock"), with the reactor core, steam generating modules and primary pumps in a single vessel.
  - There were two secondary (steam-side) loops.
  - The reactor operated on an intermediate neutron spectrum.
- Applications:
  - 1 x BM-40A reactor was installed in the three Project 705K Alfa-class submarines built in the Admiralty Shipyard in Leningrad. The first unit was commissioned in December 1977.
  - There was no BM-40A prototype. Experience with the 27/VT prototype for the 1st-generation VT-1 LMR supported development of the LMR core used in the BM-40A.



The above diagrams from the Gidropress website likely shows a cross-section of the BM-40A reactor within the outline of an Alfa submarine hull.
Source: http://www.gidropress.podolsk.ru/en/projects/nuclear-submarines.php

# OK-650 & variants
## (OK-650W, OK-650B, OK-650B3, OK-650V)

- Modular pressurized water reactor for 3rd generation Russian nuclear submarine applications, derived from the Afrikantov OK-900A reactor for Arktika-class nuclear-powered icebreakers.
- Reactor:
  - Rated at 190 – 200 MWt
  - Uranium enrichment 30 – 45%
  - The primary coolant system typically operates with forced circulation. Apparently the reactor can operate with natural circulation at low power.
- Applications:
  - OK-650W: 2 x PWRs rated @ 190 MWt used on:
    - Project 941 Typhoon-class SSBNs. These are the largest subs ever built.
  - OK-650B: 2 x PWRs rated @ 190 MWt used on:
    - Project 949 Oscar I & II-class SSGNs
  - OK-650B & 650B3: 1 x PWR rated @ 190 MWt used on:
    - Project 945 Sierra I & II-class SSNs (OK-650B)
    - Project 705 Akula I, II & III-class SSNs (OK-650B)
    - Project 685 Mike one-of-a-kind SSN (OK-650B3)
  - OK-650V: 1 x PWR @ 190 MWt used on:
    - Project 885 Yasen and at least some Project 885M improved Yasen-M class multi-purpose SSNs.
    - Project 955 Borei and at least some Project 955A improved Borei-class SSBNs.

# Small nuclear reactors for special operations subs

- Projects 1851 Nelma / X-Ray & 18511 Halibut / Paltus:
  - Modest propulsion power, estimated to be about 2,000 hp (1.5 MW); max. speed reported to be about 6 kts.
  - 1 x 10 MWt PWR attributed to NIKIET.
- Project 1910 Kashalot / Uniform:
  - Propulsion power has been reported to be about 10,0000 shp. This would require a reactor with a power level of about 50 MWt and would yield a speed > 25 knots for this small sub.
  - Reactor attributed to NIKIET.
- Project 10831 Losharik:
  - Propulsion power has been reported to be about 10,0000 shp. This would require a reactor with a power level of about 50 MWt and would yield a speed > 25 knots.
  - Reactor attributed to Afrikantov; two different designations have been reported: E-17 and Phoenix KTP-7I
    - First mentioned in February 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. This article reported that the bureau (Afrikantov) 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."

# VAU-6
## Auxiliary Nuclear Power Plant (ANPP)

- The Nikiet VAU-6 is believed to be a compact boiling water reactor (BWR) + turbo-generator packaged as a "hermitic" unit that can be installed in a submarine to serve as a continuous source of a modest amount of electric power, and thereby supplement the submarine's batteries.
- Rubin Central Design Bureau for Marine Engineering reported* taking part in the production of "a test facility with a single-block boiling water reactor with natural circulation. The plant was intended as an auxiliary power source onboard diesel electric submarines."
  - This likely was a prototype of the VAU-6; location of this prototype is not known.
  - A prototype VAU-6 was built in 1971 and a second was built in 1986.
- Applications:
  - An ANPP was installed on the Project 651E Juliett-class diesel-electric sub B-68, *Nerka* and operated from 1985 to 1990.
    - This ANPP was reported to have a net electrical output about 600 kWe (about 805 shp), which would require a reactor gross power output of about 2 MWt.
  - More recently, an ANPP was included in the electric power / propulsion system for the Project 21020 diesel-electric special operations sub B-90, *Sarov,* which was launched in 2007.
    - Details on its ANPP are not known.

* Source: Rubin website: http://ckb-rubin.ru/en/projects/naval_engineering/test_facilities/

# KPM-6 or CTS-6

## 4th-generation reactor

- For quite some time, there have been rumors that development was underway on a 4th-generation naval reactor for Russian submarine applications.
  - The new 4th-generation reactor likely is being developed by OKBM Afrikantov.
  - The new reactor's introduction appears to have been delayed for technical and/or financial reasons.
  - No operational naval reactor has been associated with the test reactor that operated in the KV-2 prototype at NITI from 1996 to 2014.
    - Rubin Central Design Bureau reported* taking part in the production of "a test facility with a single block reactor with natural coolant circulation within the entire output range." This likely was the KV-2 prototype.
    - Perhaps this was a prototype for a 4th-generation submarine reactor.
- Reactor:
  - Expected to be rated at about 190 - 200 MWt; similar to OK-650V currently being installed in Yasen and Borei-class new construction boats.
  - Uranium enrichment is not known.
- Applications:
  - Several sources speculated that a 4th-generation reactor was being developed for the Project 885M improved Yasen-class multi-purpose SSNs and the Project 955A improved Borei SSBNs.
    - The lead Project 885M boat, *Kazan*, and the lead Project 955A boat, *Knyaz Vladimir (Prince Vladimir)*, both are believed to have been launched with an Afrikantov OK-650V propulsion plant. Both boats are expected to be commissioned in 2018 - 2019.

* Source: http://ckb-rubin.ru/en/projects/naval_engineering/test_facilities/

# ABM-8

## $4^{th}$-generation reactor

- This is a $4^{th}$ generation liquid metal (lead-bismuth) reactor for Russian submarine applications.
  - Likely being developed by OKB Gidropress, which has maintained its lead-bismuth fast reactor experience through its current SVBR civil reactor designs (SVBR 75/100 and SVBR-10).
  - A new LMR reactor prototype, identified as ABM-8, is expected to be built at A.P. Aleksandrov Scientific Research Technological Institute (NITI), in Sosnovy Bor (near St. Petersburg), replacing the former KM-1 LMR prototype reactor (an OK-550), which completed decommissioning in 2015.*
- Reactor:
  - Details on the ABM-8 reactor are not known.
- Applications:
  - Possible use on a future submarine or as a compact transportable reactor unit (TRU).

* Source: 2015 NITI Annual Report

# Nuclear-powered fast attack submarines (SSN)

# Russian SSNs

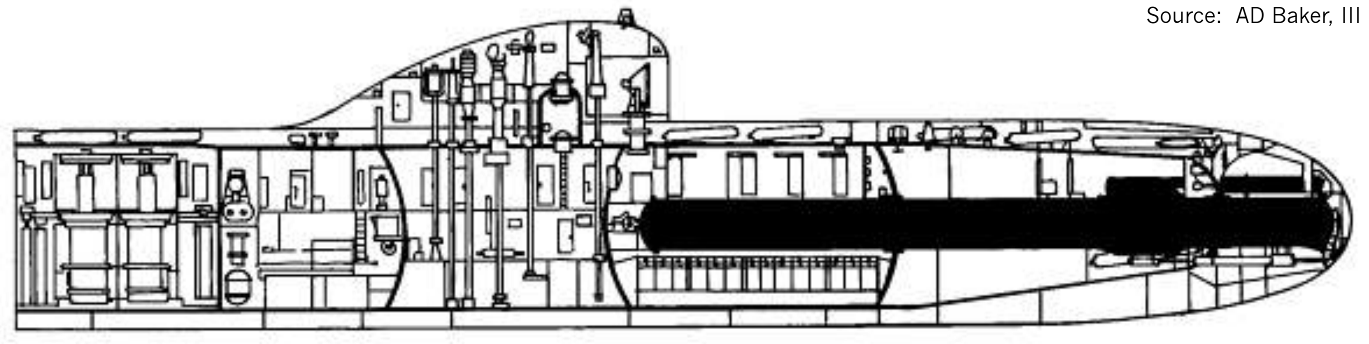
| Project # | Class | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|
| 627 | November | 1 (K-3) | 107.4 m (352.4 ft) | 7.9 m (25.9 ft) | 3065 (surf) 4750 (sub) | 2 x VM-A | 27,000 (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 | 1963 | 1963 - 68 |
| 671 | Victor I | 15 | 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 - 74 | 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 - 78 | 1972 - 97 |
| 671RTM / 671RTMK | Victor III | 26 | 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 - present |
| 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 | 1971 - 81 | 1976 - 90 |
| 705K (Severodvinsk) | Alfa (Lira) | 3 | 79.6 m (261 ft) | 9.5 m (31.2 ft) | 2280 (surf) 3610 (sub) | 1 x BM-40 LMR | 40,000 | 41 | 1977 - 81 | 1977 - 96 |
| 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) | 7,500 (surf) 8,600 (sub) | 1 x OK-650B | 36,500 | 34 | 1987 | Laid up 1987 & 92, overhaul started |
| 945A | Sierra II (Kondor) | 2 | 112 m (357.5 ft) | 12.4 m (40.7 ft) | 7,630 (surf) 9,500 (sub) | 1 x OK-650B | 36,500 | 32 | 1990 - 93 | 1990 - present |
| 945B | Sierra III (Mars) | 1 | Not known | 12.4 m (40.7 ft) | Not known | 1 x OK-650B | 36,500 | 32 | Only one laid down in 1990, scrapped in 1993 | |
| 971 & 971i | Akula I / Ii (Shchuka-B) | 3 / 4 | 110.3 m (361.9 ft) | 13.6 m (44.6 ft) | 8,140 (surf) 12,770 (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) | 8,450 (surf) 13,400 (sub) | 1 x OK-650B | 36,500 | 35 | 1988 / 2001 | 1988 - present |
| 885 | Yasen | 1 | 111 m (364.2 ft) | 12 m (39.4 ft) | 8,600 (surf) 13,800 (sub) | 1 x OK-650V | 43,000 | >30 | 2013 | 2014 - present |
| 885M | Yasen-M (Improved Yasen) | 6 (plan) | 111 m (364.2 ft) | 12 m (39.4 ft) | > 8,600 (surf) > 13,800 (sub) | 1 x OK-650V or 1 x KPM-6 (CTS-6) | TBD | >30 | 2018 - ongoing | |
| TBD | Husky | TBD | TBD | TBD | TBD | TBD | TBD | >30 | 1st in mid-2020 | |

# Project 627

## Original concept for the November-class submarine



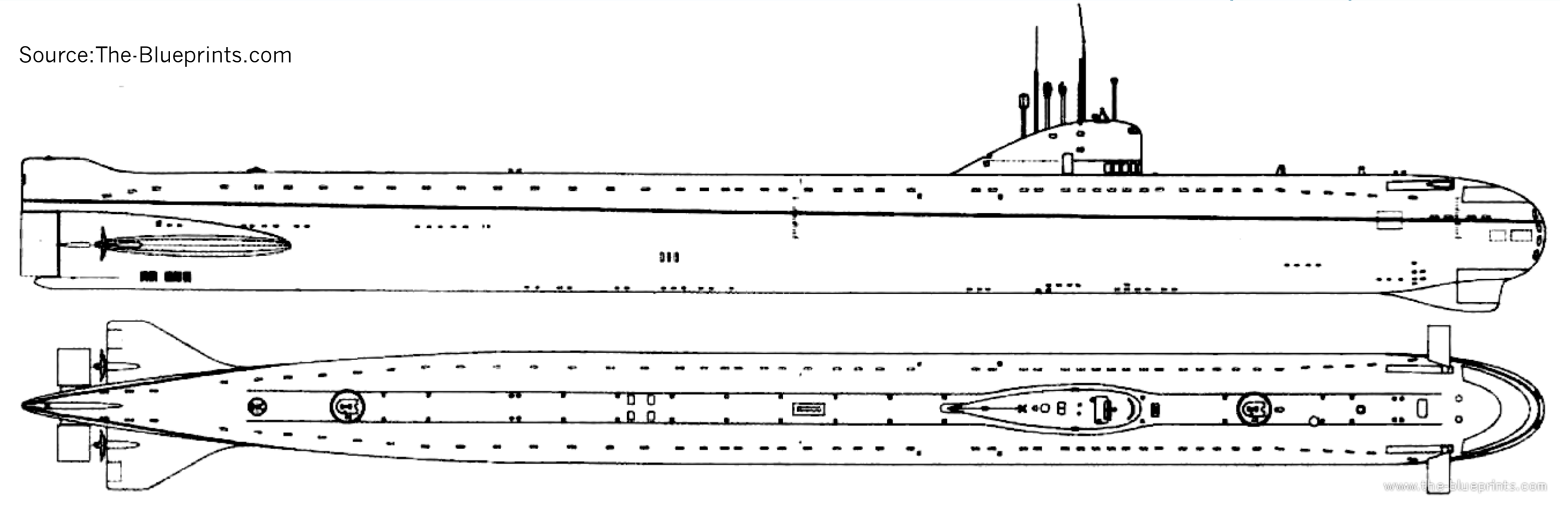
Source: AD Baker, III

Note: Also refer to Polmar, Norman & Kenneth J. Moore; 2004; Cold War Submarine, The Design and Construction of US 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 the 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 (19 – 25 miles)
  - 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 (Kit)

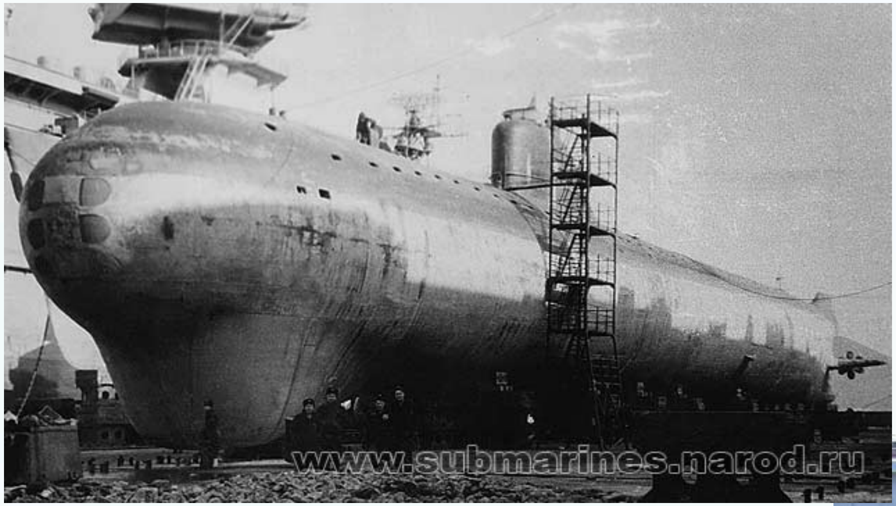
## November-class fast attack submarines (SSN)




- 4 July 1958: Project 627 submarine K-3, *Leninsky Komsomol*, was the 1st Soviet vessel to be underway on nuclear power (almost 3-1/2 years after *USS Nautilus*).
  - K-3 was the only Project 627 boat. The other November-class boats were more combat-capable Project 627A boats equipped with the same combat system as the Project 641 Foxtrot-class diesel-electric subs.
  - All Project 627 / 627A boats were designed by SKB-143 (now Malakhit Central Design Bureau, St. Petersburg). V. N. Peregudov was the submarine chief designer. These boats all were built at Soviet Shipyard No. 402 (now SEVMASH), Severodvinsk, and commissioned from 1959 to 1964.
  - Project 627 / 627A boats shared common nuclear propulsion plant and design features with Project 658 Hotel-class SSBNs and Project 659 / 675 Echo I / Echo II SSGNs (collectively known as the HEN-class).
- 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

# Project 627, 627A

## November-class fast attack submarines (SSN)




November-class boat in drydock.  Source: www.submarines.narod.ru

Armament:

- 8 x 533 mm (21 in) bow torpedo tubes
- Storage for 20 torpedoes or a greater number of mines.

Operational matters:

- In February 1968, the performance of a Soviet November-class sub surprised the US Navy when it was able to intercept and trail a high-speed carrier strike group led by the nuclear-powered aircraft carrier *USS Enterprise* (CVN-65), which was enroute to Vietnam.
- November-class subs were much noisier than their US counterparts.
- All were retired between 1987 – 1990, with an average service life of 27.1 years.

November-class boat in drydock.  Source: www.reddit.com/r/WarshipPorn/

# Leninsky Komsomol (K-3)

## 1st Soviet nuclear vessel & 1st Soviet 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.




Source, stamp image: https://en.wikipedia.org/

Source, two photos: rusnavy.com/history

# Leninsky Komsomol (K-3)

## 1st Soviet nuclear vessel & 1st Soviet sub to reach the North Pole

- September 1967: A fire that started in a hydraulic system spread through two bow compartments before it was extinguished by a $CO_2$ system. A total of 39 crew members died in the fire, most from suffocation after the $CO_2$ system discharged.
- K-3 performed 14 long-range cruises and covered 128,443 miles over 30 years of service (1958–1988).
- K-3 sat idle from 1988 to 2006 when she was moved from Gremikha to Nerpa Shipyard for decontamination and reactor compartment removal.
- 2014: Rosatom & Ministry of Defense agreed to make K-3 into a museum ship. It could be locate in Murmansk harbor at the same pier as the icebreaker Lenin, which also is a museum ship.

K-3 *Leninsky Komsomol* in drydock at the Nerpa shipyard with the much larger Oscar II K-148 *Krasnodar*, lead ship for the Oscar II class of SSGNs, which was being scrapped (circa 2012 – 2014). Source: https://www.reddit.com

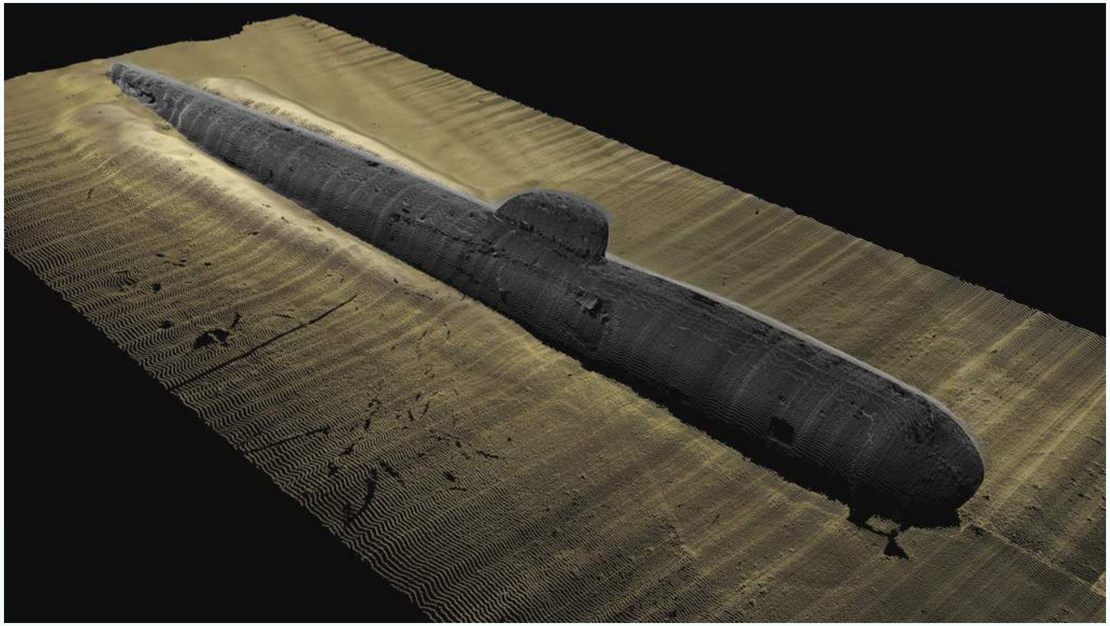
K-3 after cuts in the hull were made to remove the reactor compartment. Source: http://www.subsim.com/radioroom/

# B-159 sinking in the Barents Sea

(former November-class K-159)

Source: bellona.ru

# B-159 sinking in the Barents Sea



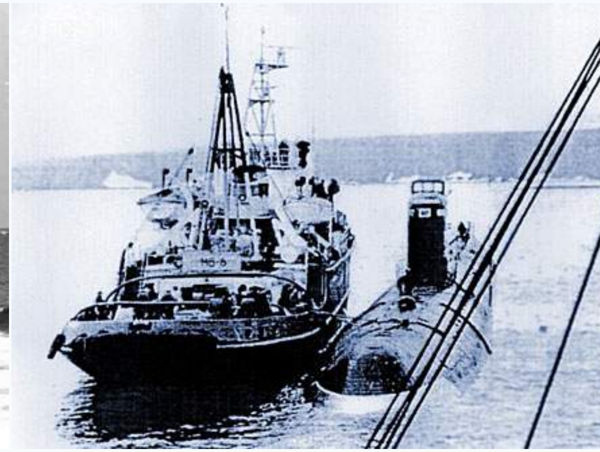
Visualization of multi-beam sonar data of B-159 from 2007 ADUS survey

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

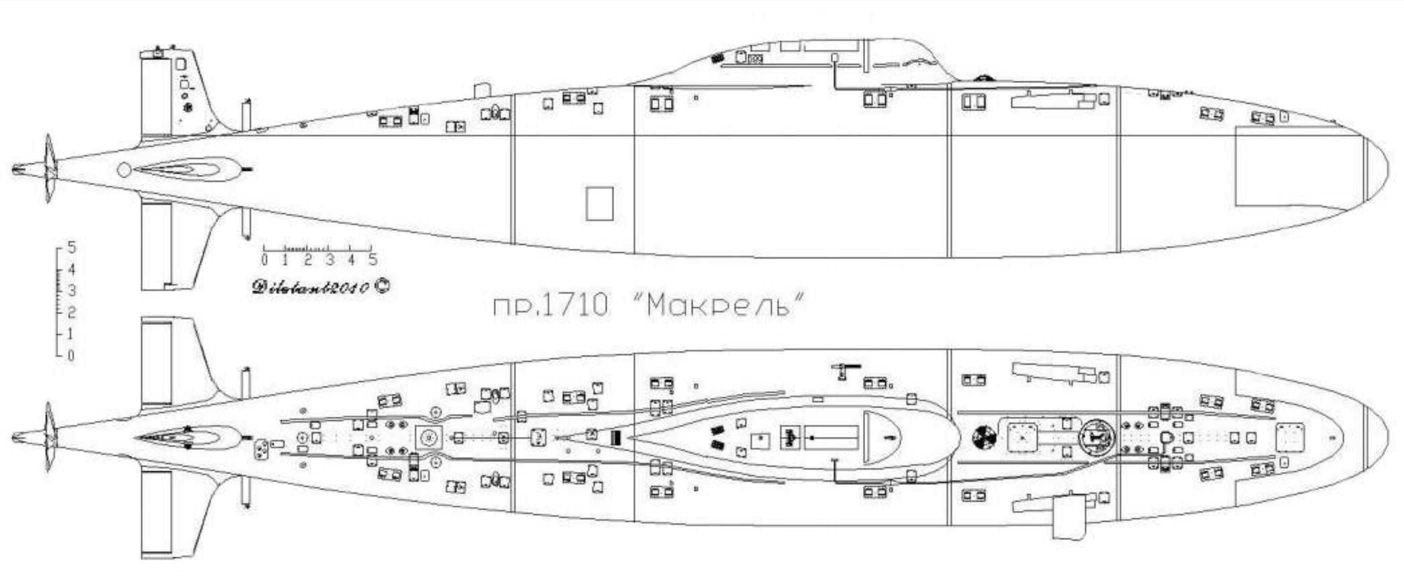
- One-of-a-kind submarine designed by SKB-143 (now Malakhit Central Design Bureau) to test a liquid metal-cooled reactor installed in a Project 627A November-class hull.
- Propulsion:
  - 2 x Gidropress VT-1 liquid metal-cooled (lead-bismuth eutectic) reactors, each rated @ 72 MWt.
  - High-pressure secondary steam would leak through the steam generators into the primary system, where it would oxidize the liquid metal coolant and create a "sludge", requiring frequent cleaning of oxide particles from the coolant.
  - 2 x steam turbines with a combined rating of 35,000 shp, 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 but never operated again.
  - The sub was scuttled on 6 Sep 1982 in shallow water in the Kara Sea, off the east coast of Novaya Zemlya.

# 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



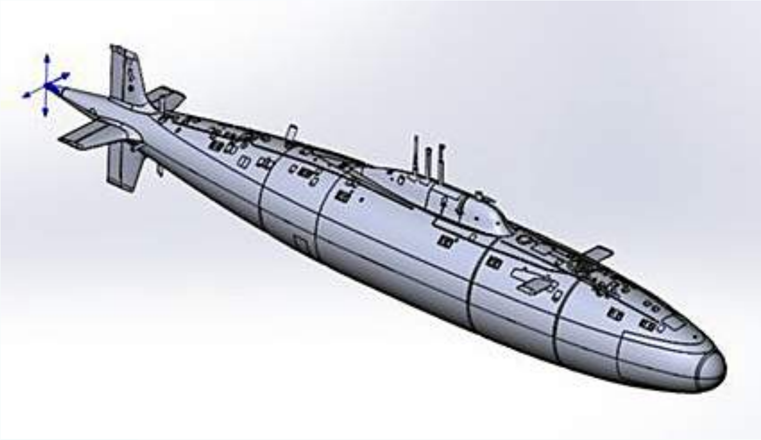
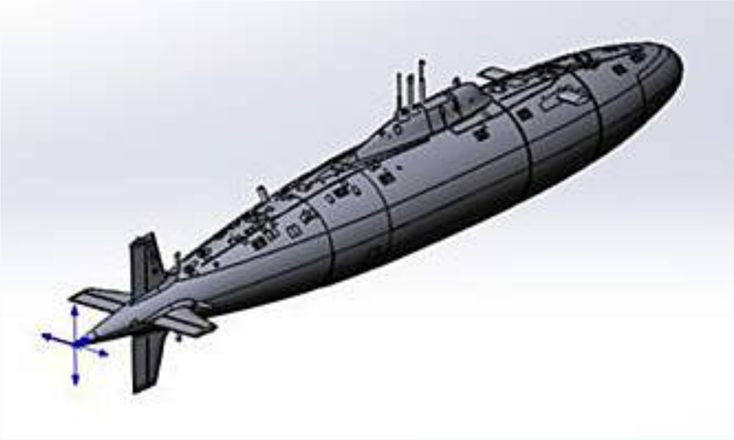

Source: adapted from https://forum.sub-driver.com/forum/

| Project | Class | # in Class | Length | Beam | Displacement (tons) | Max speed | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|
| 1710 | Mackerel (Beluga) | 1 | 62-65.5 m (203.4-214.9 ft) | 8.7 m (28.5 ft) | 1,400 (surf) 1,900 (sub) | 26.6 kts | 1987 | 1987 – 97 |

- Experimental high-speed sub developed by Malakit Design Bureau.
- Built in St. Petersburg, commissioned in 1987 and transferred via an inland waterway for testing in the Black Sea.

# Project 1710 Mackerel

## Beluga diesel-electric experimental sub S-533

Source: https://www.britmodeller.com/

- Submarine 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 *USS Albacore* diesel-electric experimental sub, which entered service the US in 1953 and tested the streamlined teardrop-shaped hull before it was introduced to the US nuclear submarine fleet. In contrast, *Beluga* was commissioned about two decades after the teardrop-shaped hull first appeared on the Soviet Victor I-class SSNs introduced in 1967.
- *Beluga* was decommissioned and scrapped in 2002.

# Project 1710 Mackerel

## Beluga diesel-electric experimental sub S-533

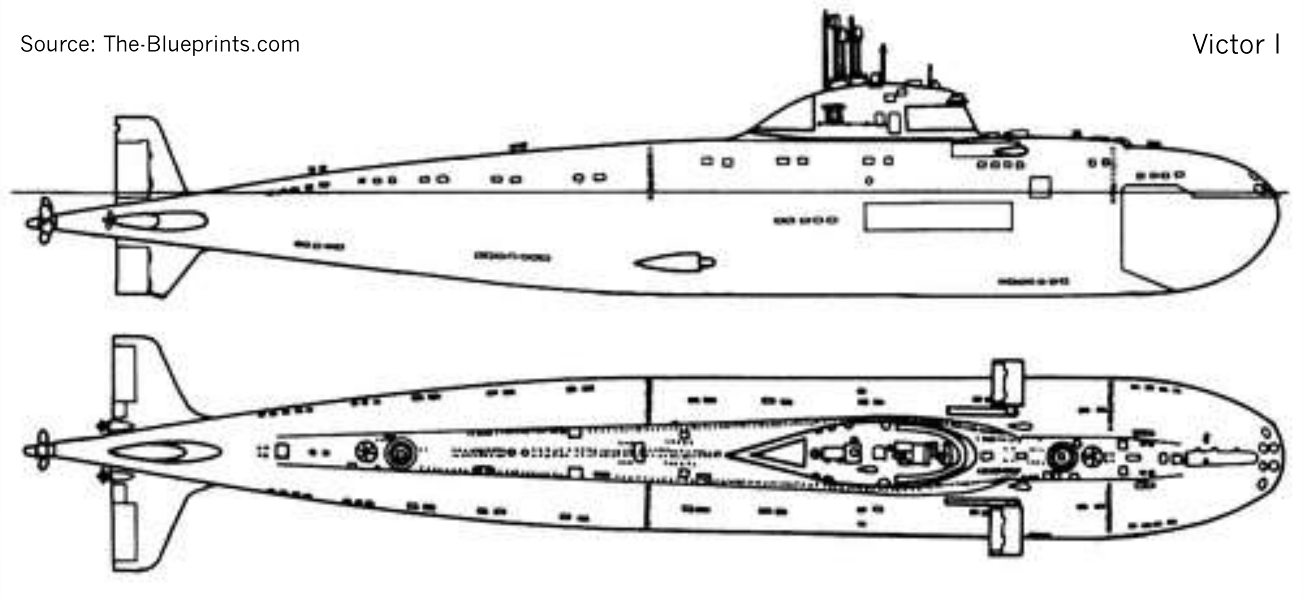
Above: This side view highlights the small sail.

Right: Project 1710 S-533 tied up alongside a Foxtrot-class diesel-electric sub.

Source, both photos: http://roteflotte.de/

# Project 671(Yorsh), 671RT (Syomga) & 671RTM / RTMK (Shchuka)

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




- Victor-class SSNs were designed by the Malakhit Central Design Bureau, St. Petersburg, as the successor to the November-class SSNs.
  - The Victor-class SSNs were the 1st Russian nuclear subs with a teardrop-shaped hull.
  - They shared common nuclear propulsion plant and design features with Project 670 Charlie-class SSGNs (collectively referred to as the Charlie/Victor-class).
- 43 Victor-class SSNs were built in three models, in three shipyards: Sudomekh Shipyard, St. Petersburg (merged with Admiralty Shipyard in 1972); Krasnoye Sormovo Shipyard, Nizhny Novgorod; and Leninskiy Komsomol Shipyard, Komsomolsk-on-Amur (Far East).
  - 15 x Project 671 Victor I SSNs were commissioned between 1967 – 1974.
  - 7 x Project 671RT Victor II SSNs were commissioned between 1972 – 1978.
  - 21 x Project 671RTM & 5 x 671RTMK Victor III SSNs were commissioned between 1977 – 1992.

# Project 671(Yorsh), 671RT (Syomga) & 671RTM / RTMK (Shchuka)

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

- 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, with various propeller configurations
  - Two small, two-blade propellers are fitted on the stern planes for slow-speed operation.
- Armament:
  - Victor I:
    - 6 x 533 mm (21 in) bow torpedo tubes; stowage for 18 weapons (torpedoes, cruise missiles, or a larger number of mines, including the nuclear-armed E53-65K torpedo).
  - 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.
    - 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 for use against large enemy vessels (e.g. aircraft carriers) that may not sink if hit by one normal-sized (533 mm / 21 in) torpedo.
    - The 650 mm torpedo tube can be fitted with a 533 mm converter to enable firing smaller size torpedoes and missiles.

# Project 671(Yorsh), 671RT (Syomga) & 671RTM / RTMK (Shchuka)

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

- Operational matters:
  - Victor-class subs were contemporary of the US Sturgeon (637)-class SSN; faster, but the earlier Victor I and II models had greater radiated noise.
    - While Victor II subs were being was, information from the Walker spy ring identified the acoustic vulnerability of the Victor-class SSNs. As a result, construction of Victor II SSNs ceased and construction was redirected to the improved Victor III.
    - Victor III was the 1st Soviet submarine to incorporate "rafting" of machinery to improve the isolation of these sound sources from the hull. The Victor III hull was lengthened by nearly 6.1 meters (20 feet) to accommodate the revised equipment layout needed for "rafting".
  - Victor III also was the 1st Soviet operational submarine with a teardrop-shaped pod on top of the tail fin for handling a towed array sonar. This feature is not on Victor I and II boats.
    - This towed array sonar system and teardrop-shaped pod was tested on the Project 667AK Akson-1 (Yankee-Pod) test submarine, which was a converted Yankee I SSBN.
  - All Victor I and II SSNs were retired by 1997. Average Victor I service life was 26.0 years, and average Victor II service life was 19.2 years.
  - 22 Victor III SSNs were retired between 1996 – 2013. The majority (18) were retired between 1996 – 2000, with an average service life of 16.9 years.
  - Three Victor III subs are believed to remain in active service in 2018: B-138, B-414 and B-448. These were the last three Victor III subs built, all Project 671RTMK boats commissioned between 1990 – 1992, and now with service lives averaging 27 years.
    - B-138, *Obninsk*, was overhauled and modernized between 2014 – 2016.

# Project 671RTM / RTMK

## Victor III-class SSN

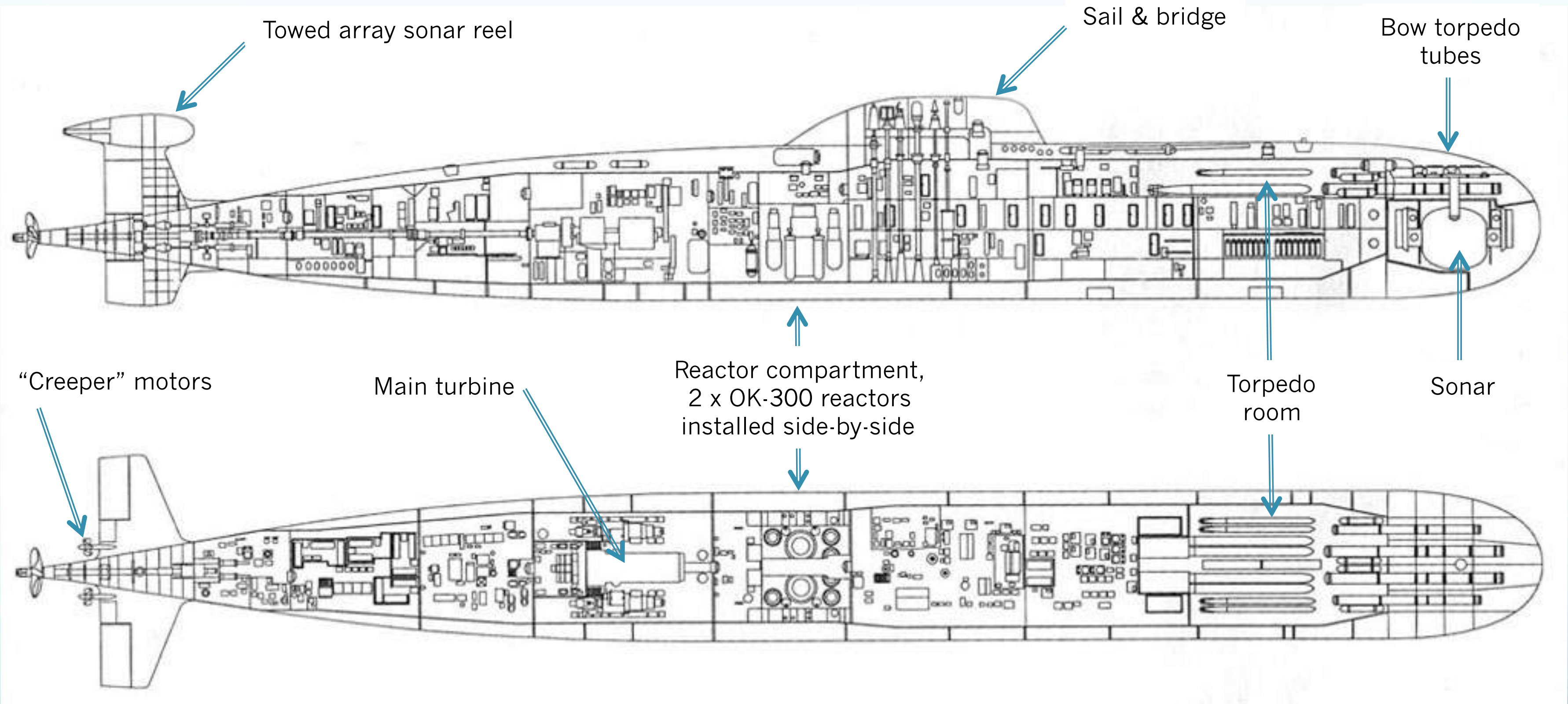
Victor III K-324 on the surface in October 1983 with a Moma class survey vessel and US Spruance-class destroyer USS Peterson (DD-969) after K-324 damaged its propeller on the towed array sonar of another US Navy ship near Bermuda. Source: https://www.reddit.com/r/WarshipPorn/

Victor III. Source: https://regnum.ru/pictures/2102112/17.html

Victor III. Source: en.wikipedia.org

# Project 671RTM / RTMK

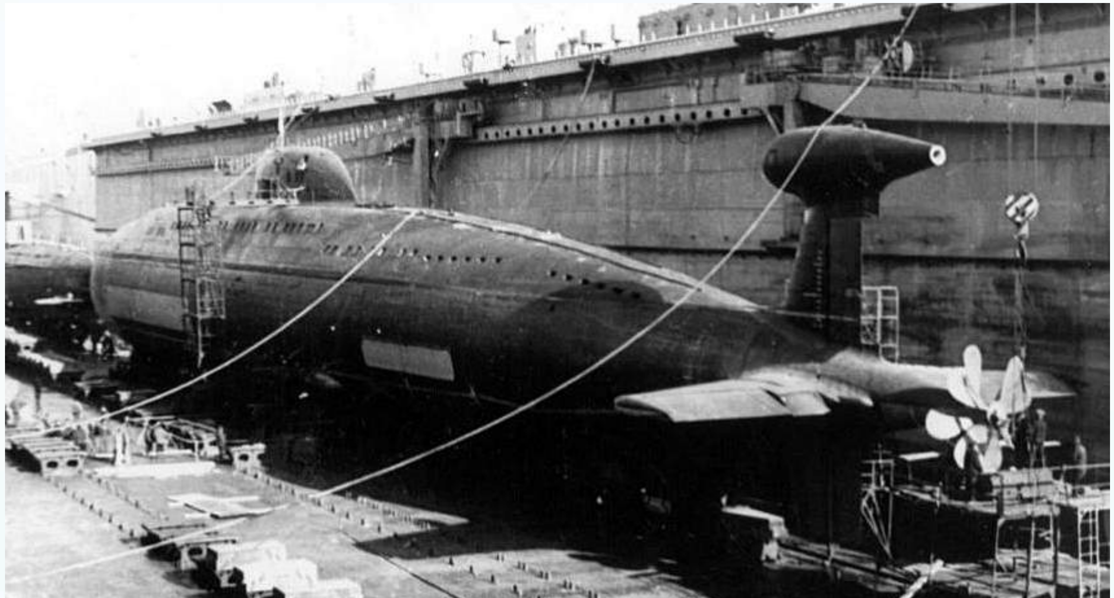
## Victor III-class SSN notional arrangement




Source: warfare.be

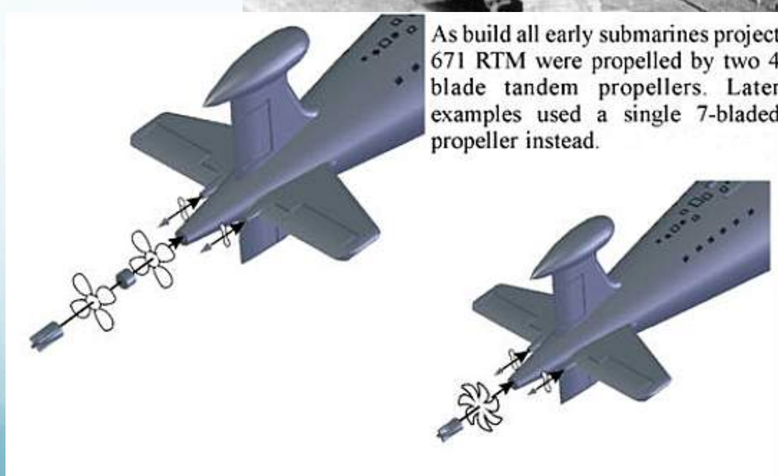
# Project 671RTM / RTMK

## Victor III in drydock

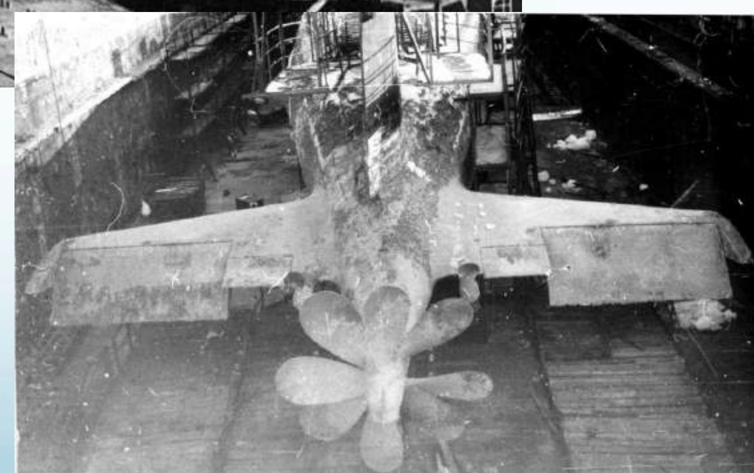


Project 671RTMK Victor III B-414 *Danil Morisovisky* in drydock showing tandem 4-bladed propellers. Source: subsim.com

Victor I and II SSNs were fitted with five-bladed propellers.



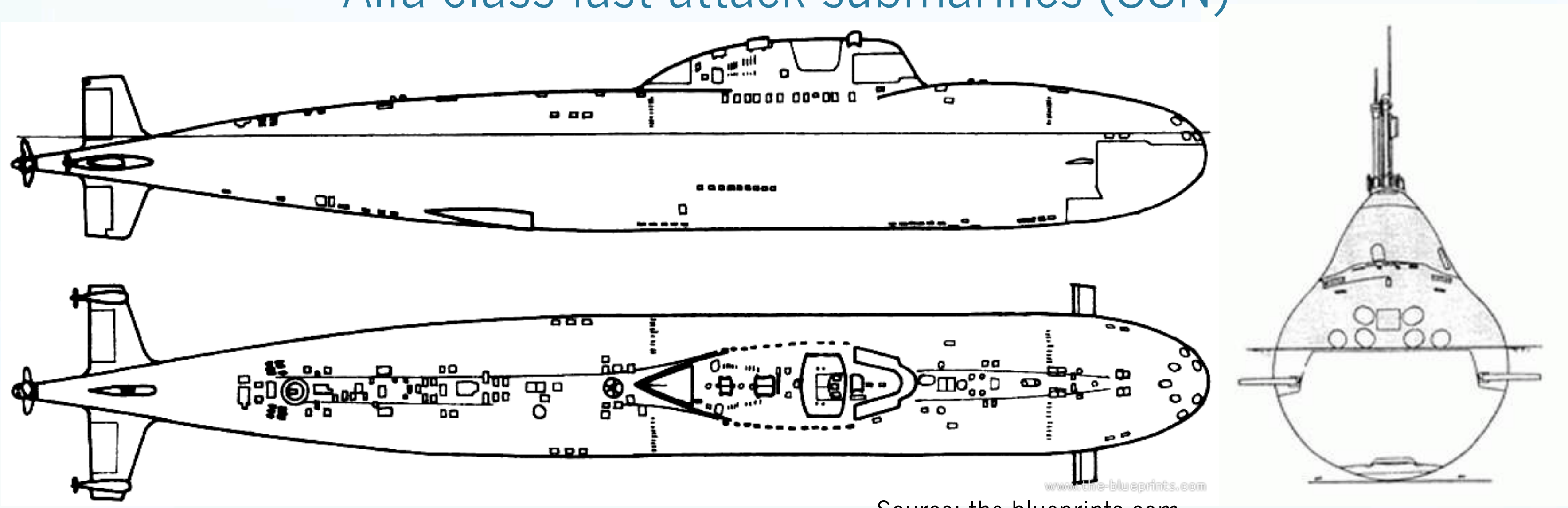

Source: http://www.steelnavy.net/OKBGrigorovVictorsFBustelo.html



Tandem 4-bladed propellers. Source: http://www.shipmodels.info/

# Project 705 & 705K (Lira)

## Alfa-class fast attack submarines (SSN)




Source: the-blueprints.com

- The Alfa-class SSN was designed by the Malakhit Central Design Bureau, St. Petersburg.
  - 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 Gidropress BM-40A lead-bismuth cooled reactor rated @ 155 MWt
  - 2 x steam turbines delivering a total of 40,000 shp to a single shaft; also 2 x 75 shp “creeper” electric motors on horizontal fins for low-speed propulsion
  - Capable of a maximum speed of about 41 kts.

# Project 705 & 705K (Lira)

## Alfa-class fast attack submarines (SSN)

- Titanium hull; maximum operating depth was 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 US SUBROC).
- Operational matters:
  - The Alfa class attack submarine had a crew of only about 30, all officers, due to the extensive use of automation.
  - The Alfa subs required a steam supply from an external source to heat the primary system and 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 typically 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.
  - The last Alfa sub, Project 705K boat K-123, was decommissioned in 1996.

# Project 705 & 705K (Lira)

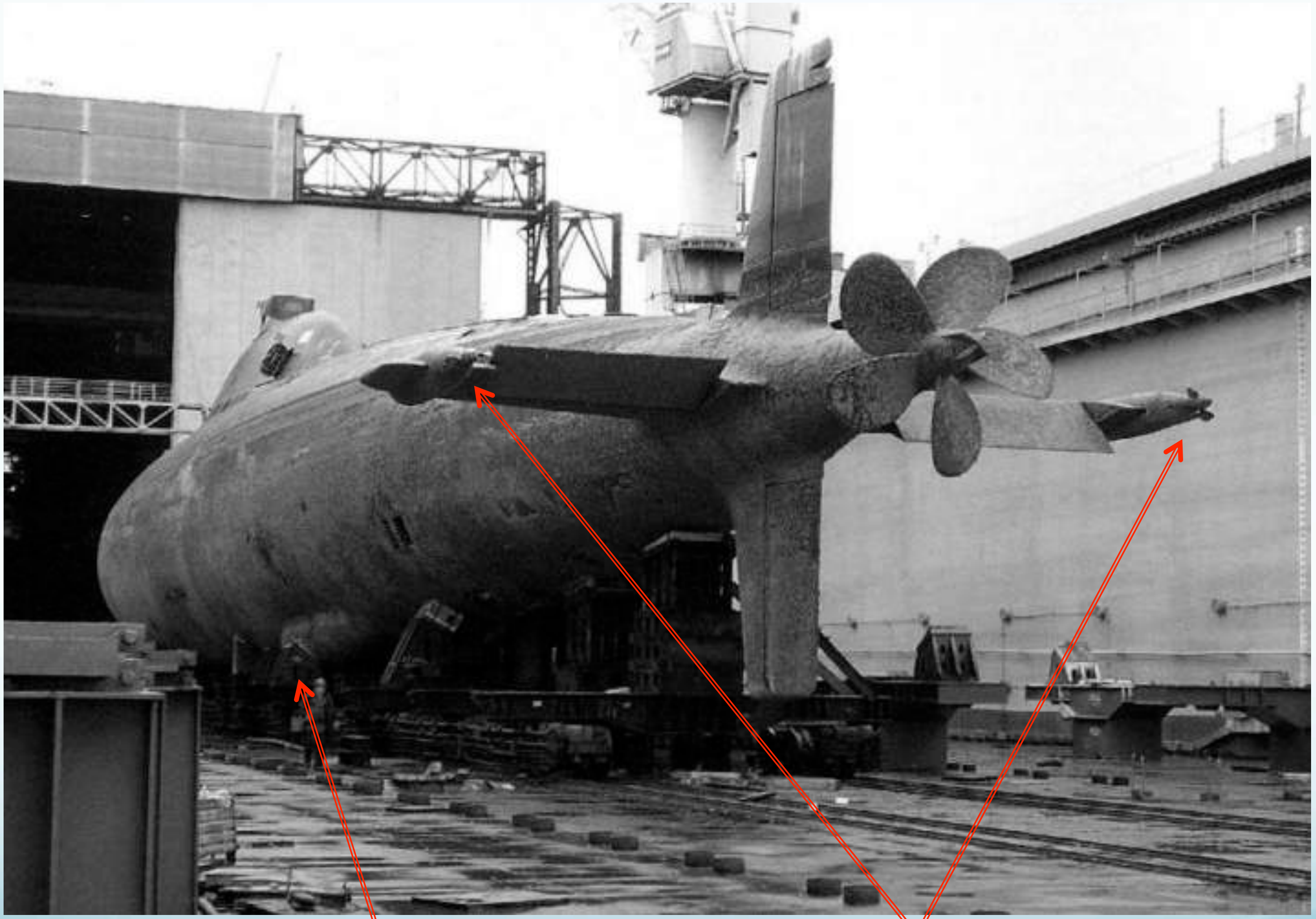
## Alfa-class fast attack submarines (SSN)

- 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 liquid metal coolant 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

# Alfa-class SSN in drydock

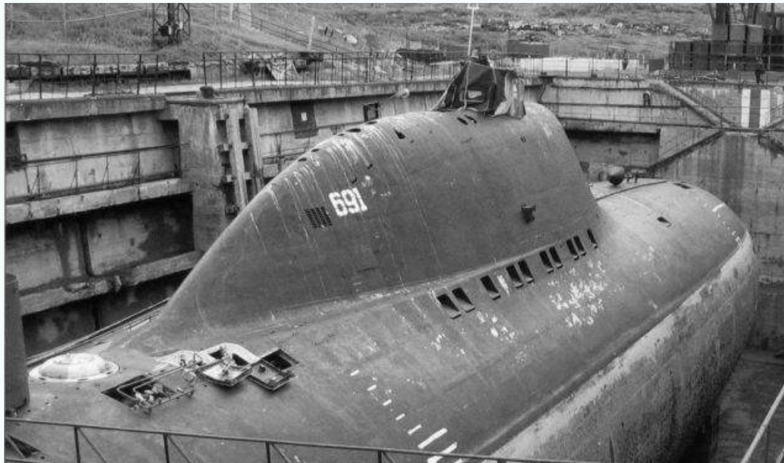


Source: subsim.com

Seawater induction scoop

“Creeper” motors

# Reactor removal from a decommissioned Alfa-class sub

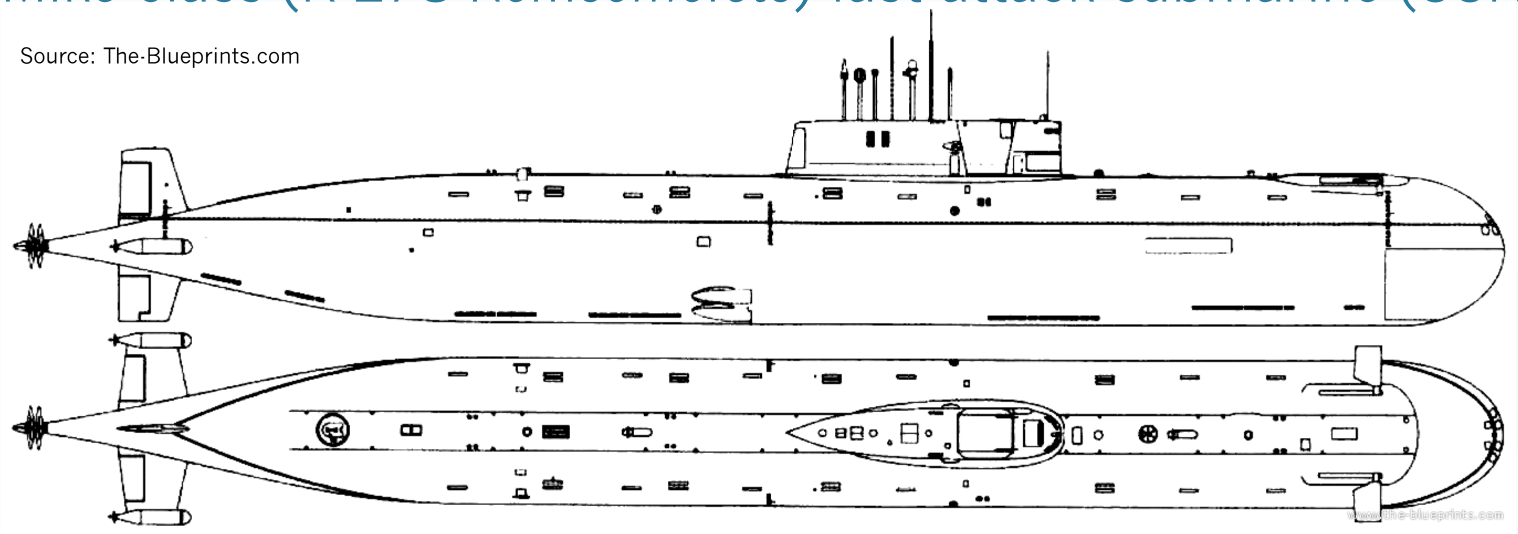



Source, photo top left:
http://foxtrotalpha.jalopnik.com

Reactor removal in a dedicated dry-dock (SD-10) in Gremikha using special equipment provided by French CEA.
Source, three photos: http://defence.pk/

# Project 685 (Plavnik)

## Mike-class (K-278 *Komsomolets*) fast attack submarine (SSN)



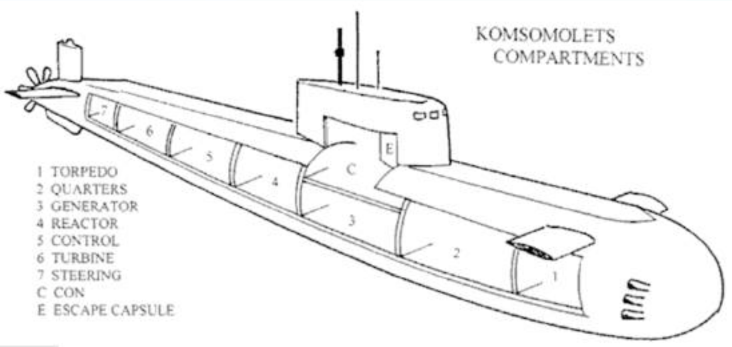

- One-of-a-kind SSN designed by Rubin Central Design Bureau, St. Petersburg, and built at the SEVMASH Shipyard in Severodvinsk.
  - Developed to test technologies for Soviet 4th generation nuclear submarines.
  - Double hull construction with a titanium inner hull comprised of seven compartments.
  - Very deep-diving, achieving a depth of 1,022 m (3,350 ft) on 4 August 1984. The K-278 received its name, *Komsomolets,* as an honor for this achievement.
  - Solid fuel gas generating system for rapid emergency surfacing. Emergency crew escape capsule in the sail.
  - Highly automated, enabling a small crew (initially 57, later increased to 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 with two tandem 4-bladed propellers, similar to Victor III.
  - 2 x electric “creeper” motors on the horizontal fins for slow speed operations.

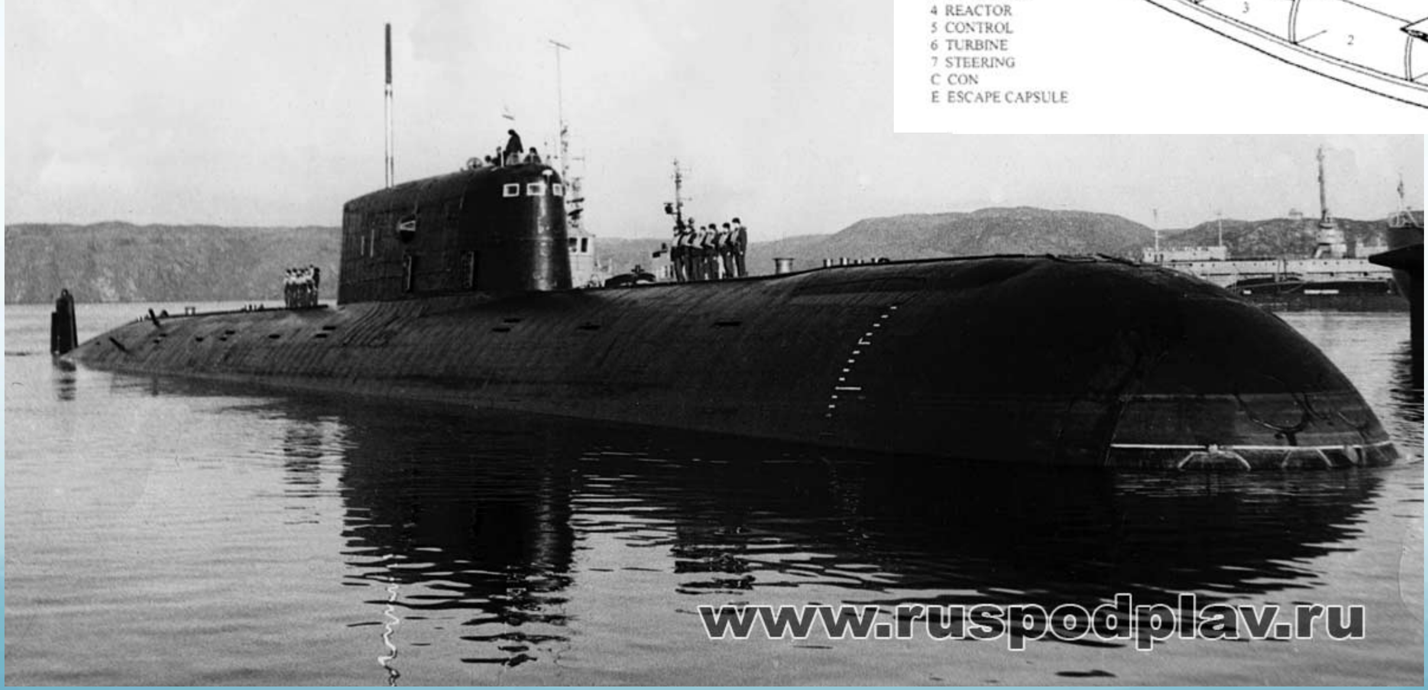
# Project 685 (Plavnik)

## Mike-class (K-278 *Komsomolets*) fast attack submarine (SSN)

- Armament: 6 x 533 mm bow torpedo tubes.
- Operational matters:
  - On 7 April 1989, K-278 had an accident at sea on her first mission and sank to a depth of 1,680 meters (5,510 ft) in the Barents Sea.

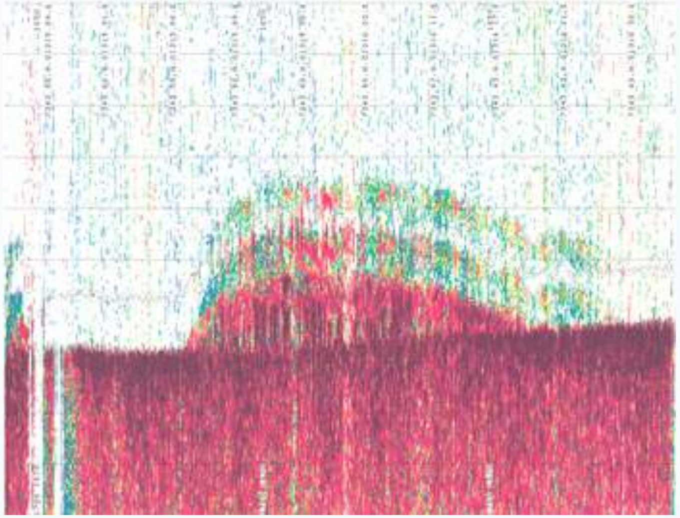
Source, right: https://www.extremetech.com/



# Mike K-278 fire and sinking in the Barents Sea

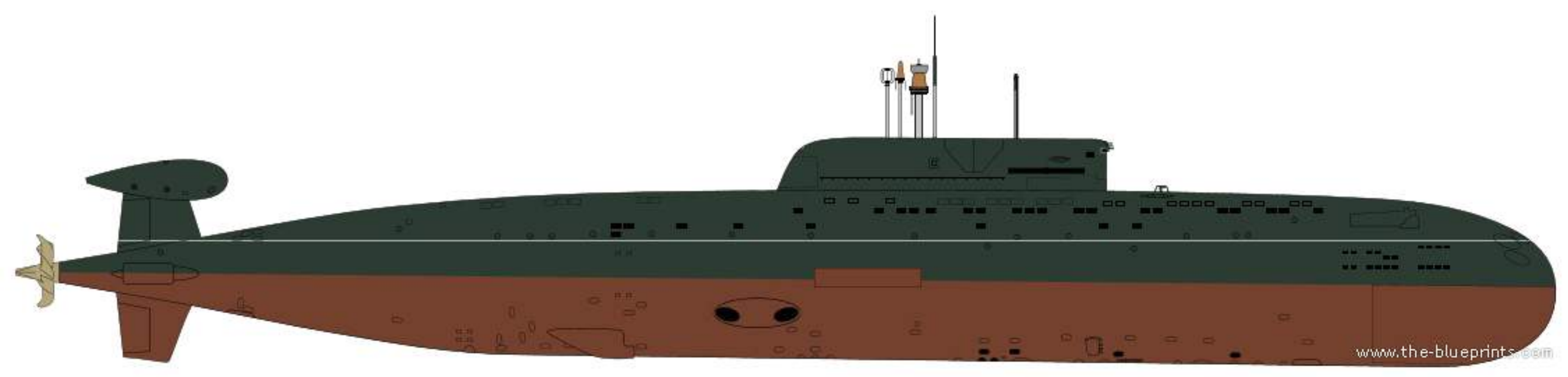
- 7 April 1989 accident sequence:
  - *K-278 Komsomolets* had a fire in its engineering compartment during the first operational patrol. Watertight doors were closed, ventilation shutdown, but fire spread by burning through bulkhead cable penetrations, and possibly from electrical short circuits.
  - 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,, both graphics: Havforskningsinstitutte, Bergen

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

# Project 945 (Barrakuda), 945A (Kondor) & 945B (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 US counterparts, to 550 meters (1,800 feet).
  - Specifically developed for search and destroy missions against US nuclear submarines.
  - Generally comparable in performance to early US Los Angeles class SSNs.
- Four Sierra-class SSNs were built at the Krasnoye Sormovo Shipyard, Nizhny Novgorod
  - 2 x Sierra I SSNs have a large pod in the stern fin for a towed array sonar system. One large emergency escape pod for the entire crew is housed in the sail.
  - 2 x Sierra II SSNs have a larger sail for two emergency escape pods and a larger pod in the stern fin. Sierra II also incorporated improved quieting and sonar and revised torpedo tubes.
  - 1 x Sierra III SSN was laid down in March 1990 but was not completed. Originally, five boats were planned. Sierra III was intended to have the *Irtysh/Amfora* spherical bow sonar array, flank arrays, and associated sonar signal processing systems tested on the Project 09780 Akson-2 Yankee Bignose. The incomplete Sierra III was scrapped in 1993, but its sonar and signal processing systems appear to have been developed for the Project 885 Yasen SSNs.

# Project 945 (Barrakuda), 945A (Kondor) & 945AB (Mars)
## Sierra I, II and III-class fast attack submarine (SSN)

- Propulsion:
  - OK-650B: 1 x PWR rated @ 190 MWt
  - 1 x steam turbine rated @ 36,500 hp; driving 1 shaft with a titanium propeller.
- Armament:
  - Sierra I: 4 x 650 mm (26 in) and 4 x 533 mm (21 in) bow torpedo tubes with storage for 40 weapons (torpedoes, anti-submarine missiles, anti-ship cruise missiles, or a greater number of mines).
  - Sierra II: 6 x 533 mm (21 in) bow torpedo tubes.
- Operational matters:
  - 11 February 1992: Sierra I K-276, *Kostroma*, collided with the US Los Angeles Flight I-class *USS Baton Rouge* (SSN-689) off Kildin Island, in the Barents Sea north of Murmansk. Both SSNs were able to return to their respective ports for repairs and both returned to service.
  - Both Sierra II boats have been overhauled:
    - *Nizhniy Novgorod*, B-534, completed its overhaul in 2008, 18 years after being commissioned in 1990.
    - *Pskov*, B-336, completed its overhaul in 2015, 22 years after being commissioned in 1993.
  - In April 2015, Russian Navy's commander-in-chief, Admiral Vladimir Chirkov, announced plans to modernize 10 SSNs by 2020, including the two Project 945 Sierra I boats, which now are being overhauled and modernized under Project 945M at the Zvezdochka Shipyard in Severodvinsk.
    - The three year overhaul includes mechanical and electrical system repairs and replacement and reactor refueling. The submarines also are expected to receive a new sonar system, a GLONASS satellite navigation system, and a new combat information management system that will enable these subs to employ modern cruise missiles like Kalibr and Zircon.

# Project 945 & 945A

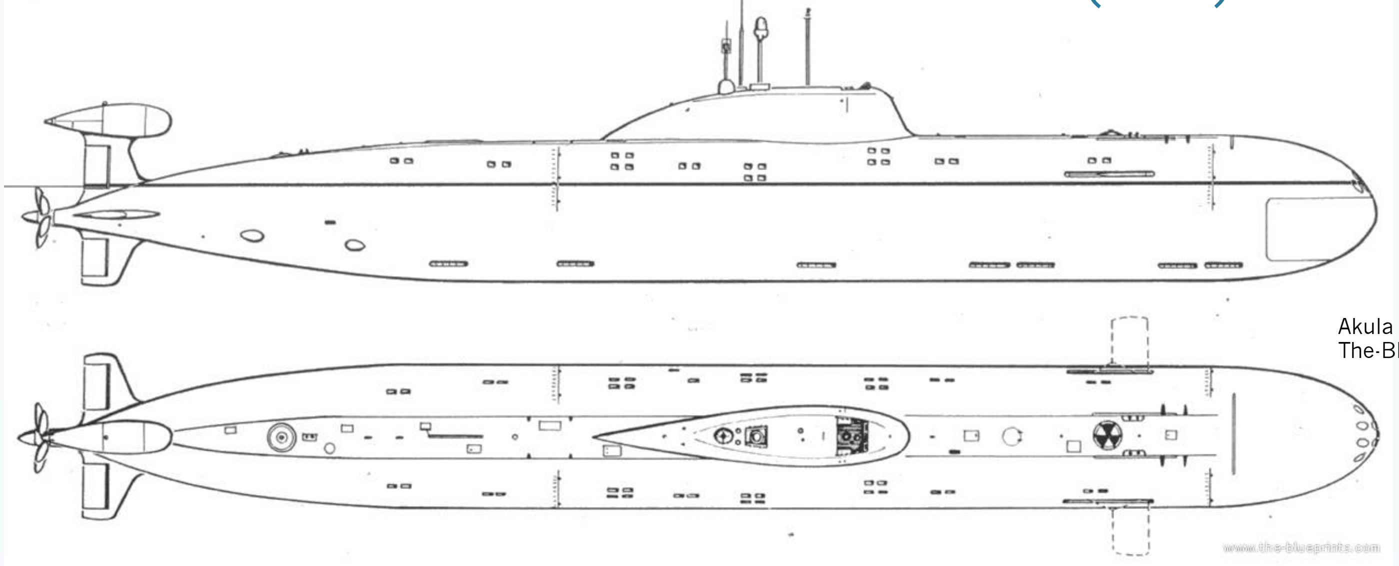

Sierra I SSN *Kostroma* escape capsule in the the sail
Source: forum.keypublishing.com


Above, Sierra I *Kostroma*. Source: http://www.military-today.com/navy/sierra_1_class.htm


Sierra II with larger, blunt sail. Source: http://carllavo.blogspot.com/

# Project 971 (Shchuka-B)

## Akula-class fast attack submarines (SSN)




Akula I. Source: The-Blueprints.com

- The steel-hulled Akula SSNs were designed by the Malakhit Central Design Bureau, St. Petersburg.
- 15 Akula SSNs were produced in two shipyards: SEVMASH Shipyard in Severodvinsk and Leninskiy Komsomol Shipyard in Komsomolsk-on-Amur (in Russia's Far East).
  - 7 x Akula I (Project 971) boats were commissioned between 1984 and 1990. Decommissioned Akula I K-480 was reconstructed as a Project 955 Borei SSBN.
  - 6 x Improved Akula I (Project 971I) boats were commissioned between 1991 to 2009. One incomplete Improved Akula I hull, K-152 (ex-Nerpa), was completed and leased to India from 2012 to 2022.
  - 1 x Akula II (Project 971U): K-157 *Vepr* is the only completed Akula II, commissioned in 1995. Two incomplete Akula II hulls, K-333 & K-337, were reconstructed as Project 955 Borei SSBNs.
  - 1 x Akula III (Project 971M): K-335 *Gepard* is the only completed Akula III, commissioned in 2001. At the time it was the most advanced Russian submarine before the Yasen-class SSN.

# Project 971 (Shchuka-B)

## Akula-class fast attack submarine (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.
- Armament:
  - 4 x 533 mm (21 in) bow torpedo tubes and stowage for 28 weapons
  - 4 x 650 mm (26 in) bow torpedo tubes and stowage for 12 weapons
  - Improved Akula & Akula II have additional 533 mm (21 in) bow torpedo tubes mounted external to the pressure hull, capable of launching decoys.
- Operational matters:
  - Akula SSNs incorporate substantial improvements in sonar performance and radiated noise reduction, and were the 1st Soviet subs to use a "skew-back" propeller for quieter operation.
  - Extensive use of automation enables a small crew of about 50, which is less than one-half the size of a crew on a comparable US SSN.
  - In early 1995 then Chief of Naval Operations Admiral Jeremy Boorda, speaking to the Senate Armed Services Committee made the following comment on the Akula SSNs:  "At tactical speeds (less than six or seven knots) the Akula is quieter than the 688 (Los Angeles-class) and is very difficult for us to detect……There are six Russian improved Akulas that are a match—better than a match—for our 688i."
  - Akula SSN deployments to the western Atlantic apparently have resumed after the Cold War:
    - 2009: First known Russian submarine deployments to the western Atlantic since the end of the Cold War. The submarines were identified as Akula-class SSNs.
    - 2012: An Akula-class SSN reportedly operated in the Gulf of Mexico undetected for over a month.

# Project 971 (Shchuka-B)

## Akula-class fast attack submarine (SSN)

- Operational matters (cont'd):
  - In April 2015, Russian Navy's commander-in-chief, Admiral Vladimir Chirkov, announced plans to modernize 10 SSNs by 2020, including several Project 971 boats.
  - India has leased two Akula SSNs from Russia:
    - Former Project 971I Improved Akula K-152, *Nerpa,* was leased for 10 years, 2011 – 2021.
    - In Dec 2014, India agreed to a 10-year lease for Project 971 Akula K-322, *Kashalot*, which will be overhauled and modernized prior to delivery in 2018.
  - As of early 2018, it appears that 11 Akula-class SSNs are either active in the Russian Navy or are undergoing a modernization overhaul for the Russian Navy.

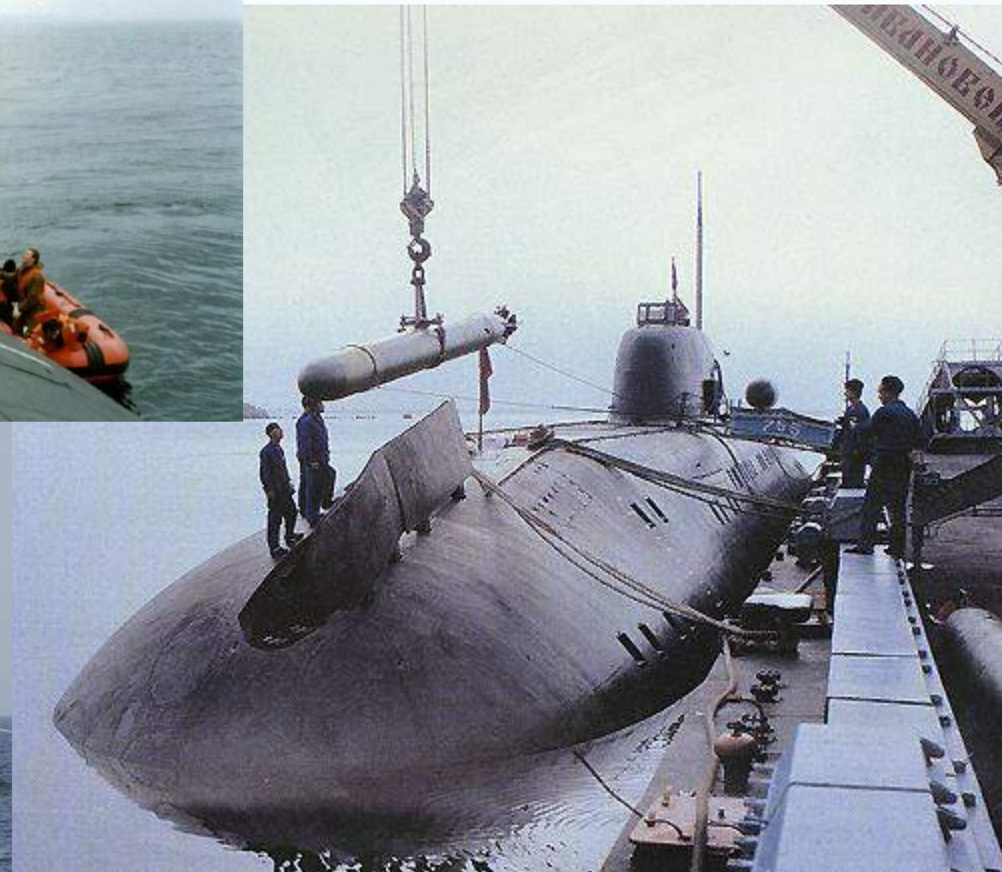
Source: www.subsim.com

# Project 971 (Shchuka-B)

## Akula-class fast attack submarine (SSN)

Left: Akula with SOKS deployed.
Source: https://forum.sub-driver.com/forum/

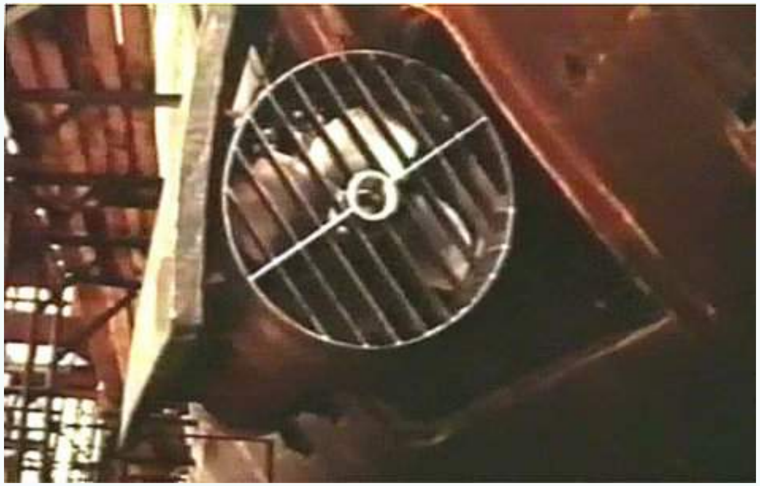
Source: www.china-sd.com



Loading a torpedo on an Akula. Source: www.subsim.com

# 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 the other sub’s sonar range while maintaining contact. Russians have wake homing torpedoes to attack 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

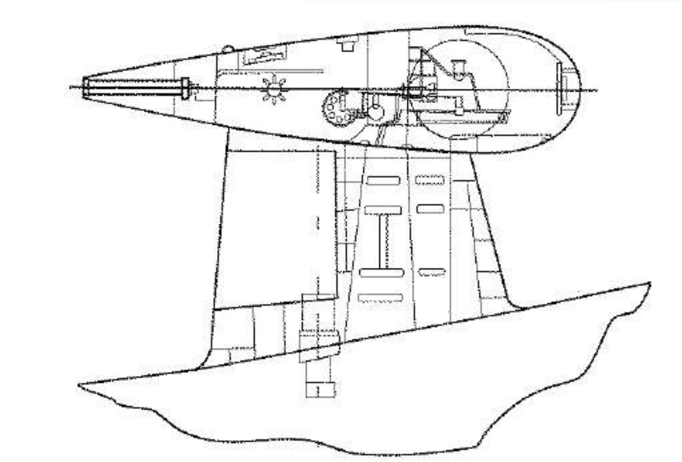
Source: https://battlemachines.wordpress.com/

# 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 skewback propeller with cruciform vortex diffuser at the tip.

Source: www.pinterest.com

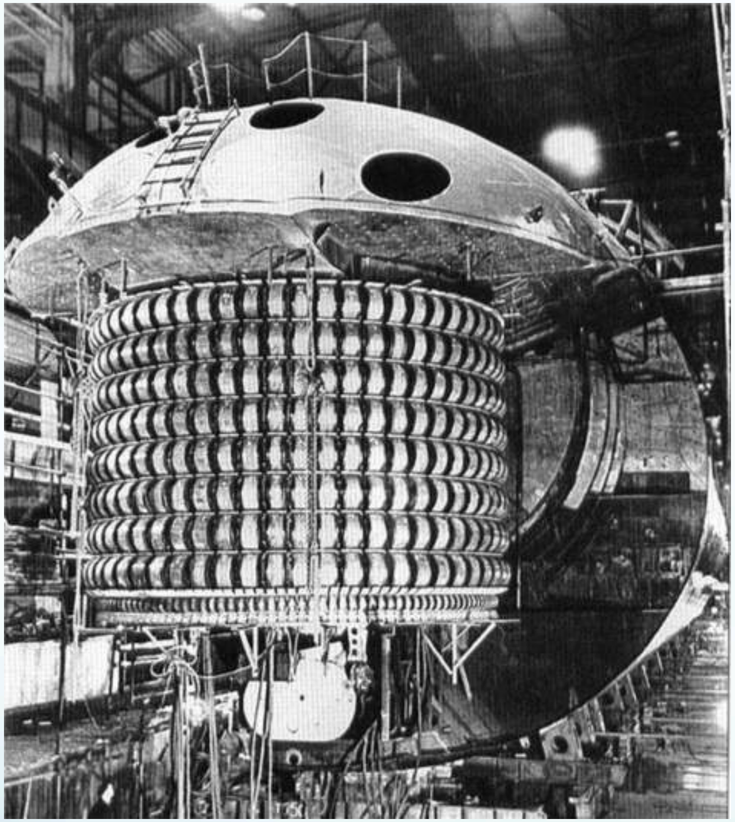
Towed-array sonar pod



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

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

# Russian bow sonar arrays



Typical Russian cylindrical bow sonar array, torpedo tubes above

Damaged Project 971i improved Akula SSN bow dome reveals the cylindrical sonar array. Torpedo tubes are above.

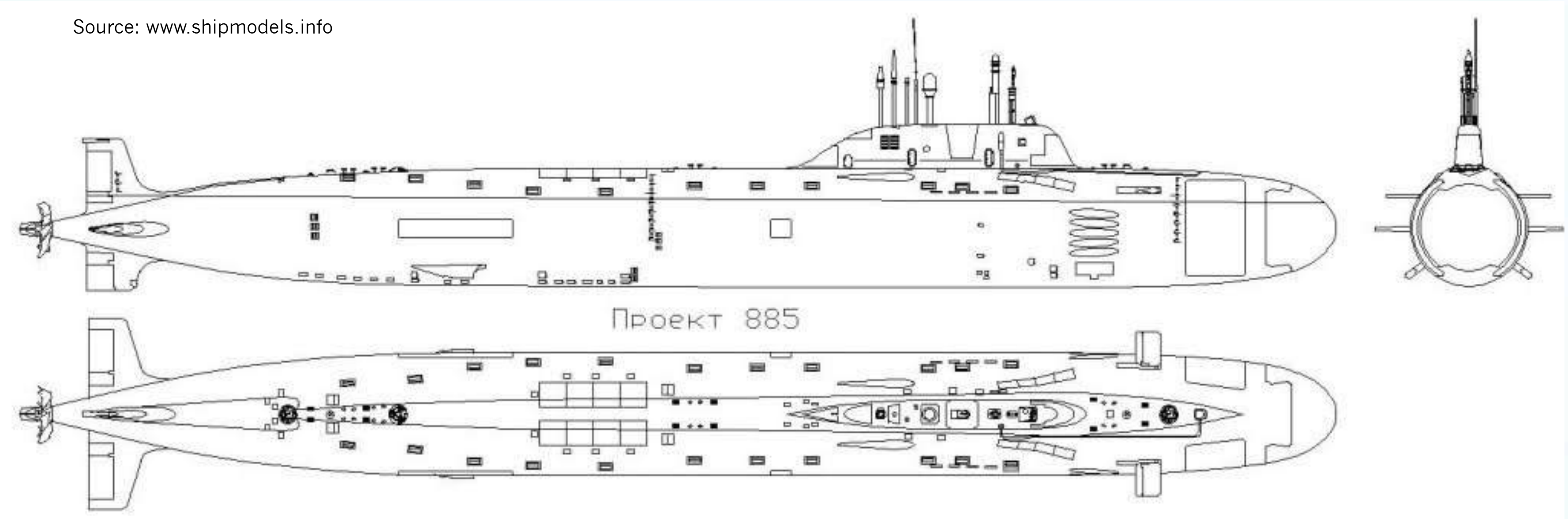
Source: http://www.navyrecognition.com/

Project 667BDRM Delta IV SSBN bow sonar array, torpedo tubes are above

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

# Project 885/885M (Yasen & Yasen-M)

## Multi-purpose submarine




- Designed by Malakhit Central Design Bureau with SSN and SSGN capabilities. Constructed at the at the SEVMASH Shipyard in Severodvinsk.
  - Expected to replace Victor III, Sierra and Akula SSNs as well as Oscar SSGNs.
- The lead ship, *Severodvinsk*, was started in 1993, was delayed for many years due to funding, was launched in 2010, and commissioned in 2013.
- This is the 1st Russian sub class with a spherical bow sonar array, similar to US practice. The sonar suite also includes conformal flank arrays and a retractable towed-array sonar.
  - The spherical sonar, flank arrays, and signal processing systems were developed and tested on the Project 09780 Akson-2 (Yankee Bignose) test submarine. These sonar systems originally were intended for operational use on the Project 945B (Mars) Sierra III SSNs, which were not built.

# Project 885/885M (Yasen & Yasen-M)

## Multi-purpose submarine

- Propulsion:
  - Project 885 Yasen: OK-650V: 1 x PWR rated @ 190 MWt
    - This is an improved version of the 3rd generation OK-650-series PWR that has been widely used in Russian submarines. Core life is expected to be about 15 years.
    - 1 x steam turbine with a rating of about 43,000 shp; driving 1 x conventional propeller
  - Project 855-M Yasen-M: OK-650V: 1 x PWR rated @ 190 MWt
    - The lead Project 885M boat, *Kazan*, is believed to have an OK-650V propulsion plant and is driven by a conventional propeller.
    - A new 4th generation nuclear propulsion plant known as KPM-6 or CTS-6, rated at 200 MWt, was planned for Yasen-class SSNs. However, the new reactor's introduction appears to have been delayed for technical and financial reasons.
- Armament:
  - 10 x midships torpedo tubes: 8 x 650 mm (26 in) and 2 x 533 mm (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 US plans for the future Virginia-class Block V – VII submarines.
  - VLS cruise missile options include:
    - 3 x P-800 Oniks (SS-N-26) cruise missiles per large diameter VLS tube.
    - 5 x Kalibr (SS-N-27 & SS-N-30A) cruise missiles per large diameter VLS tube. Kalibr is the Russian domestic version of the 3M54 Klub (Club) export cruise missile, which is available in land-attack, anti-ship, and anti-submarine versions.
    - 5 x 3M22 Zircon (SS-N-33) hypersonic cruise missiles per large diameter VLS tube; compatible with the Kalibr VLS launch tube.

# Project 885/885M (Yasen & Yasen-M)

## Multi-purpose submarine

- Operational matters:
  - Crew size is about 90, which is much smaller than the 134 person crew for a comparable US Virginia-class SSN.
  - Test depth is believed to be 600 m (1,968 ft), much greater than any US SSN.
  - Yasen-class boats are expected to be the quietest Russian submarine built to date.
  - Five Project 885M Yasen-M SSNs are under construction:
    - K-561 *Kazan:* keel laid 24 July 2009, launched 31 March 2017, expected commissioning 2018.
    - K-573 *Novosibirsk:* keel laid 26 July 2013
    - K-571 *Krasnoyarsk:* keel laid 27 July 2014
    - K-564 *Arhangelsk:* keel laid 19 March 2015
    - K-xxx *Perm:* keel laid 29 July 2016
    - K-xxx *Ulyanovsk:* keel laid 28 July 2017
  - A Yasen-class boat is estimated to cost about $3.5 billion and take about eight years to construct (based on *Kazan*). In comparison, a US Block III Virginia-class SSN costs about $2.6 billion and takes about five years to build.
  - Because of the high cost and long construction time of the Yasen-class multi-purpose submarines, the Russian Navy is unlikely to order additional boats in this class. Instead, the Russian Navy has announced plans to transition future SSN procurement to a 5th generation submarine known as the Husky-class, which will include an SSN-specific model.

# Project 885 (Yasen)

## Multi-purpose submarine

Source: Vorkunkov Maxim, www.sevmash.ru

# Project 885 (Yasen)

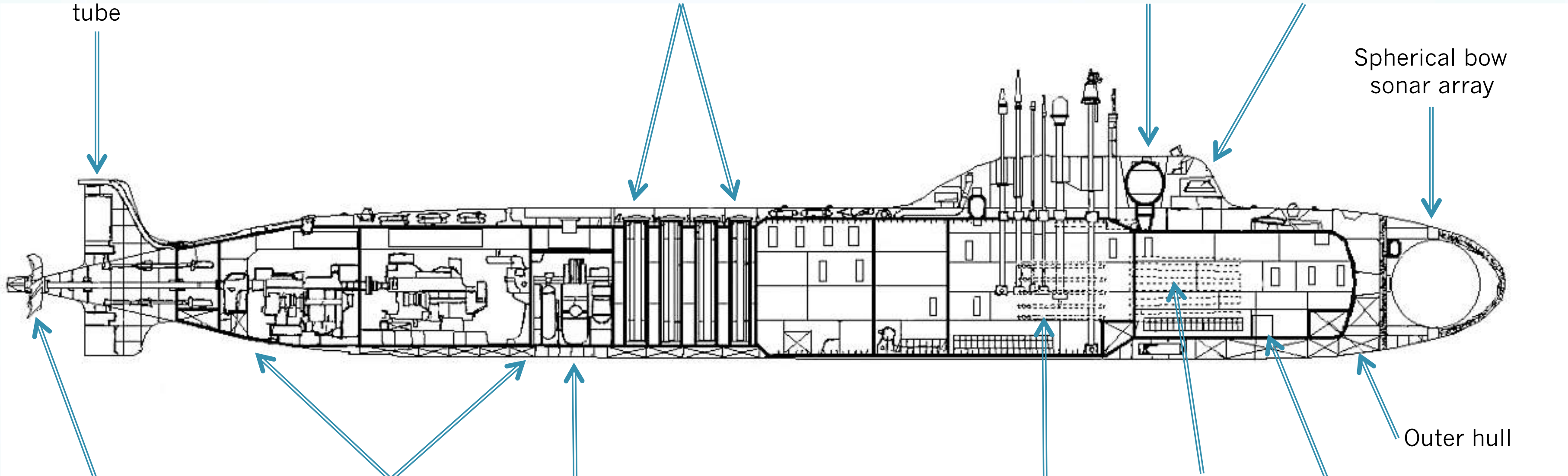
## Multi-purpose submarine

Severodvinsk. Source, above: https://navaltoday.com

Source, top R: https://sputniknews.com/military/

# Project 885 (Yasen)

## Notional arrangement




Source: adapted from dofiga.net

# Project 885 (Yasen)

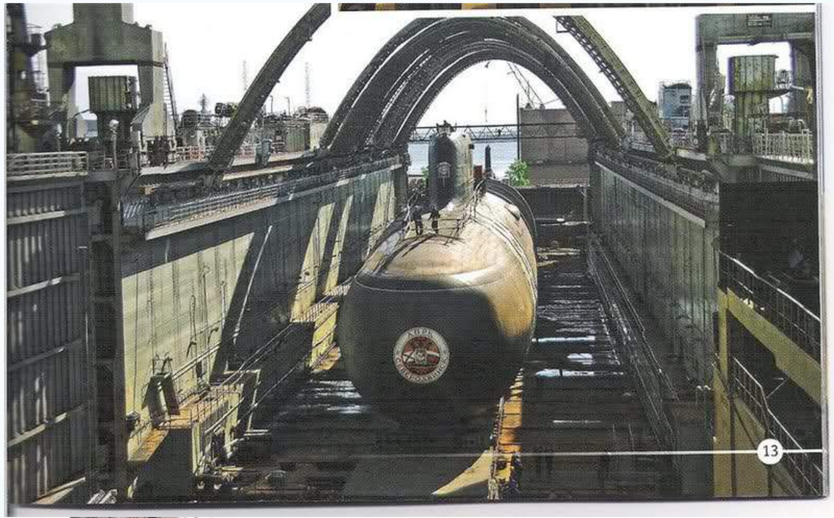
## Escape capsule test

Source: englishrussia.com/2014/11/10

# Project 885 (Yasen)

## In dry dock

Source: forums.airbase.ru



Source: http://www.russiadefence.net/

Source: https://www.revolvy.com/main/index.php?s=Severodvinsk-class

# Project 885 (Yasen)

## Cruise missile launch

Yasen-class sub launches a “Kaliber” cruise missile.
Source, both photos: http://forums.airbase.ru via http://militaryrussia.ru/blog/topic-339.html

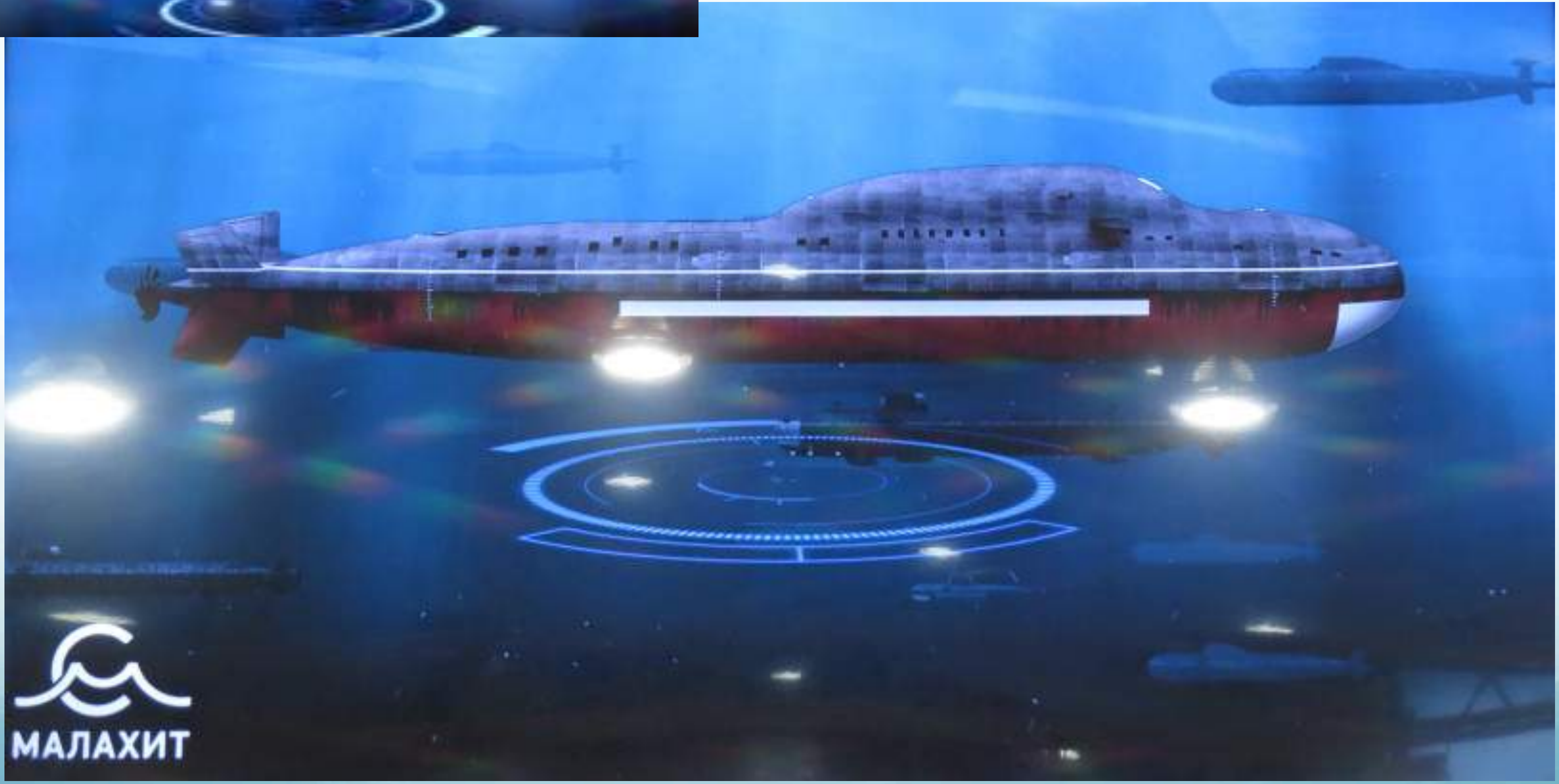
# Russian 5th generation SSN concepts

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

- The Malakhit Bureau had been developing a concept of 5th generation (multi-purpose) attack subs on its own initiative as the Russian Defense Ministry had not yet provided the company with a set of design parameters.
- 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 US 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 also will be armed with torpedoes, missiles and mines, and will make extensive use of 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 UUV can remain to accomplish the submarine's mission in the area.

# Russian 5th generation SSN concept
## 2016 defense exhibition
## Malakhit Central Design Bureau, St. Petersburg

This conceptual design of a multi-role sub was shown by designer Malachite (JSC Saint-Petersburg Marine Design Bureau Malachite) during a defense exhibition in 2016. The design features bow torpedo tubes, traditional Russian chin-mounted sonar, mid-ship large-diameter VLS tubes, flank sonar array and an X-tail with a conventional propeller.




Source: https://russianmilitaryanalysis.wordpress.com

# Project xxx (Husky)

## $5^{th}$ generation multi-role submarine

- In mid-2016, the Russian Defense Ministry signed a contract with the St. Petersburg Marine Engineering Bureau "Malachite" to develop a $5^{th}$ generation multi-role nuclear submarine.
- The goal is to produce a new class of sub that costs less than the Project 855 Yasen-class of multi-role subs, while sharing many sensors and systems. This is similar to the US motivation to develop the Virginia-class SSN as a less costly replacement for the larger Seawolf-class SSN designed during the Cold War.
- Three versions of Malachite's Husky sub were identified: SSN (interceptor), SSGN and SSBN. Building on the SSN version, hull extensions housing vertical launch system (VLS) tubes would create the SSGN and SSBN versions. This approach could yield Russian counterparts to the US Virginia-class Block I – IV SSNs and Block V to VII SSGNs.
  - The SSN version will replace Akula, Sierra and Victor III SSNs currently in the fleet.
  - The SSGN version will replace Oscar II SSGNs, which are now undergoing mid-life modernization.
  - If developed, the Husky SSBN version will complement the Borei SSBNs now entering the fleet. Note that the Rubin Central Design Bureau historically has been responsible for the design of Russian SSBNs.
- The Husky SSN with special operations force (SOF) capabilities could be similar in size to the multi-role Yasen SSN (8,000 – 9,000 ton surface displacement), although there have been reports that a smaller SSN is desired.
- Husky could be a large class of subs, with plans for production of 15 – 20 boats at a rate of one boat every two years being reported. Deliveries to the fleet may start as soon as 2026.

# Submarine-launched torpedoes & anti-submarine missiles

# Russian submarine-launched torpedoes

| Weapon | Years in service | Weight | Length | Diam | Speed / Propulsion | Range / guidance | Warhead |
|---|---|---|---|---|---|---|---|
| Type 53-58 (T5) | IOC 1958 | 1,996 kg (4,400 lb) | 7.92 m (26 ft) | 533 mm (21 in) | 40 kts | 10 km (6.2 mi)<br><br>Initial bearing, then gyroscope to maintain bearing | Nuclear @ 5 kT (RDS-9) |
| Type 65-73 | IOC 1973 | 4,750 kg (10,472 lb) | 9.14m (30 ft) | 650 mm (25.6 in) | 50 or 30 kts<br><br>Gas-turbine powered by hydrogen peroxide, kerosene and compressed air fuel | 50 km (31 mi) @ 50 kts or 100 km (62 mi) @ 30 kts<br><br>Initial bearing, then gyroscope to maintain bearing | Nuclear @ 20 kT |
| Type 65-76 and 65-76A | IOC 1976 (65-76)<br><br>IOC 1991 (65-76A) | 4,500 kg (9,921 lb) or 4,750 kg (10,472 lb) | 9.14m (30 ft) | 650 mm (25.6 in) | Similar to Type 65-73 | Type 65-76 is similar to 65-73. Type 65-76A has longer range.<br><br>Wire guided and active/passive sonar; one model has wake homing | High-explosive, 450 or 557 kg (992 or 1,268 lb). |
| Type 53-65 (family) | IOC 1965<br><br>53-65K and 53-65M IOC 1969 | 2,070 – 2,300 kg (4,560 – 5,070 lb) | 7.2 m (23.6 ft) | 533 mm (21 in) | 45 kts<br><br>53-65 and 53-65M: Kerosene-hydrogen peroxide turbine. 53-65K: Kerosene-oxygen turbine | 18 - 22 km (11-13.7 miles) depending on model<br><br>Wake homing. | High-explosive, 308 kg (679 lb) |

# Russian submarine-launched torpedoes

| Weapon | Years in service | Weight | Length | Diam | Speed / Propulsion | Range / guidance | Warhead |
|---|---|---|---|---|---|---|---|
| VA-111 Shkval | 1977 - present | 2,700 kg (6,000 lb) | 8.2 m (27 ft) | 533 mm (21 in) | 200 kts<br><br>Rocket motor | 11 – 15 km (6.8 – 9.3 mi)<br><br>Guidance: Inertial + terminal guidance | Initial model: Nuclear<br><br>Later model: High-explosive, 210 kg (460 lb) |
| UGST / Fizik | 2015 to present (to be replaced by Futlyar) | 1,980 – 2,200 kg (4,167 – 4,850 lb) | 7.2 m (23.6 ft) | 533 mm (21 in) | 50 kts (mode 1) or 30 – 35 kts (mode 2)<br><br>Otto fuel monopropellant, axial internal-combustion engine | 60 km (37 miles)<br><br>Guidance: Wire-guided, wake homing and phased array passive / active terminal homing. | High-explosive, 300 kg (661 lb) |
| Improved UGST / Futlyar (Fizik-2) | 2017 to present | Similar to UGST | Similar to UGST | 533 mm (21 in) | Up to 60 kts<br><br>Similar fuel & engine to UGST driving a pumpjet | Similar to UGST with the addition of thermal homing. | Similar to UGST |
| Poseidon (Status-6, Kanyon) | See the section: Nuclear-powered special operations submarines | | | | | | |

# Type 53-58

## T-5 nuclear torpedo

- Primary target: Aircraft carriers strike groups or fleet formations.
- T-5 IOC in 1958, named Type 53-58.
- Diameter: 533 mm (21 in)
- Length: 7.92 m (26 ft)
- Weight: 1,996 kg (4,400 lb)
- Warhead: RDS-9 nuclear warhead rated @ 5 kT
- Propulsion: Combined-cycle piston engine rated at 460 shp driving through a gearbox to two coaxial propellers.
- Max. speed: 40 kts
- Guidance: Gyroscope

T-5 on exhibit at the RFNC-VNIIEF Museum, Sarov, Nizhny Novgorod region
Source: http://www.vniief.ru/wps/wcm/connect/vniief/site/about/history/

- The RDS-9 nuclear warhead was tested several times:
  - 10 October 1954: Unsuccessful first test at Semipalatinsk, Kazakhstan
  - 21 September 1955: Successful test at Novaya Zemlya
  - 10 October 1957: In a operational test at Novaya Zemlya, Whiskey-class sub S-144 launched a T-5 torpedo against three decommissioned submarines on the surface, at a range of 10 km (6.2 miles). Two submarines sank and one was critically damaged. The RDS-9 yield was 4.8 kT.
- Thermal range for normal torpedo operation was +5 to +25 °C (41 to 77 °F), which limited its use in the Arctic.
- The Type 53-58 nuclear torpedo could be carried by most Soviet submarines. They were the type of nuclear torpedoes carried during the Cuban Missile Crisis in October 1962.

# Type 65 *Kit (Whale)*

## Heavyweight torpedo

Source: https://www.pinterest.coom

- Primary target: Aircraft carriers & other large vessels that may survive a standard torpedo hit.
- Diameter: 650 mm (25.6 in)
- Length: 9.14 m (30 ft)
- Weight: 4,500 kg (9,921 pounds) or 4,750 kg (10,472 lb)
- Warhead:
  - Type 65-73 is an unguided, 20 kT nuclear variant introduced in 1973.
  - Type 65-76 is a guided variant with a high-explosive warhead introduced in 1976. The HE warhead is either 450 or 557 kg (992 or 1,268 lb).
- Max. speed: 50 kts (93 kph)
- Type 65-76 guidance: Wire guided and active/passive sonar; one model has wake homing.
- Type 65-76A with a longer range of 100 km (62 mile) range entered service in 1991.
- Deployed only on subs with 650 mm torpedo tubes: Victor III, Sierra, Akula & Yasen SSNs; Oscar SSGNs.
- 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.

# Type 53-65

## Wake-homing torpedo

- The Type 53-65 is a family of wake-homing torpedoes designed for use against surface ships. It was introduced to the fleet in 1965.
- Sensors in the torpedo detect the churn made by ships underway. Once the torpedo senses the chopped water it will follow a ship in a S-pattern between the edges of the wakes until it finds its target. The wake sensors do not respond to US torpedo countermeasures.
- Diameter: 533 mm (21 in)
- Length: 7.2 meters (23.6 feet)
- Weight: 2,070 – 2,300 kg (4,560 – 5,070 lb)
- Warhead: 308 kg (679 lb) HE
- Propulsion:
  - 53-65 and 53-65M: Kerosene-hydrogen peroxide turbine
  - 53-65K: Kerosene-oxygen turbine
- Range: 18 - 22 km (11- 13.7 miles), depending on model
- Max. speed: 45 knots

Type 53 torpedo. Source: http://v-technologyworld.blogspot.com/

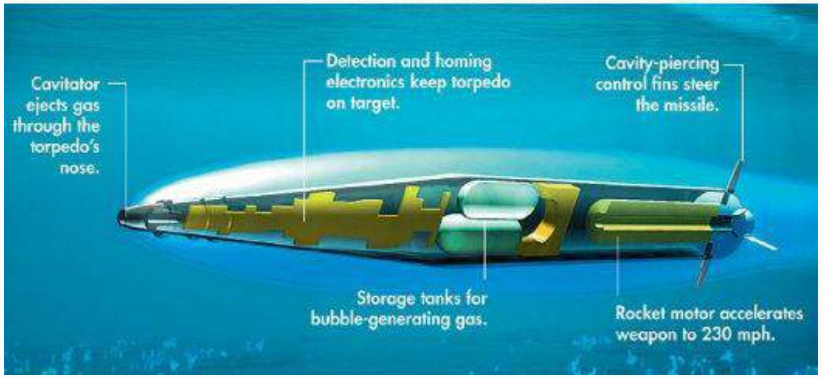
Type 53 torpedo in a Kilo 877EKM sub torpedo room.
Source: http://gentleseas.blogspot.com/2015/07/russian-torpedos.html

# 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
- 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, but in small numbers per sub (typ. 1 or 2).

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#/

# VA-111 *Shkval* (Squall)

## Rocket-propelled torpedo

Source: http://www.subsim.com/radioroom/

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

# *Fizik / Futlyar*

## Universal Deep-Water Homing Torpedo UGST / Improved UGST

- UGST / Fizik is designed to destroy surface ships and submarines. It was first displayed in 2003, and deployed in 2015.
- Diameter: 533 mm (21 in)
- Length: 7.2 meters (23.6 feet)
- Weight: 1,980 – 2,200 kg (4,167 – 4,850 lb)
- Warhead: 300 kg (661 lb) HE
- Range: 50 km (31 miles)
- Max. speed: 50 knots (mode 1) or 30 – 35 knots (mode 2)
- Guidance: Wire-guided, wake homing, passive / active acoustic terminal homing, and heat-seeking terminal homing.


Source: nevskii-bastion.ru

- An Improved UGST / Fizik torpedo known as Futlyar (or Fizik-2) has been developed by the Research Institute of Marine Hardware, St. Petersburg. The Dagdizel plant will handle its production.
  - Maximum speed of 60 knots with a pumpjet propulsor
  - Can be launched from a depth of up to 500 meters (1,640 feet)
- The Futlyar will equip the Project 955 / 955A Borei-class SSBNs and Project 885 / 885M Yasen-class SSNs. With the beginning of the Futlyar's full-rate production in 2018, the production of the UGST / Fizik torpedo will be discontinued.

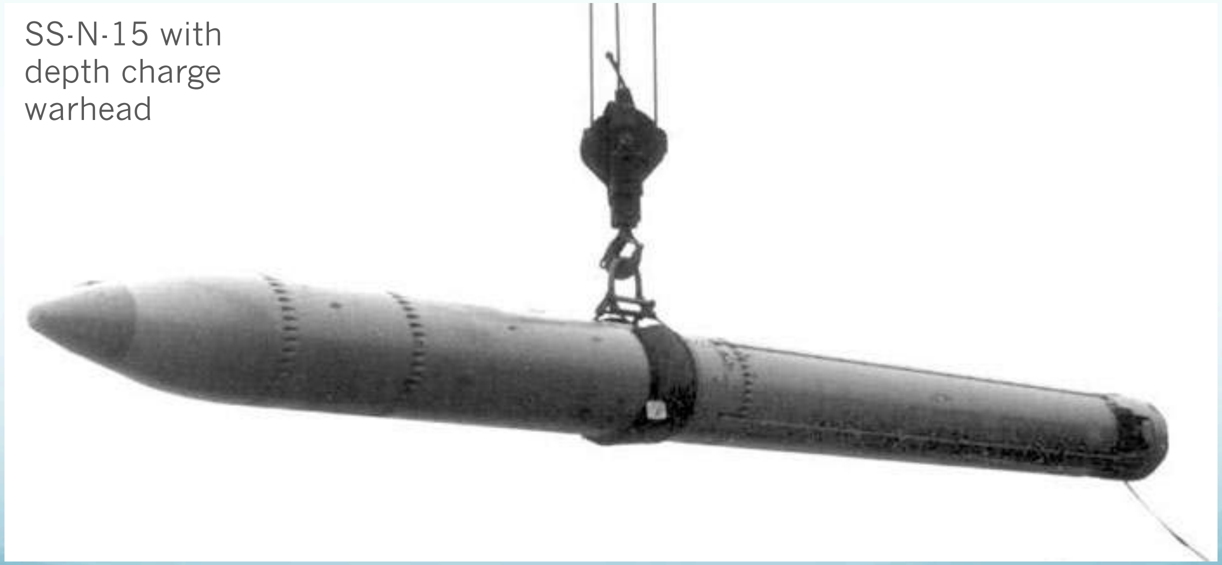
# Russian submarine-launched anti-submarine missiles

| Anti-sub missile | Years in service | Weight | Length | Diam (D) / Span (S) | Speed | Range | Guidance | Warhead |
|---|---|---|---|---|---|---|---|---|
| RPK-2 Viyoga (SS-N-15 Starfish) | 1969 – present | 2,445 kg (5,390 lb) | 8 m (26.3 ft) | D = 533 mm (21 in) | Supersonic, ballistic | 35 - 45 km (21.7 - 28.0 mi) | Inertial or inertial + homing torpedo | Nuclear depth charge or 400 mm (15.75 in) light torpedo |
| RPK-7 Vodopei (SS-N-16 Stallion) | 1984 – present | 2,800 kg (6,173 lb) | 11 m (36.1 ft) | D = 650 mm (25.6 in) | Supersonic, ballistic | 100 km (62.1 mi) | Inertial or inertial + homing torpedo | Nuclear depth charge or 400 mm (15.75 in) light torpedo |
| 91RE1 Kalibr/Klub/ Club | 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 | 400 mm (15.75 in) APR-3ME lightweight ASW torpedo with a 76 kg (168 lb) HE warhead |

# RPK-2 Vyuga

## Anti-submarine missile (Starfish / SS-N-15)

- Introduced in 1969, RPK-2 Vyuga (aka 81R) is an analog to the retired US SUBROC submarine-launched, anti-submarine missile.
- The 533 mm (21 inch) diameter RPK-2 is available in both submarine-launched and surface ship-launched versions.
- The RPK-2 can be armed with an 82R lightweight, 400 mm (15.7 inch) torpedo with a high-explosive warhead or a 90R nuclear depth charge rated at about 5 kT.
- Range is about 35 - 45 km (21.7 - 28.0 mi).



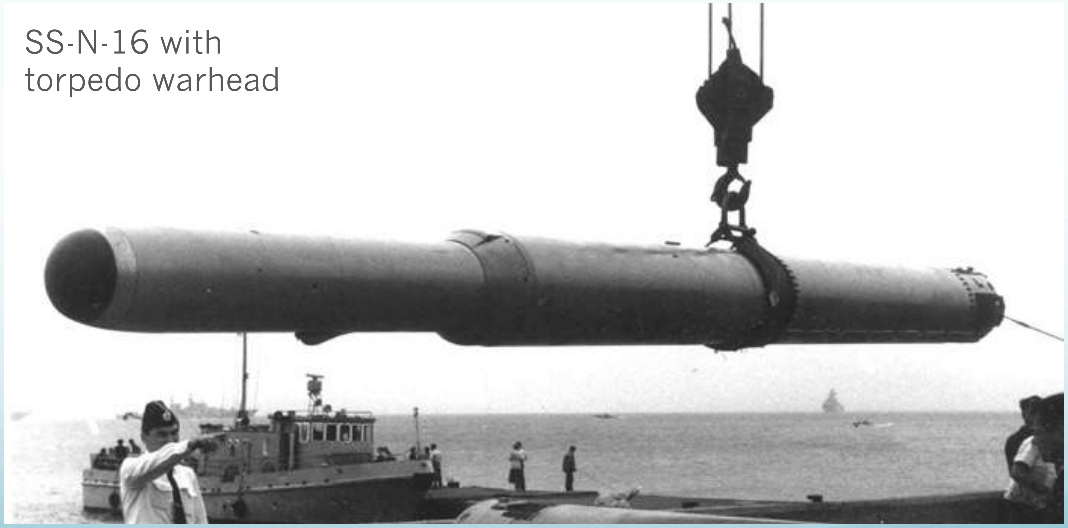
SS-N-15 with depth charge warhead

Source: http://topwar.ru/

# RPK-7 Vodopei

## Anti-submarine missiles (Stallion / SS-N-16)

- The RPK-7 a 650 mm (25.6 inch) diameter submarine-launched, anti-submarine missile that was first deployed in 1984. The surface ship-launched version is known as the RPK-6.
- The RPK-7 can be armed with a lightweight 400 mm (15.7 inch) ASW torpedo with a high-explosive warhead or a nuclear depth charge.
- Maximum range is about 100 km (62 miles).
- The RPK-6 is a similar surface ship-launched, ASW missile.




Source: http://militaryrussia.ru

# 91RE1 Kalibr / Club-S

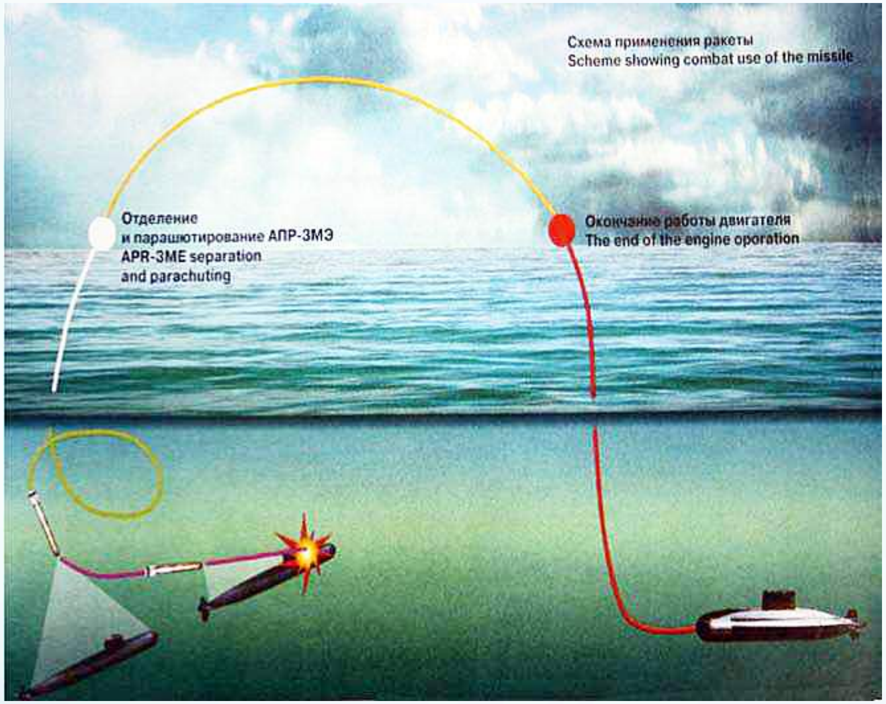
## Anti-submarine missile

- The RPK-2 Starfish and the RPK-7 Stallion are expected to be replaced by the 91RE1 Kalibr (Club-S) submarine-launched, anti-submarine missile.
- 91RE1 missile diameter is 533 mm (21 inches) and it can be launched from a standard torpedo tube.
  - Missile range is 50 km (31 miles); missile guidance is inertial.
  - Armed with a 400 mm (15.75 in) APR-3ME lightweight, ASW homing torpedo with a 76 kg (168 lb) HE warhead.
    - Torpedo speed is > 56 kts; range is > 3 km (1.9 miles)
    - Powered by a solid-propellant rocket-powered turbo-waterjet
    - Once entering water, the torpedo control surfaces enable the torpedo to travel in an unpowered spiral path without starting the engine. During this stage, the torpedo's acoustic seeker searches for targets. Once the target is acquired, the engine starts, providing very little warning time to the intended target.
    - Can engage submarines at depth from the surface down to 800 meters (2,625 ft).
- The 91RE2 (Club-N) is a similar surface ship-launched, ASW missile.

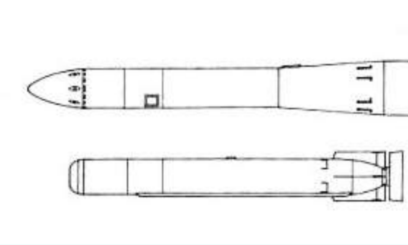
91RE1 missile: Sources, left: https://cs.wikipedia.org/wiki/3K14_Kalibr
right: https://oplatsen.wordpress.com/category/teknologi/

# 91RE1 Kalibr / Club-S

## Anti-submarine missile




91RE1 (Club-S) mission profile.



APR-3ME lightweight torpedo

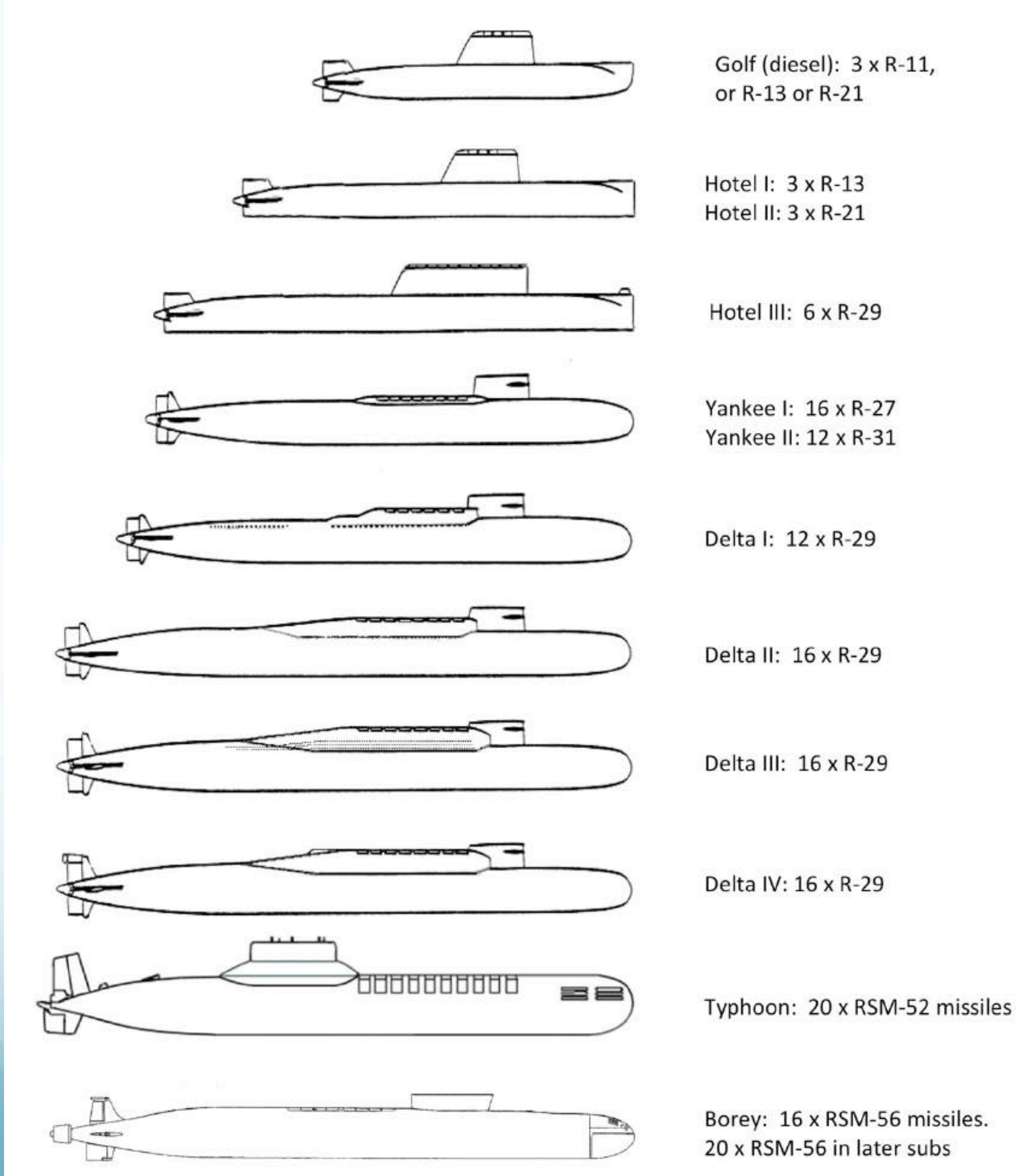
91RE1 (Club-S) control fins


Source, all graphics this page:
http://armasrusasb.blogspot.com/2017/02/misiles-antisubmarinos-delanzamiento.html

# Strategic ballistic missile submarines (SSB & SSBN)

Soviet diesel-electric SSBs are included in this section in order to provide a more complete story about the early submarines involved in the development, testing and operational deployment of submarine-launched ballistic missiles (SLBMs).

# Evolution of Soviet / Russian strategic ballistic missile submarines




Source: adapted from https://fas.org/nuke/guide/russia/slbm/index.html

# Russian SSBs & SSBNs

| Project # | Class | SLBM / launch system | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 611A | Zulu IV (likely B-62) | R-11FM / D-1 | 1 | 90.5 m (297 ft) | 7.5 m (24.6 ft) | 1,875 (surf) 2,387 (sub) | Diesel-electric | 6,000 | 16 | 1953 | 1953 - 70 |
| 611AB | Zulu V | R-11FM / D-1 | 5 | 98.9 m (324 ft) | 7.5 m (24.6 ft) | 1,890 (surf) 2,415 (sub) | Diesel-electric | 6,000 | 16 | 1956 - 57 | 1956 - 90 |
| 629 | Golf I | R-13 / D-2 | 22 | 98.4 m | 8.2 m (27 ft) | 2,794 (surf) 3,553 (sub) | Diesel-electric | 6,000 | 13 | 1959 - 62 | 1959 - 90 |
| 629A | Golf II | R-21 / D-4 | 13 Modified 629 | 98.9 m (324 ft) | 8.2 m (27 ft) | 2,792 (surf) 3,553 (sub) | Diesel-electric | 6,000 | 13 | 1966 - 72 | 1966 - 90 |
| 629B | Golf (K-142) | R-21 / D-4 | 1 | 98.9 m (324 ft) | 8.2 m (27 ft) | 2,875 (surf) 3,553 (sub) | Diesel-electric | 6,000 | 13 | 1962 | 1962 - 90 |
| 601 | Golf III (K-118) | R-29 / D-9 | 1 Modified 629 | 117.6 m (385.8 ft) | 8.2 m (27 ft) | 4,160 (surf) 5,180 (sub) | Diesel-electric | 6,000 | 13 | 1976 | 1976 - 89 |
| 605 | Golf IV (K-102) | R-27K / D-9K | 1 Modified 629 | 116 m (380.6 ft) | 8.2 m (27 ft) | 3,642 (sub) 4,540 (sub) | Diesel-electric | 6,000 | 12 | 1975 | 1975 - 80 |
| 619 | Golf V (BS-153) | R-39 / D-19 | 1 Modified 629 | 98.9 m (324 ft) | 8.2 m (27 ft) | 2,820 (surf) 3,090 (sub) | Diesel-electric | 6,000 | 13 | 1978 | 1978 - 90 |
| 658 | Hotel I | R-13 / D-2 | 8 | 114 m (374 ft) | 9.2 m (30.2 ft) | 4,080 (surf) 5,000 (sub) | 2 x VM-A | 27,000 (est) | 26 | 1960 - 62 | 1960 - 69 |
| 658M | Hotel II | R-21 / D-4 | 7 Modified 658 | 114 m (374 ft) | 9.2 m (30.2 ft) | 4,660 (surf) 5,588 (sub) | 2 x VM-A | 27,000 (est) | 26 | 1963 - 67 | 1963 - 91 |

# Russian SSBs & SSBNs

| Project # | Class | SLBM / launch system | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 701 | Hotel III (K-145) | R-29 / D-9 | 1 Modified 658 | 130 m (426 ft) | 9.2 m (30.2 ft) | 5,500 (surf) 6,400 (sub) | 2 x VM-A | 27,000 (est) | 22 | 1970 | 1970 - 89 |
| 667A | Yankee I (Navaga) | R-27 / D-5 | 34 | 132 m (433 ft) | 11.6 m (38 ft) | 7,700 (surf) 9,300 (sub) | OK-700: 2 x VM-4-2 | 34,500 | 27 | 1964 -74 | 1967 - 83 |
| 667AU | Yankee I (Nalim) | R-27U / D-5U | Modified 667A | Same | Same | Same | OK-700: 2 x VM-4-2 | 34,500 | 27 | 1972 - 83 | 1972 - 94 |
| 667AM | Yankee II (Navaga M) | R-31 / D-11 | Modified 667A | Same | Same | 7,760 (surf) 10,000 (sub) | OK-700: 2 x VM-4-2 | 34,500 | 27 | 1977 - 80 | 1980 - 90 |
| 667B | Delta I (Murena) | R-29 / D-8 | 18 | 139 m (456 ft) | 12 m (39.4 ft) | 9,000 (surf) 11,000 (sub) | OK-700: 2 x VM-4B | 34,500 | 25 | 1971 - 77 | 1973 - 98 |
| 667BD | Delta II (Murena M) | R-29 / D-8 | 4 | 155 m (508.5 ft) | 12 m (39.4 ft) | 10,500 (surf) 13,000 (sub) | OK-700: 2 x VM-4B | 34,500 | 24 | 1973 - 75 | 1975 - 96 |
| 667 BDR | Delta III (Kalmar) | R-29R / D-9 | 14 | 166 m (544.6 ft) | 12 m (39.4 ft) | 13,500 (surf) 18,200 (sub) | OK-700A 2 x VM-4S | 34,500 | 24 | 1976 - 82 | 1975 – present |
| 667 BDRM | Delta IV (Delfín) | R-29RM / D-9RM | 7 | 166 m (544.6 ft) | 12 m (39.4 ft) | 13,500 (surf) 18,200 (sub) | OK-700A 2 x VM-4SG | 34,500 | 24 | 1984 - 90 | 1984 – present |

# Russian SSBs & SSBNs

| Project # | Class | SLBM / launch system | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 941 | Typhoon (Akula) | R-39 / D-19<br><br>R-39U / D-19UTH | 6 | 175 m (574.1 ft) | 23 m (75.5) | 23,200 (surf) 33,800 (sub) | 2 x OK-650 | 99,200 | 25 | 1981 - 89 | 1981 – present |
| 955 | Borei | RSM-56 | 3 | 170 m (557.7 ft) | 13.5 m (44.3 ft) | 14,700 (surf) 24,000 (sub) | 1 x OK-650V | 43,000 | 29 | 2012 - 14 | 2012 – present |
| 955A | Improved Borei | RSM-56 | 5 planned | 170 m (557.7 ft) | 13.5 m (44.3 ft) | 14,700 (surf) 24,000 (sub) | 1 x OK-650V | 43,000 | 29 | $1^{st}$ expected in 2018 | |


# SLBM range expands potential Soviet SSBN patrol areas for CONUS targets

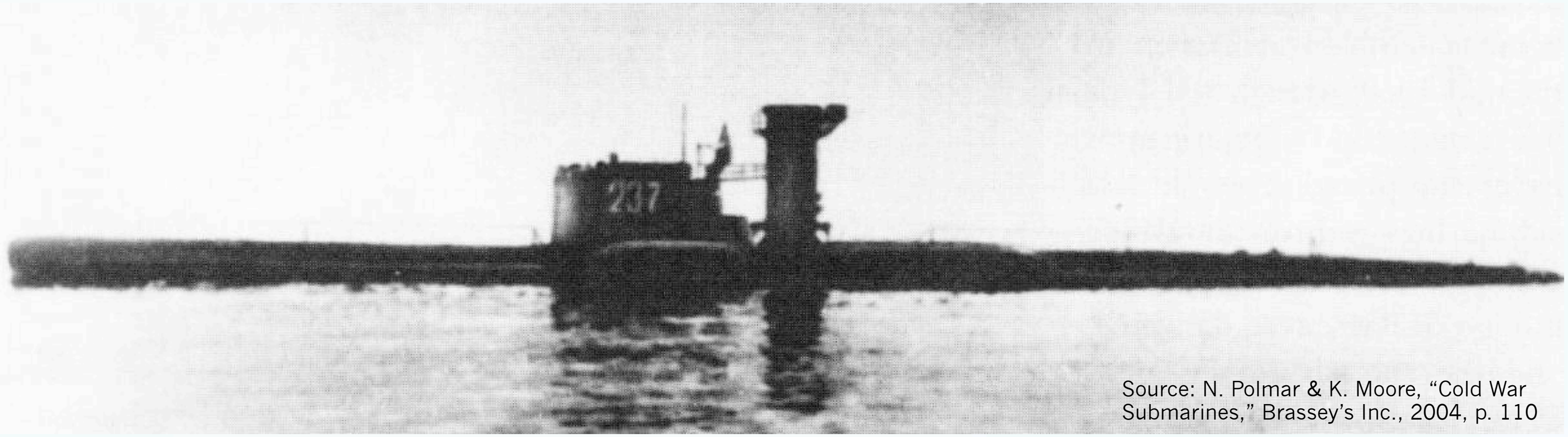
Source: T.W. Ford, "Ballistic Missile Submarines of the United States and the Soviet Union: a comparison of systems and doctrine," December 1982


# SLBM range expands potential Soviet SSBN patrol areas for US coastal targets

Source: T.W. Ford, “Ballistic Missile Submarines of the United States and the Soviet Union: a comparison of systems and doctrine,” December 1982

# Project 613

## Whiskey-class S-229 ballistic missile trials submarine



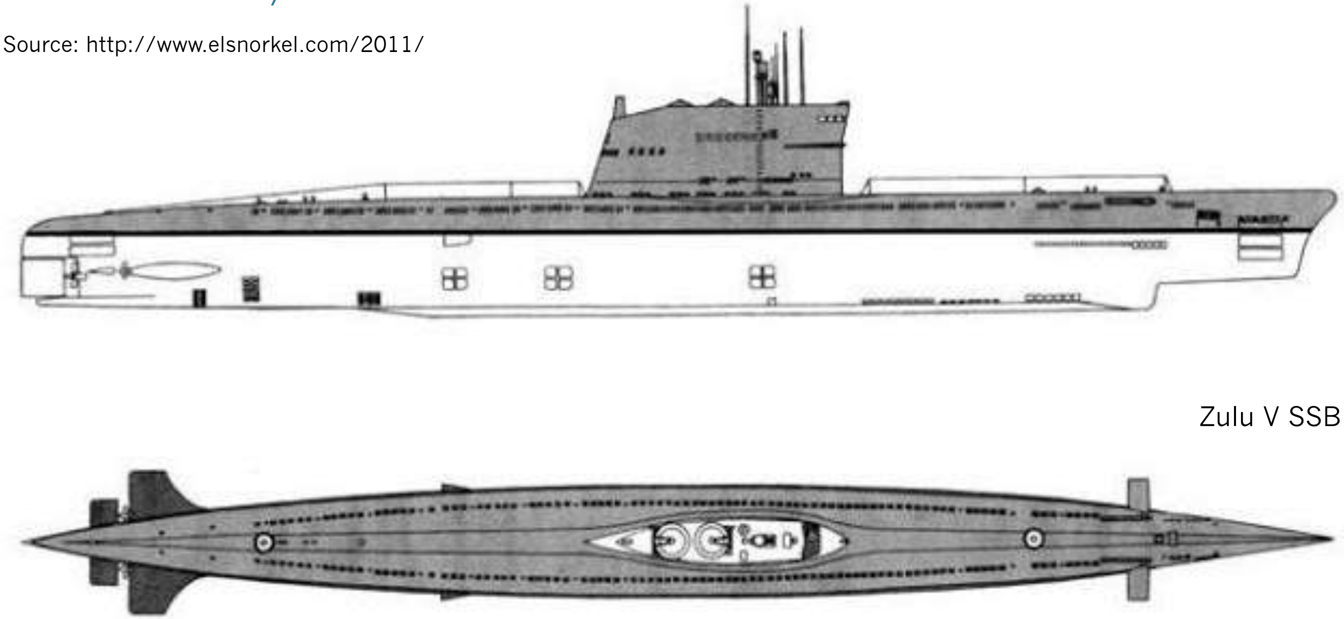

Source: N. Polmar & K. Moore, "Cold War Submarines," Brassey's Inc., 2004, p. 110

- One Whiskey-class diesel-electric sub, S-229, went through four successive rounds of modifications at Shipyard No. 444 (now Black Sea Shipyard) to support four different submarine-launched ballistic missile (SLBM) and underwater launch system development programs.
- Project V613: In 1956 – 1957, S-229 conducted trials on early ballistic missile launchers, with two S4 missile launchers, and later with one S4.5 missile launcher. The S4 and S4.5 developmental missiles had solid-fuel engines to launch them out of the launch tube underwater and a liquid propellant second stage.
- Project 613D-4: In 1961, S-229 conducted trials on the D-4 ballistic missile launch system, with one launcher for a model of an R-21 missile. A year later, the first underwater launch of an R-21 missile was conducted from the Project 629B Golf SSB, K-142.
- Project 613D-7: In 1963, S-229 conducted trials for the D-7 ballistic missile launch system, with one launcher for a model of an RT-15M missile. Late in 1964, development of the RT-15M missile and D-7 launch system were canceled
- Project 613D-5: In 1965, S-229 conducted trials for the D-5 ballistic missile launch system, with one launcher for a model of an R-27 missile. Initial operating capability (IOC) of the R-27 SLBM on Project 667A Yankee I SSBNs was in March 1968.

# Project 611A & 611AB

## Zulu IV & V-class, the world's 1st ballistic missile submarines (SSB)

Source: http://www.elsnorkel.com/2011/



Zulu V SSB

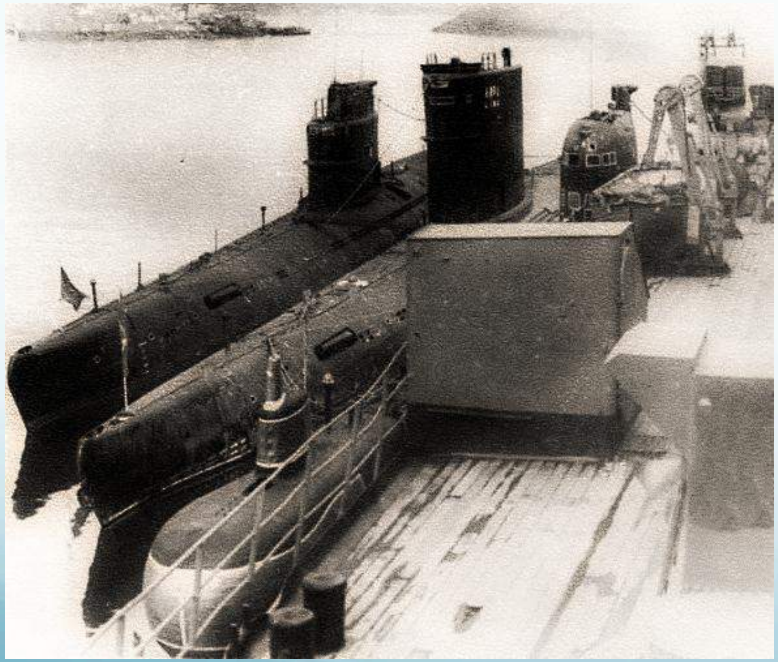
- The six boats in these classes were converted diesel-electric Project 611 Zulu-class attack submarines that received a new mid-ships missile compartment in the hull and an extended sail structure to enclose the tops of the long, watertight missile tubes.
  - Project 611A (also known as V611) Zulu IV was a single prototype boat (likely B-62, although B-67 has been cited in some sources) equipped with the D-1 missile system with a single missile tube for an R-11FM Scud-1b missile. B-62 was converted at Shipyard 402 (Sevmash) in Severodvinsk, and commissioned in December 1953
  - Project 611AB Zulu V was a five boat class equipped with the D-1 missile system and two missile tubes with R-11FM Scud-1b missiles. This was the D-1 missile launch system. Four boats were converted at Shipyard 402 (Sevmash) and one at Shipyard 199 (Komsomolsk). All were commissioned between 1956 – 1957.
- To launch a missile, the submarine had to surface, open a missile tube hatch, and raise the selected missile out of the sail. Support arms held the missile in place when it was in the raised position prior to launch. This launch cycle took about five minutes per missile.

# Project 611A & 611AB

## Zulu IV & V-class, the world's 1st ballistic missile submarines (SSB)

- Operational matters:
  - The Zulu IV prototype SSB made the 1st successful launch of an R-11FM missile from a submarine on 16 September 1955.
  - In 1959 Zulu IV B-62 was converted to carry out the first Soviet underwater launch of an SLBM, which occurred on 10 September 1960. This led to the development of the D-4 launch system, which was first used operationally starting in 1963 on Hotel II-class SSBNs. B-62 was converted to a sonar trials ship in 1966 and retired in 1970.
  - Three Zulu V SSBs were retired in 1970 – 71 (15 year service life), and two remained operational until 1990.

Zulu SS (outboard), Zulu V SSB (center), Foxtrot SS (inboard)

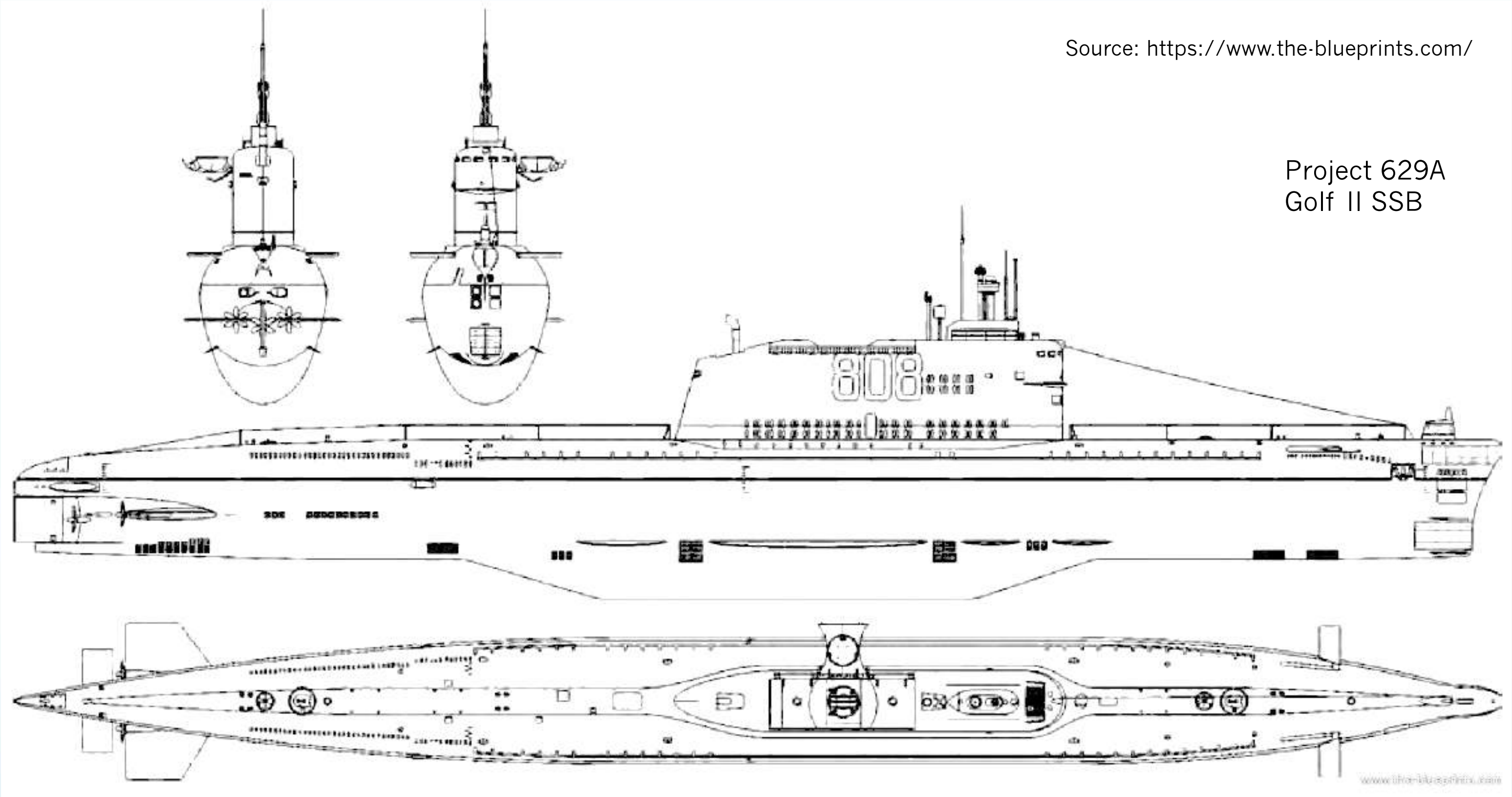


Zulu V SSB sail showing two missile tubes.

Source, two photos: http://www.elsnorkel.com/2011/

# Project 629, 629A & 629B

## Golf I & II-class diesel-electric ballistic missile submarines (SSB)




- The Golf-class SSBs were the world's 1st purpose-built ballistic missile submarines.
- OKB-16 (which later became the Malachite Central Design Bureau) developed the Project 629 SSB in the mid-1950s based on the design of the diesel-powered Project 641 Foxtrot attack submarine. All Golf SSBs had a mid-ships missile compartment housing various numbers (2 to 6) of watertight missile tubes that continued through the hull and were partially enclosed in an extended sail structure.

# Project 629, 629A & 629B

## Golf I & II-class diesel-powered ballistic missile submarines (SSB)

- Armament: Golf-class SSB variants carried a wide range SLBMs.
  - The first three Project 629 Golf I SSBs originally were armed with 3 x R-11FM SLBM and the D-1 launch system (same as Zulu V SSBs). The missile was launched with the submarine on the surface.
  - The remaining 19 Project 629 Golf I SSBs were armed with 3 x R-13 SLBMs and the D-2 launch system. The missile was launched with the submarine on the surface.
  - The single Project 629B Golf SSB, K-142, was armed with 2 x R-21 SLBMs and the D-4 launch system which was the 1st system that could launch an SLBM while submerged. The SLBM was launched from a flooded launch tube.
    - On 24 February 1962, the Project 629B Golf SSB became the first operational submarine (not a test platform) to conduct a submerged SLBM launch.
    - Under Project 629D-7, the Project 629B Golf SSBN was re-equipped in 1964 to serve as a test platform for the RT-15M SLBM and D-7 launch system designed by OKB-586, Ukraine. Missile development was cancelled before testing from the 629B could be conducted.
  - Under Project 629A, 13 Golf I SSBs were converted between 1966 and 1972 into the Golf II configuration with 3 x R-21 SLBMs and the D-4 launch system,
- 20 October 1961: In a nuclear test named *Raduga (Rainbow)*, Golf-class SSB K-102 (formerly B-121) launched an R-13 SLBM with a live 1.45 MT thermonuclear warhead from a launch point in the Barents Sea to a target 603.3 km (375 mi) away in the Novaya Zemlya nuclear test site, Area C.
- 8 March 1968: Soviet Golf II SSBN K-129, armed with three R-21 SLBMs, sank in the northern Pacific Ocean about 2,890 km (1,795 miles) northwest of Oahu, Hawaii.

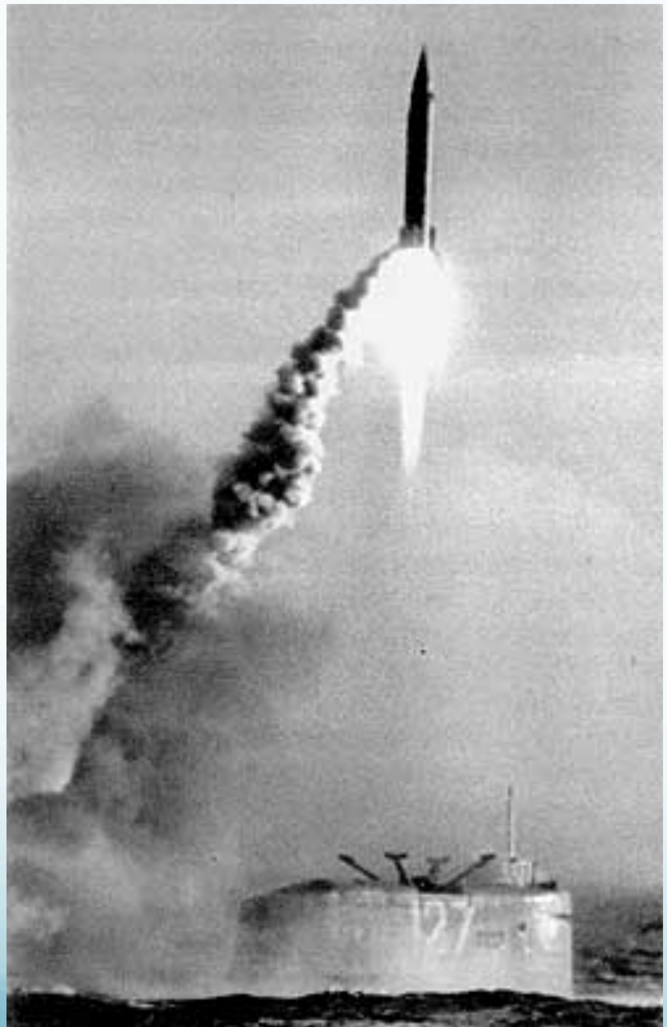
# Project 629, 629A & 629B

## Golf I & II-class diesel-powered ballistic missile submarines (SSB)

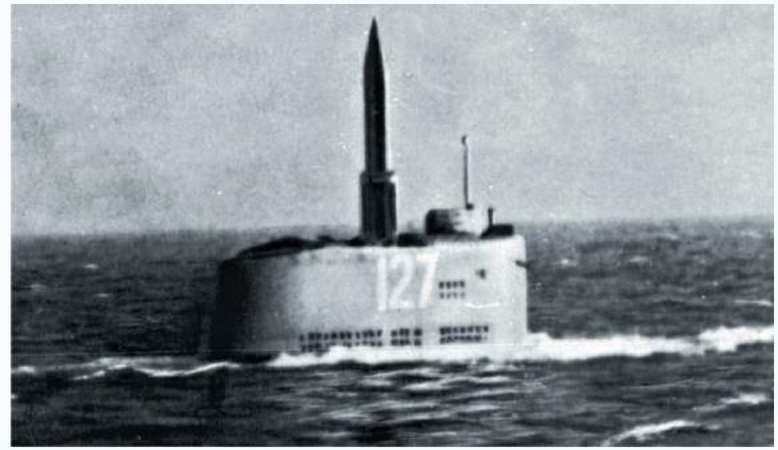
- The following Golf-class variants were not developed:
  - Project 629M powered by a nuclear reactor. The Project 658 Hotel-class SSBNs were developed instead.
  - Project V629 with the D-3 launch system for the liquid-fuel R-15 SLBM designed by Makeyev's SKB-385.
  - Project 629D-6 with the D-6 launch system for a solid-fuel SLBM designed by OKB-7 (KB Arsenal).
- All Golf SSBs were retired by 1990.
- In 1993, ten were sold to North Korea for scrap. There is speculation that the North Koreans are trying to overhaul some of these subs and restore them to operation as North Korean ballistic missile submarines.

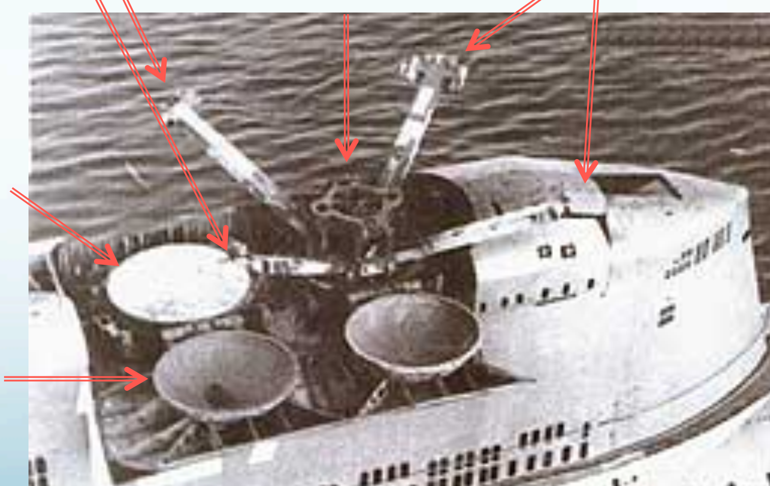
Source:
https://forum.sub-driver.com/

# Golf I SSB launches an R-11FM SLBM on the surface



Source: http://englishrussia.com/






Source, top: http://eng.makeyev.ru/; bottom: http://englishrussia.com/

# Project 629A Golf II SSB

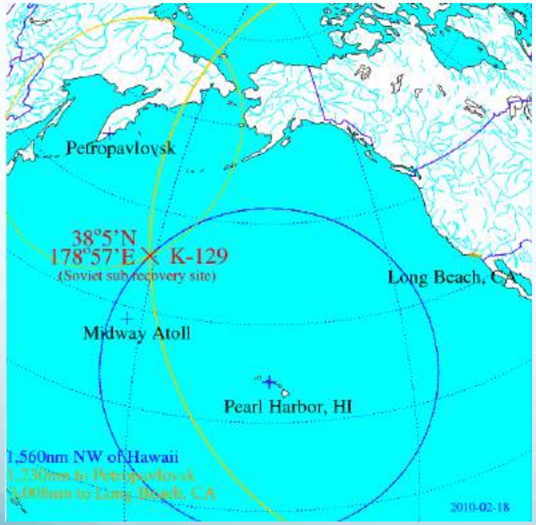
R-21 cold launch from a submerged Golf II SSB

Source, top L & R: https://fas.org/. Source, bottom: https://en.wikipedia.org/

# Project Azorian

## Attempted recovery of Golf II K-129

- On 8 March 1968, Soviet Golf II SSBN K-129, armed with three R-21 SLBMs, sank in the northern Pacific Ocean about 2,890 km (1,795 miles) northwest of Oahu, Hawaii.
  - Soviet attempts to locate the wreckage were unsuccessful.
  - Using recorded hydroacoustic data from several sources (the Adak, Alaska SOSUS station, which was designed to detect and track Soviet submarines in the open ocean, and four AFTAC stations, which were designed to monitor for covert nuclear tests), the US localized the wreck to within about five miles.
- Later in 1968, US special operations nuclear submarine *USS Halibut* (SSN-587) surveyed the ocean bottom with a towed camera pod named *Fish* and located the K-129 wreckage on the seafloor at a depth of about 4,900 m (16,000 feet).
  - K-129 had broken into two major parts about 2/3 back from the bow. The forward section, which became known as the target object (TO), likely included the SLBM launch tubes and the bow torpedo room.



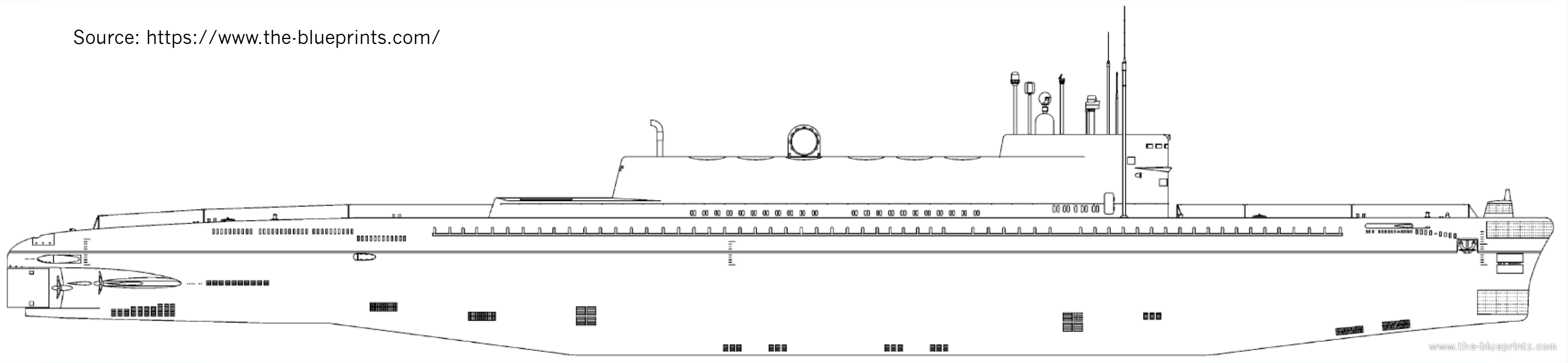

Source: https://en.wikipedia.org/wiki/Project_Azorian#/

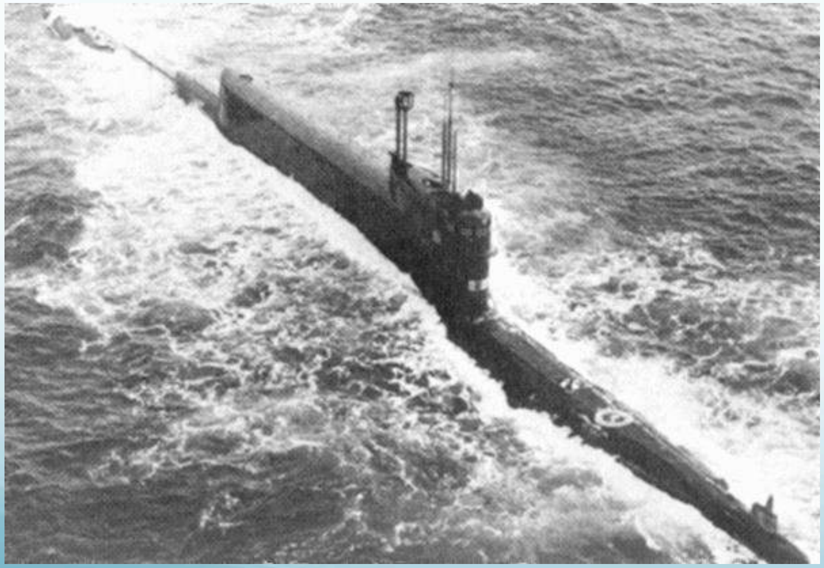
- In November 1972, construction began on the purpose-built recovery ship, the *Hughes Glomar Explorer.* A capture vehicle named *Clementine* was designed to be lowered from the recovery ship to the ocean floor, grasp around the TO, and then lift that section into the recovery ship's hold.
- Recovery operations were conducted by the *Hughes Glomar Explorer* from July – August 1974. The recovery team succeeded in grappling the TO with *Clementine*. After being raised from the seafloor, a mechanical failure in the capture vehicle resulted on about two-thirds of the TO being dropped and sinking back to the seafloor.
- Reports claim that only the bow section, with two nuclear torpedoes and the bodies of six crewmen, was recovered.

# Project 601

## Golf III-class diesel-powered ballistic missile submarine (SSB)

Source: https://www.the-blueprints.com/



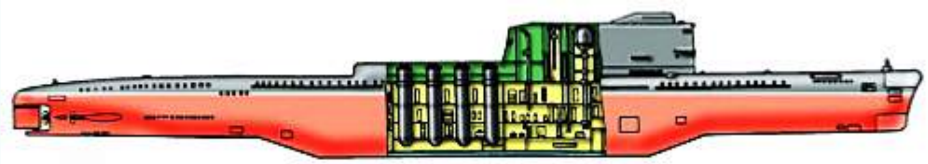



Golf III. Source: https://fas.org/nuke/guide/russia/slbm/629am_1.jpg

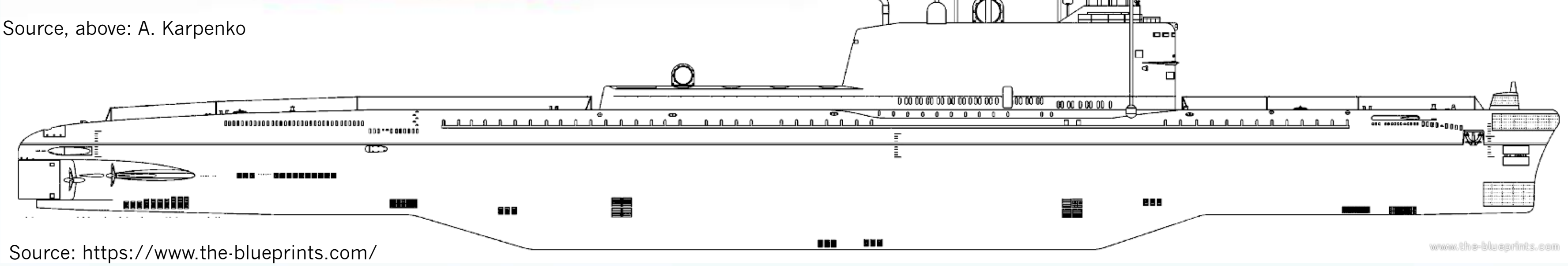
- From 1969 through 1974, Golf I SSB K-118 was converted at the Zvezdochka Shipyard, Severodvinsk, into the Golf III configuration with 6 x R-29 SLBMs and the D-9 launch system.
- Hull was lengthened by 19.2 m (63.3 ft) to 117.6 m (385.8 ft) and displacement increased from 2,794 (surf) / 3,553 (sub) to 4,160 tons (surf) / 5,180 tons (sub).
- K-118 was originally commissioned in December 1960. It was retired in 1989 after about 8 years service as a Golf I followed by about 15 years as a Golf III.

# Project 605

## Golf IV-class diesel-powered ballistic missile submarine (SSB)



Source, above: A. Karpenko

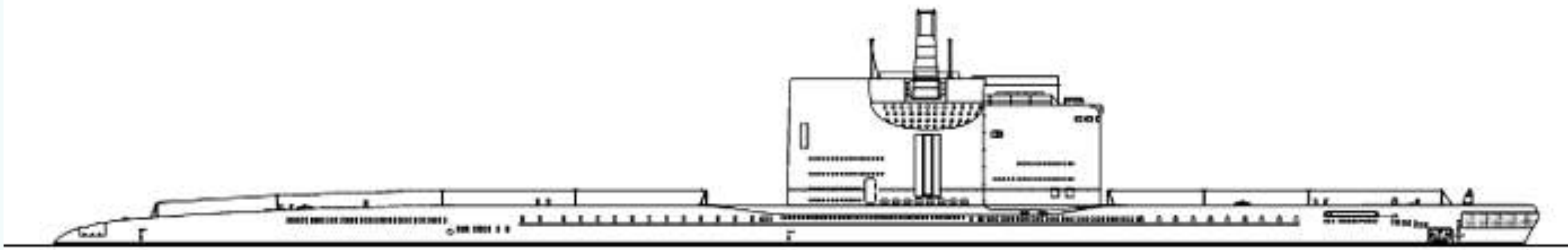



Source: https://www.the-blueprints.com/

- From 1974 through 1975, Golf I SSB K-102 was converted at the Zvezdochka Shipyard, Severodvinsk, into the Golf IV configuration:
  - It was lengthened in 18.3 meters (60 feet) and outfitted with the D-5K launch system for 4 x R-27K or R-27 SLBMs. The R-27K was intended for use against moving fleets of surface ships.
  - Rekord-2 fire control system and the Kasatka B-605 target acquisition system
  - Various improvements to the navigation and communications systems.
- Initial submarine testing of the R-27K SLBM was conducted 9 -18 December 1972 followed by additional tests from 11 September to 4 December 1973. Following these initial tests, the K-102 continued making trial launches with both the R-27 and the R-27K. The R-27K was accepted for service on 15 August 1975.
- However, the R-27K never became operational, since every launch tube used for the R-27K counted as a strategic missile in the SALT agreement. The strategic warheads on the R-27 & R-27U were more important.
- K-102 was retired in July 1980.

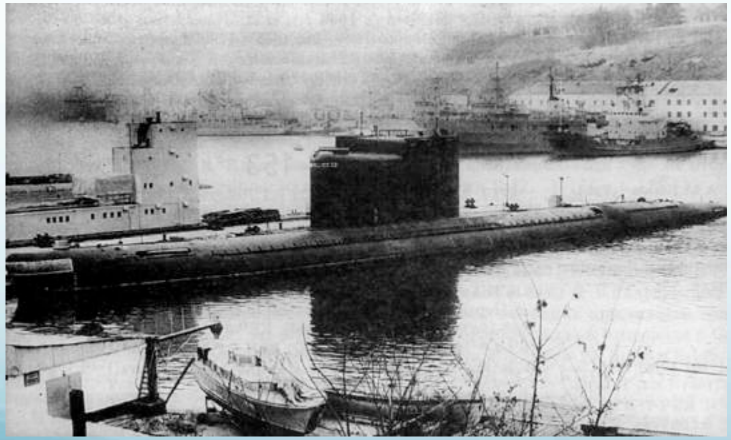
# Project 619

## Golf V-class diesel-powered ballistic missile submarine (SSB)

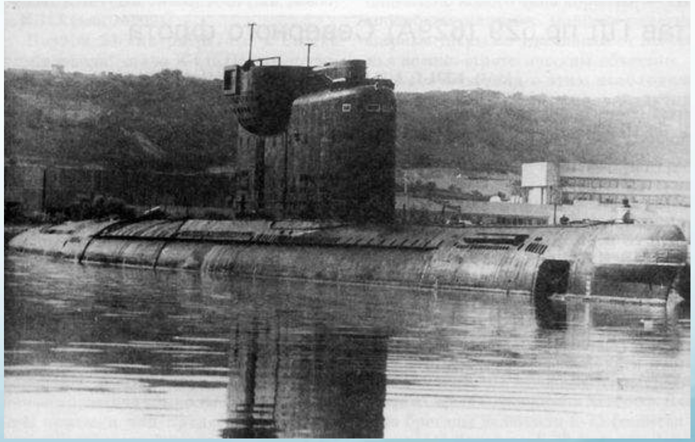


Source: http://russianships.info/eng/submarines/project_629.htm

- From 1976 - 1978, one Golf II SSB, K-153, was outfitted at Sevmash Shipyard, Severodvinsk, with a single launcher to carry out tests of the R-39 SLBM and the D-19 launch system that was being developed for use on the Project 941 Typhoon SSBN.
- 1979: Seven R-39 launch tests were conducted from K-153.
- 1990: K-153 (BS-153) retired.



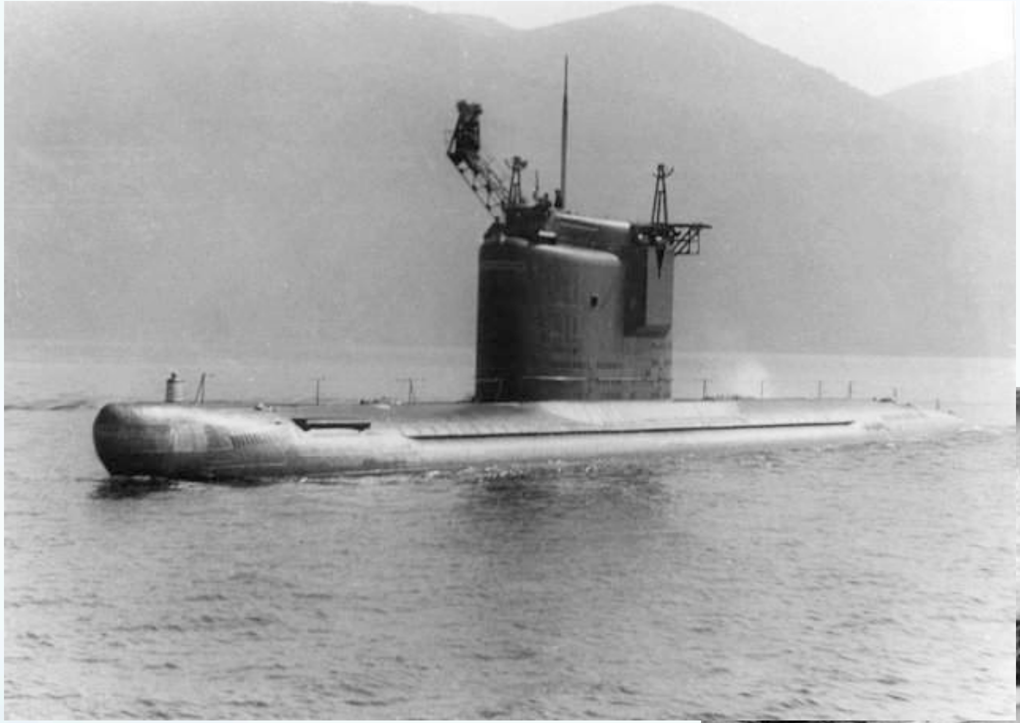
Golf V K-153. Source: https://forum.sub-driver.com/



Golf V K-153. Source: http://forums.airbase.ru/

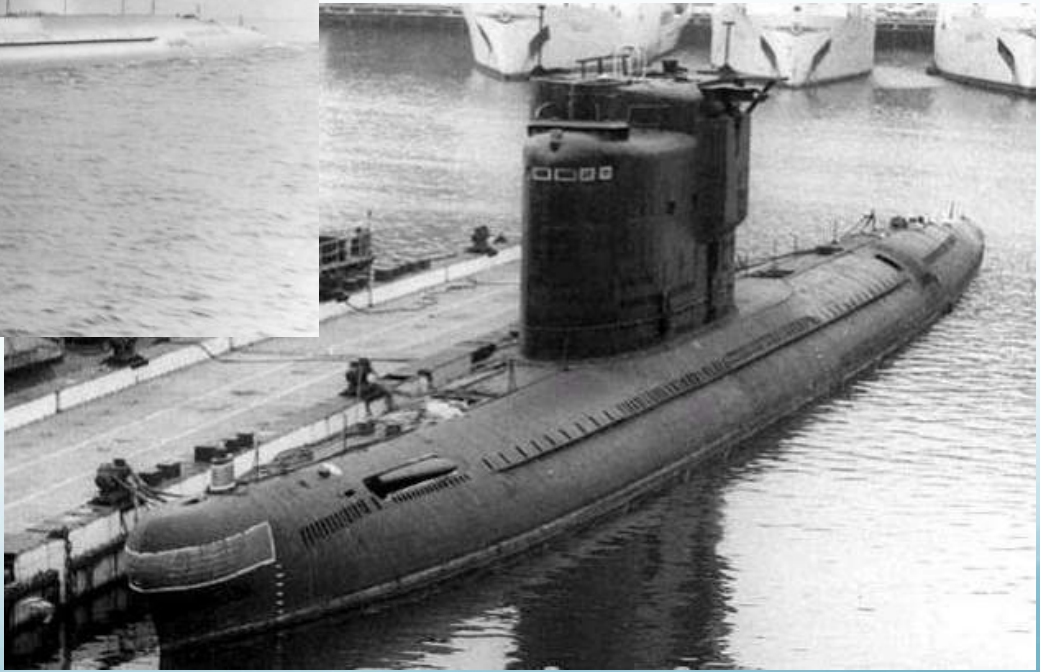
# Project 619

## Golf V-class diesel-powered ballistic missile submarine (SSB)



Golf V K-153. Source: http://forums.airbase.ru/

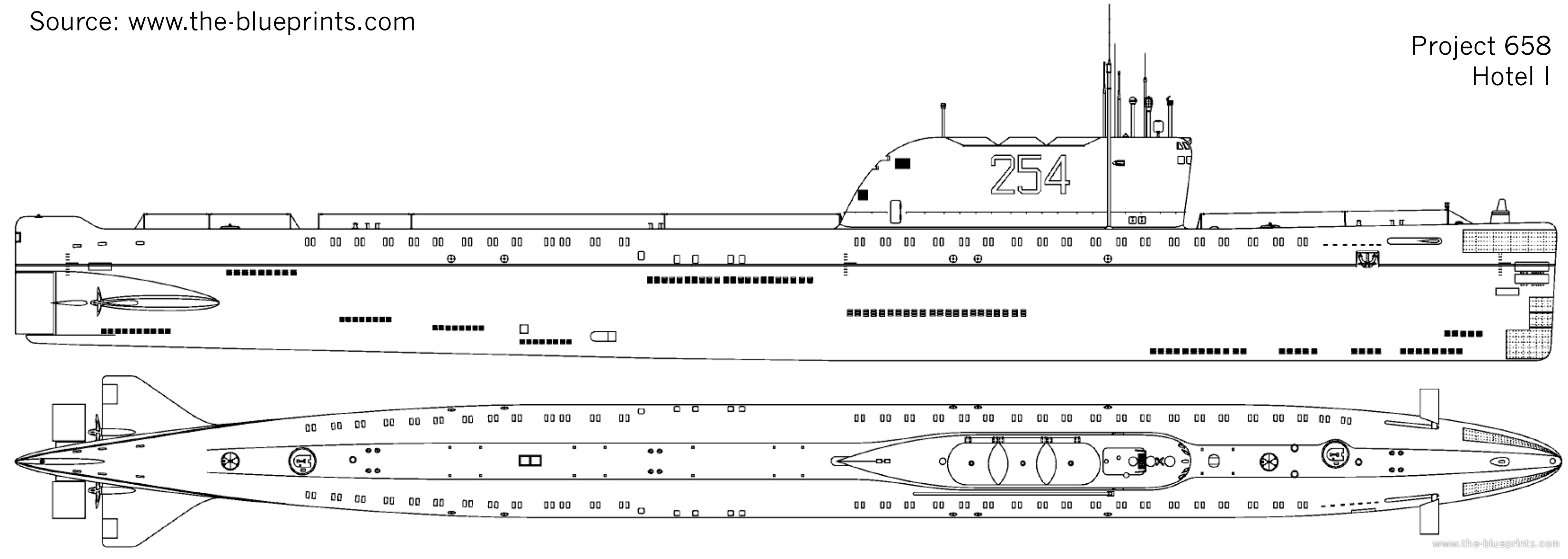
Equipped with a single launcher in the sail to carry out tests of the R-39 SLBM for the Typhoon-class SSBN.



Golf V K-153. Source: http://submarine.narod.ru/

# Project 658 & 658M

## Hotel I & II-class strategic ballistic missile submarines (SSBN)

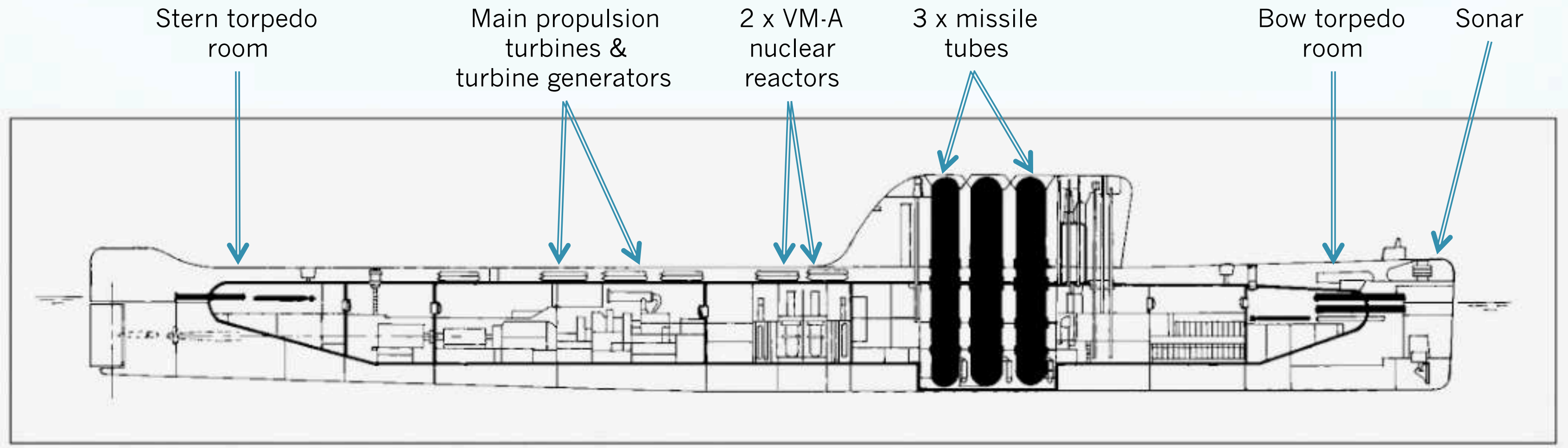



- Soviet Union's 1st SSBN; shared common nuclear propulsion plant and design features Project 659 / 675 Echo I / Echo II SSGNs and Project 627 November-class SSNs (collectively referred to as the HEN-class).
  - All were built at Soviet Shipyard No. 402 (now SEVMASH), Severodvinsk.
- Propulsion:
  - 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

# Project 658 & 658M

## Hotel I & II-class strategic ballistic missile submarines (SSBN)

- 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: 3 x R-13 SLBMs. D-2 launch system required launch when surfaced; three missiles could be fired within 12 minutes after surfacing.
  - Hotel II: 3 x R-21 SLBMs. D-4 launch system allowed submerged launch from a depth of 40 – 60 meters (131 – 197 feet).
- Operational matters:
  - Seven of the eight Hotel I (Project 658) subs were upgraded to Hotel II (Project 658M) configuration.
  - All Hotel SSBNs were retired by 1991.

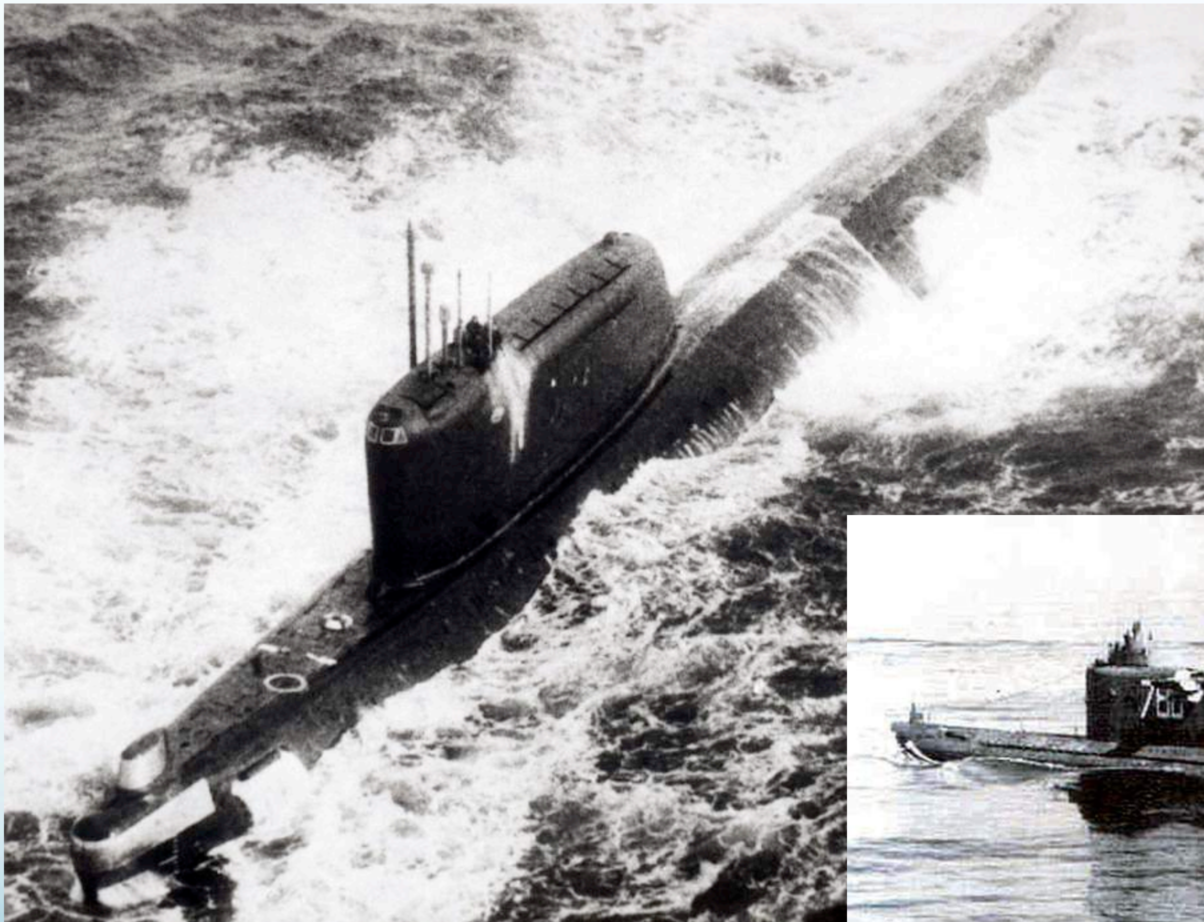



*Project 658/Hotel I SSBN. LOA 373 ft 11 in (114.0 m)* (©A.D. Baker, III)

Source: Figure from Polmar, Norman & Kenneth J. Moore; 2004; Cold War Submarine, The Design and Construction of US and Soviet Submarines; Potomac Books, Inc.; Washington, D.C.; p. 112

# Project 658 & 658M

## Hotel I & II-class strategic ballistic missile submarines (SSBN)



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

Hotel II. Source: forum.home.news.cn

# Hotel K-19 series of accidents

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

- Before commissioning of the 1st Hotel SSBN, K-17:
  - 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 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.

# Hotel K-19 series of accidents

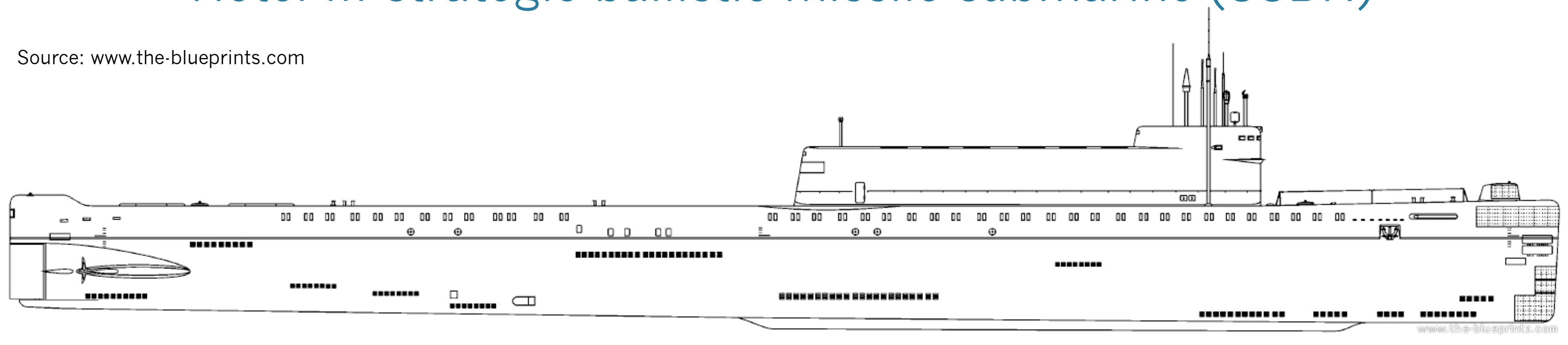
## (Bad luck sub nicknamed "Hiroshima" and "Day of Judgment")

- After commissioning (cont'd)
  - 15 November 1969: K-19 collided with the US 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 1,300 km (808 miles) 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.
  - 15 June - 5 November 1972: K-19 was repaired and put back into service. In August 1982 a sailor died following an electrical short circuit.
  - 19 April 1990: K-19 was decommissioned after a service life of about 29 years and the death of 37 sailors and injury of many more.
  - 1994: K-19 was transferred to the naval repair yard at Polyarny until March 2002, when it was towed to the Nerpa Shipyard, Snezhnogorsk, Murmansk, to be scrapped.

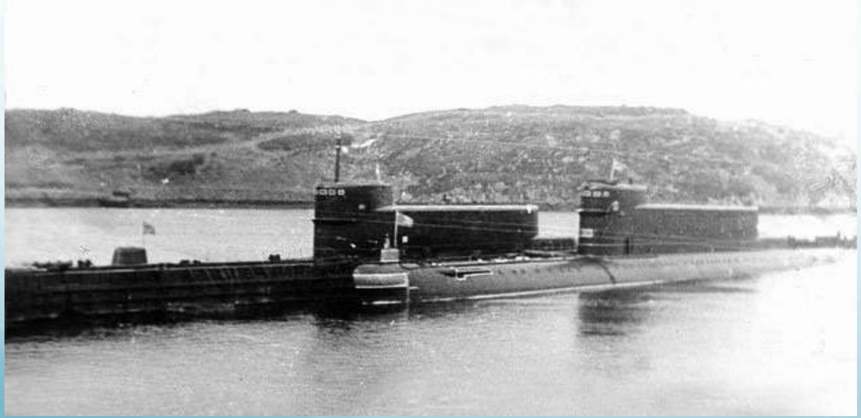
# Project 701

## Hotel III strategic ballistic missile submarine (SSBN)

Source: www.the-blueprints.com



- One unit, K-145, was converted to the Hotel III configuration in 1969 – 70; similar to Golf III.
- 6 x R-29 SLBMs in an extended missile compartment behind the sail, with the D-9 launch system, which permitted missile launch while submerged.
- Served as a testbed for the R-29 SLBM before returning to combat service in 1976.
- The R-29 SLBM was used operationally on Delta-class SSBNs.



Hotel III (L) & Golf III (R). Source, two photos: www.deepstorm.ru


Hotel III

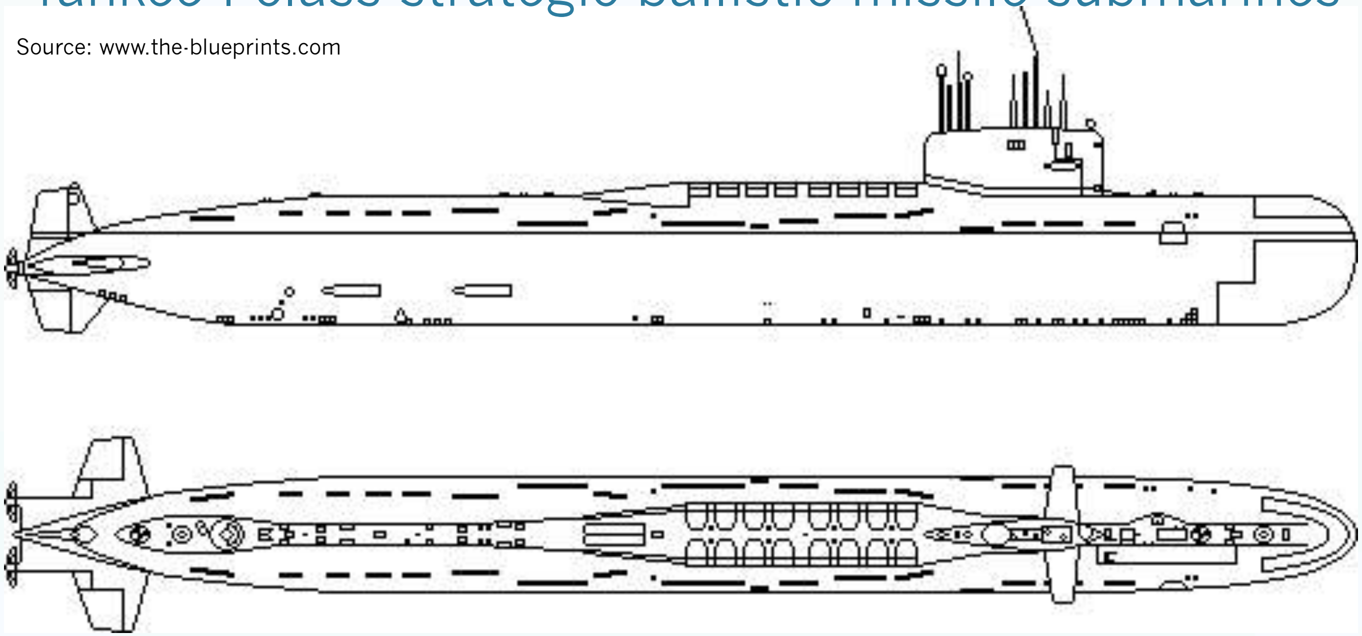
# Example Russian SSBN deterrent patrol areas

## Hotel I & II and Yankee I SSBNs, 1960s – 80s

Source: fas.org

# Project 667A (Navaga) & 667AU (Nalim)

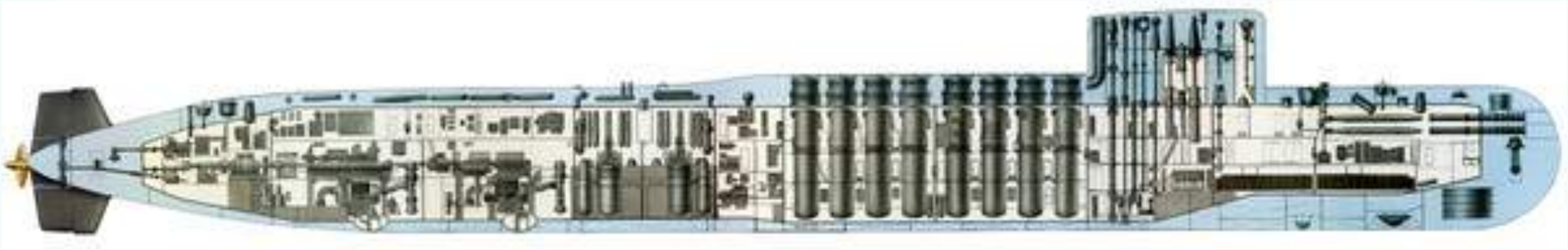
## Yankee I class strategic ballistic missile submarines




- Yankee I SSBNs were counterparts to the US Polaris SSBNs and carried their SLBMs in missile tubes that were entirely within the hull.
  - The Yankee I SSBN was designed by the Rubin Central Design Bureau, St. Petersburg, and approved in 1962.
  - 34 Yankee I SSBNs were produced in two shipyards: SEVMASH Shipyard in Severodvinsk and Leninskiy Komsomol Shipyard in Komsomolsk-on-Amur (in Russia's Far East).
  - There were 24 x Project 667A and 10 x Project 667AU Yankee I SSBNs. The first boat entered service in 1964 and the last boat retired in 1994.
  - In comparison, 41 US Navy Polaris SSBNs were in service from 1959 to 1995.

# Project 667A (Navaga) & 667AU (Nalim)

## Yankee I strategic ballistic missile submarines



Source: Rubin Central Design Bureau for Marine Engineering

- Design evolution:
  - One of the original Project 667 submarine designs was intended to carry three very large Beriev P-100 strategic cruise missiles. This original plan was rejected. (Ref: Steven J. Zalonga, “The Kremlin's Nuclear Sword,” Smithsonian Institution Press, 2002)
  - A later Project 667 iteration was intended to be armed with eight R-21 SLBMs, which were used on Golf II-class SSBs and Hotel II-class SSBNs. (Ref. Norman Polmar & Kenneth J. Moore; “Cold War Submarines,” Brassey’s, Inc., 2004)
  - Eventually the Project 667A design evolved into the Naviga (Yankee I) SSBN armed with the new generation of storable liquid propellant R-27 SLBMs developed by Makeyev Rocket Design Bureau.
- Propulsion:
  - OK-700: 2 x VM-4-2 PWRs, each rated @ 90 MWt
  - Two independent secondary power trains, each with 2 x main turbines and a reduction gear driving a single shaft and propeller. The two trains have a combined rating of about 34,500 shaft horsepower.

# Project 667A (Navaga) & 667AU (Nalim)

## Yankee I strategic ballistic missile submarines

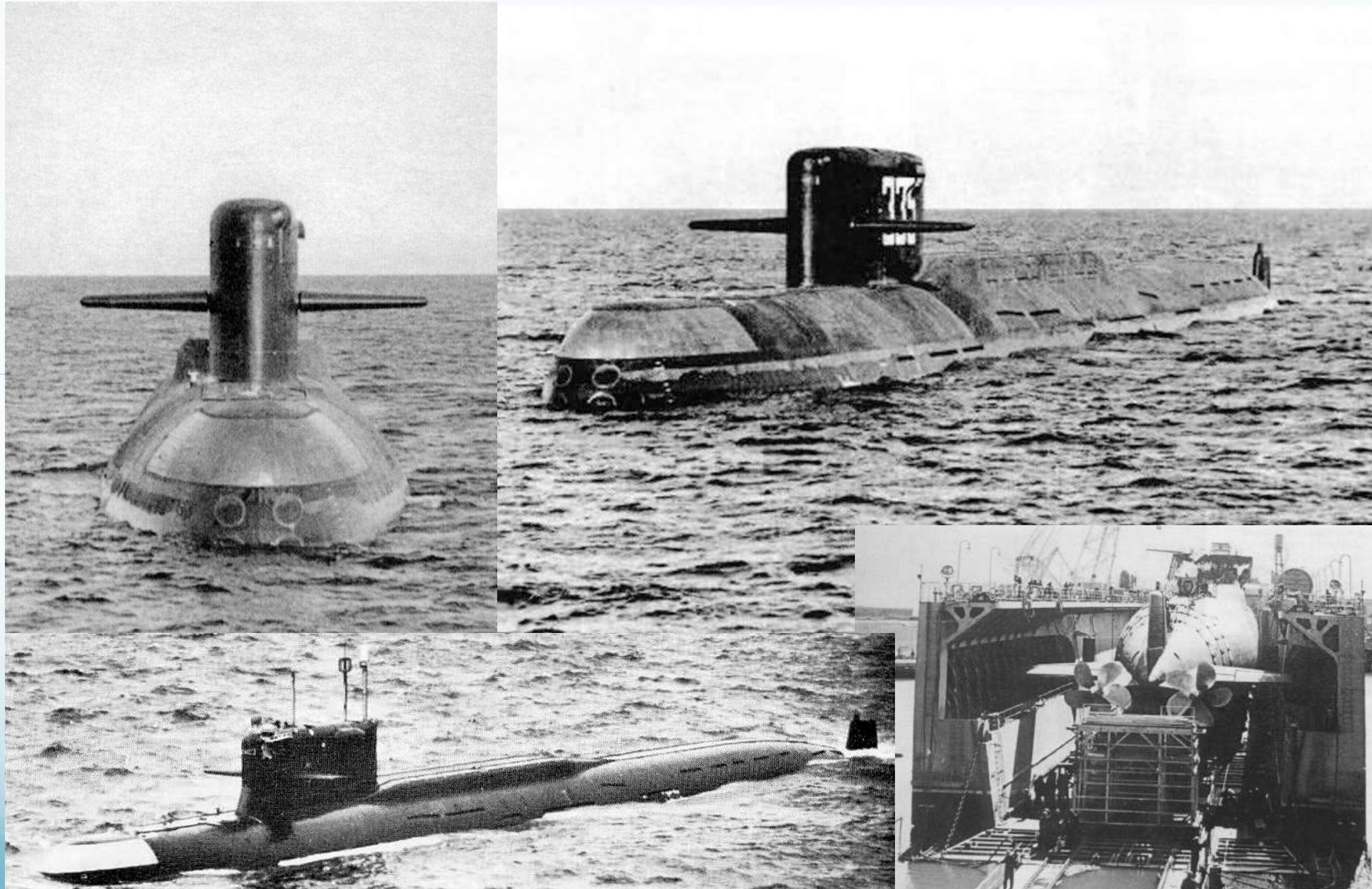
- Armament: The primary difference between Projects 667A & 667AU was in the missile system.
  - Project 667A: 16 x R-27 SLBMs & D-5 launch system.
  - Project 667AU: 16 x R-27U SLBMs & D-5U launch system.
  - Both had 4 x 533 mm (21 inch) and 2 x 400 mm (16 inch) bow torpedo tubes.
- Operational matters:
  - July 1967: The lead Yankee I, K-137, completed sea trials. At the end of 1967 it joined the Northern Fleet.
  - The R-27 SLBMs could be launched from a depth of 40 - 50 meters (131 – 164 feet) while the submarine was moving at 3 - 4 knots. The missiles were fired in salvos each comprising four missiles. Eight minutes were needed for pre-launch preparation and, within a salvo, the missiles were fired at intervals of 8 seconds.
  - USSR continuously maintained several forward-deployed Yankee I SSBNs in patrol areas off the US East and West coasts.
  - Yankee-class SSBNs were capable of operating in Arctic waters.
  - Yankee I sub K-219 sank in the Atlantic in 1986 due to an accidental explosion in a missile tube believed to be caused by the interaction of hydrazine rocket fuel and seawater that was slowly leaking into a missile tube.

# Project 667A (Navaga) & 667AU (Nalim)
## Yankee I strategic ballistic missile submarines

- Operational matters (cont'd):
  - Between 1979 and 1994 the Yankee I SSBNs were retired at a rate driven primarily by nuclear arms treaty limits (SALT I, START I, START II), as were their US Polaris SSBN counterparts.
  - During their 30-year fleet operational life (1964 – 1994), the Project 667A / 667AU Yankee I and 667AM Yankee II SSBNs conducted 590 deterrent patrols.
- Yankee variants:
  - Many Yankee I SSBNs were modified for special roles, including:
    - 1 x Project 667AM (Naviga M) Yankee II SSBN & test sub for R-31 SLBM
    - 1 x Project 667M (Andromeda) Yankee Sidecar cruise missile test sub (SSGN)
    - 7 x Project 667AT (Grusza) 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
  - A concept had been developed under Project 667V for a Yankee variant armed with R-27K anti-ship ballistic missiles and equipped with with the D-5K launch system. This Yankee SSBN variant was not developed, although the R-27K missile was developed and tested on the Golf IV SSB. While the R-27K could fit in the launch tubes of the Project 667A and 667AU Yankee SSBNs, these subs lacked the necessary fire control system to target and launch the R-27K anti-ship version of the R-27 missile.

# Project 667A (Navaga) & 667AU (Nalim)

## Yankee I strategic ballistic missile submarines



Yankee I.  Source, four photos: http://www.shipmodels.info/mws_forum/

# 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 its 14 remaining nuclear-armed missiles sank in the Hatteras Abyssal Plain, to a depth of 6,000 m (18,000 ft).

Photo source: https://commons.wikimedia.org/

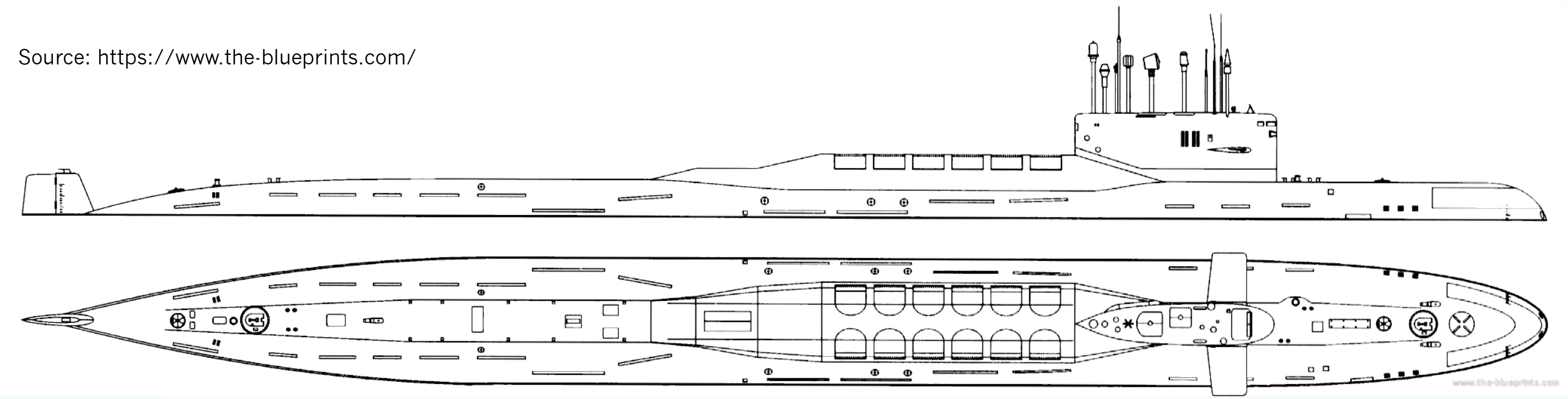

Map source: https://en.wikipedia.org/

- 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.

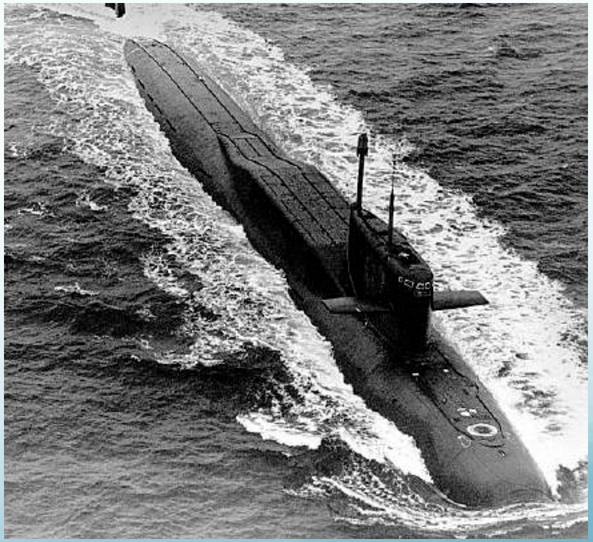
# Project 667AM (Navaga M)

## Yankee II strategic ballistic missile submarine

Source: https://www.the-blueprints.com/



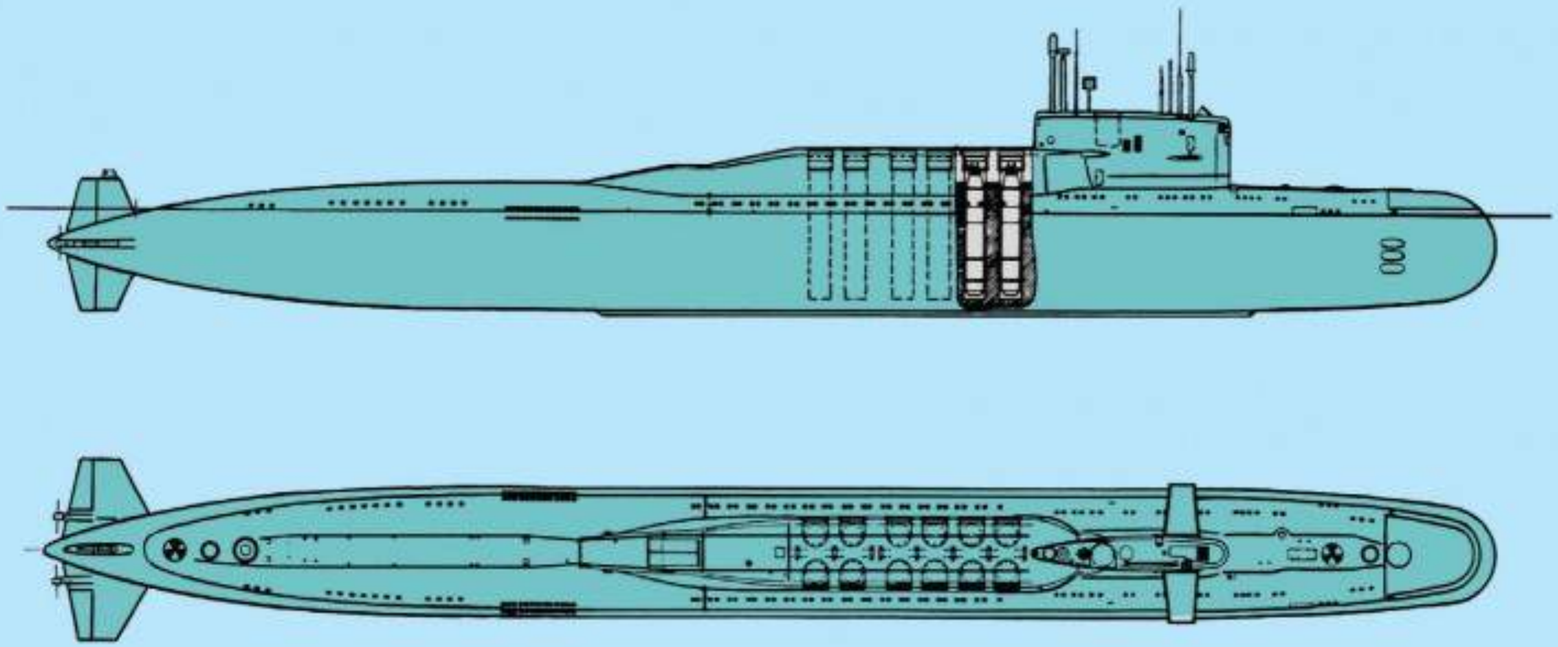
- There was only one Yankee II conversion under Project 667AM. Yankee I SSBN K-140 (the 2nd Yankee I boat) was converted at the Zvezdochka Shipyard, Severodvinsk, from 1977 to 1980, to become the one-of-a-kind Yankee II used to test the R-31 (SS-N-17) SLBM.
  - Armed with 12 x R-31 SLBMs with the D-11 launch system.
  - This was the Soviet Navy's 1st solid propellant SLBM and 1st cold-launched SLBM, which did not require flooding the launch tube before launching the missile.
  - Updated with new combat information & navigation systems.
  - Missile deck was taller & shorter than Yankee I; similar to a Delta I.
- After the test program, K-140 continued operation as the only SSBN armed with the R-31 SLBMs.
- All R-31 SLBMs were disposed of by launching from K-140 between 17 September - 1 December 1990; all were successful. Thereafter, K-140 was decommissioned and scrapped.



Source: defenseimagry.mil / Wikipedia

# Project 667B (Murena)

## Delta I-class strategic ballistic missile submarine



Source: http://eng.makeyev.ru/activities/missile-systems/2/RaketaR29/

- This 18 boat class of SSBNs was designed by the Rubin Central Design Bureau, St. Petersburg. Ten were built at SEVMASH Shipyard in Severodvinsk and eight were built at the Leninskiy Komsomol Shipyard in Komsomolsk-on-Amur (in Russia's Far East). All were commissioned between 1972 -1977.
- Basic layout was similar to the Yankee II, but with a taller missile deck aft of the sail.
- Propulsion, same as Yankee I:
  - OK-700: 2 x VM-4B PWRs each rated @ 90 MWt
  - 2 x main turbines each with a combined rating of about 34,500 hp; driving 2 shafts

# Project 667B (Murena)

## Delta I-class strategic ballistic missile submarine

- Armament:
  - Originally 12 x R-29 SLBMs in missile tubes inside the pressure hull with the D-9 missile launch system.
  - Seven Delta I SSBNs (K-450, -460, -472, -475, -497, -500 and -512) were modernized with the D-9D launch system and the R-29D SLBM, which were first used on the Delta II SSBNs.
  - 4 x 533 mm (21 inch) and 2 x 400 mm (16 inch) bow torpedo tubes.
- Operational matters:
  - The range of the R-29 SLBM was adequate to reach US targets from patrol areas in the Barents and Norwegian Seas and the Arctic Ocean. The Delta I no longer had to venture into waters monitored by the US SOSUS sonar network.

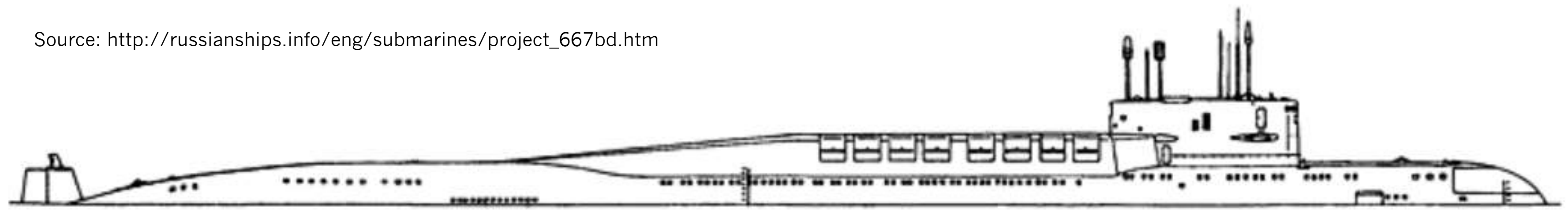
Delta I. Note the distinctive notch at the back of the missile deck.
Source: http://enrique262.tumblr.com/

- Crew complement was 120, with 37 officers.
- Most Delta I SSBNs were decommissioned between 1992 and 1999, with two Pacific Fleet units not being decommissioned until 2004.
- Average Delta I service life was 19.6 years for 15 boats. Three other boats had substantially longer service lives: K-447 (30.5 years), K-457 (26 years) and K-500 (28 years).

# Project 667BD (Murena M)

## Delta II-class strategic ballistic missile submarine

Source: http://russianships.info/eng/submarines/project_667bd.htm

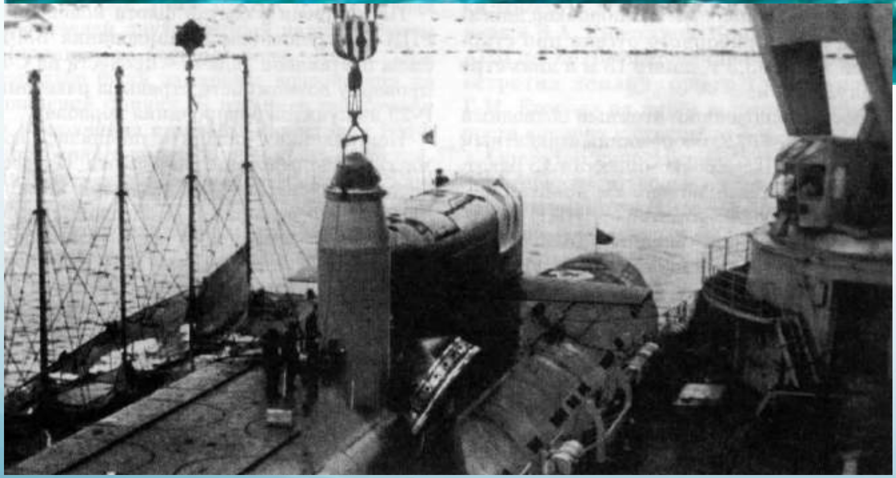


- This was a 4 boat class designed by the Rubin Central Design Bureau, St. Petersburg, and built at the SEVMASH Shipyard in Severodvinsk. All were commissioned in 1975.
- The Delta II SSBNs were 16 meters (52 ft) longer than the Delta I to allow the installation of four more missile tubes. The Delta II SSBNs also implemented sound silencing features to provide quieter operation, including: mounting the main turbines and turbine generators on sound isolated "rafts" and supporting piping systems with sound isolating rubber mounts. Delta II SSBNs also used acoustic coating on the hull.
- Propulsion, same as Delta I:
  - OK-700: 2 x VM-4B PWRs each rated @ 90 MWt
  - 2 x main turbines each with a combined rating of about 34,500 shp; driving 2 shafts
- Armament:
  - 16 x R-29D SLBMs in missile tubes inside the pressure hull; D-9D launch system.
  - 4 x 533 mm (21 inch) and 2 x 400 mm (16 inch) bow torpedo tubes.

# Project 667BD (Murena M)

## Delta II-class strategic ballistic missile submarine

Delta II. Source: http://eng.makeyev.ru/activities/missile-systems/2/R29D/

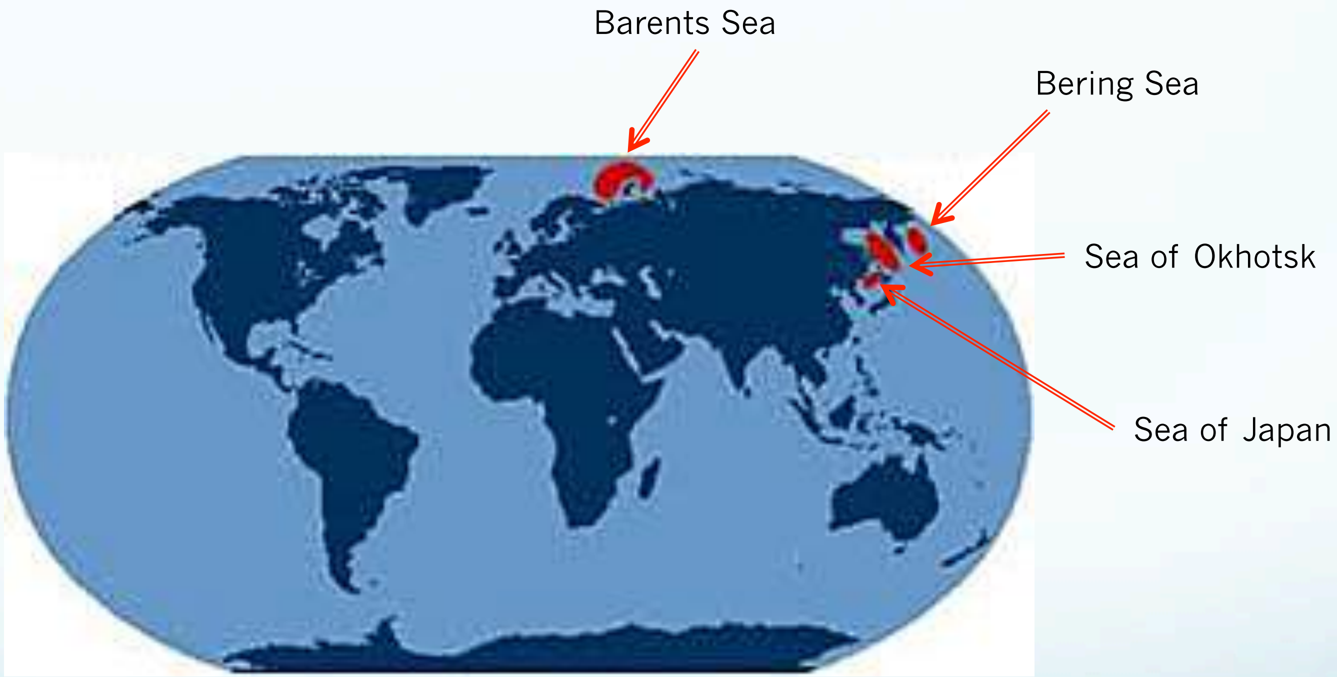


R-29 being loaded onto a Delta I or II SSBN, circa late 1970s.
Source: http://www.shipmodels.info/mws_forum/

- Operational matters:
  - The longer range of the R-29D SLBM (9,100 km / 5,654 mi vs. 7,800 km / 4,847 mi for the R-29 used on Delta I) enabled the Delta II SSBN patrol areas to be located closer to Soviet protected waters.
  - All four Delta II SSBNs were decommissioned in 1995, with an average service life of 20 years.

# Example Russian SSBN deterrent patrol areas

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

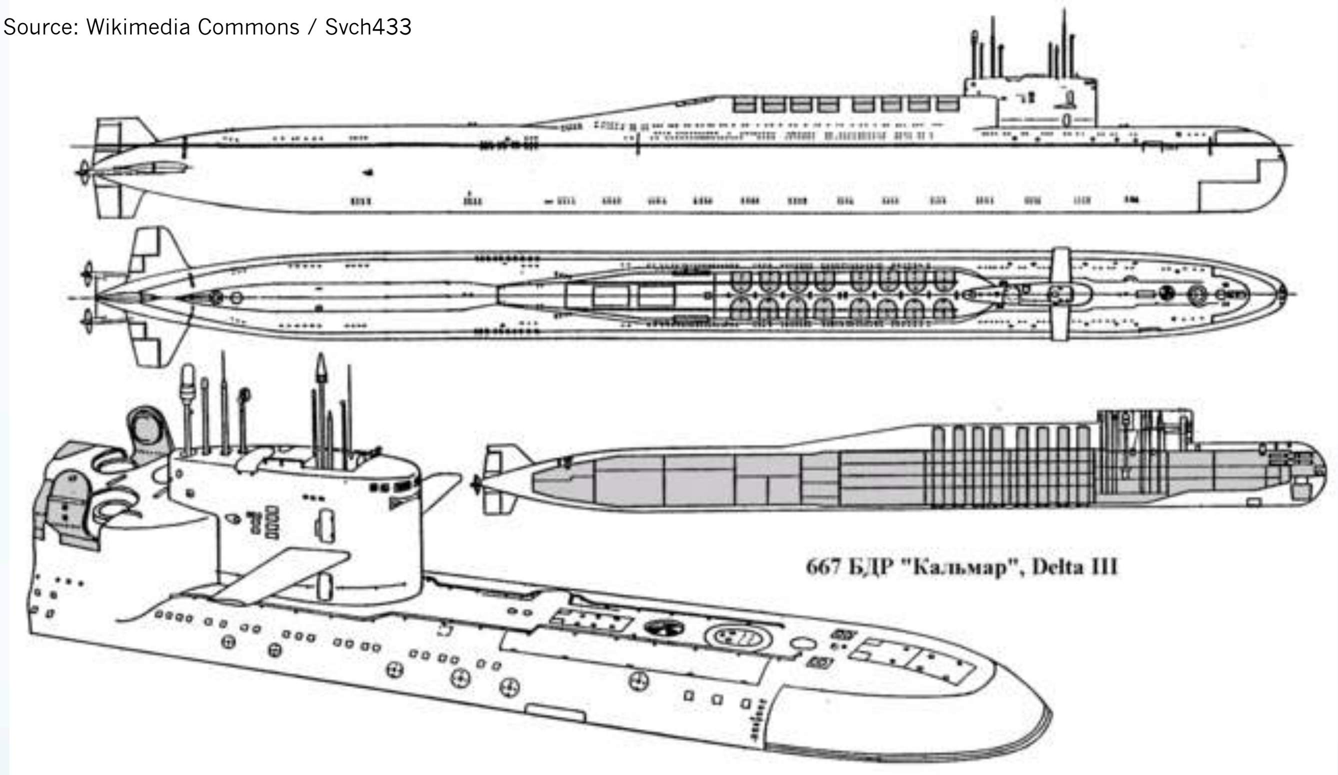



Source: fas.org

# Project 667BDR (Kal'mar)

## Delta III strategic ballistic missile submarines

Source: Wikimedia Commons / Svch433




- Delta III is a substantial upgrade over the Delta I & Delta II subs, armed with more advanced versions of the R-29 SLBM.
- There were 14 SSBNs in this class, all built at SEVMASH in Severodvinsk. All were commissioned between 1977 and 1983.
- Propulsion:
  - OK-700A: 2 x VM-4 variants (4S/4SG) PWRs, each rated @ 90 MWt
  - 2 x main turbines with a combined rating of about 34,500 shp; driving 2 shafts

# Project 667BDR (Kal'mar)

## Delta III strategic ballistic missile submarines

- Armament:
  - 16 x R-29R / RSM-50 SLBMs with the D-9R launch system introduced in 1977.
    - R-29R was the 1st Soviet SLBM with MIRV (multiple, independently targetable reentry vehicle) warheads.
    - The Delta III SSBN has deployed upgraded versions of the original R-29R as they were introduced over the following three decades: R-29RL (1979), R-29RK (1982), R-29RKU (1987), R-29RKU01 (1990) and the latest version, R-29RKU02 (2006).
  - 4 x 533 mm (21 inch) and 2 x 400 mm (16 inch) bow torpedo tubes; storage for 12 - 16 torpedoes.
- Operational matters:
  - With the retirement of the R-39 SLBM and the Typhoon SSBNs by 2004, some Delta III's were retained in service.
  - In September, 2015, Russian Defense Minister Sergei Shoigu reported that six nuclear submarines already are undergoing modernization at the Zvezda shipyard at Bolshoy Kamen on Russia's Pacific coast. The stated goal was to extend their service life by 20 years and to bring the boats up to the technological level of Russia's most modern nuclear-powered submarines.
    - Delta III K-44, *Ryazan,* was among these boats. It was overhauled from 2012 – 2016 and re-entered the fleet in early 2017.
  - As of mid-2018, there is only one Delta III boat remaining in the Russian fleet: K-44 *Ryazan*, which continues to serve in the Pacific Fleet *Rayzan* was the last Delta III SSBN. It was commissioned in September 1982, giving it a service life of almost 36 years. Two older Delta III SSBNs, K-223 *Podolsk* and K-433 *Svyatoy Georgiy Pobedonosets,* were retired in early 2018.
  - Under Project 09786, Delta III K-129 was modified at Zvezdochka Shipyard, Severodvinsk, from 1994 – 2002 to become a special operations PLA "mothership" (small submarine carrier). It was renamed BS-136 *Orenburg II* and assigned to the Northern Fleet.

# Project 667BDR (Kal'mar)

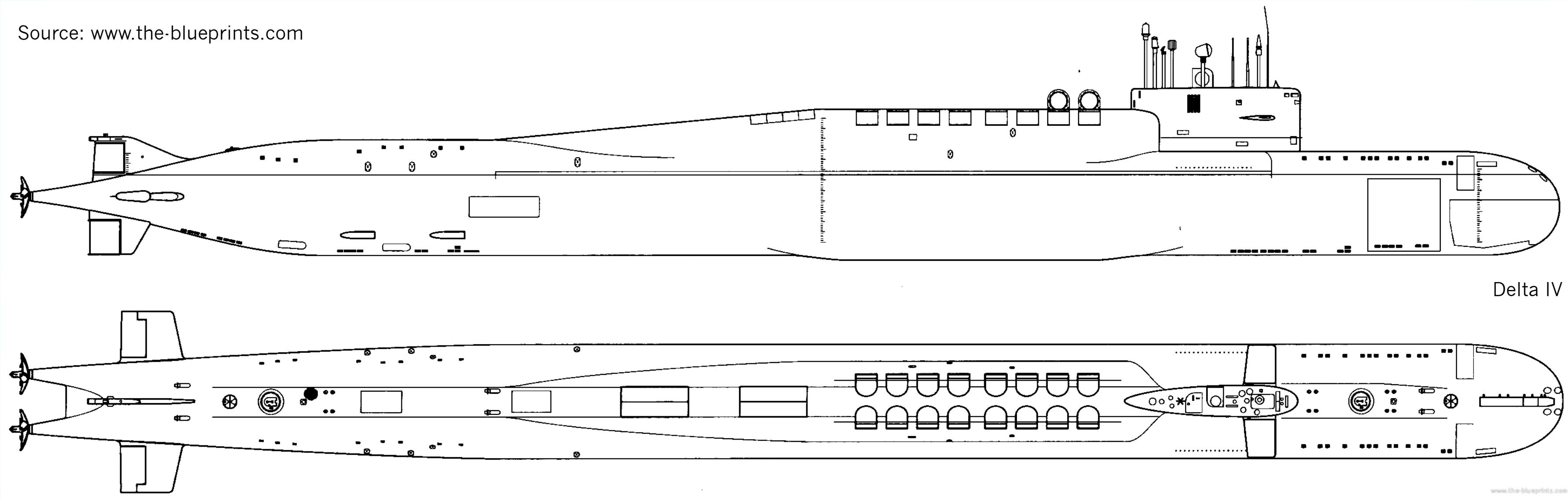
## Delta III strategic ballistic missile submarines

Delta III K-433, *Svyatoy Georgiy Pobedonosets*. Source, top: https://commons.wikimedia.org/; bottom: http://www.navyrecognition.com/

Delta K-211, *Petropavlovsk-Kamchatskiy* dockside. Source: https://i.pinimg.com/originals/

# Project 667BDRM (Delfin)

## Delta IV-class strategic ballistic missile submarines




- There are 7 Delta IV SSBNs, all built at SEVMASH in Severodvinsk. All were commissioned between 1984 and 1990. Delta IV SSBNs were substantial upgrades over the Delta III subs.
- Propulsion:
  - OK-700A: 2 x VM-4 variants (4S/4SG) PWRs, each rated @ 90 MWt
  - 2 x main turbines with a combined rating of about 34,500 shp; driving 2 x shafts and propellers.
- Armament:
  - 16 x R-29RM / RSM-54 SLBMs with the D-9RM launch system introduced in 1986. The Delta IV SSBN has deployed upgraded versions of the original R-29RM as they were introduced over the following three decades: R-29RMU (1988), R-29RMU1 (2002), R-29RMU2 (2007), and the latest version, R-29RMU2.1 Lainer (2014).
  - 4 x 533 mm (21 inch) bow torpedo tubes; storage for 12 - 16 torpedoes or other devices. Unlike Delta III, Delta IV is equipped with the TRV-671 RTM missile-torpedo system, which is capable of using all types of torpedoes, anti-submarine torpedo-missiles and anti-hydroacoustic devices.

# Project 667BDRM (Delfin)

## Delta 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 at high latitudes.
  - Delta IV SSBNs are capable of launching any number of missiles in a single salvo. This was demonstrated by *Operation Behemoth:*
    - In *Operation Behemoth 1* on 6 August 1989, submerged Delta IV sub K-84, *Yekaterinburg*, attempted to salvo launch all 16 R-29RM SLBMs. The attempt failed when an oxidizer leak in missile 6 caused a fire that destroyed the missile in the launch tube.
    - In *Operation Behemoth 2* on 6 August 1991, submerged Delta IV sub K-407, *Novomoskovsk,* became the world's only submarine to fire an all-missile salvo, launching 16 R-29RM SLBMs in 244 seconds. The first and the last missiles hit their targets. All others were destroyed on command after launch.
  - 7 July 1998: Russia conducted the 1st ever orbital launch from a submarine (Delta IV K-407, *Novomoskovsk*), placing two small satellites in orbit using a modified R-29RM SLBM.
  - 1999 to December 2016: Under Project 09787, one Delta IV unit, K-64, was removed from SSBN service and converted to be a PLA "mothership" for a small, special operations submarine. The conversion was done at the Zvezdochka Shipyard in Severodvinsk.
  - July 1998: Russian Federation decision to modernize the Delta IV SSBNs and restart production of an updated R-29RM SLBM.
    - Thru 2012, six Delta IV units were overhauled and modernized at the Zvezdochka Shipyard, to handle the R-29RMU2 Sineva SLBM. An average overhaul lasted five years.
    - 29 December 2011: A shipyard fire during overhaul damaged Delta IV K-84, *Yekaterinburg.*
  - In 2014, the first Delta IV subs became operational with the newer R-29RMU2.1 Lainer SLBM, which is replacing the R-29RMU2 Sineva.
    - R-29RMU2.1 Lainer is expected to ensure the viability of Delta IV class submarines until at least 2030.

# Project 667 BDRM (Delfin)

## Delta IV strategic ballistic missile submarine


Source, top L & R, bottom L: forum.sub-driver.com

Source, bottom R: Military-Today.com

# Project 667 BDRM (Delfin)

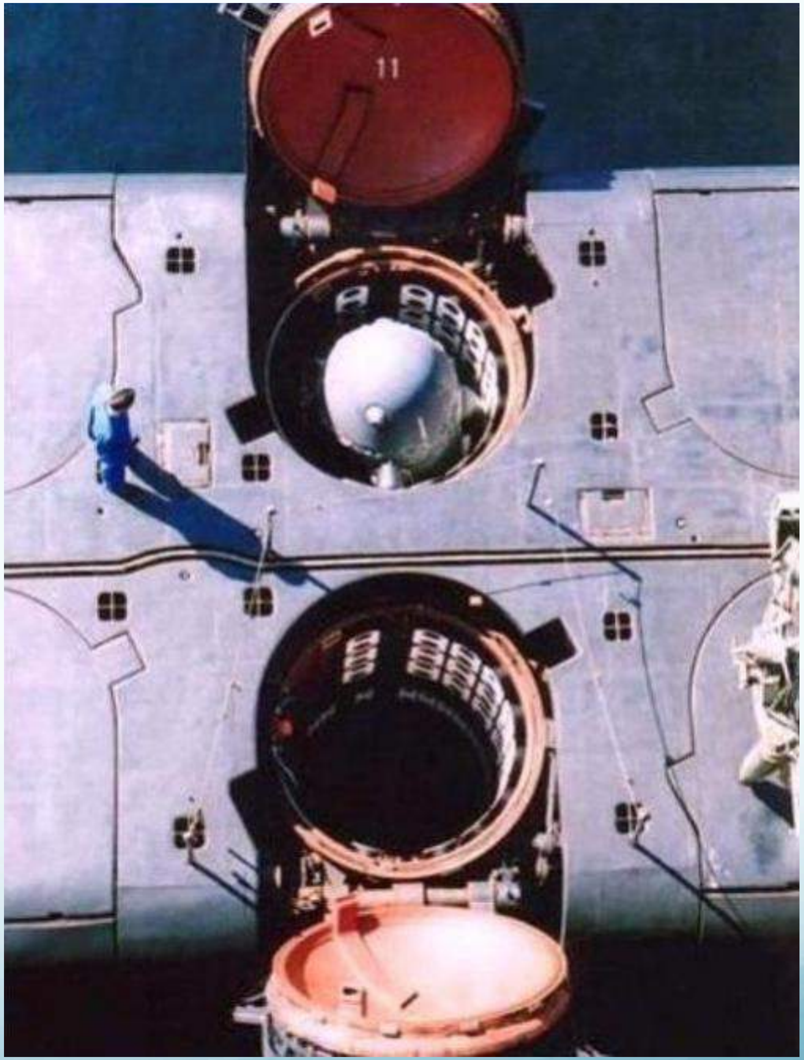
## Delta IV SSBN in drydock

Delta IV K-117, *Bryansk.* Source: red-stars.org

Source, top R: https://forum.sub-driver.com/
Source, top L: Pinterest
Source, bottom R: https://www.strategypage.com/

# Project 667 BDRM (Delfin)

## Delta IV SSBN loading an R-29 SLBM



Source, two photos: https://forum.sub-driver.com/

# Project 667 BDRM (Delfin)

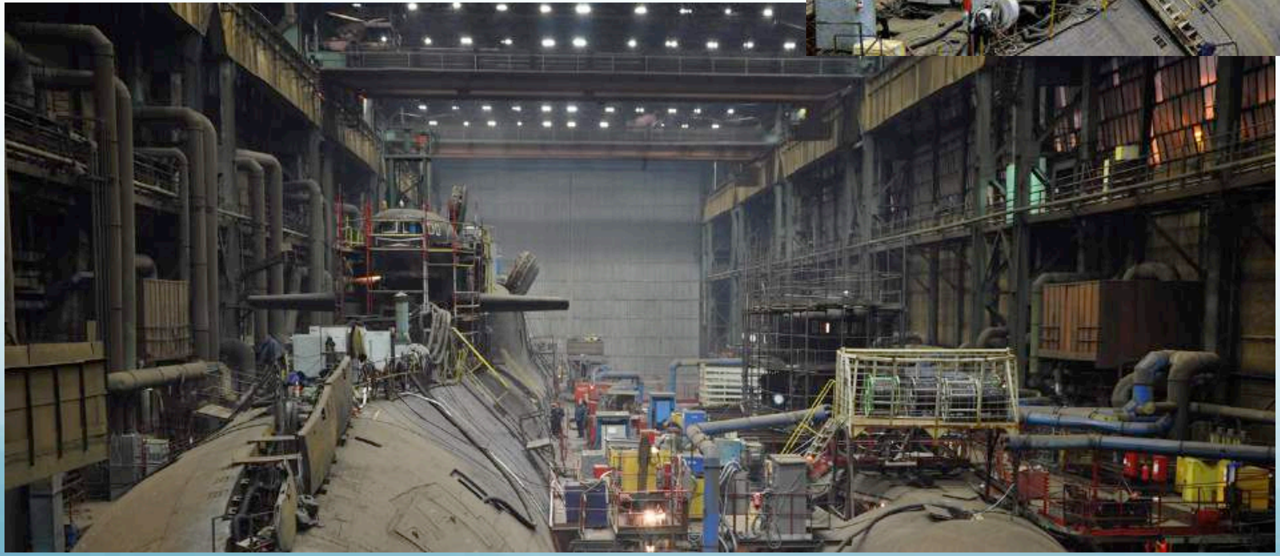
## Delta IV Arctic launch

Source: http://misilactual.blogspot.com/2013/09/, originally from Edward L. Cooper DIA 1985


Source, top: forum.sub-driver.com
Source, bottom: Military-Today.com

# Project 667 BDRM (Delfin)

## Delta IV SSBNs during overhaul

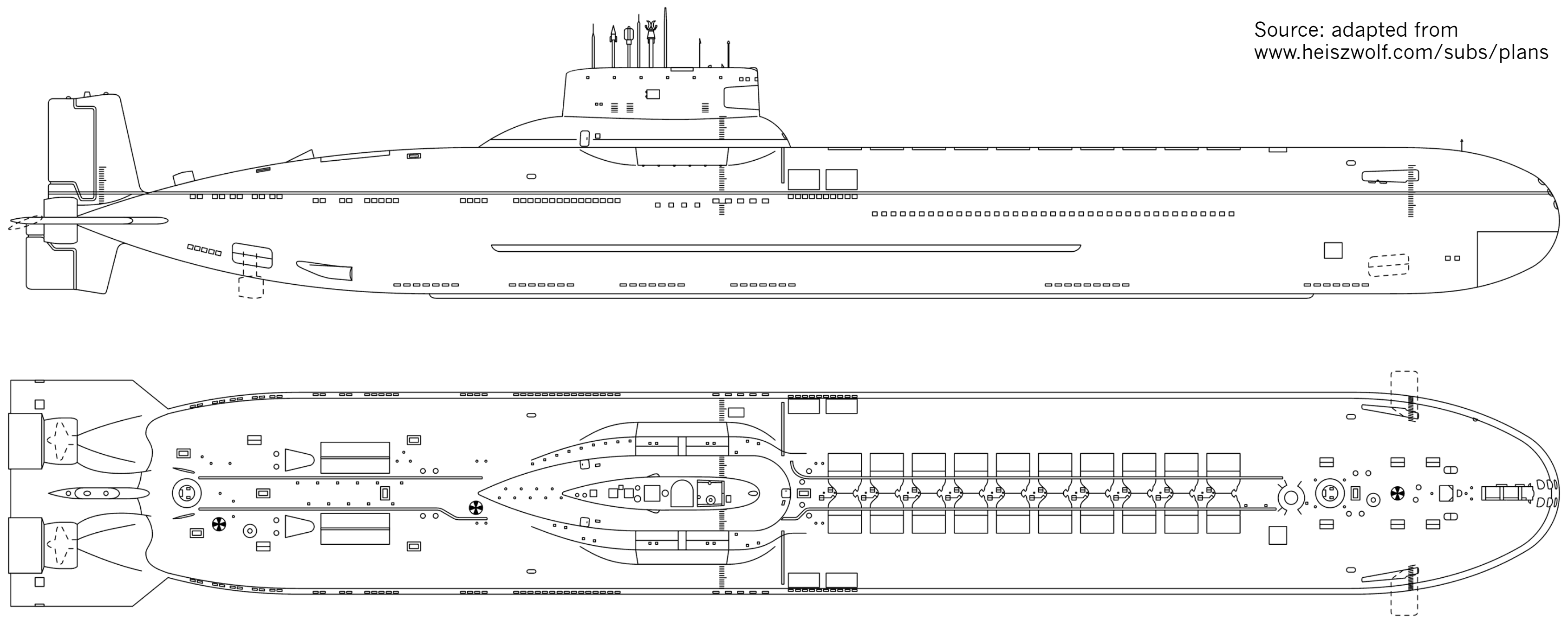


Top left: K-117, *Bryansk*.
Source: http://www.navyrecognition.com/

Top right & bottom: K-84, *Yekaterinburg*.
Source: https://www.reddit.com/

# Project 941 (Akula)

## Typhoon-class strategic ballistic missile submarine (SSBN)




- Largest submarine ever built. Multi-hull design with five inner hulls with 19 compartments.
- Designed by Rubin Central Design Bureau. Six subs built at the SEVMASH Shipyard in Severodvinsk and commissioned between 1981 – 1989; plus one incomplete hull, which was scrapped.
- Propulsion:
  - OK-650: 2 x PWRs each rated @ 190 MWt
  - 2 x main turbines with a combined rating of about 99,200 shp (74 MW); driving 2 shafts with shrouded propellers
- Armament:
  - 20 x R-39 (RSM-52) SLBMs with the D-19 launch system. The missile launch tubes are forward of the sail, in a free-flood area between two, long cylindrical submarine pressure hulls. The improved R-39U was adopted in 1988.
  - 6 x 533 mm (21 in) bow torpedo tubes

# Project 941 (Akula)

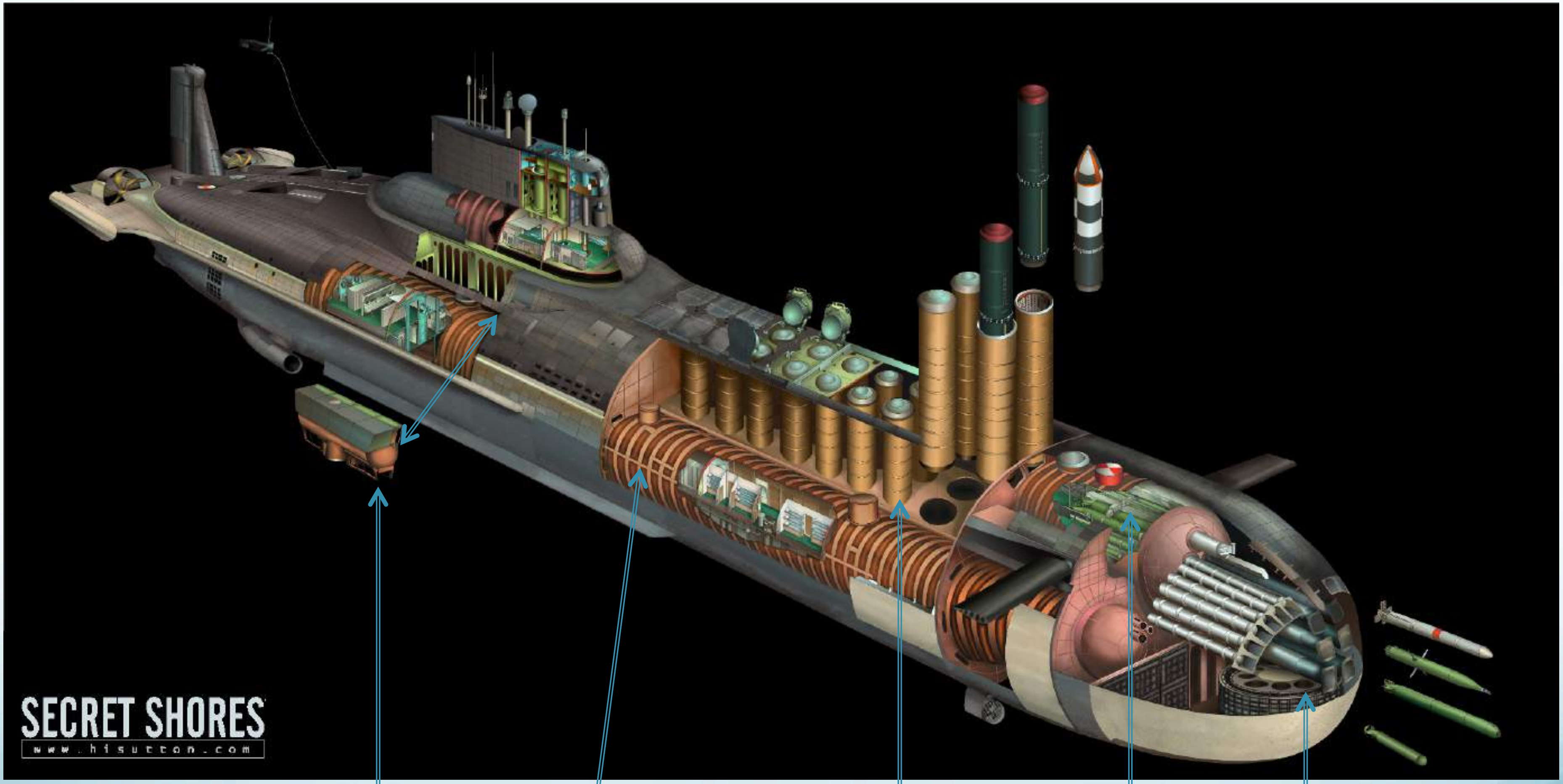
## Typhoon-class strategic ballistic missile submarine (SSBN)

- Operational matters:
  - On 25 Aug 1995, a Typhoon SSBN surfaced at the North Pole, through 2.5 m (8 ft) of ice, and launched an 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 R-39 SLBMs were decommissioned by 2006.
  - Under Project 941UM, one Typhoon sub, *Dimitry Donskoy*, TK-208, was overhauled and by 2003 had two launch tubes configured for testing the RSM-56 Bulava SLBM, then being developed for the Borei-class SSBN. It also was refueled in 2003. This unit is in active service in 2018.
  - Three previously operational Typhoons have been scrapped (TK-12, TK-13 & TK-202). Their active service life averaged 13 years.
  - The two youngest Typhoons (TK-17 & TK-20) were decommissioned in 2006 & 2004, respectively, and are being held "in reserve". When retired, their average active service life was 17 years. The fate of these two Typhoon subs has not been finalized.

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

# Project 941 (Akula)

## Typhoon-class strategic ballistic missile submarine (SSBN)




Source: www.hisutton.com

Crew escape pod

One of several inner (pressure) hulls

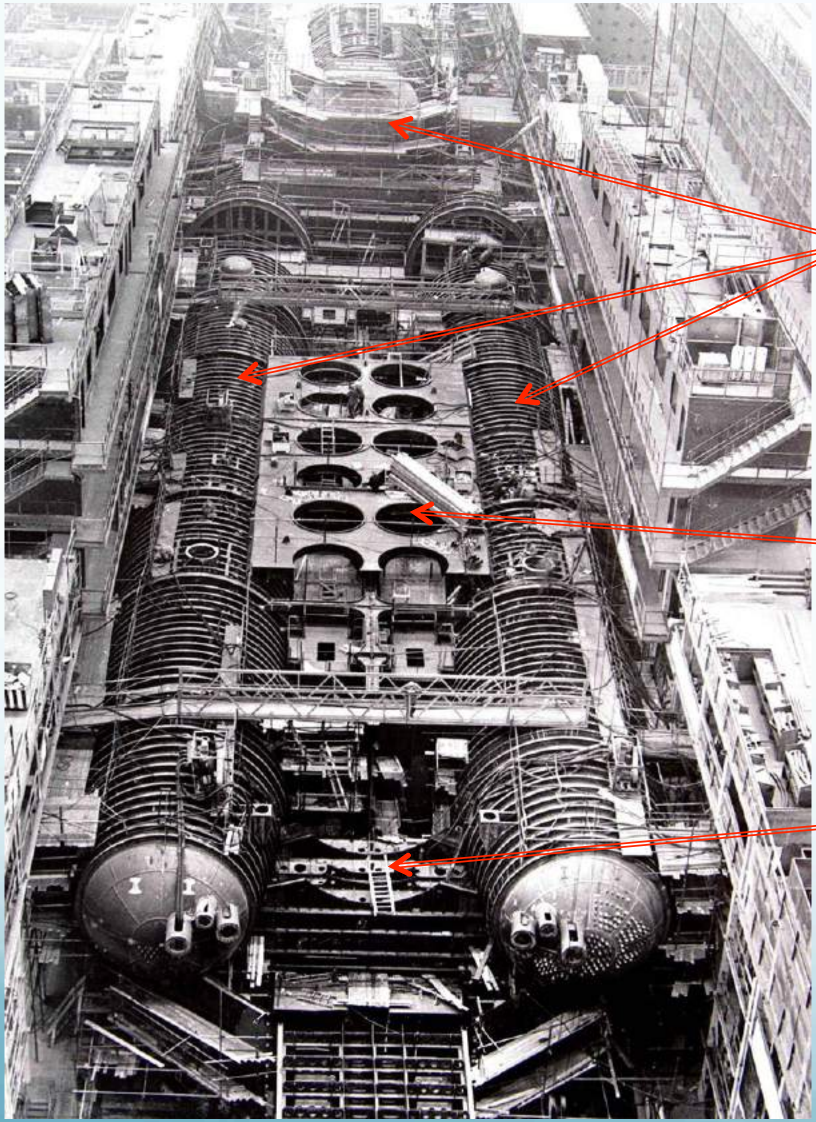
20 x R-39 SLBM launch tubes installed in the free-flood area between two long pressure hulls

Torpedo room

Cylindrical sonar array

# Project 941 (Akula)

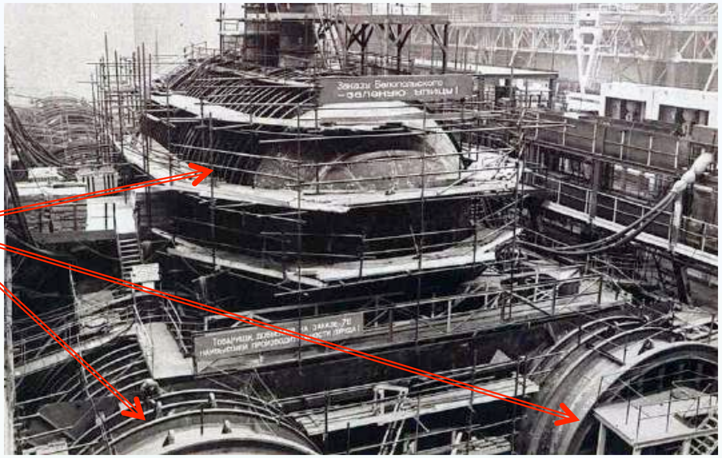
## Typhoon-class SSBN under construction



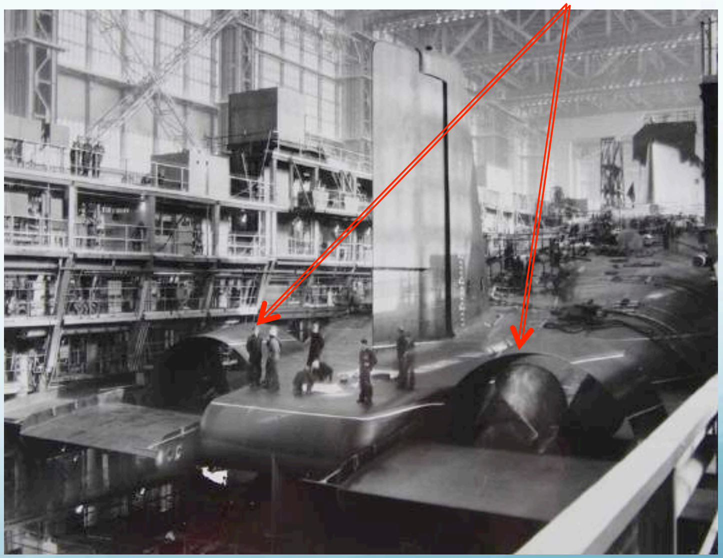
Pressure hull

Missile tubes to be installed here, outside the pressure hull

Pressure hull for Torpedo room not yet installed



Shrouded propellers



Source, three photos: http://warwall.ru/news/

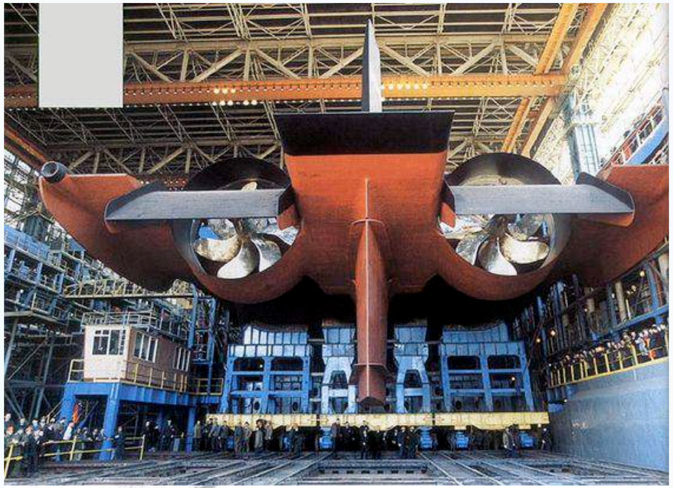
# Project 941 (Akula)

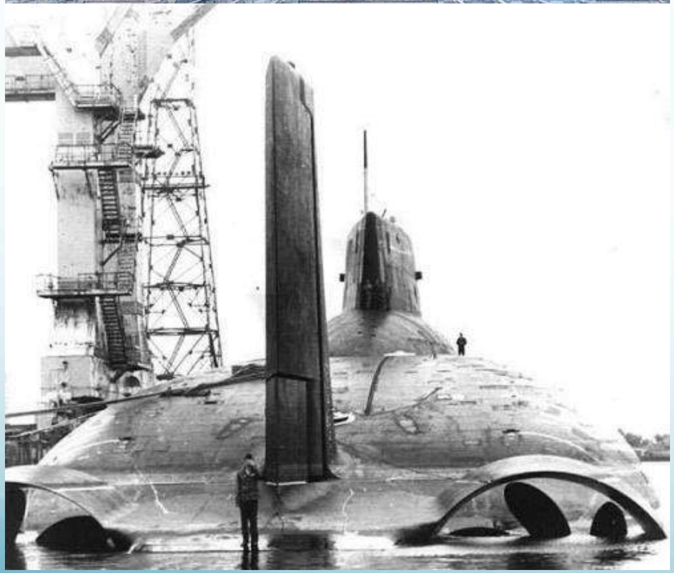
## Typhoon-class SSBN in drydock

Source: http://www.air-defense.net/forum/topic/7178-photos-sna-et-snle/?page=49

# Project 941 (Akula)

## Typhoon-class SSBN – details of the shrouded propellers





Source: top: https://matterbetter.com/
bottom: tumblr.com

Source: https://imgur.com/BwCZ2yC

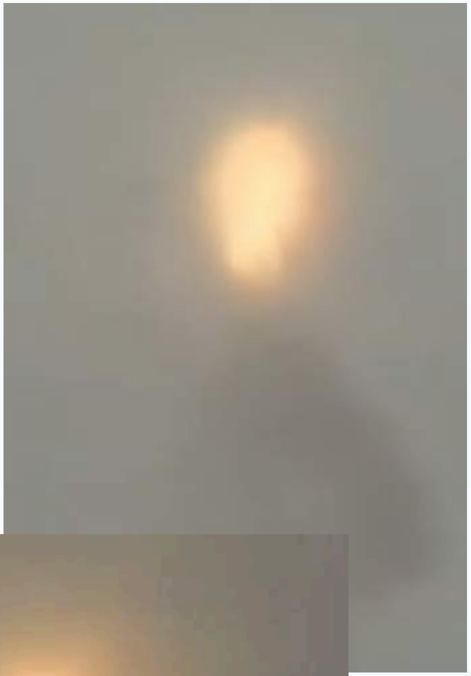
# Project 941 (Akula)

## Five of the six Typhoon-class SSBNs


Source: http://site.6park.com/

# Project 941 (Akula)

## Typhoon SSBN Arctic SLBM launch



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

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

# Project 941 (Akula)

## Typhoon-class SSBN being dismantled

TK-202 being dismantled in 2007.
Source: http://www.air-defense.net/forum/topic/7178-photos-sna-et-snle/?page=49

# Project 941 (Akula)

## Typhoon-class SSBN being dismantled

Source: http://entiredocumentaries.blogspot.com

Source: https://www.youtube.com/watch?v=DxYm-OzvLjA

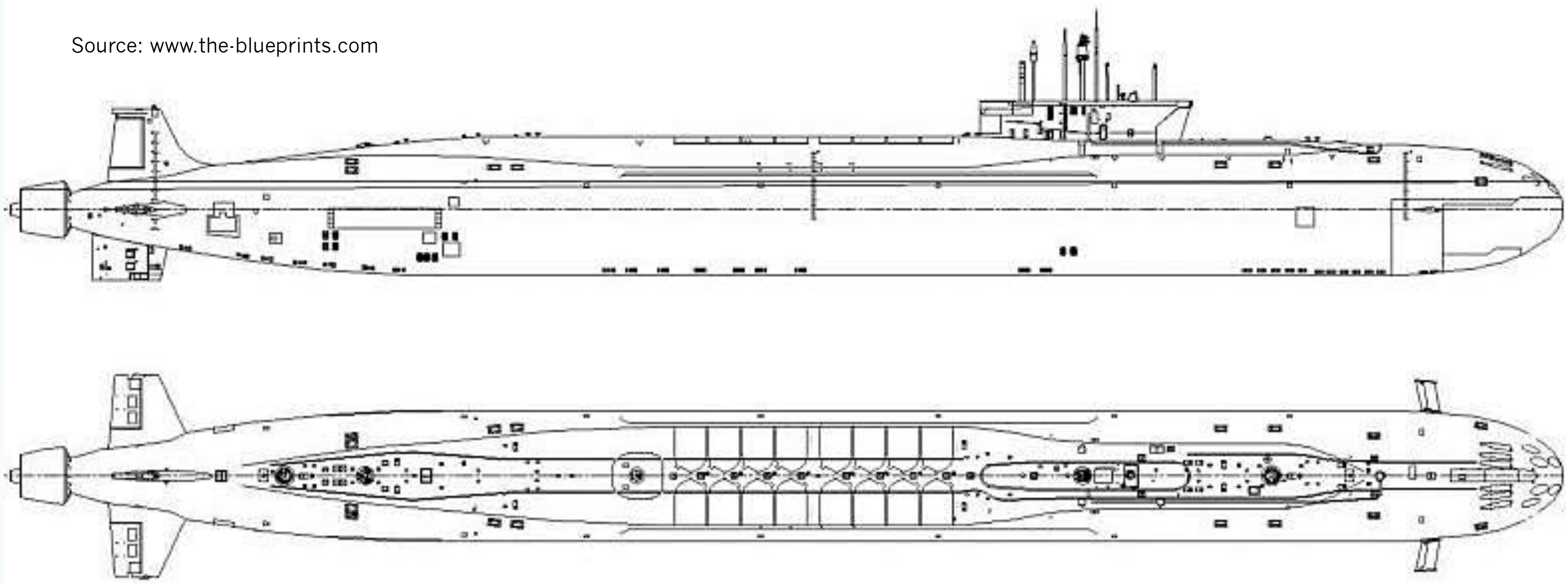
Typhoon reactor compartment removed and sealed.
Source: Pinterest

Typhoon reactor compartments afloat.
Source:  https://www.reddit.com/

# Project 955 & 955A (Borei)

## Borei-class strategic missile submarine (SSBN)

Source: www.the-blueprints.com



- 4th generation SSBN.
  - Designed by the Rubin Central Design Bureau, St. Petersburg, to replace the Delta III, Delta IV and Typhoon SSBNs. All are being built at the SEVMASH Shipyard in Severodvinsk.
  - The lead ship of this class, *Yuri Dolgoruky*, was the first submarine launched by Russia after the Soviet era. Its keel was laid in 1996, but construction was paused for several years. The boat finally was commissioned in 2013.
  - The three Project 955 (09551) Borei SSBNs were built with hull sections originally intended for late-model Project 971 Akula-class SSNs.
  - The subsequent five Project 955A (09552) improved Borei SSBNs are not reusing such parts from other submarines.

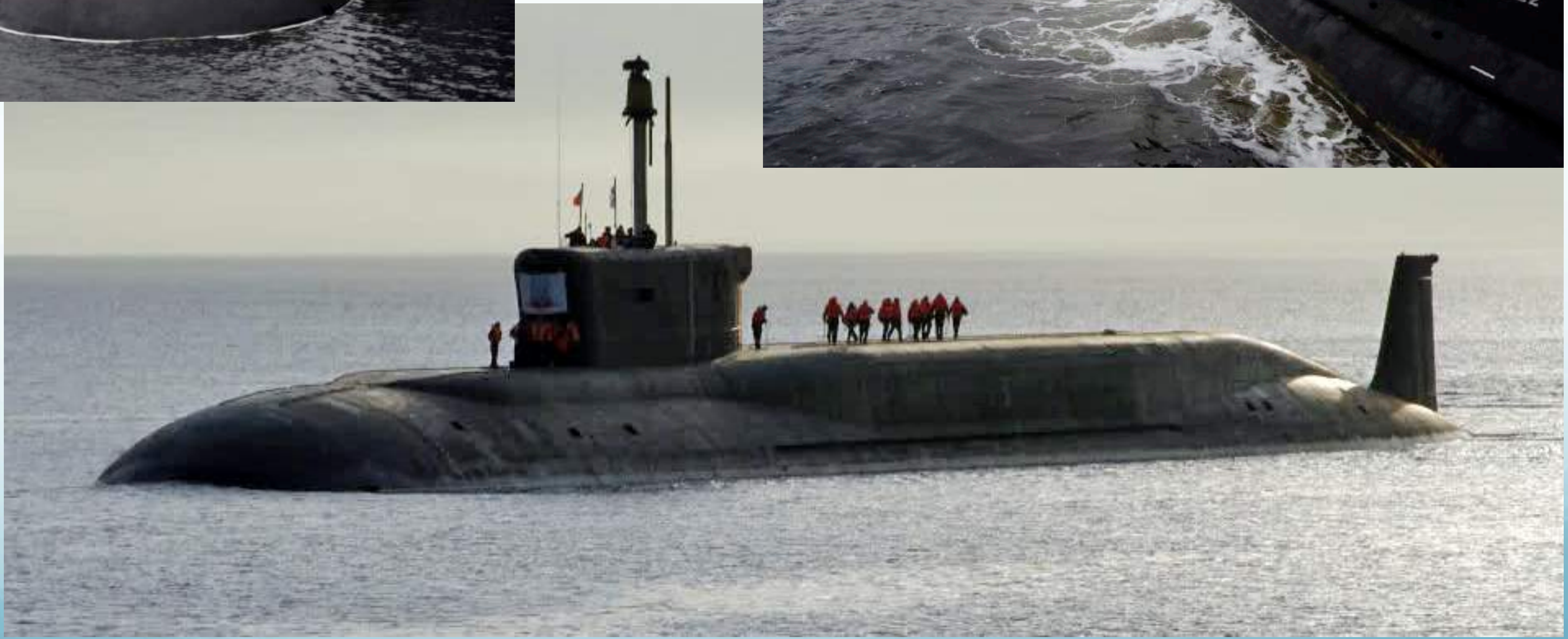
# Project 955 & 955A (Borei)

## Borei-class strategic missile submarine (SSBN)

- Propulsion:
  - Project 955 Borei: OK-650V: 1 x PWR rated @ 190 MWt
    - This is an improved version of the 3rd generation OK-650-series PWR that has been widely used in Russian submarines. Core life is expected to be about 15 years.
    - 1 x steam turbine with a rating of about 43,000 shp; driving 1 x pump-jet. Borei is the 1st Russian submarine class to use a pump-jet.
  - Project 955A improved Borei: OK-650V: 1 x PWR rated @ 190 MWt
    - A new 4th generation nuclear propulsion plant, identified as a KPM-6 or CTS-6 in some sources, rated at 200 MWt, was planned for Borei-class SSBNs. However, the new reactor's introduction appears to have been delayed for technical and financial reasons.
    - The first Project 955A boat, *Knyaz Vladimir (Prince Vladimir),* is reported to have an OK-650V nuclear propulsion plant and appears to have a larger pump-jet than *Yuri Dolgorukiy.*
- Armament:
  - Borei-class SSBNs originally were intended to be armed with the R-39UTTKh Bark (RSM-52V, SS-N-28) SLBM and the D-19UTTKh launch system developed by Makeyev Rocket Design Bureau. After a series of test failures, development was cancelled in September 1998. The Borei-class SSBNs were redesigned to handle the RSM-56 Bulava SLBM designed by the Moscow Institute of Thermal Technology (MITT).
  - Project 955:
    - 16 x strategic missile tubes inside the pressure hull for RSM-56 Bulava SLBMs, each armed with 6 -10 independently targeted, maneuverable, 100 – 150 kiloton warheads.
    - 6 x 533 mm (21 in) bow torpedo tubes.
  - Project 955A:
    - 20 x strategic missile tubes inside the pressure hull for RSM-56 Bulava SLBMs.
    - 6 x 533 mm (21 in) bow torpedo tubes.

# Project 955 (Borei)

## Borei-class strategic missile submarine (SSBN)



Source, three photos: www.shipmodels.info/

# Project 955 & 955A (Borei)

## Borei-class strategic missile submarine (SSBN)

- Operational matters:
  - As with prior Russian classes of SSBNs, Borei-class SSBNs are capable of operating in the Arctic and surfacing through the ice to launch missiles.
  - The Project 955 lead ship, *Yuri Dolgorukiy*, joined the Northern Fleet in December 2013 and received its full complement of RSM-56 missiles in 2014.
  - The other two Project 955 boats, *Alexander Nevskiy* & *Vladimir Monomakh*, joined the Pacific Fleet in 2015 and 2016, respectively.
  - Five Project 955A improved Borei SSBNs are under construction at SEVMASH:
    - *Knyaz Vladimir (Prince Vladimir):* keel laid 30 July 2012, launched 17 November 2017, expected commissioning 2018 - 2019.
    - *Knyaz Oleg (Prince Oleg):* keel laid 27 July 2014
    - *Generalissimus Suvorov (General Suvrov):* keel laid 26 December 2014
    - *Imperator Aleksandr III (Emperor Alexander III):* keel laid 18 December 2015
    - *Knyaz Pozharskiy (Prince Pozharskiy):* keel laid 23 December 2016
  - All five Project 955A SSBNs are expected to be commissioned by 2025.
  - Project 955A boats are distinguished by their improved stealth capability, more advanced electronic systems and more comfortable conditions for the crew of 107.
  - The Russian Defense Ministry plans to have the eight Borei-class SSBNs as the backbone of the naval component of the country's strategic nuclear deterrent.
  - On 17 November 2017, the Chief of Russia's General Staff, Valery Gerasimov, announced at a Russian Defense Ministry board meeting that work had been launched to develop a Borei-B SSBN with improved characteristics.

# Project 955 Borei & Project 941 Typhoon SSBNs

Borei & Typhoon SSBNs

Source: failheap-challenge.com

# Project 955 (Borei)

## Building K-550 *Aleksandr Nevskiy*

Source, four photos: http://www.shipmodels.info/mws_forum/

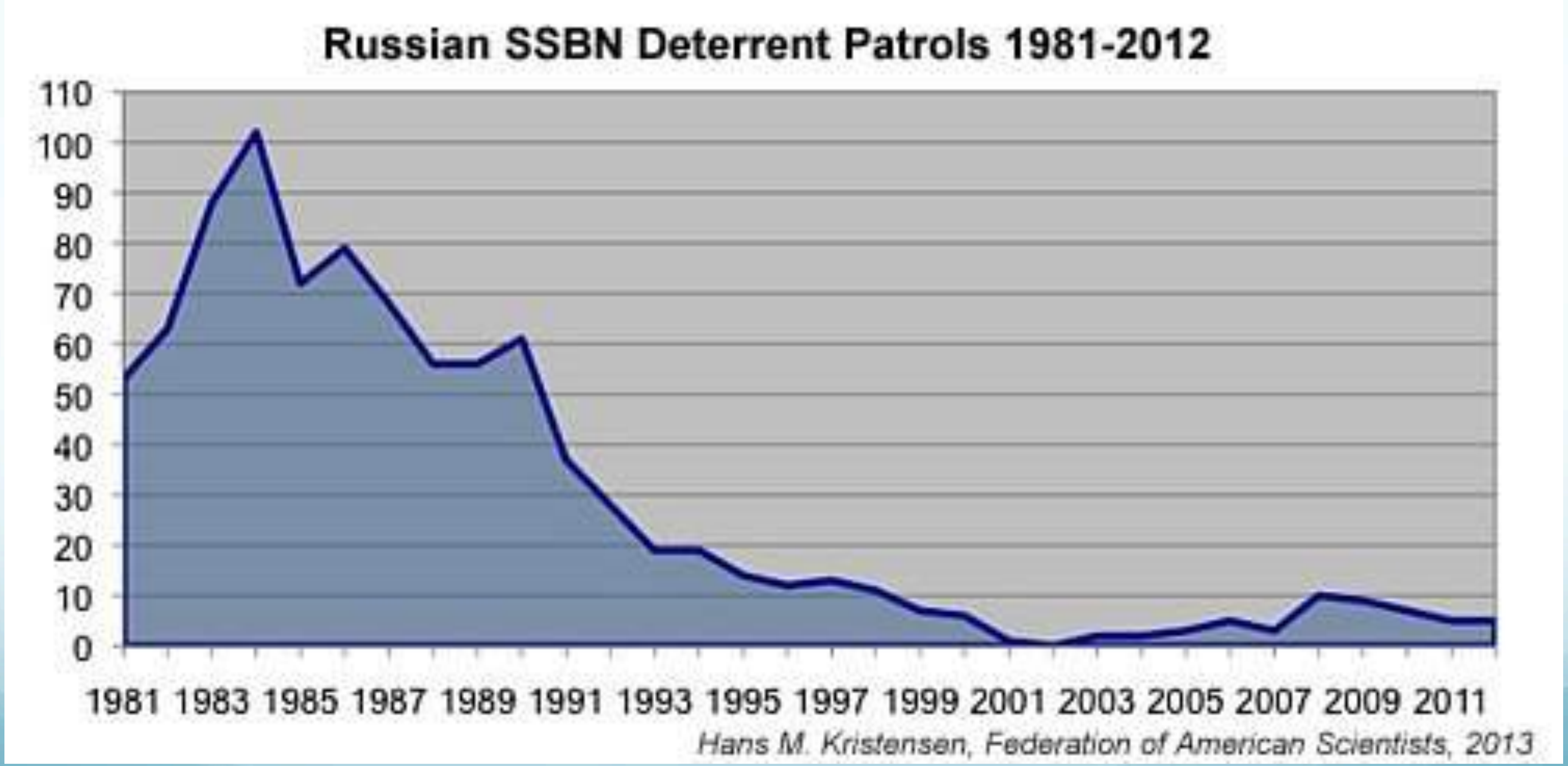
# Project 955 (Borei)

## Borei-class SSBN in drydock

*Yuri Dolgoruky* shrouded pump-jet
Source: http://oborona.ru


Source: http://forums.airbase.ru

# Trend in number of annual deterrent patrols by Russian SSBNs




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

# Submarine-launched ballistic missiles (SLBM)

# Russian SLBMs

| SLBM | Launch system | Years in service (platform) | Weight | Length | Diam | # of stages | Range | Warheads |
|---|---|---|---|---|---|---|---|---|
| R-11FM (8A61FM) (SS-1c Scud) | D-1 | 1959 – 1967 (Zulu IV & V, Golf I) | 4,899 kg (10,800 lb) | 10.4 m (34.1 ft) | 0.88 m (2.89 ft) | 1 liquid | 150 km (93 mi) | 1 x 0.5 MT, did not separate from missile body |
| R-13 (4K50) (SS-N-4 Sark) | D-2 | 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-15 | D-3 | design phase only circa 1955 – 58 (Project 639) | | | | | 1,000 km (621 mi) | Nuclear |
| R-21 (4K55) (SS-N-5) | D-4 | 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 | 1,300 km (808 mi) | 1 x 800 kT |
| R-21A (4K55A) (SS-N-5A) | D-4 | 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 | 1,650 km (1,025 mi) | 1 x 800 kT |
| R-27 (RSM-25) (4K10) (SS-N-6 Mod I Serb) | D-5 | 1968 (Yankee I) | 14,200 kg (31,306 lb) | 8.89 m (29.2 ft) | 1.5 m (4.92 ft) | 1 liquid | 2,400 km (1,491 mi) | 1 x 1 MT |
| R-27U (RSM-25) (4K10) (SS-N-6 Mod III Serb) | D-5U | 1974 (Yankee I) | 14,200 kg (31,306 lb) | 8.89 m (29.2 ft) | 1.5 m (4.92 ft) | 1 liquid | 3,000 km (1,864 mi) | 3 x 200 kT cluster |

# Russian SLBMs

| SLBM | Launch system | Years in service (platform) | Weight | Length | Diam | # of stages | Range | Warheads |
|---|---|---|---|---|---|---|---|---|
| R-27K anti-ship SLBM (4K18) (SS-N-6 Mod II Serb or SS-NX-13) | D-5K | Accepted in 1975, but not operational (Golf IV) | 12,020 kg (26,500 lb) | 9.0 m (29.5 ft) | 1.5 m (4.92 ft) | 2 liquid | 650 – 740 km (404 – 460 mi) | 1 x 0.5 – 1.0 MT |
| OKB-7 (KB Arsenal) SLBM | D-6 | Design phase only circa 1958 – 61 | | | | 2 solid | | Nuclear |
| RT-15M (4K22) | D-7 | Design & test phases circa 1961 – 64 | 45,359 kg (100,000 lb) | 10.5 m (34.4 ft) | 1.5 m (4.92 ft) | 2 solid | 2,400 km (1,491 mi) | Nuclear |
| R-29 / R-29D Vysota (RSM-40) (4K75) (SS-N-8 Sawfly) | D-9 / D-9D | 1974 – 89 (Golf III); 1974 - 94 (Hotel III, Delta I); 1978 - 96 (Delta II) | 32,800 kg (72,312 lb) | 13.0 m (42.7 ft) | 1.8 m (5.90 ft) | 2 liquid | R-29: 7,800 km (4,847 mi)<br><br>R-29D: 9,100 km (5,654 mi) | 1 x 0.6 – 1.5 MT |
| R-29R Volna & variants R-29RL, R-29RK, R-29RKU, R-29RKU-01 (RSM-50) (4K75R) (SS-N-18 Stingray) | D-9R | 1983 – about 2006 (Delta III) | 35,300 kg (77,823 lb) | 14.4 m (47.2 ft) | 1.8 m (5.90 ft) | 2 liquid + MIRV bus | Single warhead: 8,000 km (4,971 mi)<br><br>MIRV warheads: 6,500 km (4,039 mi) | 1 x 450 kT or 3 x 200 kT MIRV or 7 x 100 kT MIRV |

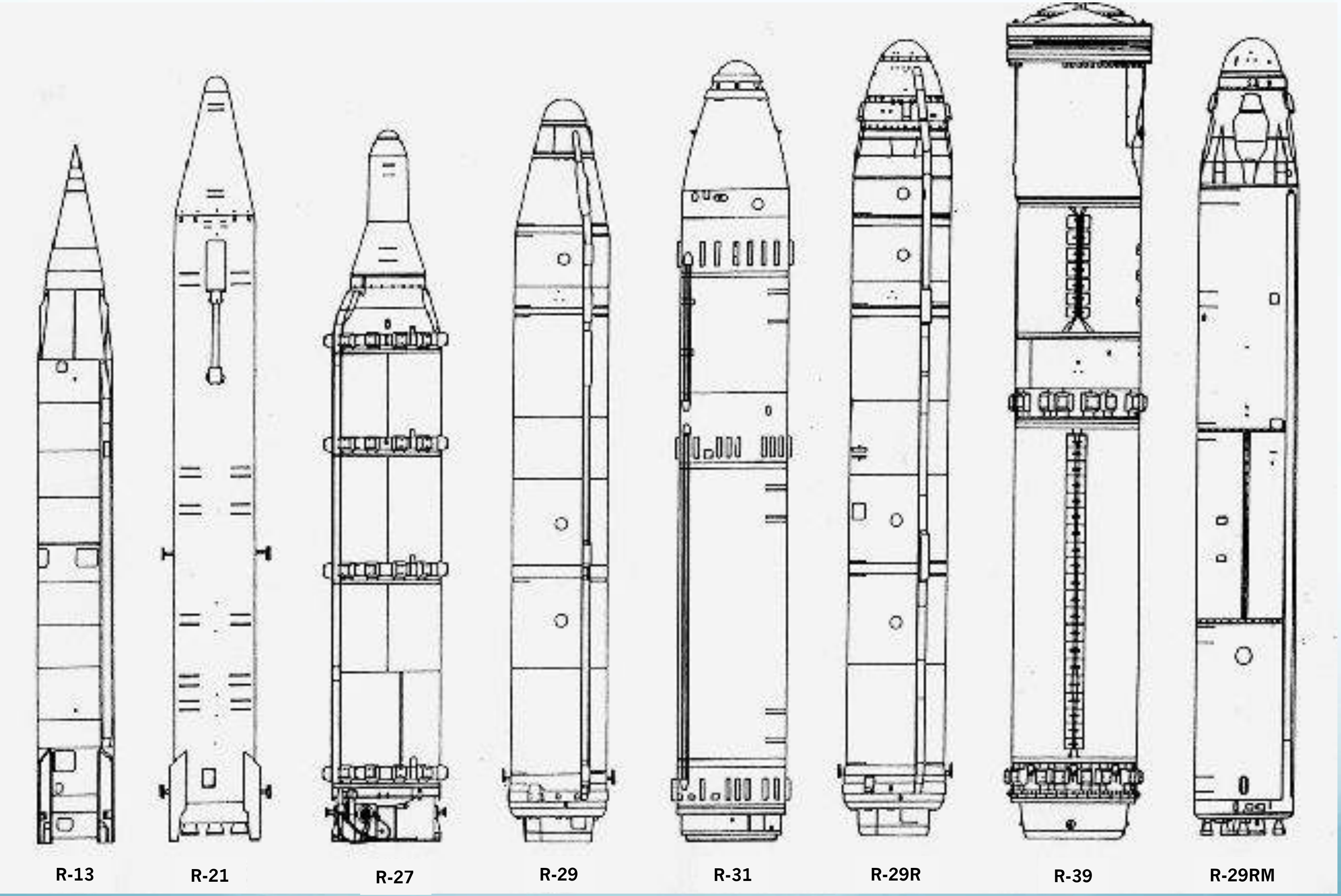
# Russian SLBMs

| SLBM | Launch system | Years in service (platform) | Weight | Length | Diam | # of stages | Range | Warheads |
|---|---|---|---|---|---|---|---|---|
| R-29RKU-02 | D-9R variant | 2006 – present (Delta III) | 35,300 kg (77,823 lb) | 14.4 m (47.2 ft) | 1.8 m (5.90 ft) | 2 liquid + MIRV bus | Single warhead: 8,000 km (4,971 mi)<br><br>MIRV warheads: 6,500 km (4,039 mi) | 1 x 450 kT or 3 x 200 kT MIRV or 7 x 100 kT MIRV |
| R-29RM Shtil & variants R-29RMU, R-29RMU1<br><br>(RSM-54) (4K75RM) (SS-N-23 Skif) | D-9RM | 1986 - 2010 (Delta IV) | 40,300 kg (88,846 lb) | 14.8 m (48.6 ft) | 1.9 m (6.23 ft) | 3 liquid + MIRV bus | 8,500 km (5,282 mi) | 4 x 100 kT MIRV |
| R-29RMU2 Sineva | D-9RMU variant | 2007 - present (Delta IV) | 40,300 kg (88,846 lb) | 14.8 m (48.6 ft) | 1.9 m (6.23 ft) | 3 liquid + MIRV bus | 8,300-12,000 km depending on payload (5,157-7,456 mi) | Up to 12 low-yield MIRVs |
| R-29RMU2.1 Lainer | D-9RMU variant | 2014 - present (Delta IV) | 40,300 kg (88,846 lb) | 15.0 m (49.2 ft) | 1.9 m (6.23 ft) | 3 liquid + MIRV bus | 8,300-12,000 km depending on payload (5,157-7,456 mi) | Up to 12 low-yield MIRV |
| R-31 (RSM-45) (3M17) (SS-N-17 Snipe) | D-11 | 1980 - 91 (Yankee II) | 26,840 kg (59,172 lb) | 10.6 m (34.8 ft) | 1.54 m (5.05 ft) | 2 Solid | 4,200 km (2,610 mi) | 1 x 500 kT |

# Russian SLBMs

| SLBM | Launch system | Years in service (platform) | Weight | Length | Diam | # of stages | Range | Warheads |
|---|---|---|---|---|---|---|---|---|
| R-33 anti-ship SLBM (SS-N-8) | D-13 | Design phase only circa 1971 – 75 (Delta I) | 26,640 – 35,300 kg | 12.96 – 14.1 m (42.5 – 46.3 ft) | 1.8 m (5.9 ft) | 2 liquid | 1,200 – 1,600 km (746 – 994 mi) | Nuclear or conventional |
| R-39 Rif / Taifun (RSM-52) (3M65) (SS-N-20 Sturgeon) | D-19 | 1983 - 2004 (Typhoon) | 84,000 kg (185,188 lb) | 16.0 m (52.5 ft) | 2.4 m (7.87 ft) | 3 solid + MIRV bus | 8,300 km (5,157 mi) | Up to 10 x 100 – 200 kT MIRV |
| R-39U (aka R-39M) | D-19UTH | 1988 - 2004 (Typhoon) | 84,000 kg (185,188 lb) | 16.0 m (52.5 ft) | 2.4 m (7.87 ft) | 3 solid + MIRV bus | >8,047 km (>5,000 mi) | Up to 10 x MIRV |
| R-39UTTKh Bark (RSM-52V) (3M91) (SS-N-28) | D-19UTTKh | Development cancelled Sep 1998 (Typhoon, Borei) | | 16.0 m (52.5 ft) + 1.7 m (5.6 ft) extendable nose cone | 2.4 m (7.87 ft) | 3 solid + MIRV bus | | MIRV |
| RSM-56 Bulava (3M30) (SS-NX-32) | | 2014 – present (Borei) | 33,500 kg (73,855 lb) | 11.5 m (37.7 ft) | 2.0 m (6.56 ft) | 3 solid + MIRV bus | > 9,000 km (>5,600 mi) | Up to 10 x 100 -150 kT, maneuverable MIRV |

# Comparison of Russian SLBMs




Source: http://army-news.ru/2016/06/sol-raketnoj-gonki/

# First generation Soviet SLBMs


Source: http://eng.makeyev.ru/activities/missile-systems/

- All were single-stage, liquid-fuel SLBMs with a single nuclear warhead.
- R-11FM and R-13 were launched from a submarine on the surface. The R-21 was the first Soviet SLBM that could be launched from a submerged submarine.
- Missile range increased dramatically in just five years, from 150 km (93 mi) for the R-11FM to 1,650 km (1,025 mi) for the R-21A.
- Victor Makeyev's SKB-38 (now Makeyev Rocket Design Bureau) was well on its way to becoming the Soviet Union's dominant supplier of SLBMs.

Victor Petrovich Makeyev
https://topwar.ru/

# R-11FM

## The world's 1st operational SLBM (8A61FM, SS-1c Scud)

- Naval variant of the land-based Scud (SS-1, Scud-A) using the D-1 launch system. The missile is housed in a watertight vertical launch tube in an extended sail structure and launched from a surfaced submarine.
- Initial design was done by Sergei Korolev's OKB-1. The program was transferred to Victor Makeyev's SKB-385 in August 1955.
- Single stage, storable liquid-fuel missile. Range was about 150 km (93 miles) with a single 0.5 MT nuclear warhead.
- The missile's flight path was controlled by an inertial navigation system and graphite fins in the rocket exhaust, much like a German V-2.
- 18 April 1953: 1st test launch of the R-11 missile.
- February 1955: 1st test launch of the naval R-11FM from land.
- 16 September 1955: 1st launch of an R-11FM from a submarine on the surface: the Project V-611 Zulu IV prototype SSB.
- August – October 1956: Extended cruise by the Project V-611 Zulu IV to validate missile performance at sea.
- 20 February 1959: The R11FM and D-1 launch system became operational as the world's first SLBM on Project 611 Zulu-class and later on Project 629 Golf-class diesel-electric submarines.
- 1967: Withdrawn from service; replaced by the R-13.

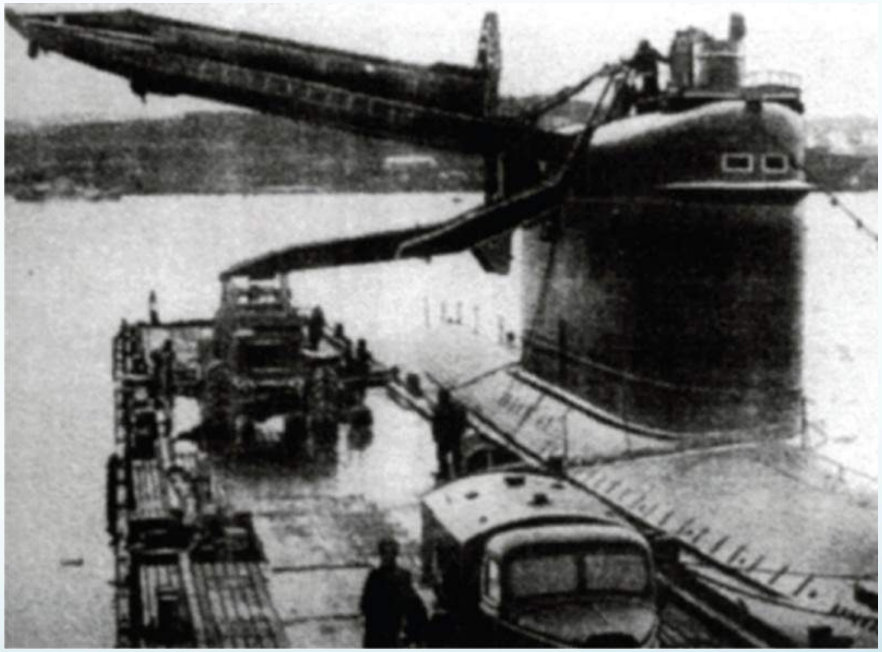
R-11FM cutaway
Source: http://www.astronautix.com/r/r-11fm.html

R-11FM warhead section.
Source: http://eng.makeyev.ru/

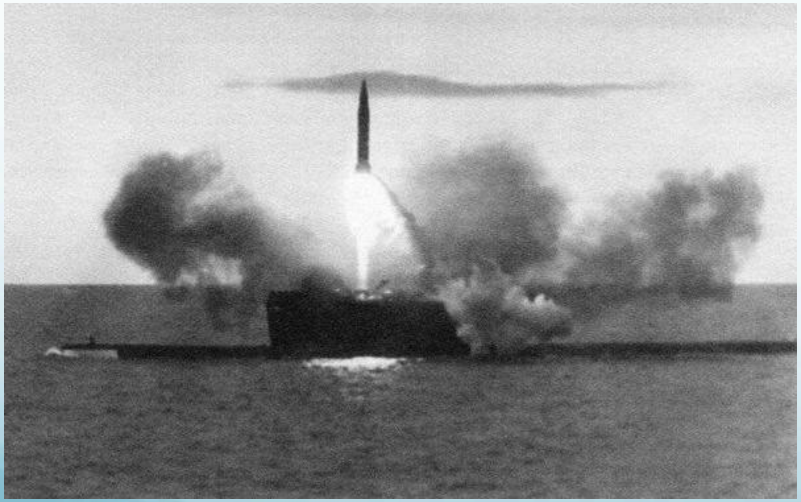
# R-11FM

## SS-1c Scud, the world's 1st operational SLBM

R-11FM on parade.  Source: http://eng.makeyev.ru/



Loading an R-11FM. Source: http://eng.makeyev.ru/



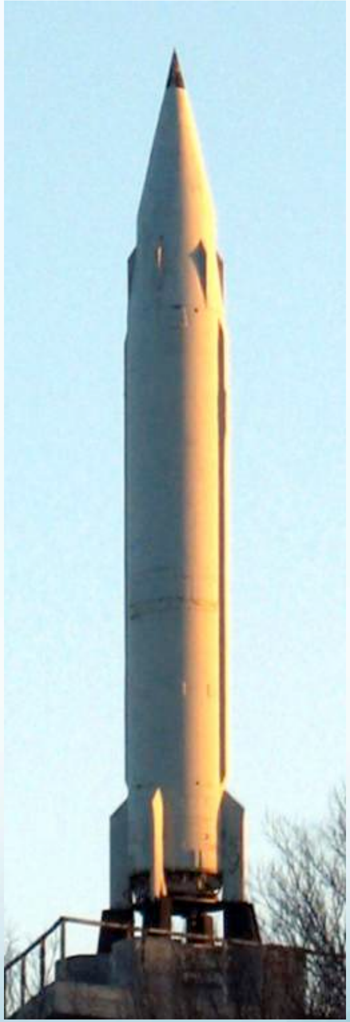
R-11FM launch from a Project 611 Zulu-class SSB.
Source: https://www.quora.com/

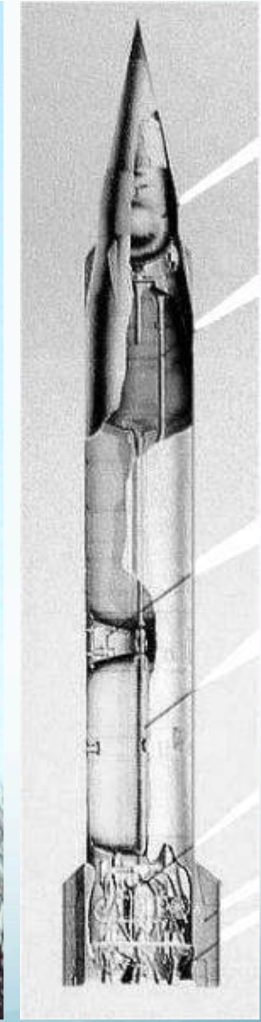
# R-13

## (4K50, SS-N-4, Sark)

- 25 July 1955: Development of the R-13 was authorized by the Soviet Supreme Council.
- Initial design by Korolev's OKB-1. The program was transferred to Victor Makeyev's SKB-385 later in 1955.
- This single-stage, storable liquid-fuel missile was developed as a replacement for the R-11FM, for use on Project 629 Golf-class diesel-electric SSBs and Project 658 Hotel-class nuclear-powered SSBNs.
- The R-13 missile and D-2 launch system were designed for launching an SLBM from a surfaced submarine.
- An inertial navigation system and small vernier thrusters controlled the missile's flight path.
- Range was about 600 km (370 miles) with a single 1 – 2 MT nuclear warhead.
- 13 October 1961: Entered into service
- 1975: Withdrawn from service, replaced by the R-21.

R-13 reentry vehicle. Source: http://eng.makeyev.ru/





Source, two graphics: https://defence.pk/pdf/threads/soviet-liquid-fuel-missiles-of-r-ur-designation.330006/

# Nuclear test *Raduga* (Rainbow)

## 1st armed SLBM nuclear test

- 20 October 1961: In a nuclear test named *Raduga (Rainbow)*, Golf-class SSB K-102 (formerly B-121) launched an R-13 SLBM with a live thermonuclear warhead from a launch point in the Barents Sea to a target 603.3 km (375 mi) away in the Novaya Zemlya nuclear test site, Area C.
- This was the first ever test of an SLBM with a live nuclear warhead. The US conducted a similar test with an armed Polaris A2 SLBM more than six months later, on 6 May 1962 (Operation Dominic, Shot Frigate Bird).


Source: Adapted from Google maps

- When Golf-class SSB K-102 reached the specified launch point in the Barents Sea, she could not establish her position accurately due to cloudiness and snowfall. An R-13 missile without a nuclear warhead was fired first. It missed the intended target by a wide margin.
- It was decided to continue the test in spite of bad weather. The second (armed) R-13 missile detonated in the intended target area at an altitude of 1,000 meters (3,281 ft) with a yield of 1.45 MT.

# R-15 SLBM
## D-3 launch system

- 1955: Initial development of the single stage R-15 missile and D-3 launch system was started by Mikhail K. Yangel, who headed OKB-586, Dnepropetrovsk, Ukraine.
  - The missile was designed to be launched from the surface, but it would be hot-launched directly out of the missile tube without being elevated out of the sail structure, as was done previously with the D-1 and D-2 launch systems.
  - Missile range: about 1,000 km (621 mi).
- 20 March 1958: Development of the R-15 and D-3 launch system was officially authorized.
- Intended to be used on the Project 639 nuclear-powered SSBN designed by SKB-143 (now Malakite), chief designer V.P. Funikov. This SSBN was never built.
  - 6,000 ton surface displacement, 4 x propeller shafts, 3 x R-15 missile tubes amidships, in an arrangement similar to Zulu and Golf-class SSBs and Hotel-class SSBNs.
- 1958: Under Project V629, Central Design Bureau OKB-16 developed a design for a modified diesel-electric Golf-class submarine to carry one R-15 missile.
- December 1958: Development of the R-15 missile, the D-3 launch system and the submarines was canceled.
  - Because of the large overall dimensions and weight of the R-15 missile, and the need to be launched from the surface, these systems had poor technical and tactical characteristics relative to other missiles and launch systems then under development.
- OKB-586 proposed two additional sub-surface launched SLBM designs that were not implemented:
  - R-19: a 1,000-km (621 mi) range for Project 639 submarine.
  - R-20: a 600-km (373 mi) range for Project 629 submarine.

# R-21 & R-21A
## (SS-N-5 Sark)

- The R-21 SLBM and D-4 launch system were designed by the Makeyev Rocket Design Bureau as replacements for the R-13, for use on Project 629 Golf II SSBs and Project 658 Hotel II SSBNs.
- 20 March 1958: The Soviet government issued a decree approving the development of the R-21 SLBM and D-4 launch system.
- This single-stage SLBM was fueled by storable liquid propellant.
- The D-4 launch system gave the Soviets their 1st SLBM underwater launch capability.
  - Missiles could be launched at sea states up to 5, submarine speed up to 4 knots, and depth of 40-50 meters (131-164 ft.).
  - Time to prepare the first missile for launch was about 30 min. Time to launch three missiles was no more than 10 min.
  - Cold launch: solid rocket gas generator ejected the missile from the flooded launch tube before the main rocket motor ignited.
  - Smaller diameter launch tube than the R-13 while more than doubling the missile's range to 1,300 km (808 mi).
- Under Project 613D-4, Whiskey-class testbed sub S-229 was modified in 1961 to conducted trials on the D-4 ballistic missile launch system, with one launcher for a model of an R-21 missile.

Source, left: http://eng.makeyev.ru/
Source, right: "Russian Strategic Nuclear Forces," MIT Press, 2001, p. 316

# R-21 & R-21A
## (SS-N-5 Sark)

- 24 February 1962: 1st submerged launch from the Project 629B Golf sub.
- 15 May 1963 – 1967: Replaced R-11FM & R-13 SLBMs when introduced to the fleet.
- Upgraded R-21A had a longer range: 1,600 km (994 mi).
- 1991: R-21 retired along with the last Hotel II SSBNs after a service life of 28 years.


R-21 reentry vehicle. Source: http://eng.makeyev.ru/

R-21 launch. Source: http://eng.makeyev.ru/activities/missile-systems/1/RaketaR21/

# R-27 family
## (RSM-25, SS-N-6 Serb)

- Designed by the Makeyev Rocket Design Bureau.
- The R-27 and R-27U SLBMs were single-stage, inertially-guided missiles fueled by storable liquid propellant.
- The D-5 launch system enabled a missile to be launched from a flooded tube of a submerged SSBN at sea state up to 5, submarine speed up to 4 knots and depth of 40 to 50 meters (131 – 164 ft).
- The propulsion system consisted of a single main engine. Flight control was implemented by two small attitude control rockets in the base of the missile, mounted at 45° to the longitudinal axis.


Source: http://eng.makeyev.ru/activities/missile-systems/

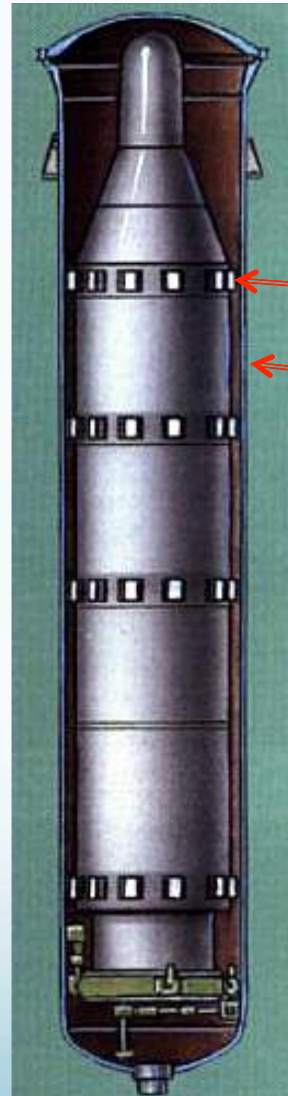
- 1962: Soviet government orders development of the R-27 SLBM and D-5 launch system.
- 1965: Under Project 613D-5, the Whiskey-class testbed sub S-229 was modified to conduct trials for the D-5 ballistic missile launch system, with one launcher for a model of an R-27 missile.
- 1966: 1st R-27 test flight from land; 1967: from a submarine
- March 1968: Initial operating capability (IOC) of the R-27 (SS-N-6 Mod I) single warhead SLBM on Project 667A Yankee I SSBNs.
- January 1974: IOC of the R-27U (SS-N-6 Mod III) multiple warhead SLBM on Project 667AU Yankee I SSBNs.
- 1975: IOC of the R-27K SLBM on the Project 605 Golf IV SSB, however, this missile was not operationally deployed.
- 1988: Last R-27 retired. Missile service life was 20 years.
- 1994: Last R-27U retired, also 20 year service life.

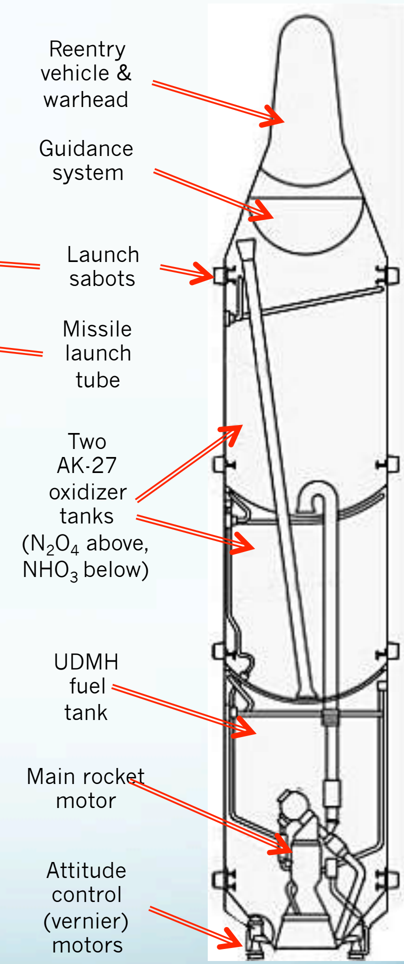
# R-27

## (RSM-25, SS-N-6 Mod I)

- R-27 was the first Soviet sea-based, small-size, intermediate range missile.
    - Longer range, than the R-21 SLBM in a shorter and lighter weight  missile, which allowed the launch tube volume to be reduced by a factor of 2.5.
    - The rocket motor is installed inside the fuel tank to minimize overall missile length.
- R-27 was deployed on Project 667A Yankee I SSBNs with the D-5 launch system.

R-27 reentry vehicle (left) and missile casing (right)
Source, above: http://eng.makeyev.ru/activities/missile-systems/2/RaketaR27/





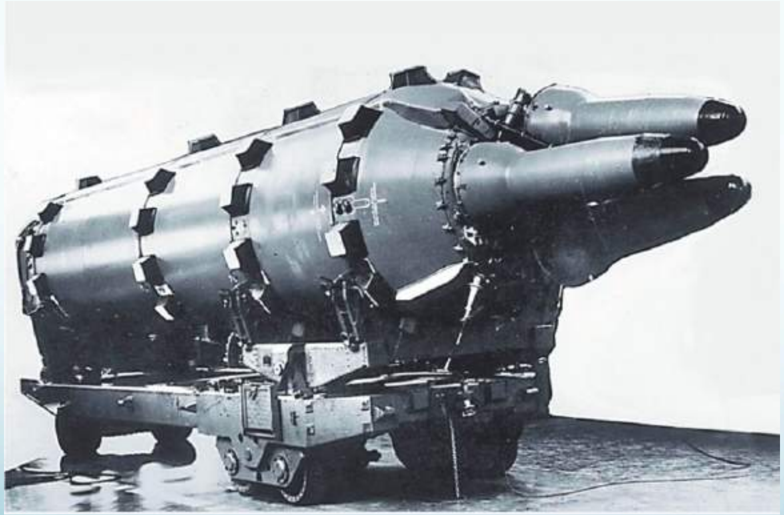

Source, above: adapted from http://www.wikiwand.com/es/R-27_Zyb

Source, left: https://www.armscontrolwonk.com/

# R-27U
## (RSM-25, SS-N-6 Mod III)

- The R-27U was an improvement on the original R-27, with longer range (3,000 km, 1,864 miles) and greater accuracy (CEP 1.3 km, 0.8 mile).
- The R-27U missile could be fitted with two types of warheads:
  - An advanced single warhead with a yield of about 1 MT, or
  - A cluster of three, smaller, lower-yield (about 200 kT) warheads that were not independently targeted.
- This SLBM was carried on Project 667AU Yankee I SSBNs with the D-5U launch system.

R-27U single warhead reentry vehicle.

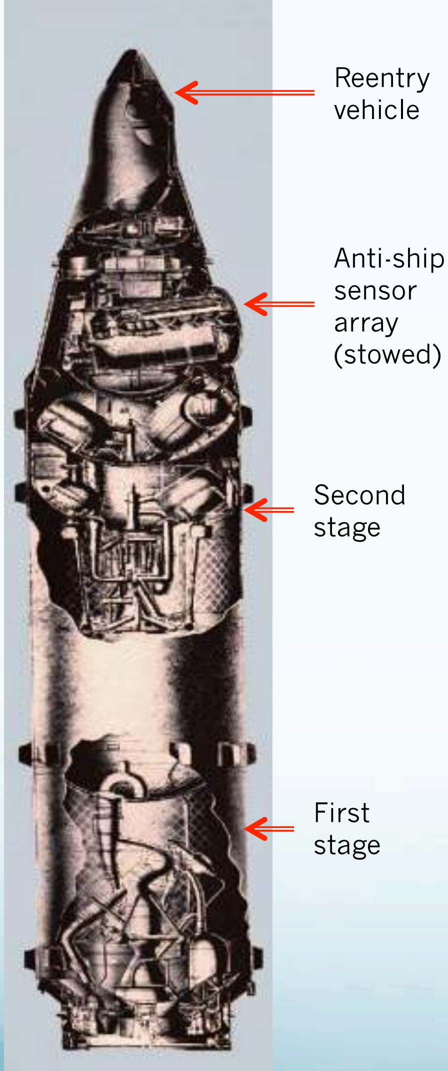


R-27U with a three reentry vehicle cluster
Source, three photos:
http://eng.makeyev.ru/activities/missile-systems/2/RaketaR27U/

One reentry vehicle of a three-RV cluster warhead.

# R-27K

## (RSM-25, SS-N-6 Mod II or SS-NX-13)

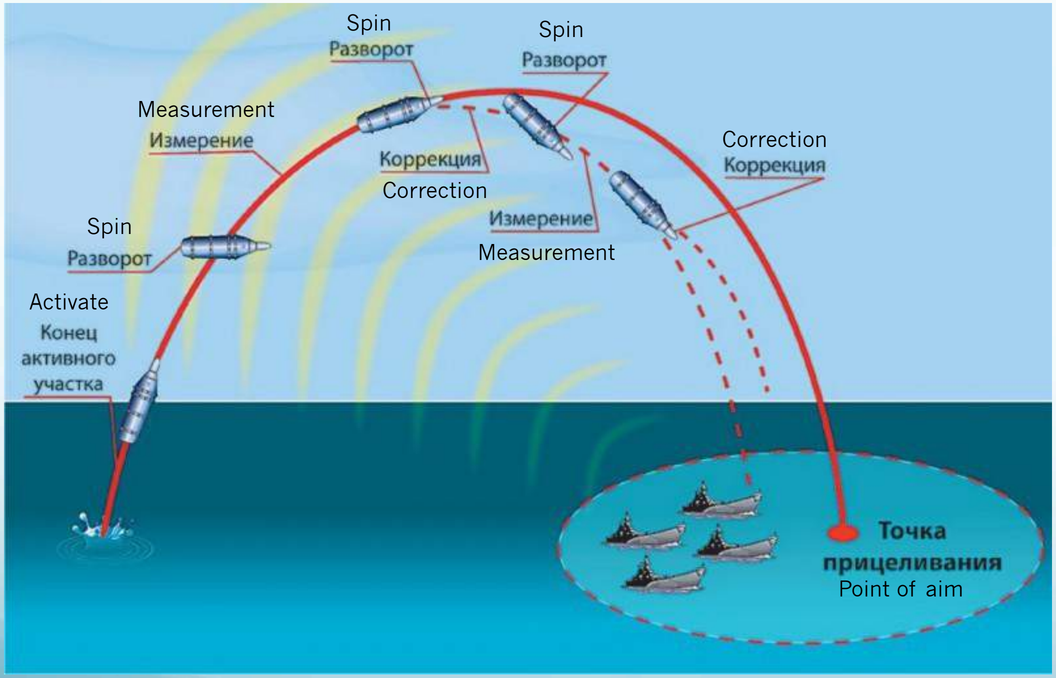



R-27K missile cutaway
Source: http://eng.makeyev.ru/

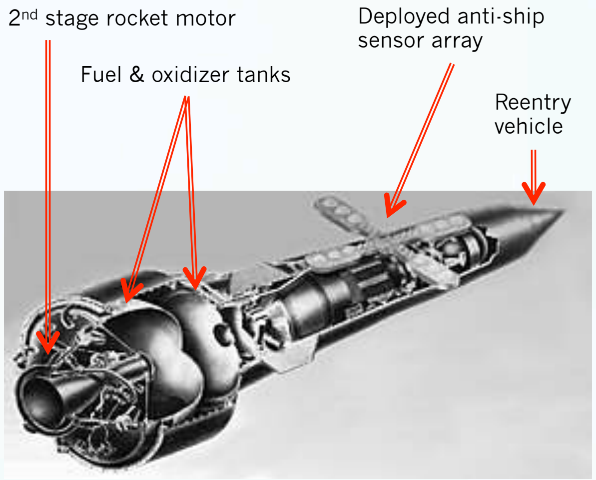
- The R-27K is a substantially different two-stage, liquid fueled, single warhead missile designed to be launched from underwater for use against moving formations of ships at sea (i.e., US carrier strike groups).
- 1972: First test launches from the Golf IV SSB K-102 with the D-5K launch system.
- 1975: IOC of the R-27K SLBM on the Project 605 Golf IV SSB, however, this missile was not operationally deployed.
- Although the R-27K could fit in the launch tubes of the Project 667A Yankee SSBNs, these subs lacked the necessary equipment to target and fire the missile.
- Project 667V, which was not developed, would have produced a Yankee variant armed with R-27K anti-ship ballistic missiles and equipped with with the D-5K launch system.
- The R-27K never became operational, primarily because every launch tube used for the R-27K counted as a strategic missile under the SALT strategic arms agreement. The strategic warheads on the R-27 & R-27U were more important than the R-27K's unique anti-ship capability.

# R-27K
## (RSM-25, SS-N-6 Mod II or SS-NX-13)

- Using external targeting data, the R-27K would have been launched against naval targets at a range of 650–740 km (404 – 460 mi).
- The R-27K mid-course guidance was based on passive reception of radar impulses from enemy ship forces and ballistic trajectory correction with repeated ignition of the 2nd stage engine while in the exo-atmospheric portion of the ballistic trajectory.
- The MAneuvering Re-entry Vehicle (MaRV) would then home in on the target with a CEP of 400 yards (370 m). Warhead yield was between 0.5 – 1.0 MT.




R-27K mid-course guidance
Source, one graphics + photo: http://eng.makeyev.ru/activities/missile-systems/2/RaketaR27K/

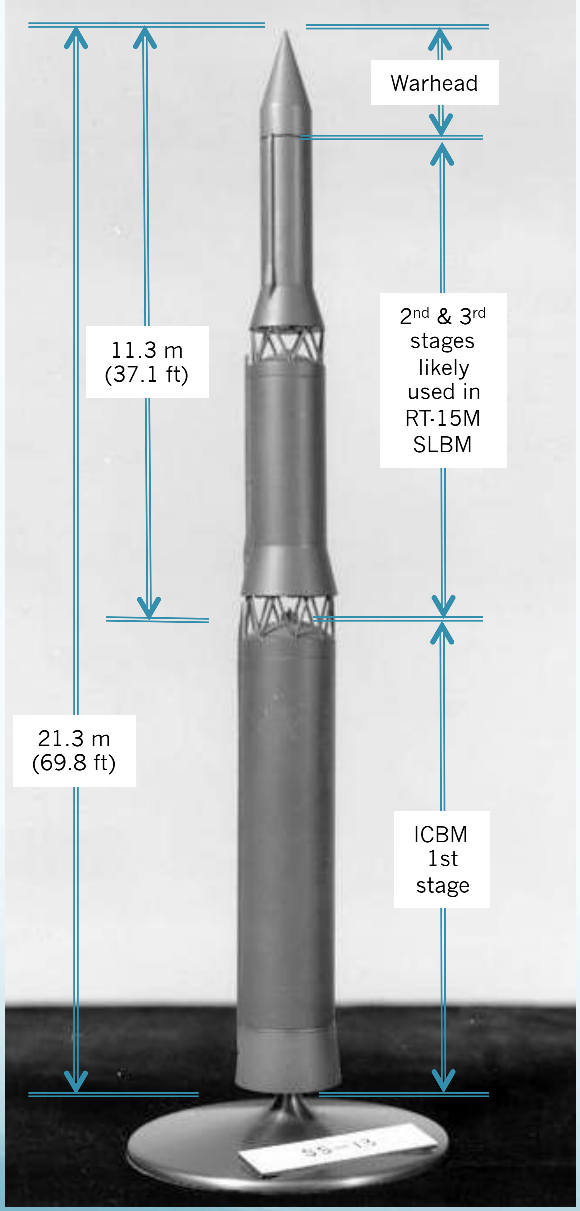



R-27K second stage with anti-ship sensor array deployed.
Source: adapted from
https://www.secretprojects.co.uk/

R-27K reentry vehicle

# OKB-7 (KB Arsenal) SLBM
## (D-6 launch system)

- 1958 - 1960: Two versions of the D-6 launch system for solid-fuel missiles were studied by OKB-7 (aka KB Arsenal, Central Design Bureau No. 7; now Arsenal Design Bureau, TsBK-7) in St. Petersburg.
  - One used a missile with a single, large diameter, solid rocket motor using propellants that were already in production for use in unguided tactical rockets.
  - The second version focused on a new missile incorporating new solid propellants using a crystal oxidizer and fuel, with the first and second stages consisting of clusters of four separate solid rocket motors.
  - Intended for use on Project 629 (Golf) SSBs, 658 (Hotel) and 667 (Yankee) SSBNs
- The overall dimensions of either missile would have been too large for a vertical launch tube inside the submarine's pressure hull. The submarine design proposed by Central Design Bureau No. 18 (now Rubin Central Design Bureau for Marine Engineering, SKB-18) called for two missile tubes on each side of the submarine, outside the pressure hull.
  - In their stowed position, the missile tubes were horizontal.
  - To launch the missiles, the submarine would surface and the missile tubes would be raised to the vertical position.
- 1960: The preliminary design of the D-6 launch system was complete.
- 18 June 1960: KB Arsenal was directed by the USSR Council of Ministers to begin the detailed design of the D-6 launch system.
- Under Project 629D-6, a Golf-class SSB was to be modified to serve as a testbed for the new SLBM and the D-6 launch system.
- 4 June 1961: The program was cancelled.



RT-2 ICBM, which was the basis for RT-15M SLBM
Source: https://fas.org/

# RT-15M SLBM
## (D-7 launch system)

- RT-15M (4K22) was a solid-fuel, two-stage SLBM believed to be derived from the 2nd and 3rd stages of the land-based ICBM RT-2 (SS-13 Savage) designed originally by Sergei Korolev's OKB-1.
- 4 April 1961: Ministerial Council authorized Victor Makeyev's SKB-385 to develop the RT-15M SLBM and the D-7 launch system for use on the Project 667 Yankee-class SSBN.
  - RT-15M will have a range of about 2,400 km (1,491 mi), and a launch weight of about 50 tons
- Under Project 613D-7, Whiskey-class testbed submarine S-229 was modified in 1963 to conducted trials for the D-7 ballistic missile launch system, with one launcher for a model of an RT-15M missile.
- Under Project 629D-7 the single Project 629B Golf-class SSBN was to be re-equipped to serve as a test platform for the RT-15M and D-7 launch system.
- mid-1964: Ejection tests from an underwater launch platform were conducted. However, planned launch tests from a modified Project 613 (Whiskey-class) submarine and flight tests from the Project 629B SSBN were not conducted.
- Later in 1964, development of the RT-15M missile and D-7 launch system were canceled.
  - Because of the large overall dimensions and weight of the RT-15 missile, and less than expected range, these systems had poor technical and tactical characteristics relative to other missiles and launch systems then under development.

# R-29 family

- All are designed by the Makeyev Rocket Design Bureau and use storable liquid fuel propellant: fuel is unsymmetrical dimethylhydrazine (UDMH); oxidizer is nitrogen tetroxide.
- Cold-launch system enables the SLBM to be launched submerged or surfaced.

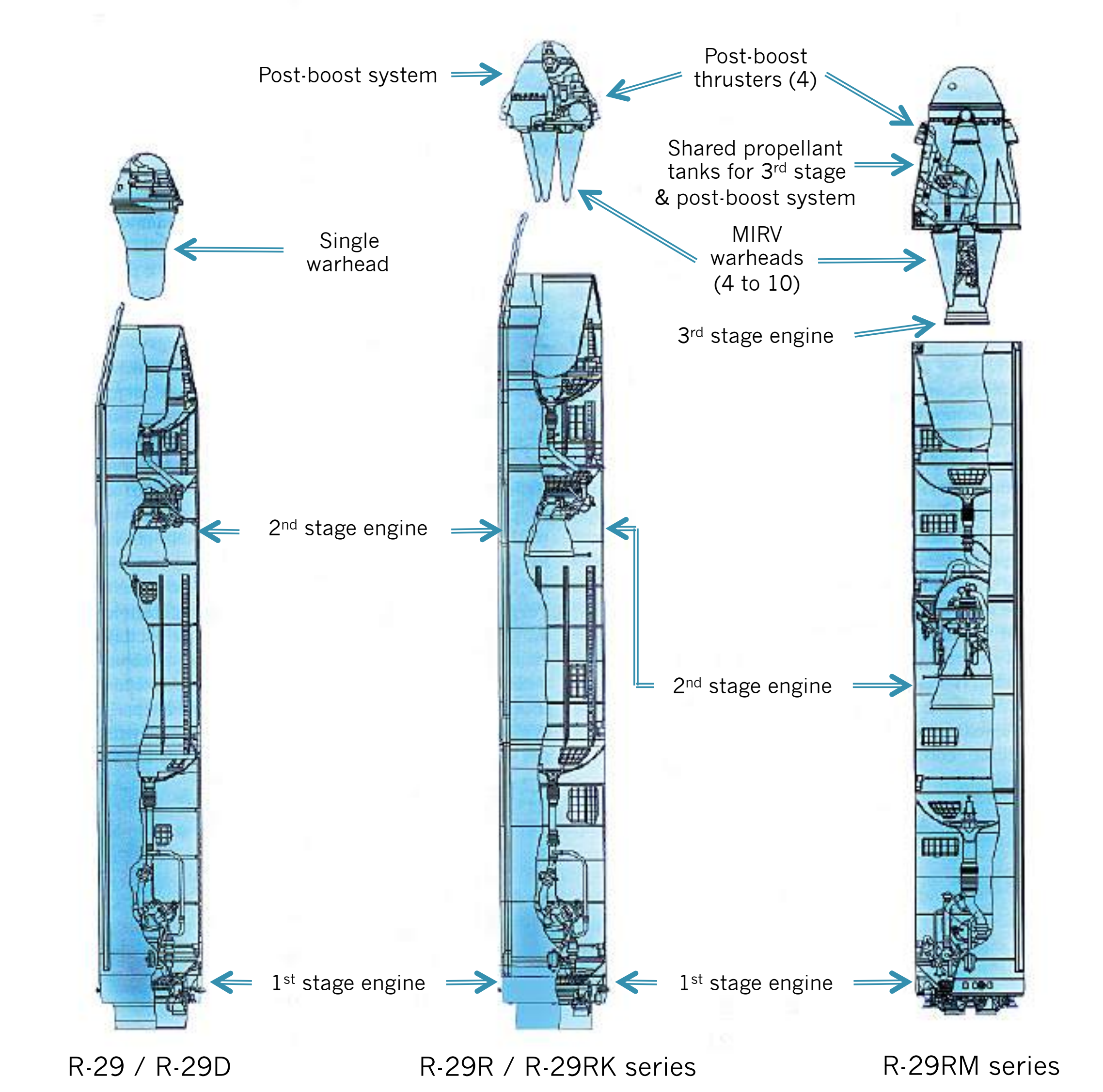
R-29R / RK-series 2-stage, MIRV warhead models used on Delta III SSBNs


R-29 2-stage, single warhead models used on Golf III SSB & Hotel III, Delta I & II SSBNs

R-29RM-series 3-stage, MIRV warhead models used on Delta IV SSBNs

Source: adapted from http://eng.makeyev.ru/activities/missile-systems/

# Comparison of R-29 SLBMs




Source: adapted from http://bastion-karpenko.ru/brpl-170311/

<u>From left to right:</u>

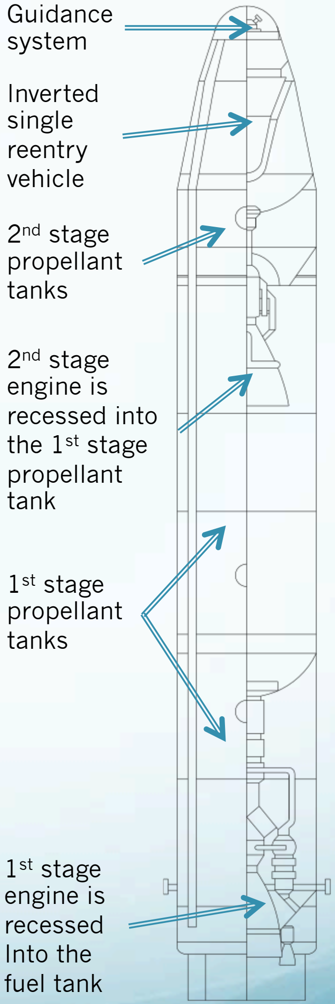
R-29 / R-29D
(RSM-40, SS-N-8)
used on Hotel III,
Delta I & II

R-29R / R-29RK series
(RSM-50, SS-N-18)
used on Delta III

R-29RM series
(RSM-54, SS-N-23)
used on Delta IV

# R-29 / R-29D Vysota
## (RSM-40, 4K75 / 4K75D, SS-N-8 Mod I / II Sawfly)

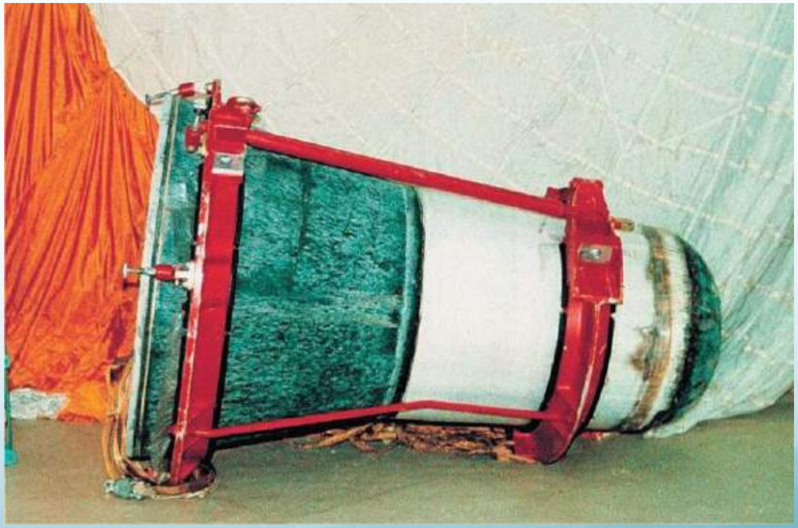
- Developed by Makeyev starting in 1964.
- Design features included:
  - 1st Soviet SLBM with an all-welded body
  - Compact design with the rocket engines recessed into the propellant tanks (like the R-27) provided longer range: 7,800 km (4,847 miles); three times the range of the R-27 SLBM
  - Two-stage SLBM, single warhead, increased throw-weight
  - Improved accuracy; 1st Soviet use of an onboard digital computer and celestial correction of the flight trajectory
  - 1st deployment of penetration aids on a Soviet SLBM
  - Underwater or surface launch with D-9 launch system
  - More compact layout of the missile and launch tube
  - Capable of ripple firing (short intervals between multiple individual missile launches)
- 15 December 1971: 1st submarine launch of an R-29. Test subs were the Project 701 Golf III SSB, K-145, and the lead Project 667B Delta I SSBN.
- 1st SLBM fired from high Arctic latitudes.
- 12 March 1974: The system was accepted for use aboard the Golf III SSB, the Hotel III SSBN and 18 Delta I SSBNs.
  - The long range of the R-29 enabled the Soviet SSBN patrol areas to be moved closer to the USSR, into areas that could be protected by their ASW forces.




Source, left: http://eng.makeyev.ru/
Source, right: adapted from https://en.wikipedia.org/wiki/R-29_Vysota

# R-29 / R-29D Vysota
## (RSM-40, 4K75 / 4K75D, SS-N-8 Mod I / II Sawfly)

- R-29D development started in 1976
  - Penetration aids removed
  - Increased range by 1,300 km to  9,100 km (5,654 mi)
  - Simpler manufacturing
  - Updated D-9D launch system
- Entered service in 1978 on Delta II SSBNs, each of which was armed with 16 D-9D SLBMs.
- Two Delta I SSBNs, K-523 and K-530, were modernized with the R-29D SLBM and D-9D launch system.



R-29D launched from a submarine in the Arctic icepack.
Source, two photos: http://eng.makeyev.ru/activities/missile-systems/2/R29D/

R-29 reentry vehicle.

# R-29R Volna

## (RSM-50, 3M40, SS-N-18 Stingray)

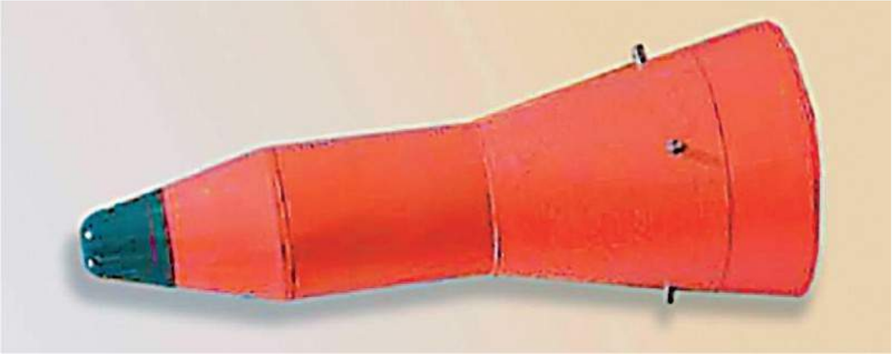
Source: http://eng.makeyev.ru/activities/missile-systems/3/RaketaR29R/

- Improved version of the R-29.
  - 1st Soviet SLBM designed to carry multiple, independently targetable reentry vehicle (MIRV) warheads. Originally designed to carry three or seven MIRVs or a single warhead.
  - Two-stage + MIRV propulsion bus; storable liquid-fuel.
  - The propulsion bus manages the independent targeting and deployment of the MIRV warheads. Four small liquid fuel thrusters are arranged around the conical nose cap provide post-boost propulsion.
  - Upgraded inertial navigation system with satellite-assisted navigation for greater accuracy.
  - D-9R launch system.
- Missile range with MIRV warheads is 6,500 km (4,039 mi), or 8,000 km (4,971 mi) with a single warhead.
- February 1973: R-29R development began.
- November 1976: 1st test flight; with testing thru October 1978.
- 1979: R-29R entered service only on Delta III-class SSBNs, which carry 16 SLBMs.
- Upgraded versions of the original R-29R were introduced over the following three decades: R-29RL (1979), R-29RK (1982), R-29RKU (1987), R-29RKU01 (1990), and the latest version, R-29RKU02 (2006).

# R-29R Volna

## (RSM-50, 3M40, SS-N-18 Stingray)

Reentry vehicle for single warhead.



Reentry vehicle for MIRV warhead.

R-29R-series on transporter. Source, three photos: http://eng.makeyev.ru/activities/missile-systems/3/RaketaR29R/

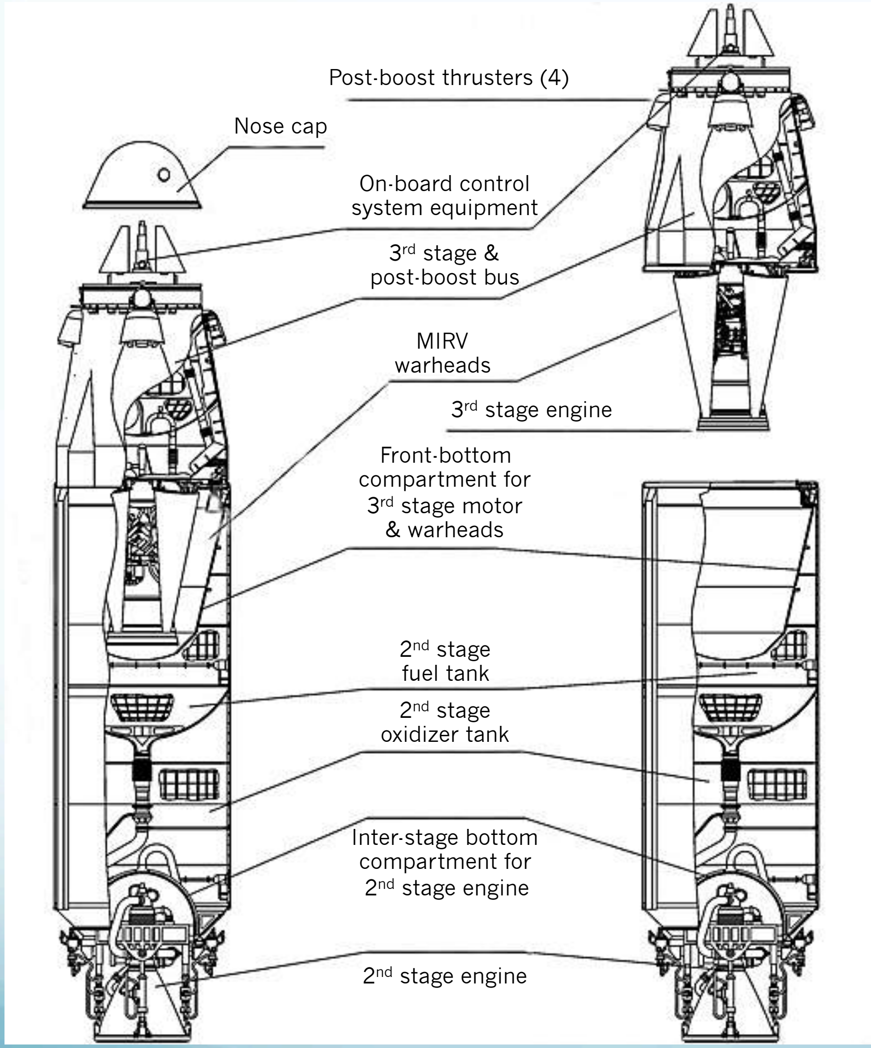
# R-29R variants for Delta III SSBNs

- R-29RL / D-9RL launch system:
  - Development started in 1975.  Entered service in 1979.
  - Launch system updated to handle simultaneous operation of the R-29 and R-29RL
  - Seven reentry vehicles with improved medium-yield warheads.
- R-29RK / D-9RK launch system:
  - Development started in 1980.  Entered service in 1982.
  - New high-speed, small-size warheads
  - Maximum range increased by 5-6%, greater accuracy, MIRV warhead target footprint increased.
- R-29RKU / D-9RKU launch system:
  - Development started in 1985.  Entered service in 1987.
  - New lower-yield warheads
  - Improved capability for launching at high Arctic latitudes
  - Adaptive and module structure of the missile and the missile launch system was implemented. Makeyev reports: “The shipborne digital computer system, systems of missile complexes, missile and shore service equipment ensured operation and launch from the 667BDR (Delta III) submarine of updated and non-updated R-29R missiles in any combination in the agreed upon quantity.”
- R-29RKU-01 / D-9RKU01 launch system:
  - Development started in 1986. Entered service in 1990.
  - New medium-yield warhead likely based on an R-29RM warhead.
- R-29RKU-02, Stantsia-2:
  - Development started in 2003. Entered service in 2006.
  - Objective was to prolong the service life of the R-29RKU-01 by re-equipping it with warheads of higher effectiveness and safety, with minimum modifications in the missile and launch system.
  - Original service life extension target was 2015 – 2017.  Three Delta III SSBNs with this SLBM and launch system were still in commission in early 2018.

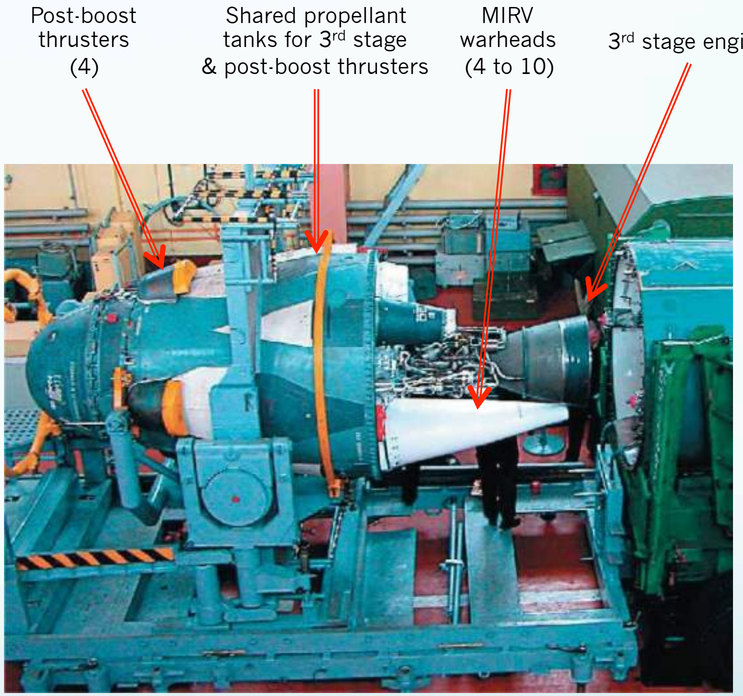
# R-29RM Shtil
## (RSM-54, 3M37, SS-N-23 Skiff)

- Developed from the R-29R, with significant improvements. Features include:
  - Three stages vs. two stages
  - Capable of carrying four to ten MIRV warheads. The 3rd stage propulsion system is integrated with the MIRV bus propulsion system, with the two systems using common propellant tanks.
  - Larger missile diameter: 1.9 vs. 1.8 m (74.8 vs. 70.7 inches) in the same diameter missile tube
  - Longer missile: 14.8 vs. 14.1 m (48.6 vs. 46.3 ft)
  - Astro-inertial guidance
  - D-9RM launch system
- 1979: Work on the R-29M began
- June 1983: 1st R-29RM test flight.
- 1986: Accepted by the Navy for service on Project 667BDRM (Delta IV)-class SSBNs. The ten warhead version was not deployed.
- 6 August 1991, Operation Behemoth-2: Delta IV *Novomoskovsk* (K-407) launched a full salvo of 16 x R-29RM SLBMs (more than 650 tons of missiles) in 244 seconds (14 second launch interval). The first and last missiles hit their targets. All others were intentionally destroyed after launch.
- One upgraded version, the R-29RMU, entered service in 1988.
- Production ended in 1998, but was restarted in 1999. Three updated versions have been introduced since then: R-29RMU1 (2002), R-29RMU2 (2007), and the latest version, R-29RMU2.1 Lainer (2014)
- Delta IV SSBNs are being updated during scheduled overhauls to handle the R-29RMU2.1 Lainer.

# R-29RM-series warhead section
## (RSM-54, 3M37, SS-N-23 Skiff)




Source: adapted from http://bastion-karpenko.ru/




R-29RM 3rd stage and warhead section with some MIRV warheads removed, showing 3rd stage engine installation.
Photo source: http://eng.makeyev.ru/activities/missile-systems/

# R-29RM-series missile handling
(RSM-54, 3M37, SS-N-23 Skiff)

Source, three photos: http://eng.makeyev.ru/activities/missile-systems/

# R-29RM variants for Delta IV SSBNs

- R-29RMU / D-9RMU launch system:
  - Development started in 1986. Entered service in 1988.
  - Increased resistance to damage effects of a nuclear explosion.
  - Employ flat trajectories with short time of flight to a target.
  - Four-unit medium-yield MIRVs; can be refitted with a ten-MIRV lower-yield warheads.
  - D-9RMU can handle a mix of R-29RMU and R-29RM missiles.
- R-29RMU1 Stantsia / D-9RMU1 launch system:
  - Development started in 1996. Flight tests were completed in July 2001 and this SLBM entered service in 2002.
  - New medium-yield warhead of increased safety on the basis of the R-39UTTKh missile warhead.
  - Improved accuracy.
- R-29RMU2 Sineva (SS-N-23M1) / D-9RMU2 launch system:
  - Development started in 1998 as a result of the Russian Federation decision in July to modernize the Delta IV SSBNs and restart production of an updated R-29RM SLBM, with no changes in the previous stage dimensions.
  - Flight tests began in 2003 and were completed in June 2004. Entered service in 2007. 96 missiles were produced.
- R-29RMU2.1 Lainer (SS-NX-31):
  - Development started in 2009. Entered service in 2014.
  - Existing R-29RMU2 Sineva SLBMs are reported to have been upgraded to the R-29RMU2.1 Lainer SLBM standard.

# R-29RMU2.1 Lainer
## (SS-NX-31)

- The Lainer missiles can be equipped with 10 low-yield warheads and penetration aids, or 8 warheads of the same power class with advanced penetration aids, or 4 warheads of the medium-yield class with penetration aids.
- Range at full load: 8,300 km (5,157 mi); range at reduced load: up to 12,000 km (7,456 mi).
- Astro-inertial guidance with GLONASS satellite navigation update capability; CEP 350 m (1,148 ft).
- Lainer missiles can carry a mixed complete set of warheads of different yields. The operation of any combination of missiles and their combat load aboard the Project 667BDRM Delta IV SSBNs is enabled by the Arbat-U2.1 updated shipborne digital computer system.


Source: http://eng.makeyev.ru/activities/missile-systems/Narubegevekov/Lainer/

R-29RMU2.1 on transporter
Source: http://www.military-today.com/missiles/

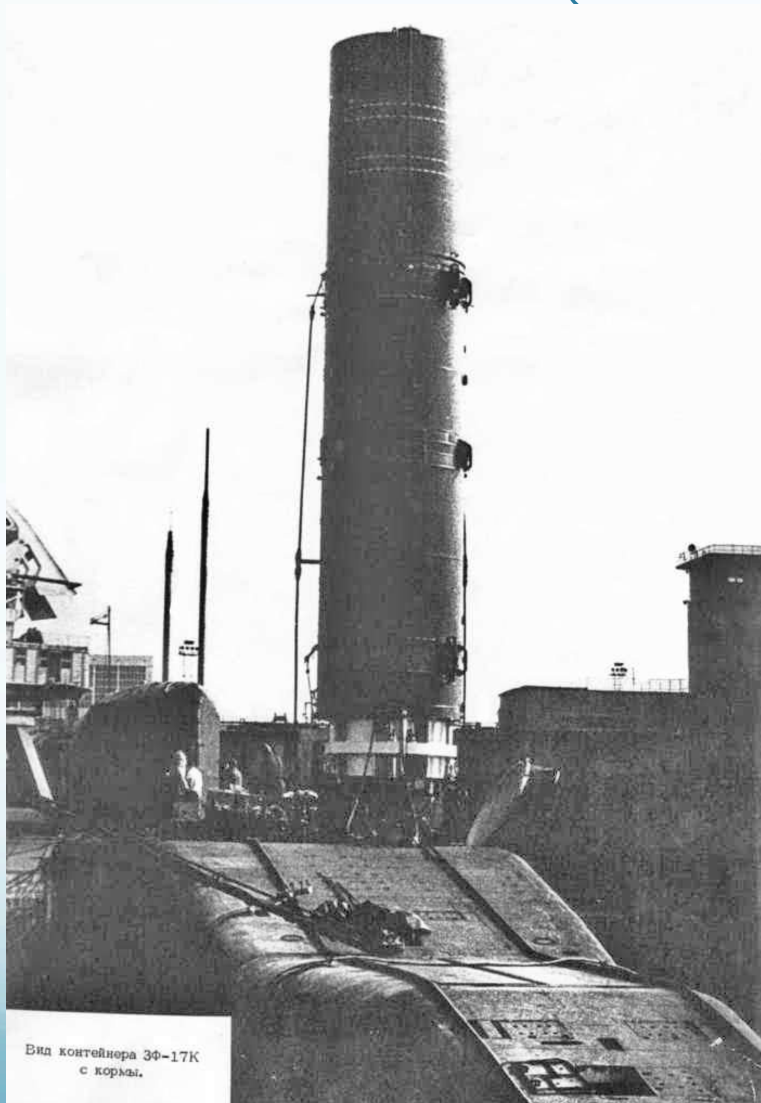
# R-29RMU2.1 Lainer
## (SS-NX-31)

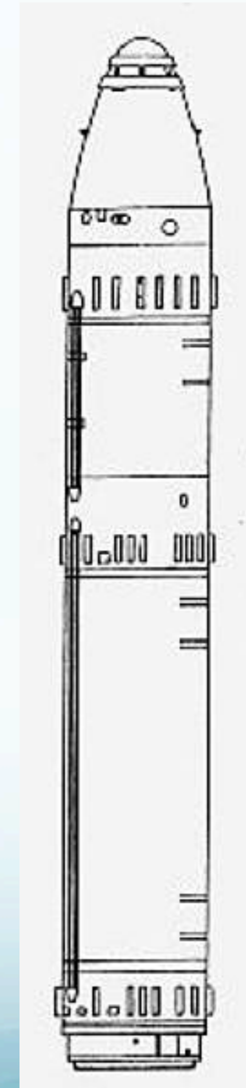

R-29RMU2.1 test launch from a Delta IV SSBN.  Source, both photos: http://www.military-today.com/missiles/r29rmu21_layner.htm

# R-31 Snipe
## (RSM-45, SS-N-17)

- Developed by the Arsenal Design Bureau (TsBK-7), St. Petersburg, starting in June 1971.
  - 1st solid-fuel Soviet SLBM. Two stages.
  - 1st Soviet ballistic missile with astro-inertial guidance.
  - Cold-launch system ejected the missile from the launch tube before rocket motor is ignited.
  - Range was 4,200 km (2,610 mi).
  - Armed with a single 500 kT warhead.
- While having better performance and simpler handling than the storable liquid-fuel R-27 SLBMs on Yankee I SSBNs, the R-31's performance was exceeded by the R-29, which was developed at the same time by Makeyev.
- R-31 was deployed only on the Yankee II SSBN, K-140: 12 x R-31 SLBMs with the D-11 launch system.
  - December 1976: First test launch from K-140
  - March 1980: Entered service
- All R-31 SLBMs were disposed of by launching from K-140 between 17 September to 1 December 1990; all of them were successful. Thereafter, K-140 was decommissioned and scrapped.

# R-31 Snipe
## (RSM-45, SS-N-17)



Right: R-31
Source: http://army-news.ru/2016/06/sol-raketnoj-gonki/

Left:
R-31 being loaded onto Yankee II K-140.
Source: http://www.shipmodels.info/mws_forum/

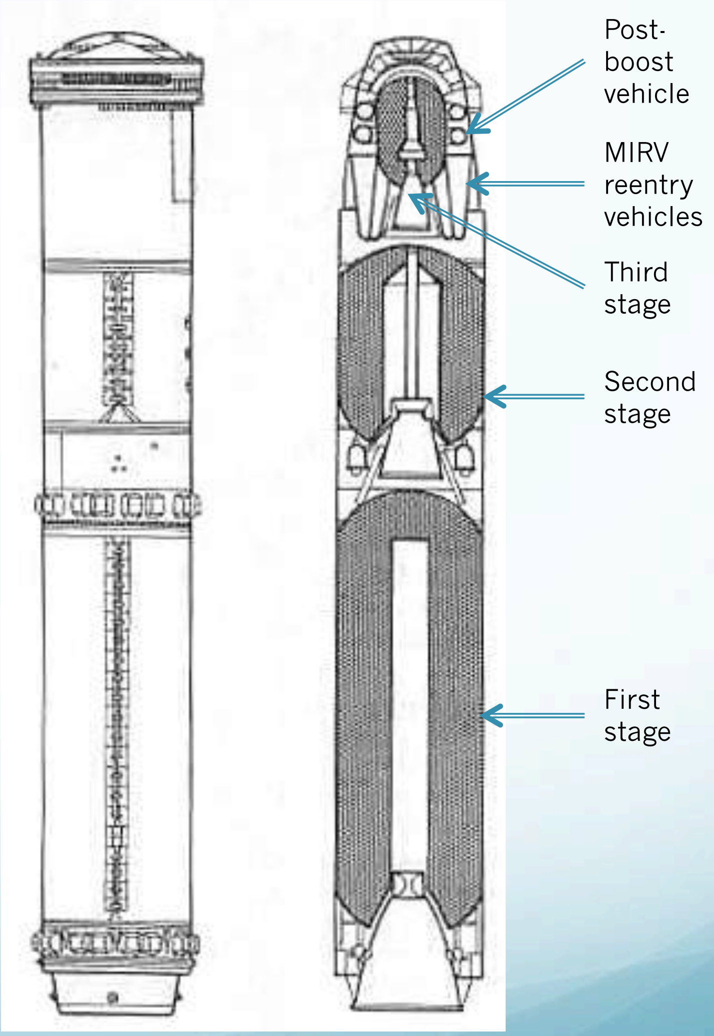
# R-33 SLBM
## (SS-N-8 anti-ship SLBM)

- June 1971: The Soviet government ordered the Makeyev Rocket Design Bureau to develop the D-13 launch system and the R-33 missile equipped for the anti-ship mission with a warhead section that would be guided to the target by a combined (active-passive) sighting device and terminal homing.
  - Primary targets were carrier strike groups and convoys.
  - High accuracy made it possible to use a small nuclear warhead or a conventional warhead.
  - Intended for deployment on Project 667B Delta I SSBNs.
- December 1971: Council of Chief Designers established required system characteristics.
- Late 1972: A preliminary design was presented and a new decree was issued, specifying the stages of development. Tests of the missile from a submarine originally were set for 1977.
  - Mass and dimensions of the R-33 SLBM were similar to the R-29 SLBM.
  - Expected range was about 2,000 km; much longer than the R-29K anti-ship SLBM.
- June 1974: Development problems persisted Issues included:
  - Range decreased to 1,200 – 1,600 km as the front end of the missile (target sensor array & warhead) took up a greater portion of the missile than expected.
  - Operation of the combined sighting device was affected by plasma formation.
  - Antenna required protection from thermal and mechanical impacts during ballistic flight.
  - Target designation system needed improvement.
- 1975: Funding for the program was terminated due to continued development problems and provisions of the SALT Treaty, which classified anti-ship ballistic missiles as strategic weapons.

# R-39 Rif

## (RSM-52, 3M65 / 3M20 / 3R65, SS-N-20 Sturgeon)

- 1973: Makeyev Rocket Center started development of the R-39.
- This is the largest SLBM ever built: length 16.1 m (52.8 ft.), diameter 2.4 m (7.9 ft.), weight 84,000 kg (185,000 lb); much larger than the US Trident D-5.
- Three-stage, solid-propellant SLBM.
- Cold-launch system enables the SLBM to be launched submerged or surfaced.
- Up to 10 MIRV warheads can be mounted on a payload bus surrounding the third-stage solid rocket. Two small liquid-propellant engines provided for post-boost maneuvering.
- The missile structure allowed for replacing reentry vehicles and the equipment bay without unloading the R-39 from its launch tube.
- The R-39 SLBM and the D-19 launch system were tested on the Golf V K-153 and deployed only on Typhoon-class SSBNs.
- 1983: R-39 entered service.

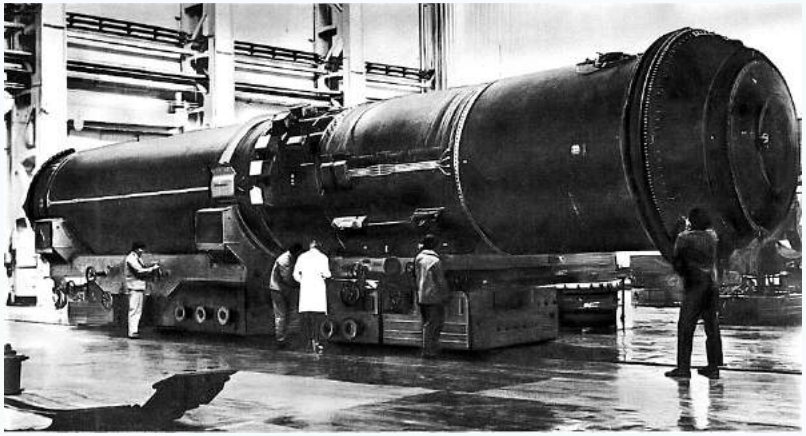



R-39 missile storage canister (left) and missile cross-section (right). Source: adapted from http://cakra401.blogspot.com/

# R-39 Rif

## (RSM-52, 3M65 / 3M20 / 3R65, SS-N-20 Sturgeon)

R-39 ground handling.  Source: http://eng.makeyev.ru/activities/missile-systems/3/RaketaR39/



R-39 launch canister.
Source: Source: http://site.6park.com/


R-39 canister being loaded onto a Project 941 Typhoon-class SSBN.
Source: http://wikimapia.org/14426881/

# R-39U & R-39UTTKh

## Advanced versions of the R-39 SLBM

- R-39U and D-19UTH launch system (also known as R-39M):
  - Incorporated a new small, low-yield warhead originally developed for the R-29RMU.
  - MIRVs could engage targets over a wider area and engage shorter-range targets.
  - Capability of launching from high Arctic latitudes was confirmed with special test launches.
  - 1985: Development started.
  - 1988: R-39U entered service on Typhoon-class SSBNs.
- R-39UTTKh Bark (RSM-52V, SS-N-28) and the D-19UTTKh launch system:
  - Intended to be the next update for this SLBM family.
    - Medium-yield warheads, more resistant to EMP effects; re-entry vehicles capable of maneuvering trajectories (flat, high-angle, with random drifts in arbitrary planes); improved accuracy.
    - Intended for deployment on Typhoon- and Borei-class SSBNs.
  - 1992: Development tests started on improved engines.
  - 1993: 1st flight test from land.
  - Under Project 941U, some Typhoon-class SSBNs were being retrofitted with the the D-19UTTKh launch system.
  - A series of three test failures in November 1993, December 1994, and November 1997 led to a decision by the Ministries of Economy and Defense in September 1998 to cancel R-39U development.
    - Borei-class SSBNs were redesigned to handle the RSM-56 Bulava SLBM.
- Under the terms of the Start I and Start II treaties, R-39 missiles were removed from service starting in 1996. All were removed from service by 2004.
  - All but one Typhoon SSBN has been decommissioned. One unit, TK-208, was modified and used as a test platform for the RSM-56 Bulava SLBM. It remains in service as of early 2018.

# R-39UTTKh Bark

## Final version of the R-39 SLBM family

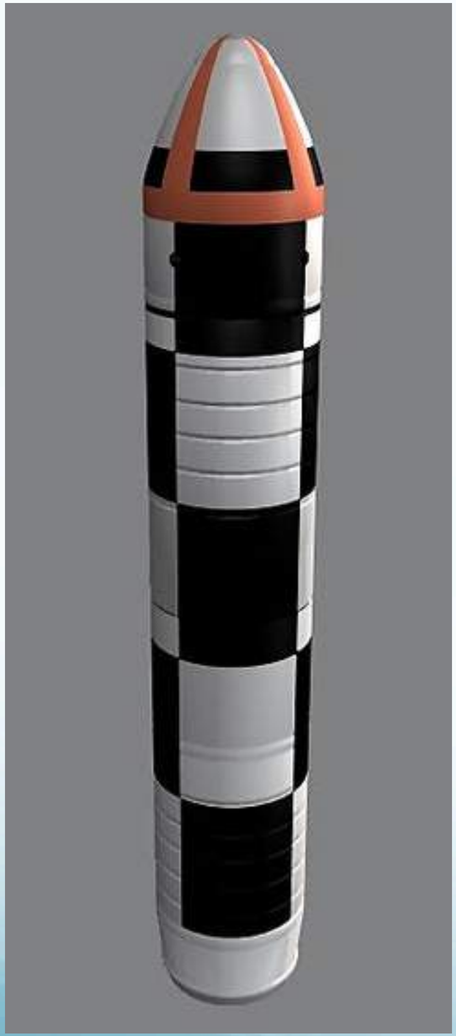
The design of this SLBM incorporated a new design element: an aerodynamic carbon-fiber nose fairing with a flexible, conical, inflatable aerostructure that extended after launch to 1.7 m (5.6 ft) in length. This aerodynamic fairing reduced drag during atmospheric flight and was ejected after 2nd stage burn was complete.

Far Left: R-39UTTKh storage canister, which would be placed in an SSBN launch tube.
Source: http://eng.makeyev.ru/activities/missile-systems/3/RaketaR39UTTHBark/

Center Left: R-39UTTKh missile cross-section showing the three solid rocket stages and the MIRV location behind the retracted nose fairing.

Above: Nose fairing shown retracted (left) and extended (right).
Source: http://militaryrussia.ru/blog/topic-441.html

# RSM-56 Bulava
## (3M30 / 3K30, SS-NX-30 or SS-N-32)



Source: https://thaimilitaryandasianregion

- Designed by Moscow Institute of Thermal Technology (MITT), Moscow, as a replacement for the R-39.
- Three-stage solid propellant rocket + liquid fuel post-boost bus.
- Carries up to ten maneuverable MIRV reentry vehicles with 150 kT warheads and penetration aids.
- 1st RSM-56 submarine test launch occurred on 27 Sep 2005 from Typhoon SSBN TK-208, *Dimitriy Donskoy.*

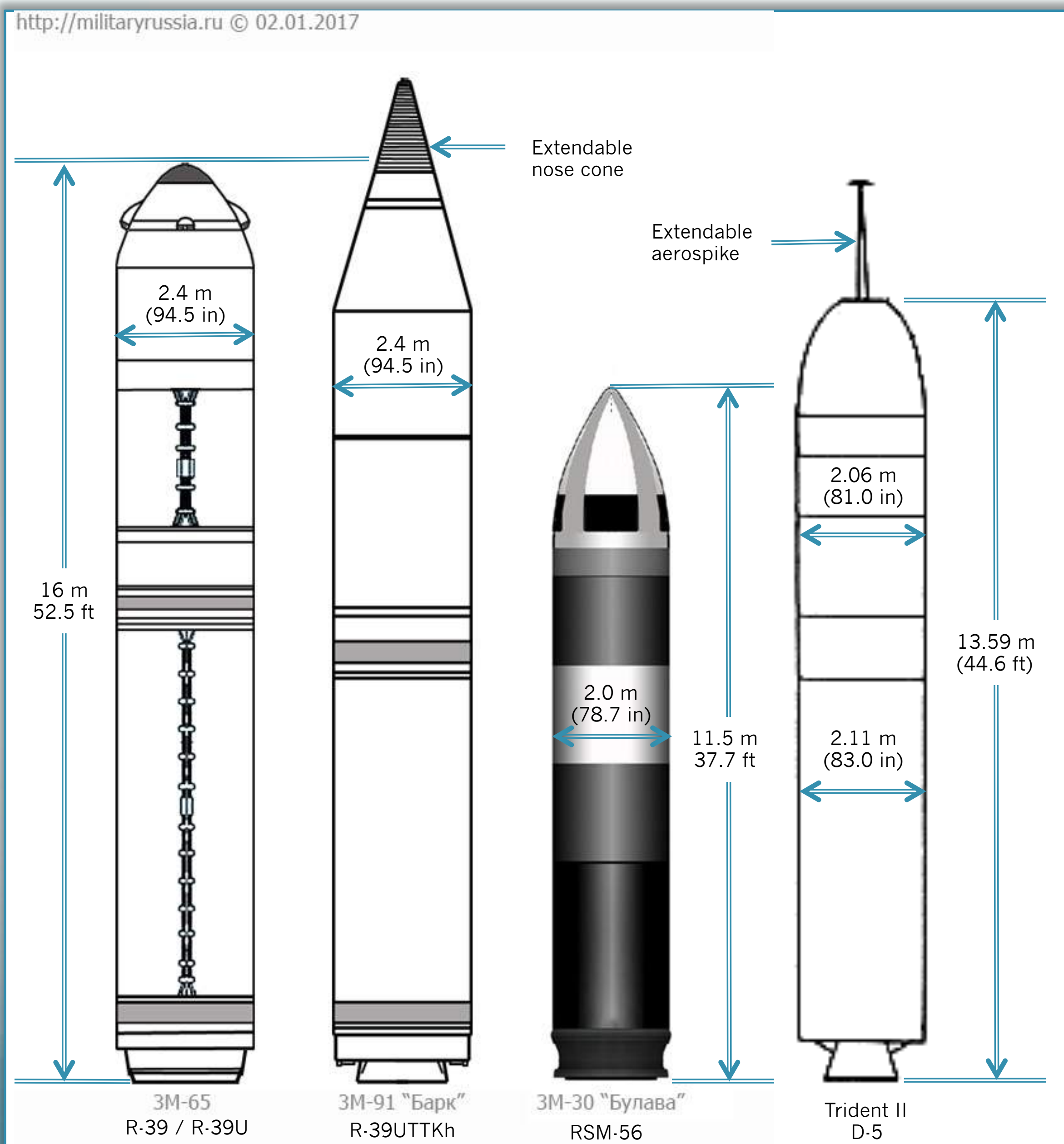
RSM-56 3rd stage & warhead section.
Source: https://thaimilitaryandasianregion.wordpress.com/

- 28 June 2011: Launched for the first time from a Borei-class SSBN, *Yuri Dolgorukiy,* followed on 27 August 2011 by the first full-range test flight, which demonstrated a range of over 9,000 km (5,600 mi).
- There have been numerous RSM-56 test failures and additional failures following deployment on Borei-class SSBNs.
- October 2015: Bulava became operational aboard *Yuri Dolgorukiy.*

# RSM-56 Bulava
## (3M30 / 3K30, SS-NX-30 or SS-N-32)

Left: RSM-56 submerged launch.  Source: DefenseUpdate.com

Loading an RSM-56 in its storage canister onto a Borei-class SSBN. Source: https://thaimilitaryandasianregion.wordpress.com/




# Comparison of Russian R-39 Rif / Taifun, R-39UTTKh Bark, RSM-56 Bulava & US Trident II D-5 SLBMs

Source: Adapted from http://militaryrussia.ru/blog/topic-441.html and https://fas.org/nuke/guide/usa/slbm/d-5.htm

# Cruise missile submarines (SSG & SSGN)

Early Soviet diesel-electric SSGs are included in this section in order to provide a more complete story about the early submarines involved in the development, testing and operational deployment of submarine-launched cruise missiles.

# Evolution of Soviet / Russian SSGs & SSGNs

Whiskey Twin Cylinder SSG

Whiskey Long Bin SSG

Echo I SSGN

Juliett SSG

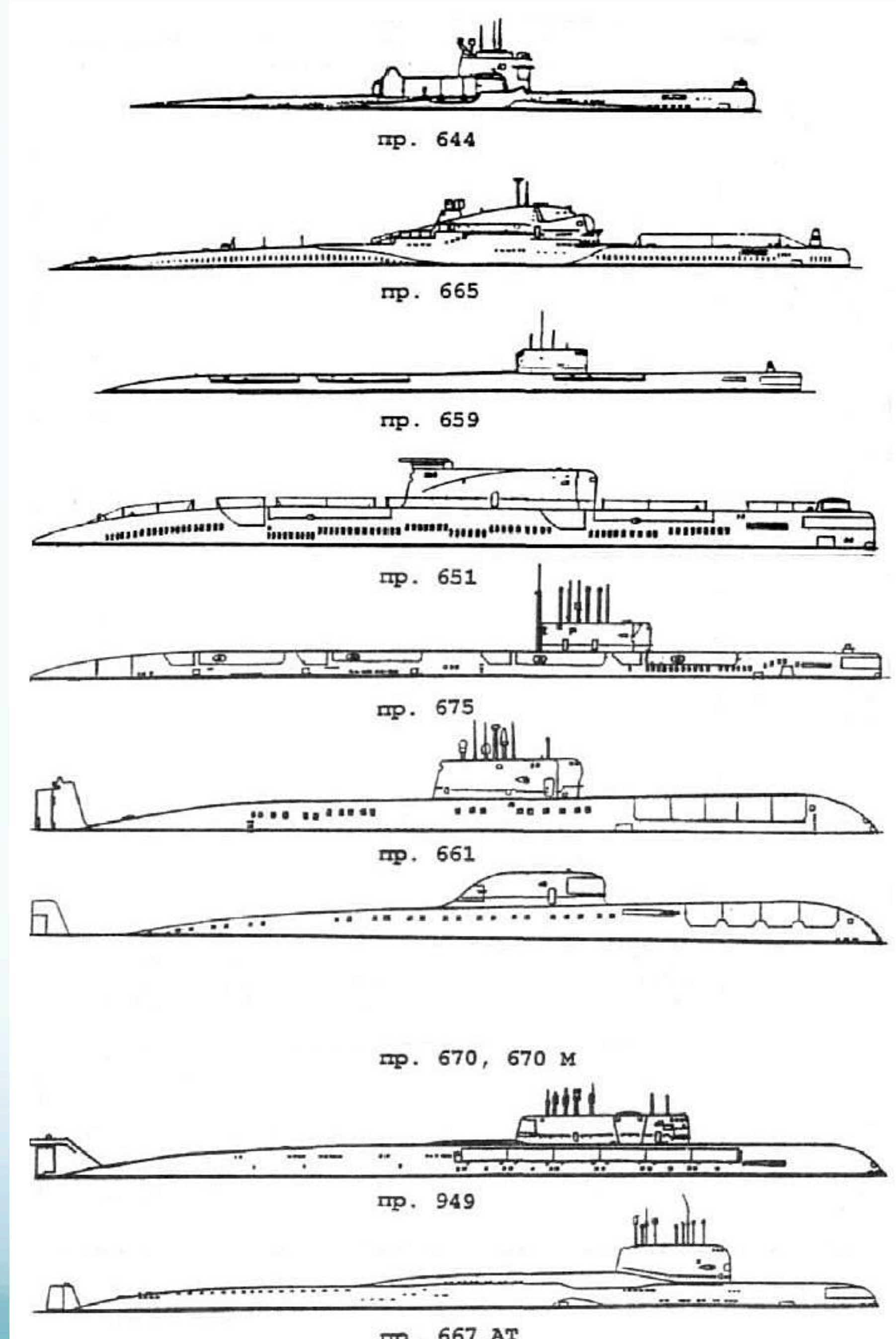
Echo II SSGN

Papa SSGN

Charlie I & II SSGN

Oscar I & II SSGN

Yankee Notch SSGN




Source: https://fas.org

# Russian SSGNs

| Project # | Class | Cruise missile | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P613 | Whiskey single cylinder | P-5 | 1 ex-Whiskey | 76 m (249 ft) | 6.3 m (20.7 ft) | 1,045 (surf) 1,342 (sub) | Diesel-electric | 4,000 | 11.5 | 1957 | 1957 - 1962 |
| 644 | Whiskey twin cylinder | P-5, P-7 | 6 ex-Whiskey | 76 m (249 ft) | 6.3 m (20.7 ft) | 1,160 (surf) 1,473 (sub) | Diesel-electric | 4,000 | 11.5 | 1959 - 62 | 1959 – 1970s |
| 665 | Whiskey long bin | P-5 | 6 ex-Whiskey | > 76 m (> 249 ft) | 6.3 m (20.7 ft) | 1,480 (surf) 1,920 (sub) | Diesel-electric | 4,000 | 8 | 1961 - 64 | 1961 – 1970s |
| 651 | Juliett | P-5, P-6, P-500 | 16 | 90 m (281.8 ft) | 10 m (23 ft) | 3,225 (surf) 4,203 (sub) | Diesel-electric | 9,750 | 18 | 1963 - 68 | 1963 - 1994 |
| 659 | Echo I | P-5 | 5 | 111.0 m (364.2 ft) | 9.2 m (30.2 ft) | 3,768 (surf) 4,920 (sub) | 2 x VM-A | 27,000 | 24 | 1961 - 63 | 1961 - 89 |
| 675 | Echo II | P-6, P-500, P-1000 | 29 | 115.0 m (377.3 ft) | 9.2 m (30.2 ft) | 4,415 (surf) 5,760 (sub) | 2 x VM-A | 27,000 | 22 | 1963 - 68 | 1963 - 95 |
| 670 | Charlie I | P-70 | 11 | 94.3 m (309.4 ft) | 9.9 m (32.5 ft) | 3,574 (surf) 4,980 (sub) | OK-350: 1 x VM-4-1 | 17,000 | 24 | 1968 - 73 | 1968 - 92 |
| 670M | Charlie II | P-120<br><br>1 unit, P-160 | 6 | 104.9 m (344.2 ft) | 9.9 m (32.5 ft) | 4,372 (surf) 5,500 (sub) | OK-350: 1 x VM-4-1 | 17,000 | 24 | 1973 - 80 | 1973 - 94 |
| 667M | Yankee Sidecar (Andromeda) | Kh-90 | 1 ex-Yankee I | 153 m (502 ft) | 15 m (49.2 ft) | 10,500 (surf) 13,650 (sub) | OK-700: 2 x VM-4-2 | 34,500 | 25 | 1982 | 1983 - 88 |

# Russian SSGNs

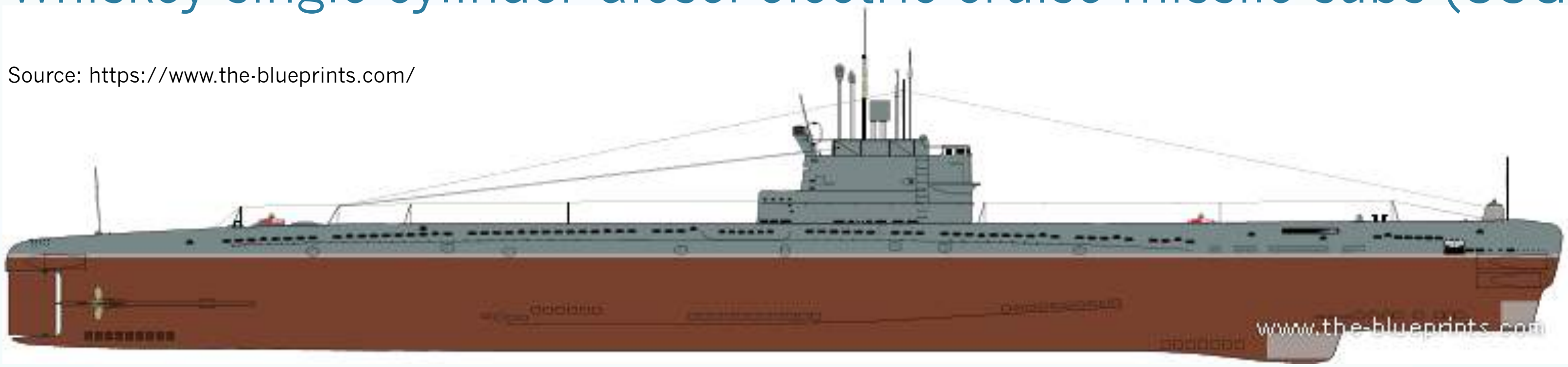
| Project # | Class | Cruise missile | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 667AT | Yankee Notch (Grusza) | RK-55 | 4 ex-Yankee I | 141.5 m (464.2 ft) | 12.8 m (42 ft) | 8,880 (surf) 11,500 (sub) | OK-700: 2 x VM-4-2 | 34,500 | 25 | 1982 - 91 | 1983 – 94 |
| 661 | Papa (Anchar) | P-70, P120 | 1 | 106.9 m (350.7 ft) | 11.6 m (38 ft) | 5,280 (surf) 7,100 (sub) | 2 x VM-5m | 68,000 | 44.7 | 1969 | 1969 – 80 |
| 949 | Oscar I (Granit) | P-700 | 2 | 143 m (469.2 ft) | 18.2 m (59.7 ft) | 12,500 (surf) 15,500 (sub) | 2 x OK-650B | 73,000 | 30 | 1982 - 83 | 1983 - 96 |
| 949A | Oscar II (Antei) | P-700 | 10 + 2 not complete | 154 m (505.3 ft) | 18.2 m (59.7 ft) | 13,400 (surf) 16,400 (sub) | 2 x OK-650B | 73,000 | 30 | 1986 - 96 | 1986 - present |
| 949AM | Oscar II update (Antei) | P-800, 3M54, 3M14, 3M22 | Up to 8 updated Oscar II | 154 m (505.3 ft) | 18.2 m (59.7 ft) | 13,400 (surf) 16,400 (sub) (est.) | 2 x OK-650B | 73,000 | 30 | | |
| 885 * | Yasen | P-800, 3M54, 3M14, 3M22 | 1 | 111 m (364.2 ft) | 12 m (39.4 ft) | 8,600 (surf) 13,800 (sub) | 1 x OK-650V | 38,500 | >30 (est) | 2013 | 2014 - present |
| 885M * | Yasen-M | P-800, 3M54, 3M14, 3M22 | 7 (plan, 2015) | 111 m (364.2 ft) | 12 m (39.4 ft) | > 8,600 (surf) > 13,800 (sub) | 1 x OK-650V or 1 x KPM-6 (CTS-6) | TBD | >30 (est) | 2018 - ongoing | |

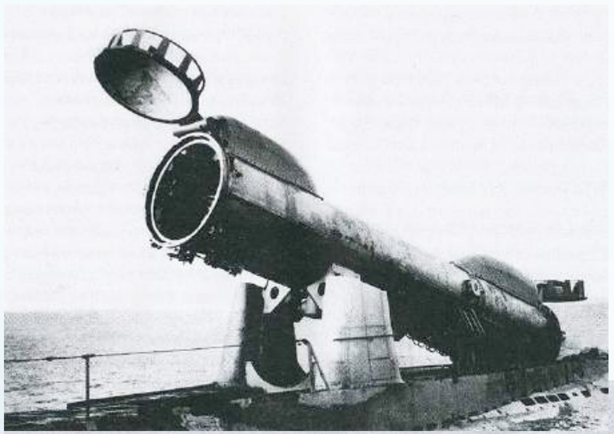
* Project 885 & 885M Yasen SSNs are included in this SSGN table because they are multi-purpose boats that carry a significant inventory of cruise missiles in mid-ships vertical launch system (VLS) missile tubes and can perform the function of an SSGN along with their SSN functions. See the SSN section of this document for details on these multi-purpose SSNs.

# Project 613

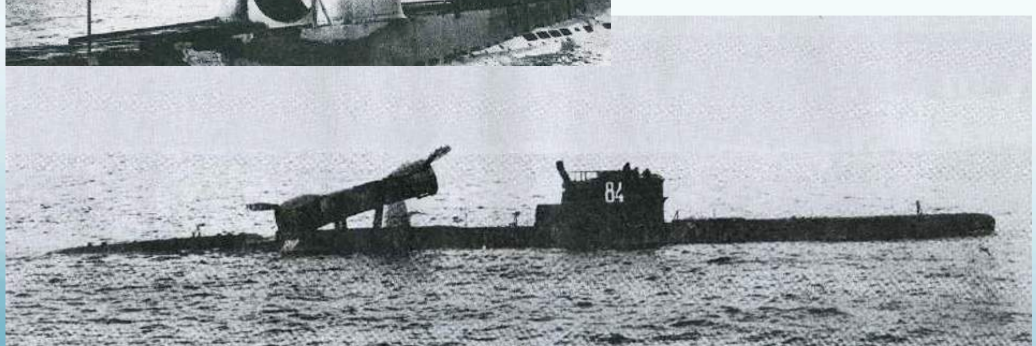
## Whiskey single-cylinder diesel-electric cruise missile subs (SSG)

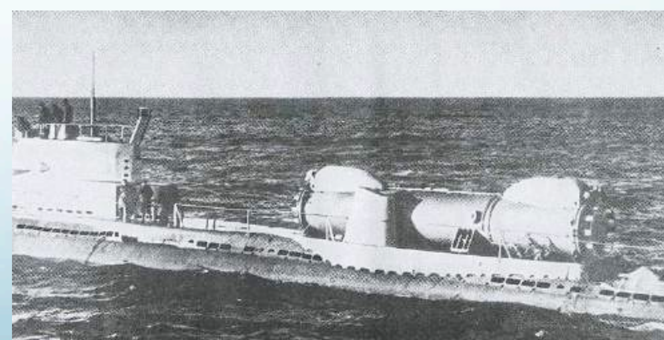
Source: https://www.the-blueprints.com/



- 1957: One Whiskey SS (above), S-146, was modified to test the P-5 cruise missile with a single launch tube installed on the deck behind the sail.
- With the sub on the surface, the launch tube was raised to fire the missile over the sail of the sub. The tests proved the basic launch system concept implemented by the Soviet Union in their later Whiskey, Juliett and Echo cruise missile submarines.
- 1962: The launcher was removed.



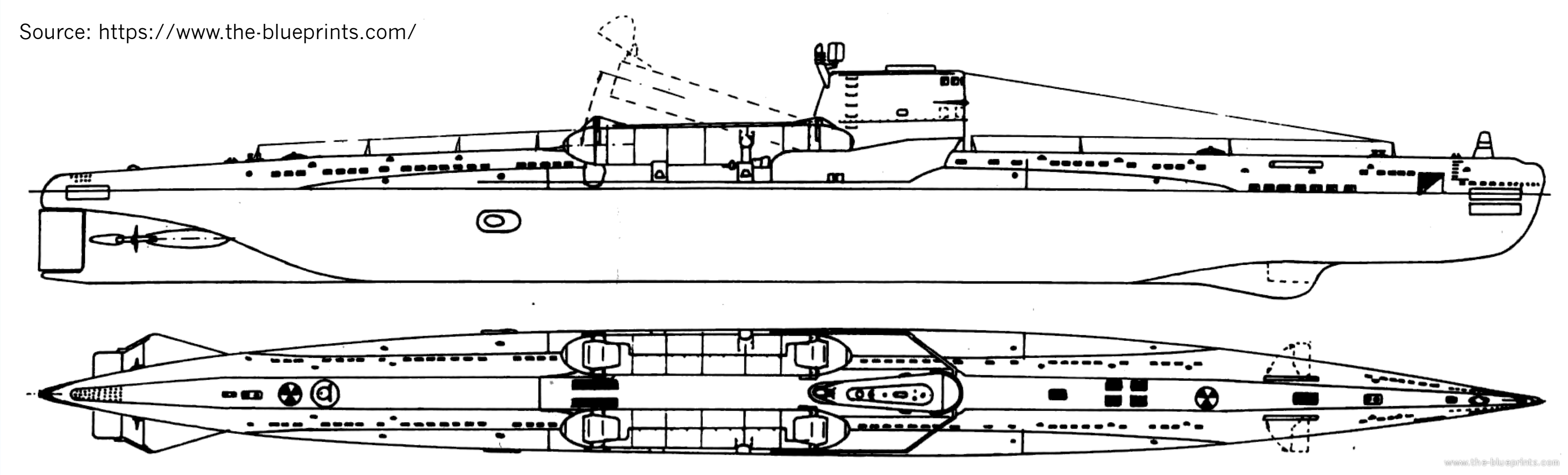



Source, three photos: https://forum.sub-driver.com/forum/

# Project 644

## Whiskey twin-cylinder diesel-electric cruise missile subs (SSG)

Source: https://www.the-blueprints.com/



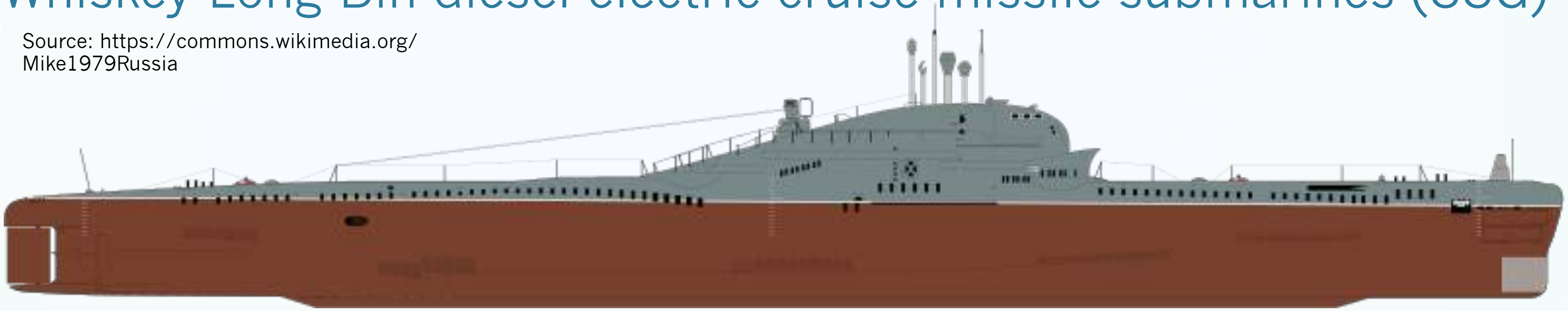
Source: https://en.wikipedia.org/

- Six Whiskey-class subs, S-44, S-46, S-69, S-80, S-158 & S-162, were converted to Whiskey Twin Cylinder SSBs  between 1959 – 1962.
- Armanent:  2 x P-5 Shaddock nuclear-armed, land-attack cruise missiles housed in separate waterproof cylindrical launch tubes. With the sub on the surface, the launch tubes were raised and fired aft over the stern. Note the blast shields forward of the launch tubes.
- Project 644D: S-162 was modified in 1960 to carry 2 x P-5D cruise missiles.
- Project 644-7: S-158 was modified in 1964 to carry 2 x P-7 cruise missiles.
- Replaced by Juliett SSGs and Echo SSGNs.

# Project 665

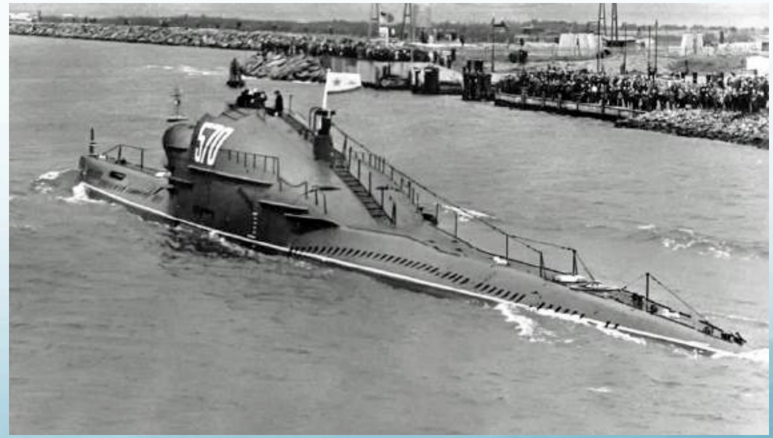
## Whiskey Long Bin diesel-electric cruise missile submarines (SSG)

Source: https://commons.wikimedia.org/
Mike1979Russia



- Between 1961 – 64, six Whiskey-class subs, S-61, S-64, S-142, S-152, S-155 & S-164, were converted to the Whiskey Long Bin SSG configuration. The conversion required chopping the hull in two and inserting an new mid-section containing the very large sail, which encloses four forward-firing missile launch tubes.
- Armament: 4 x P-5 nuclear-armed, land-attack cruise missiles in launch tubes angled up at 14 degrees.
- The size of the sail degraded the sub's stability and made them difficult to maneuver, reduced their submerged top speed and increased their self-generated noise underwater.
- These SSBs were operational until the late 1970s. They were replaced by Juliett SSGs and Echo SSGNs.

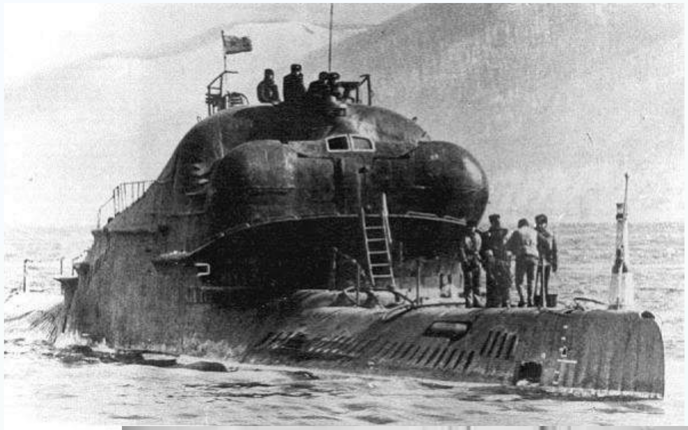

Source: http://www.subart.net/whiskylongbin.htm

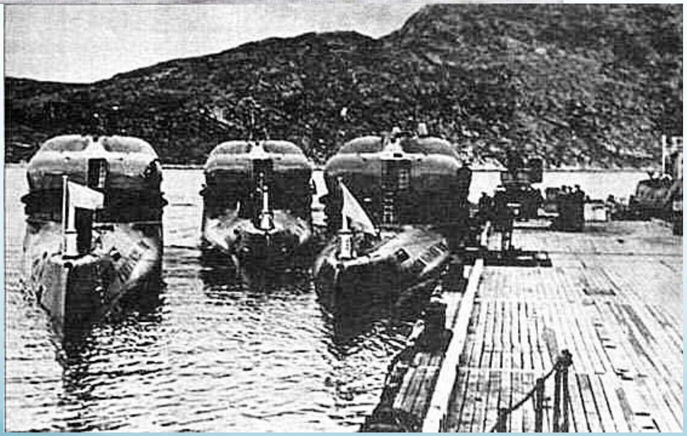


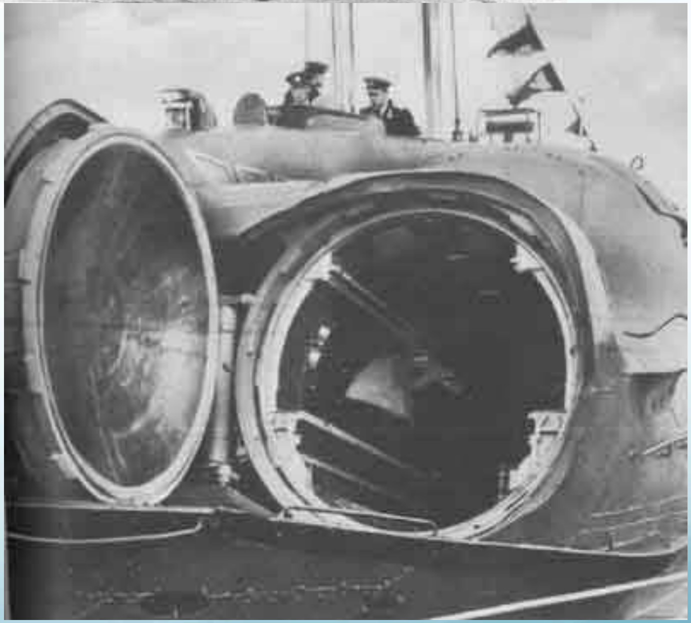

Source: https://forum.sub-driver.com/forum/

# Project 665

## Whiskey Long Bin diesel-electric cruise missile submarines (SSG)





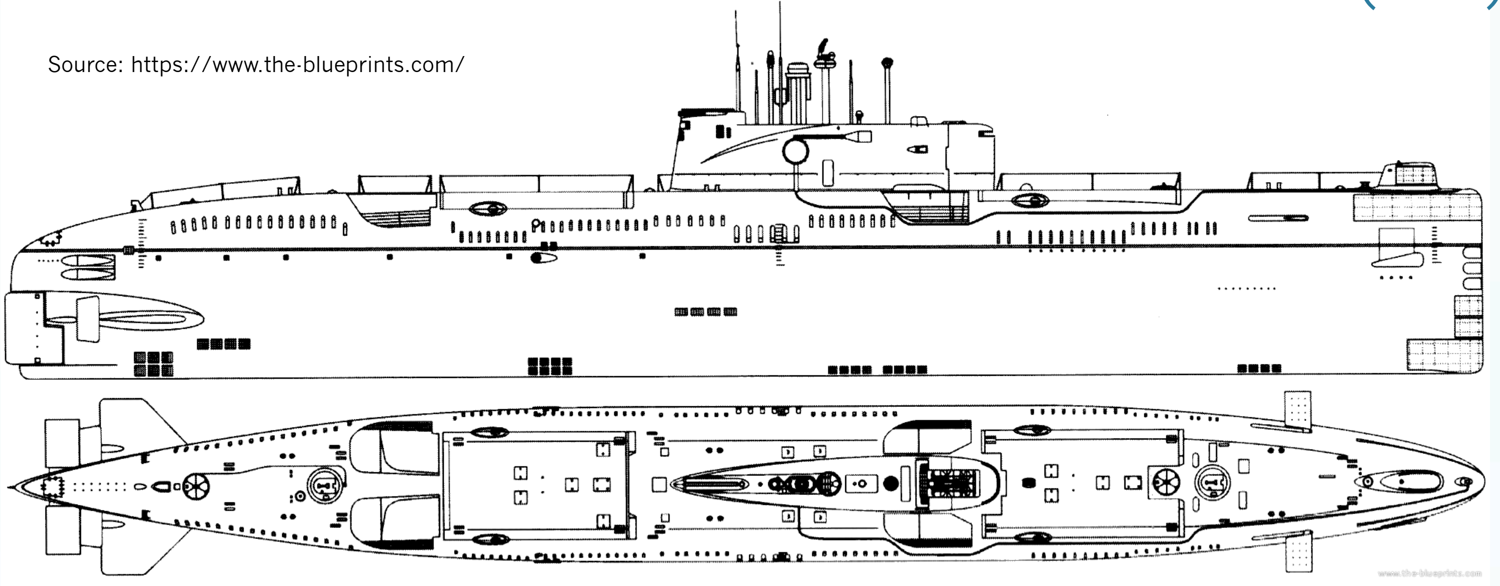


Source, photos bottom L: http://www.naval.com.br/

Source, three photos top R & R, bottom R:
https://forum.sub-driver.com/forum/

# Project 651

## Juliett-class diesel-electric cruise missile submarines (SSG)




- Designed in the late 1950s to provide the Soviet Navy with a nuclear strike capability against land targets along the US coast and aircraft carriers. The Juliett was designed after the Echo-class SSGN and was built as a hedge against delays in Echo-class SSGN construction.
  - Original plans called for 35 SSGs in this class. However, only 16 were built between 1963 – 1968.
- Four cruise missiles were stored in watertight launch tubes that were retracted and flush with the top deck of the submarine when not in use. To conduct a launch, the submarine surfaced, cruised at less than four knots and raised the launchers. The process to launch the first missile would take about five minutes after surfacing; subsequent missiles could be launched at ten second intervals.

# Project 651

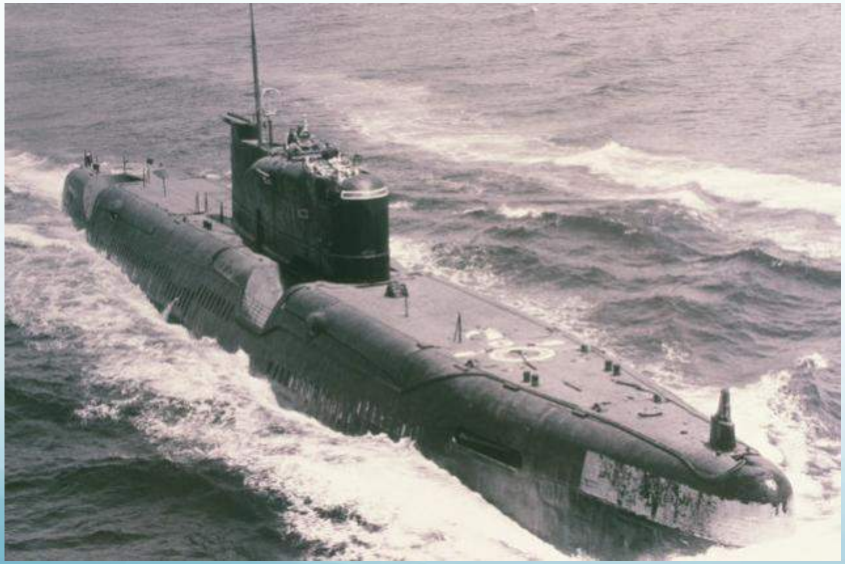
## Juliett-class diesel-electric cruise missile submarines (SSG)

Source: https://forum.sub-driver.com/forum/

- Armament: Originally 4 x P-5 nuclear-armed, land-attack cruise missiles.
  - After SSBNs entered the Soviet fleet, the P-5 was replaced by P-6 nuclear-armed cruise missiles intended for attacking aircraft carriers. A large target guidance antenna was built into the forward edge of the sail structure, which opened by rotating.
  - One Juliett SSG was fitted with a satellite downlink for acquiring targeting information that enabled use of P-500 anti-ship cruise missiles.
- All Juliett SSGs were retired between 1989 - 1994.

# Project 651

## Juliett-class diesel-electric cruise missile submarines (SSG)



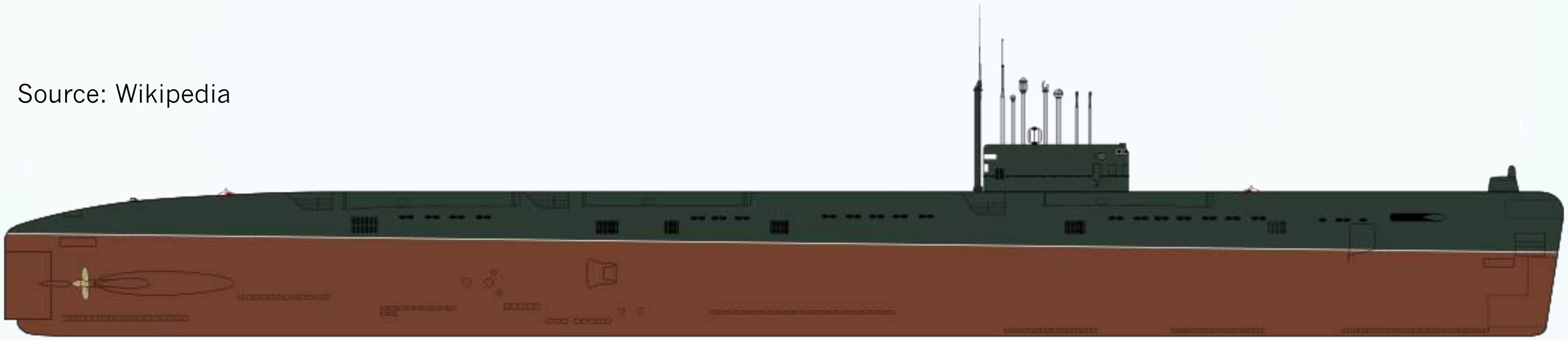

Above: Large guidance antenna for anti-ship cruise missile mid-course guidance was built into the forward edge of the sail structure, which opened by rotating.

Source, three photos: https://forum.sub-driver.com/forum/

# Project 659

## Echo I-class 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 five Echo I boats were built in the Russian Far East at the Komsomolsk-on-Amur Shipyard between 1961 to 1963. All were deployed in the Far East.
- Propulsion:
  - 2 x VM-A PWRs each rated @ 70 MWt. 2 x steam turbines with a combined output of about 27,000 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)

- 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.

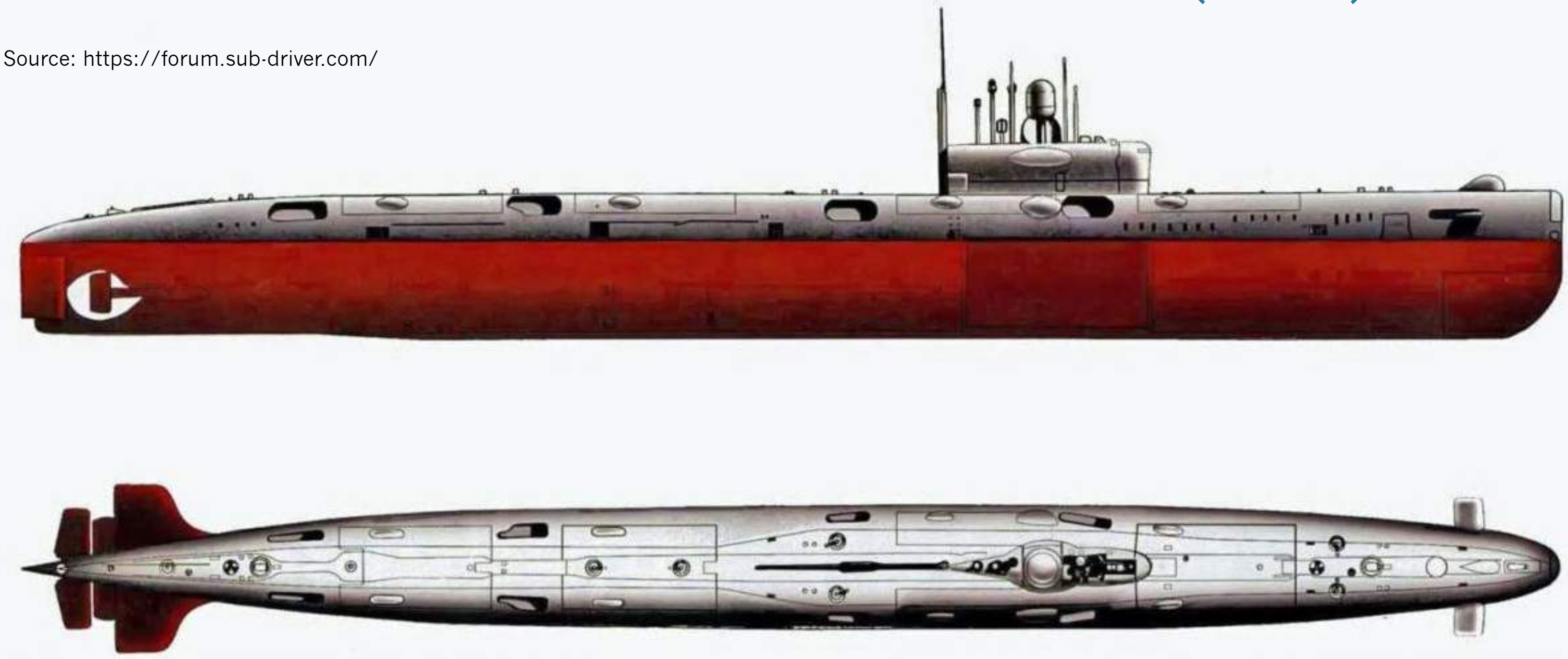

Source: http://wordforge.net/index.php

- 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.

# Project 675

## Echo II-class cruise missile submarines (SSGN)

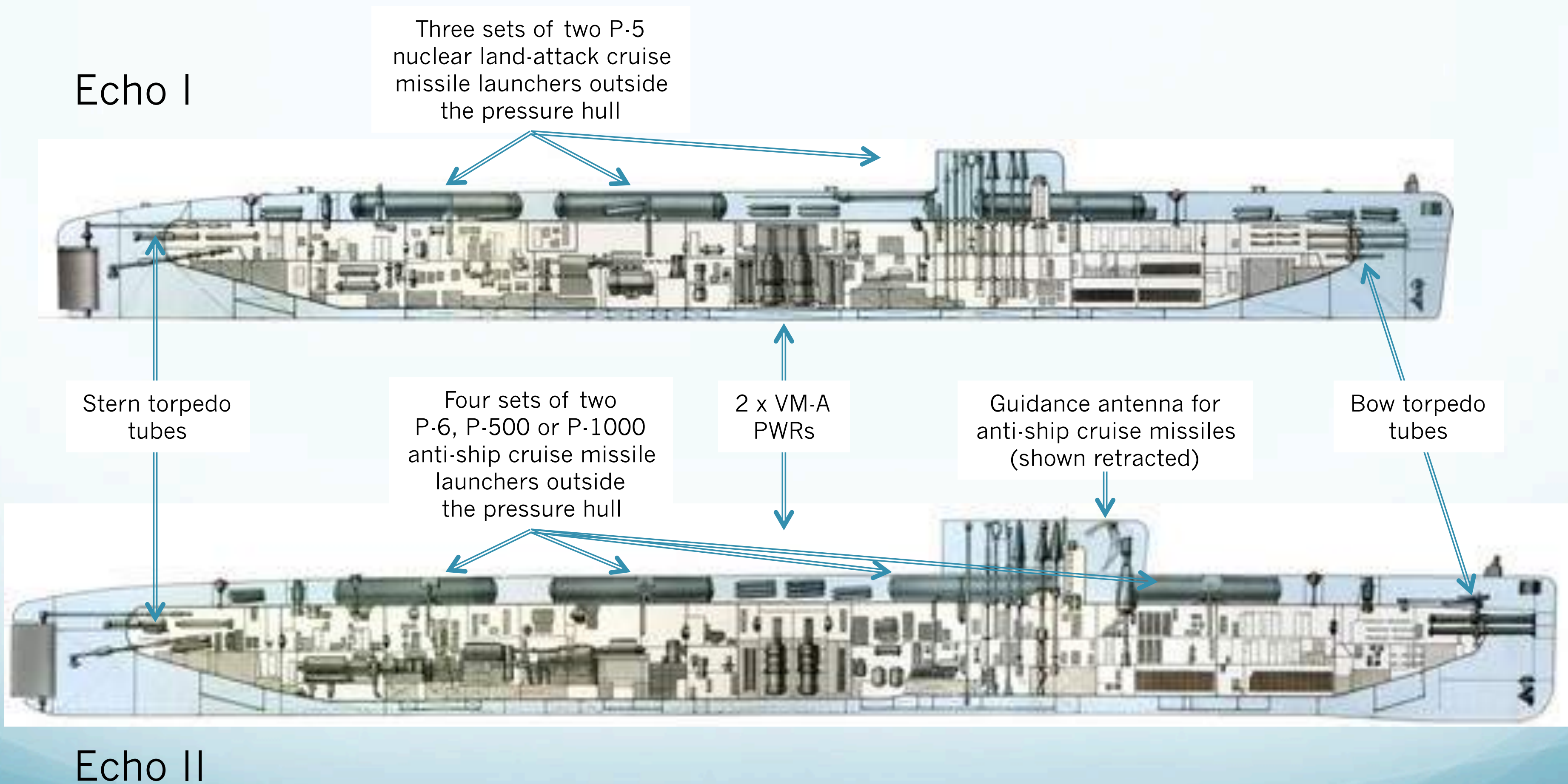
Source: https://forum.sub-driver.com/



- Echo II is an enlarged version of the Echo I SSGN designed for anti-shipping missions by Rubin Central Design Bureau for Marine Engineering.
  - Hull lengthen 5 m (16.4 ft) to accommodate an additional 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).
- The 29 subs in this class were built between 1963 - 1968; 16 were built at SEVMASH, in Severodvinsk, and 13 were built in the Far East at the Komsomolsk-on-Amur Shipyard.

# Comparison of Projects 659 & 675

## Echo I & II cruise missile subs (SSGN)




Source: Rubin Central Design Bureau for Marine Engineering

# Project 675

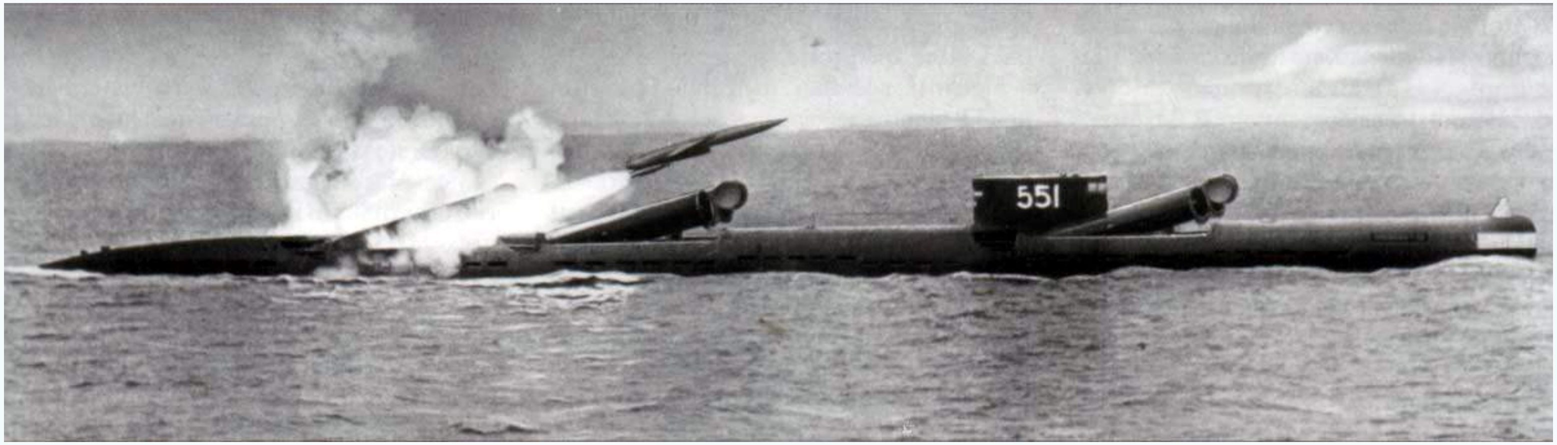
## Echo II-class cruise missile submarines (SSGN)

- Propulsion:
  - 2 x VM-A PWRs each rated @ 70 MWt. 2 x steam turbines with a combined output of about 27,000 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. Twenty minutes were required to launch all eight missiles.
    - Some Echo II boats were modified to carry 8 x P-500 or P-1000 cruise missiles.
  - 4 x 533 mm (21 in) torpedo tubes in the bow + 2 x 406 mm (16 in) torpedo tubes in the stern.
- 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.

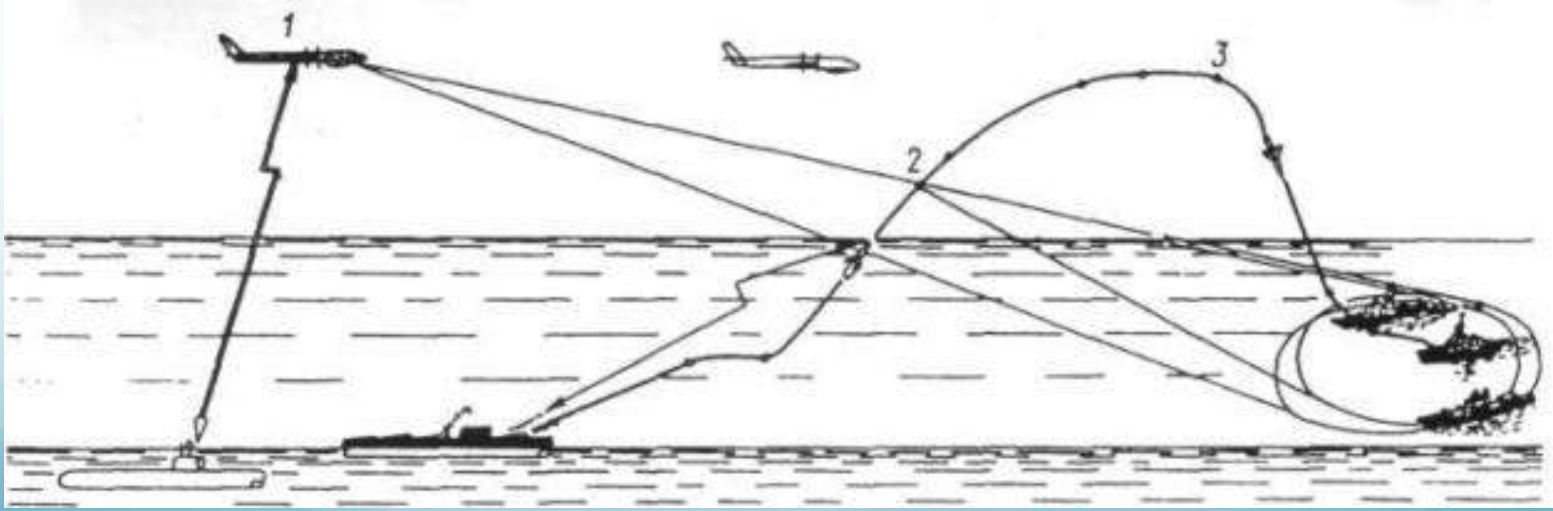
# Project 675

## Echo II launching an anti-ship cruise missile

Echo II must launch its anti-ship missiles while surfaced (P-6 missile launch shown).




Echo II anti-ship cruise missile mission profile: 1 = sub receives targeting data from aircraft; 2 = mid-course missile guidance via data link from sub or from aircraft; 3 = terminal radar homing




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

# Project 675

## Echo II-class cruise missile submarines (SSGN)

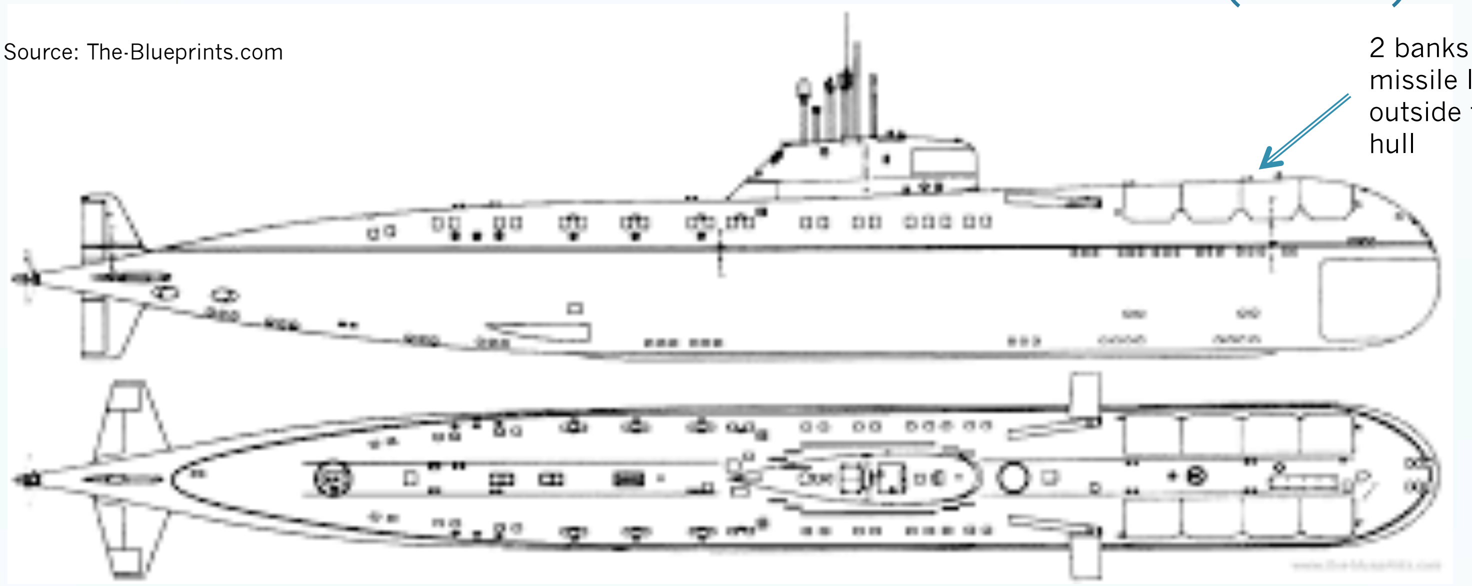
Reactor accidents in Echo II SSGNs:

- 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.

Source: https://forum.sub-driver.com/

# Project 670 (Skat) & 670M (Čajka)

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




- The Charlie-class SSGN was designed to attack US carrier strike groups. It was a counterpart of the Victor-class SSN. Both were designed by SKB-143, which was a predecessor of the Malakhit Central Design Bureau in St. Petersburg.
  - All Charlie-class SSGNs had two banks of four cruise missile launchers in the bow, angled up, outside the submarine's pressure hull.
  - The Charlie I SSGN was the 1st Soviet submarine to deploy with submerged-launch anti-ship cruise missiles.
- Eleven Charlie I SSGNs were built between 1967 – 1972 and six Charlie II SSGNs were built between 1973 – 1980, all at the Krasnoye Sormovo Shipyard (*Factory-112),* Nizhny Novgorod.

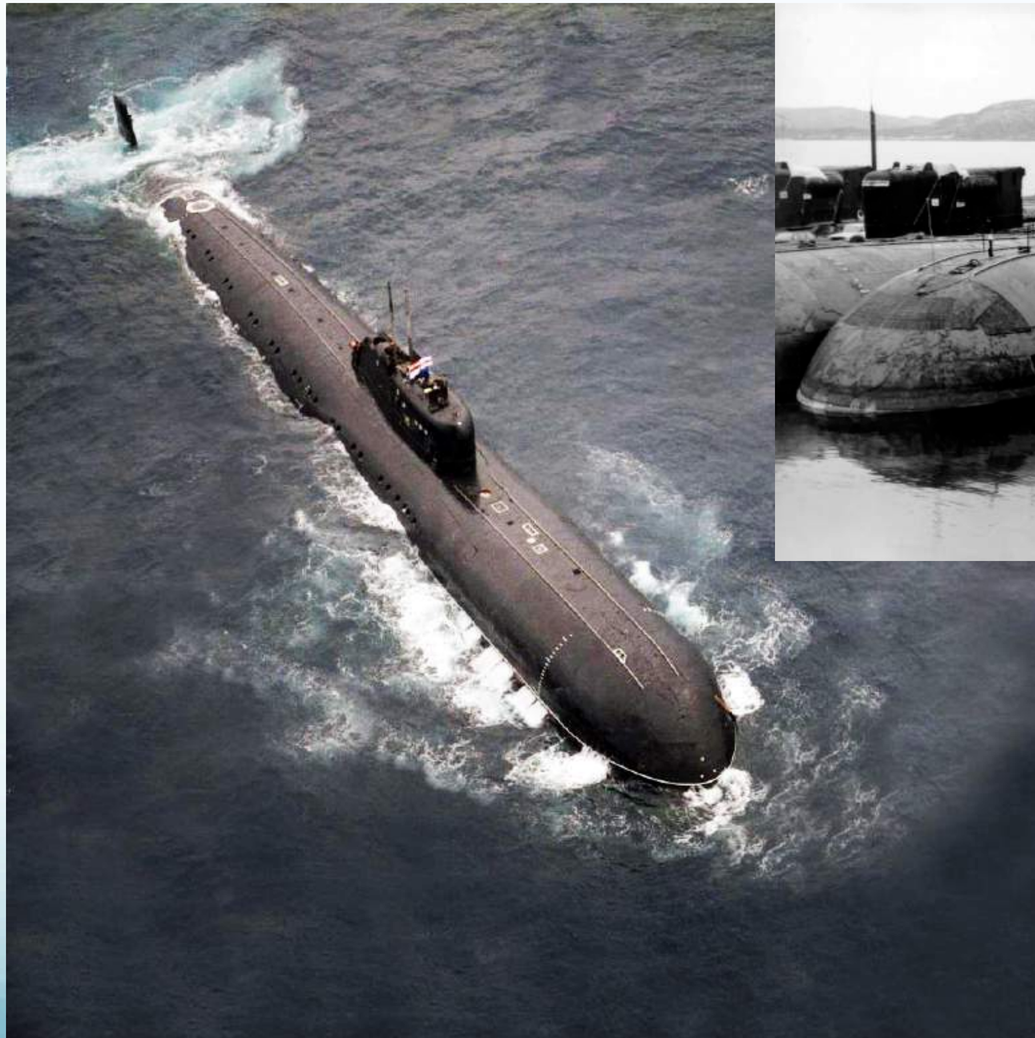
# Project 670 (Skat) & 670M (Čajka)

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

- Propulsion: Unlike most other Soviet nuclear submarines of the time, the Charlie-class SSGNs had a single nuclear reactor and a single propeller, analogous to the common design practice in the US
  - 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, Charlie I:
  - 8 x P-70 cruise missiles
  - 6 x 533 mm (21 inch) bow torpedo tubes and stowage for 12 weapons such as SAET-60 or SET-53M torpedoes or the RPK-2 Vyuga (81R) anti-submarine guided missile.
- Armament, Charlie II:
  - 8 x P-120 cruise missiles. One unit, K-452, was modernized from 1986 – 1992 and armed with 8 x P-160 cruise missiles.
  - 2 x 650 mm (26 inch) bow torpedo tubes for heavyweight Type 65 torpedoes intended for use against large surface ships and advanced submarines.
  - 4 x 533 mm (21 inch) bow torpedo tubes.
- Operational matters:
  - Charlie I K-429 sank in the Pacific off the Kamchatka Peninsula in 1983 with 16 fatalities. The boat was recovered.
  - Charlie I K-43 was leased to the Indian Navy as the *Chakra* from January 1988 – March 1991.
  - Most Charlie I boats were retired between 1990 – 1994, with one boat not being retired until 1998. Average service life was 22.8 years.
  - Charlie II boats were retired between 1991 – 1998, with an average service life of 16.4 years.

# Project 670 (Skat) & 670M (Čajka)

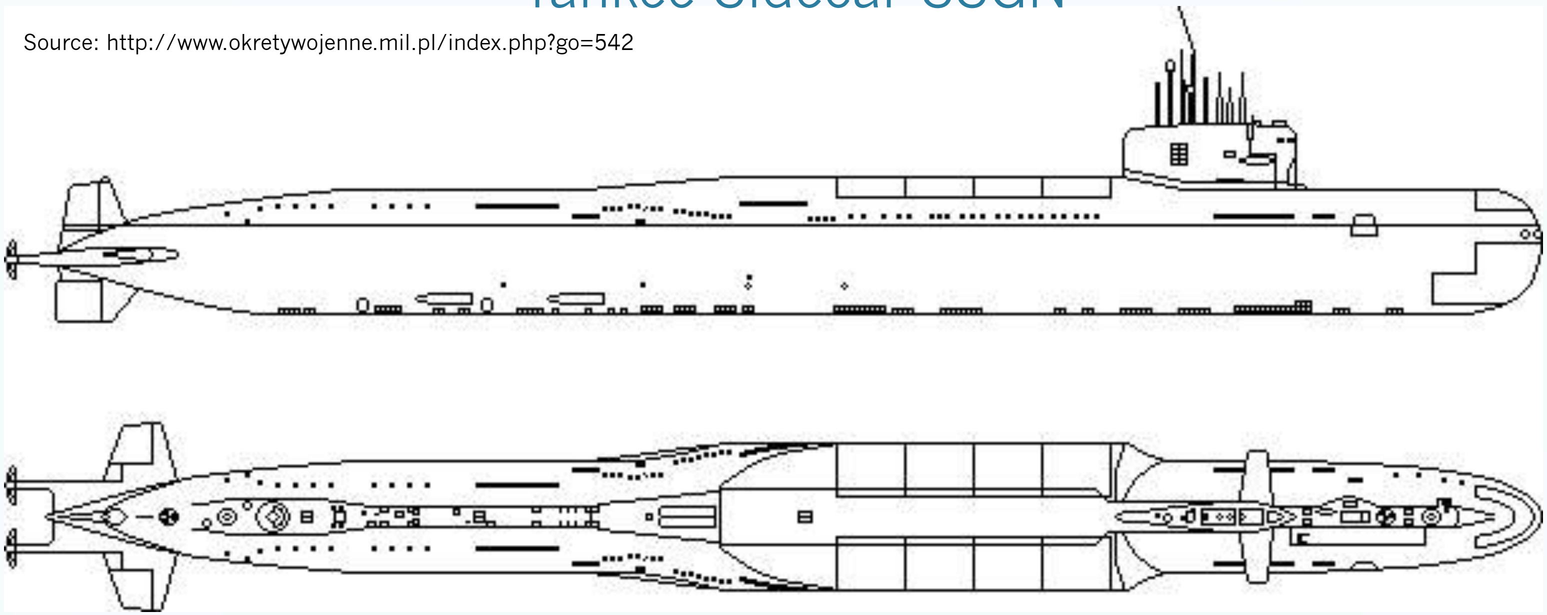
## Charlie I & II-class cruise missile submarines (SSGN)



Source, three photos: https://forum.sub-driver.com/forum/

# Project 667M (Andromeda)

## Yankee Sidecar SSGN



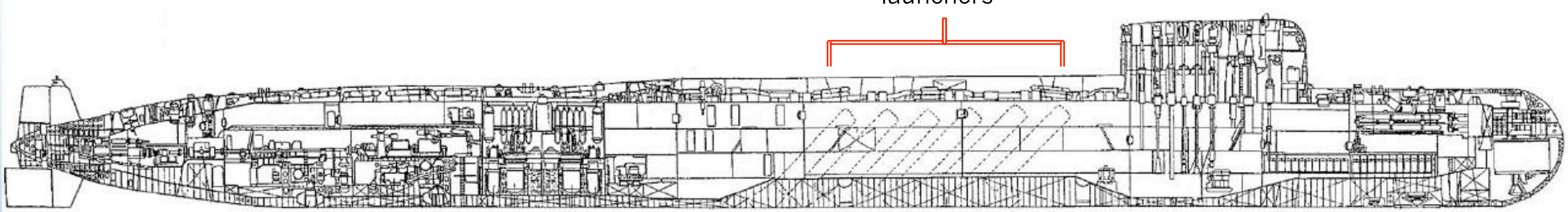

- One Yankee Sidecar SSGN (K-420) was converted in 1983 from a former Yankee I SSBN.  Rubin Central Design Bureau was responsible for the Project 667M design.
  - Tested the P-750 (Kh-80, SS-N-24) nuclear-armed, land attack cruise missile.
  - Established the basic cruise missile launcher arrangement 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
  - Two independent secondary power trains, each with 2 x main turbines and a reduction gear driving a single shaft and propeller. The two trains have a combined rating of about 34,500 shp.

# Project 667M (Andromeda)

## Yankee Sidecar SSGN

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

Source, two photos : www.shipmodels.info




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

# Project 667M (Andromeda)

## Yankee Sidecar SSGN

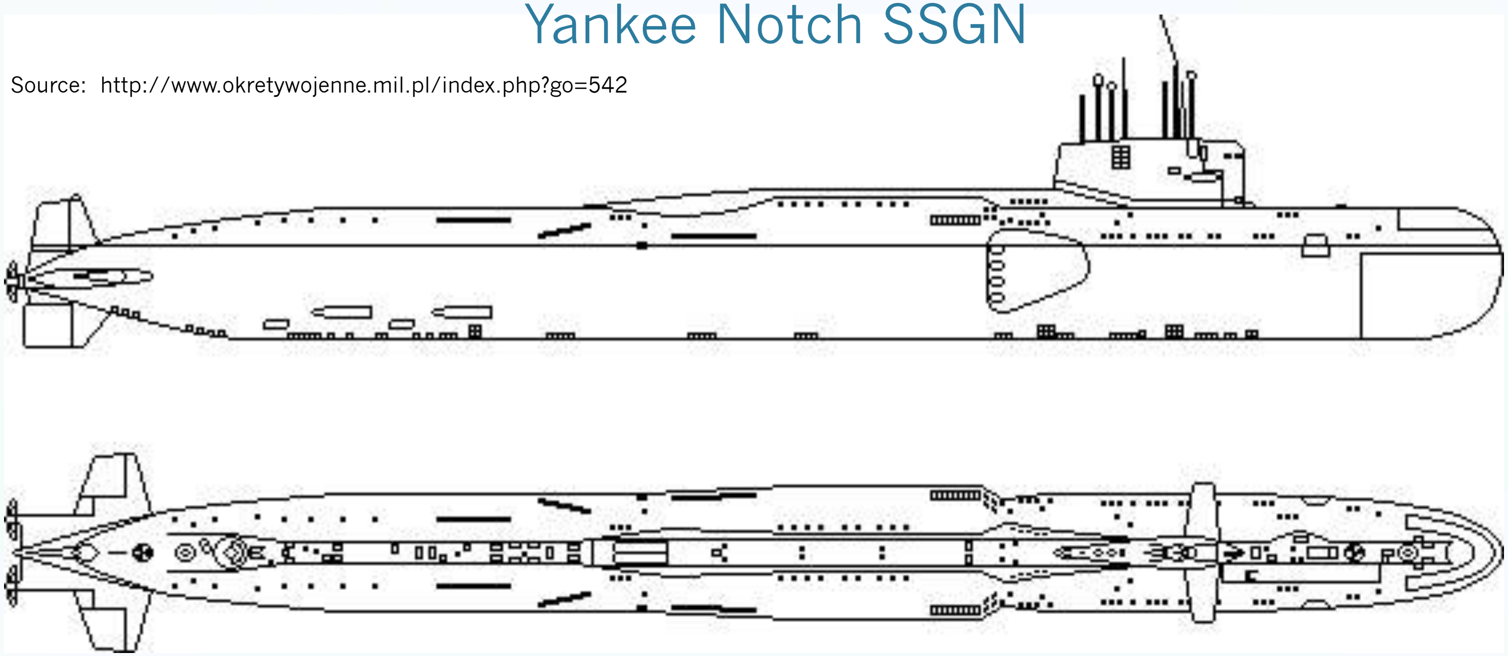
- Armament:
  - 12 x launchers for the P-750 (Kh-80, SS-N-24) nuclear-armed, supersonic land attack cruise missiles installed amidships, on the flanks of the submarine, outside the pressure hull.
  - 4 x 533 mm (21 in) and 2 x 406 mm (16 in) torpedo tubes in the bow
- Operational matters:
  - The SS-NX-24 was an experimental cruise missile. The missile was not adopted and the entire program was canceled as a result of the Intermediate-range Nuclear Forces (INF) Treaty, which became effective on 1 June 1988.
  - The K-420 became a weapon system without a weapon and was scrapped in the 1990s.

K-420 scrapped.
Source: https://forum.sub-driver.com/forum/

“Sidecar” mounted cruise missile launchers.

# Project 667AT (Grusza)

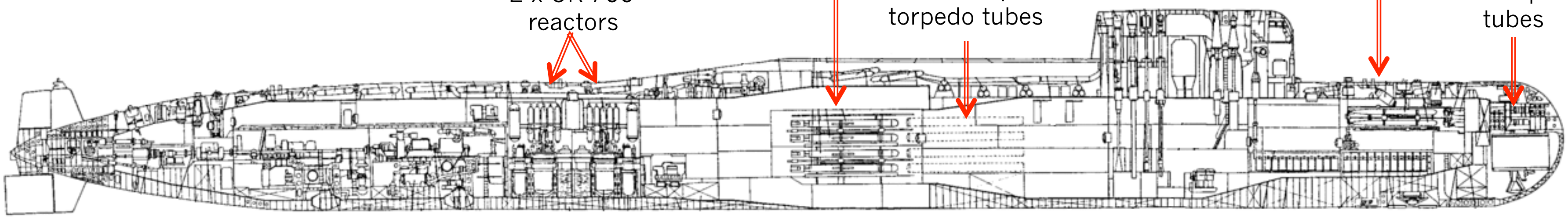
## Yankee Notch SSGN




- Seven Yankee I SSBNs were to be converted into Project 667AT Yankee Notch SSGNs (K-236, -395, -399, -408, -415, -418, & -423), but only four were completed between 1982 and early 1991. Rubin Central Design Bureau developed the Project 667AT design.
- The conversion removed the former SLBM compartment and inserted a new mid-ship cruise missile compartment in its place. This increased the overall length of the sub by 12 m (39.4 feet) to 141.5 m (464.2 feet), and displacement increased to 11,500 tons submerged.
- Propulsion, same as Yankee I:
  - OK-700: 2 x VM-4-2 PWRs, each rated @ 90 MWt
  - Two independent secondary power trains, each with 2 x main turbines and a reduction gear driving a single shaft and propeller. The two trains had a combined rating of about 34,500 shp.

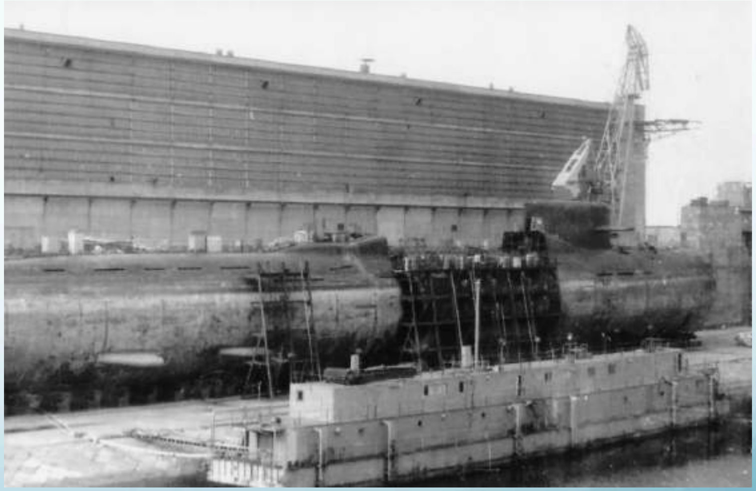
# Project 667AT (Grusza)

## Yankee Notch SSGN




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

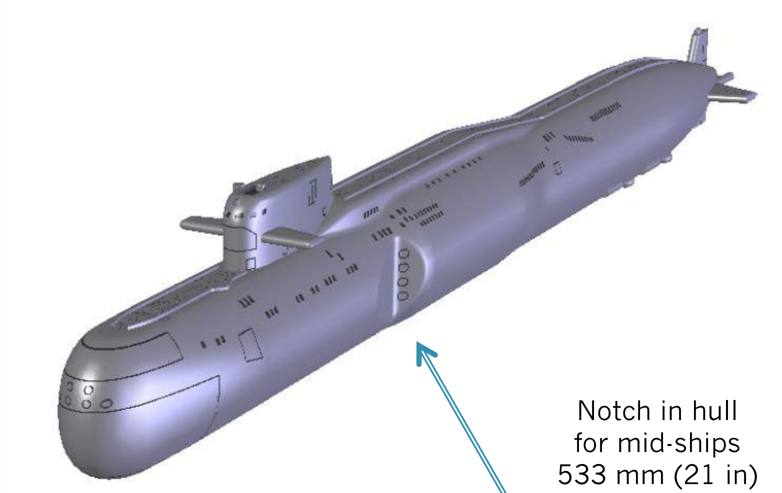
- Armament:
  - 4 x 533 mm (21 inch) and 2 x 406 mm (16 inch) torpedo tubes in the bow
  - 8 x additional 533 mm torpedo tubes installed mid-ships for launching SS-N-21 Sampson (RK-55 Granat / S-10) subsonic, land-attack cruise missiles. Storage was provided for 32 - 40 missiles. The new tubes and missile magazine were in the space previously occupied by strategic ballistic missiles plus a 12 m (39.4 feet) hull extension.
- Operational matters:
  - Most were retired by in the 1990s.

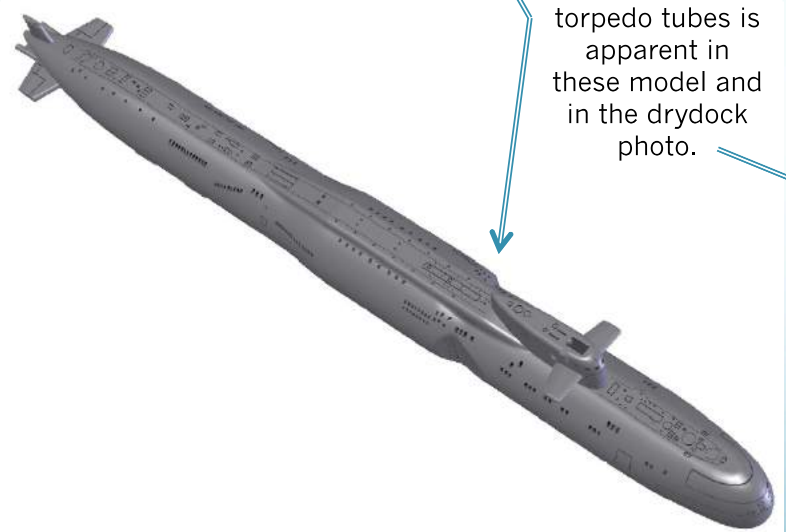


Converting a Yankee Notch. Source: https://forum.sub-driver.com/

# Project 667AT (Grusza)

## Yankee Notch SSGN





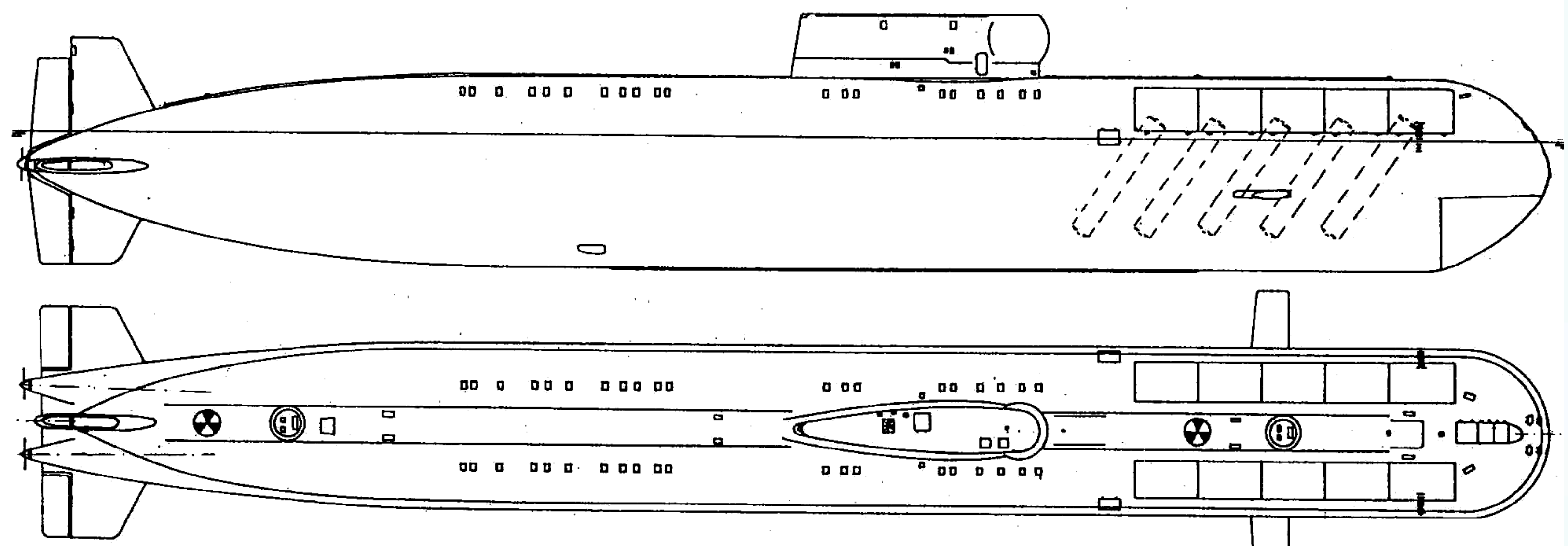
Source: https://forum.sub-driver.com/forum/

Notch in hull for mid-ships 533 mm (21 in) cruise missile / torpedo tubes is apparent in these model and in the drydock photo.

Source, top: https://forum.sub-driver.com/
Source, bottom: www.shipmodels.info

# Project 661 (Anchar)

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



Source: The-Blueprints.com

- This one-of-a-kind SSGN was designed by Malakhit (Malachite) Central Design Bureau, St. Petersburg, and built at the SEVMASH Shipyard in Severodvinsk.  The keel was laid on 28 December 1963 and was commissioned on 31 December 1969.
- K-222 (formerly K-162) was the first submarine with a titanium hull (inner and outer hulls, 5 compartments).
  - It was 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. K-222 was the only sub to use this reactor.
  - 2 x steam turbines with a combined rating of  68,000 hp driving 2 x shafts.

# Project 661 (Anchar)

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

- 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.
- Operational matters:
  - K-222 is the world's fastest submarine, with a maximum sustained speed of 44.7 kts. At that speed, significant damage occurred to topside fixtures.
  - Maximum diving depth was about 400 meters (1,312 feet).
  - Crew complement: 82
  - K-222 was expensive to build and very noisy when underway.

Angled cruise missile launchers in the bow free-flood area. Source, above: http://moremhod.info/index.php/

Papa cruising on the surface. Source: en.wikipedia.org

# Project 661 (Anchar)

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

- Reactor accident, 1980:
  - More than 10 years after commissioning, K-222 was in the Sevmash shipyard in Severodvinsk for a major overhaul. On 30 Sep 1980, one of K-222's nuclear reactors was damaged during maintenance. BELLONA reported [1] the following accident sequence:
    - During the course of work, the submarine's crew left for lunch leaving the factory personnel on board the vessel.
    - As a result of a breach in procedural instructions, power was sent through the safety rod mechanisms of one reactor without the controls also being engaged.
    - Following a failure in the automatic equipment, there was an uncontrolled raising of the control rods with a subsequent uncontrolled start up of one reactor, severely damaging the VM-5M reactor core.
    - One source claims that the primary circuit of the integral PWR was destroyed. There were no casualties and no contamination of the surrounding area was reported.
  - The damaged reactor was not repaired or replaced. By 1984, K-222 was placed in reserve storage, moored at Belomorsk Naval Base in Severodvinsk.
  - The K-222 was an experimental prototype. Nuclear fuel could not be removed from the VM-5M reactor in the same way as in other contemporary Russian naval PWRs. Two different outcomes have been reported:
    - The two reactors were de-fueled and the reactors were dumped without fuel in the Techeniye Inlet at Novaya Zemlya in 1988 [2].
    - The reactor compartment was removed with the reactors and nuclear fuel still on board, as no provisions had been made in the design for removing the reactors [3].
  - Beginning on 5 March 2010, K-222 was dismantled at the Sevmash shipyard, which was the only shipyard capable of dismantling the titanium hull.

Sources:
(1) http://spb.org.ru/bellona/ehome/russia/nfl/nfl8.htm
(2) http://large.stanford.edu/courses/2017/ph241/lowet2/docs/nks-rak-2-96-tr-c3.pdf
(3) https://en.wikipedia.org/wiki/Soviet_submarine_K-222#cite_note-CIS-4

# Project 661 (Anchar)

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

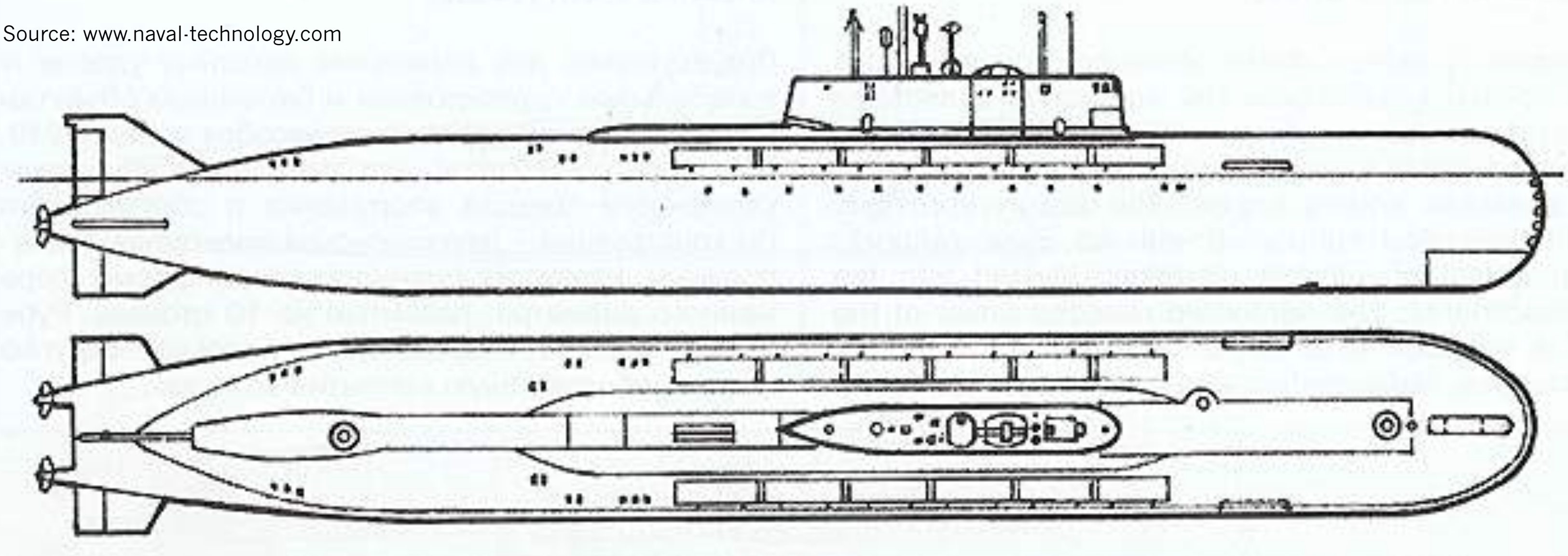
Source: http://www.storvik.com

Source: http://www.subsim.com/radioroom/

# Project 949 (Granit) & 949A (Antei)

## Oscar I & II-class cruise missile submarines (SSGN)

Source: www.naval-technology.com



- This is the largest Russian cruise missile submarine built. It was designed by the Rubin Central Design Bureau, St. Petersburg, and built at the SEVMASH Shipyard in Severodvinsk.
  - 2 x Project 949 Oscar I SSGNs were commissioned in 1980 and 1983.
  - 11 x Oscar II SSGNs were commissioned between 1986 and 1994.
  - The Oscar II is about 10 meters (33 ft) longer than its predecessor. Both classes have a "VSK" crew escape capsule in the sail, which can accommodate 110 people.
- Propulsion:
  - OK-650B: 2 x PWRs, each rated @ 190 MWt
  - 2 x steam turbines with a combined rating of 73,000 hp; driving 2 x shafts

# Project 949 (Granit) & 949A (Antei)

## Oscar I & II-class cruise missile submarines (SSGN)

- Armament:
  - Mid-ship cruise missile tubes on the flanks of the submarine, outside the pressure hull, originally for 24 x P-700 Granit (SS-N-19).
    - Under the START treaty, nuclear warheads for these missiles have been replaced with high explosives.
  - 4 x 533 mm and 2 x 650 mm torpedo tubes for torpedoes, missiles (SS-N-15 or SS-N-16 anti-submarine missiles) and mines.
- Operational matters:
  - Like the Kirov-class CGNs, Oscar-class SSGNs originally were designed to defeat an American aircraft carrier strike group by firing a salvo of many supersonic P-700 cruise missiles, which may overwhelm the battle group's defenses.
  - The Oscar II class boats are fitted with a floating antenna buoy to receive satellite navigation signals, target designation data and radio messages while submerged.
  - K-141, *Kursk*, sank on 12 Aug 2000. The majority of the sub was salvaged in 2001.
  - Currently there are eight Oscar II-class SSGNs in the Russian fleet. All were commissioned between 1988 and 1996 and had very little operational use during the decade following the dissolution of the Soviet Union.
  - In 2011, Rubin Design Bureau developed a plan to modernize Oscar-class SSGNs. This plan was accepted by the Russian government and has been designated Project 949AM. All Oscar-class SSGNs are expected to have a remaining service life of about 20 years following modernization.

# Project 949 (Granit) & 949A (Antei)

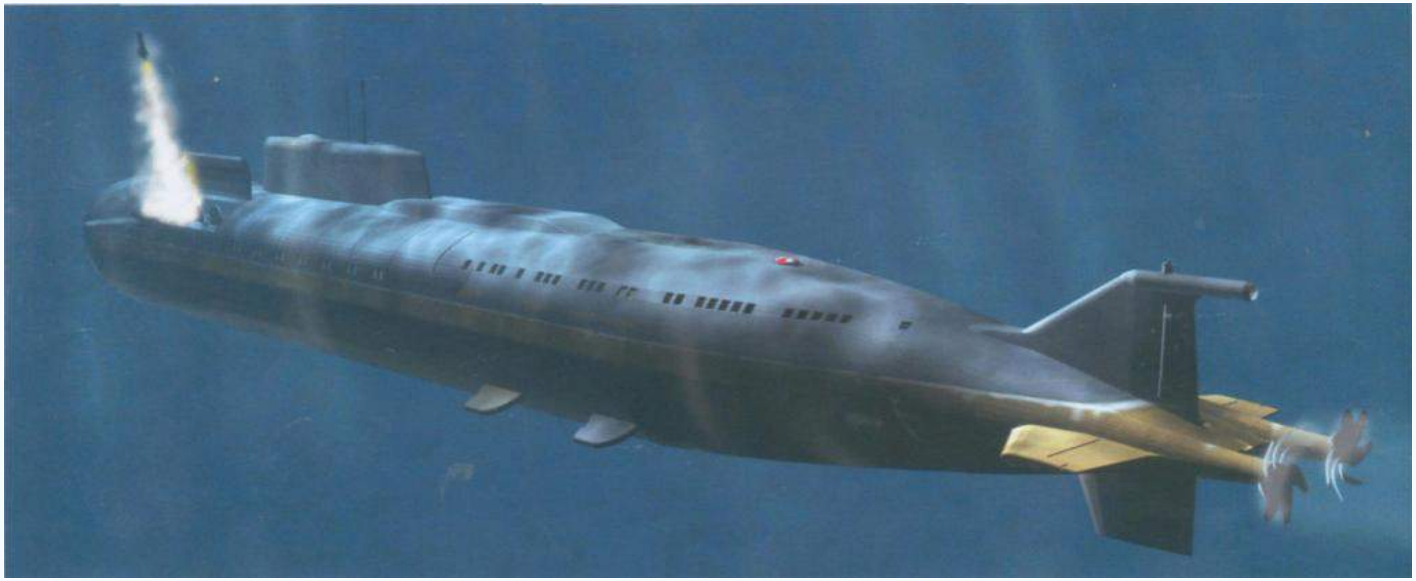
## Oscar I & II-class cruise missile submarines (SSGN)

- Operational matters (cont'd):
  - Under Project 09852, the incomplete hull of K-139 *Belgorod* was redesigned as a PLA "mothership" for small special operations submarines such as the manned Project 18511 Halibut / Paltus or the larger Project 10831 Losharik, or a large UUV similar to Harpsichord.
    - It also has been rumored that the *Belgorod* conversion includes adding provisions for the submarine to carry the very large Kanyon (Status-6) strategic, nuclear-armed and nuclear-powered torpedos in the flank free-flood areas previously occupied by the cruise missile launch tubes.
  - Two additional incomplete Oscar II hulls, K-135 *Volgograd* and K-*165 Bernaul*, have not been scrapped and may be available to re-start construction.


Source, above: https://en.wikipedia.org/

# Project 949 (Granit) & 949A (Antei)

## Oscar I & II-class cruise missile submarines (SSGN)



Source, above: https://forum.sub-driver.com/

Source, above: https://www.sinodefenceforum.com/

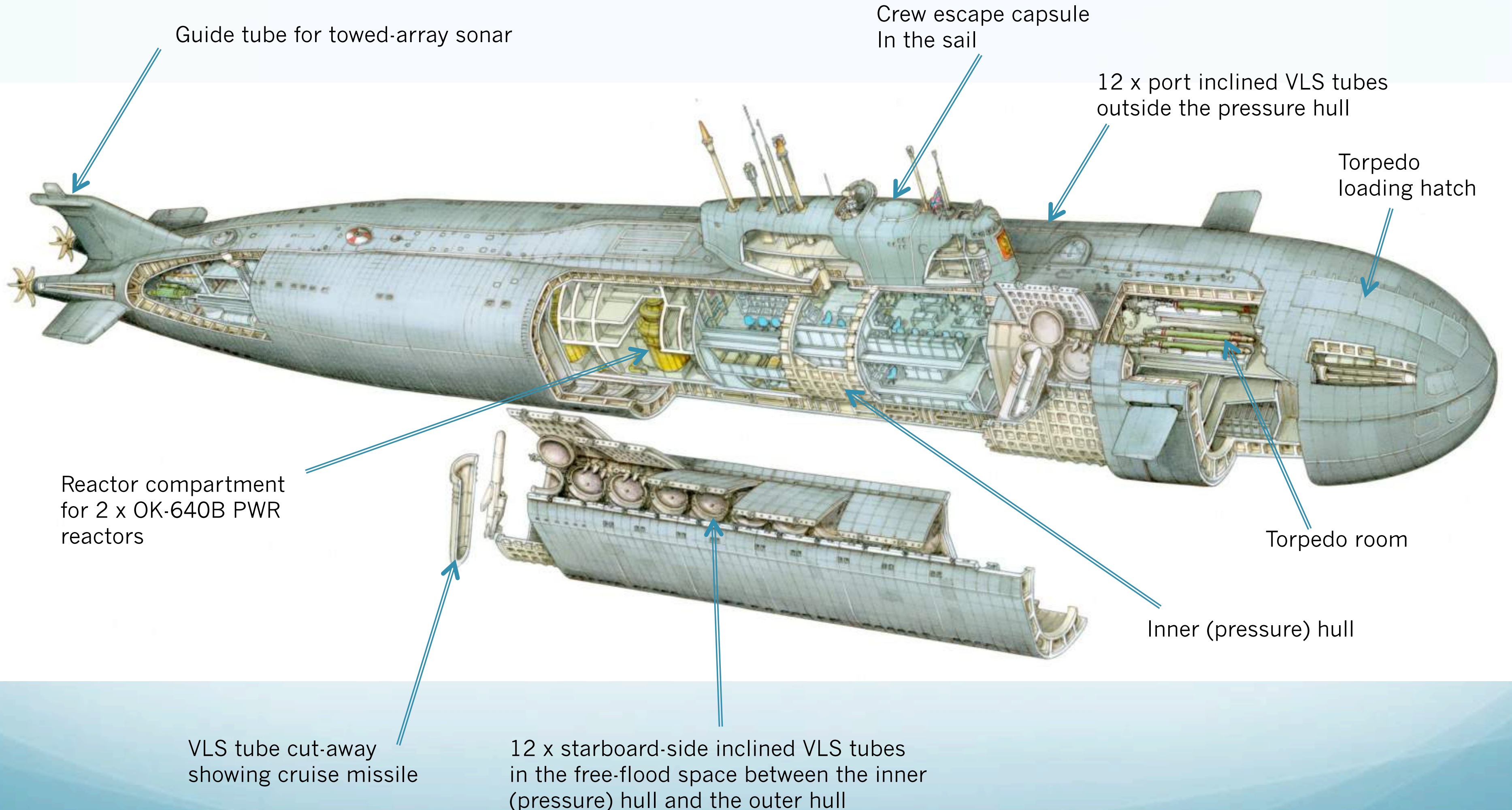
Left:
Oscar II-class SSGN *Omsk* with flank cruise missile hatches & bow torpedo loading hatch open.

Right:
Handling a P-700 Granit anti-ship cruise missile on an Oscar II.

Source: https://www.reddit.com/

# Project 949 (Granit) & 949A (Antei)

## Oscar I & II-class SSGN notional cut-away drawing




Source: adapted from sinodefenceforum.com

# Project 949AM (Antei)

## Updated Oscar II-class cruise missile submarines (SSGN)

- Project 949AM, developed by the Rubin Design Bureau, will lead to the modernization of eight Oscar II SSGNs.
  - On 5 April 2013, the Ministry of Defense and Zvezda Shipyard (Bolshoi Kamen), near Vladivostok in the Russian Far East, signed a contract to modernize the first Oscar II-class SSGN.
  - The four Pacific Fleet Oscar II SSGNs will be modernized, starting in 2018 with the *Irkutsk*. The other three Pacific Fleet boats, *Omsk, Tomsk*, and *Tver*, are expected to complete their modernizations by 2025.
- The Oscar II mid-life update addresses both ship and combat systems, including:
  - Replacing all 24 Granit cruise missile launch tubes with new launch tubes that can carry three modern cruise missiles or similar-sized devices, for a total of 72 missiles / devices.
    - Cruise missiles that will be compatible with the new launch tubes include the P-800 Oniks, 3M54 Klub (Club) anti-ship missile, 3M14 Klub (Club) land-attack missile, and the 3M22 Zircon (Tsirkon) maneuvering hypersonic cruise missile.
  - Updating the torpedo room and replacing Type 40 torpedoes with UGST and SAET 60M dual-purpose torpedoes.
  - Replacing hull-mounted sonar, flank sonar and towed-array sonar with modern sonars.
  - Installing the *Omnibus-M* combat information system.
  - Upgrading shipboard control and auxiliary systems, replacing periscopes and updating the electronic support measures (ESM) suite.
  - Adding the capability to carry and deploy the Harpsichord 2P and similar large autonomous underwater vehicles (AUV).
- Total cost of the modernization program is expected to be about $2.9B.

# Oscar II SSGN in drydock

Oscar II-class SSGN with bow torpedo loading hatch & torpedo tube doors open.

Source, two photos: https://forum.sub-driver.com/

Oscar II with all missile doors open. Source: https://www.sinodefenceforum.com/

# Oscar II SSGN in drydock

Source, inserts top L & bottom R: https://forum.sub-driver.com/
Source, main photo:  reddir.com / silenc_hr

Seawater coolant inlet scoops and discharge.

# 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.

Visualization of the Kursk wreck site

Source: SubArt.net

- Kursk sank in 108 m (354 ft) of water.

- 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

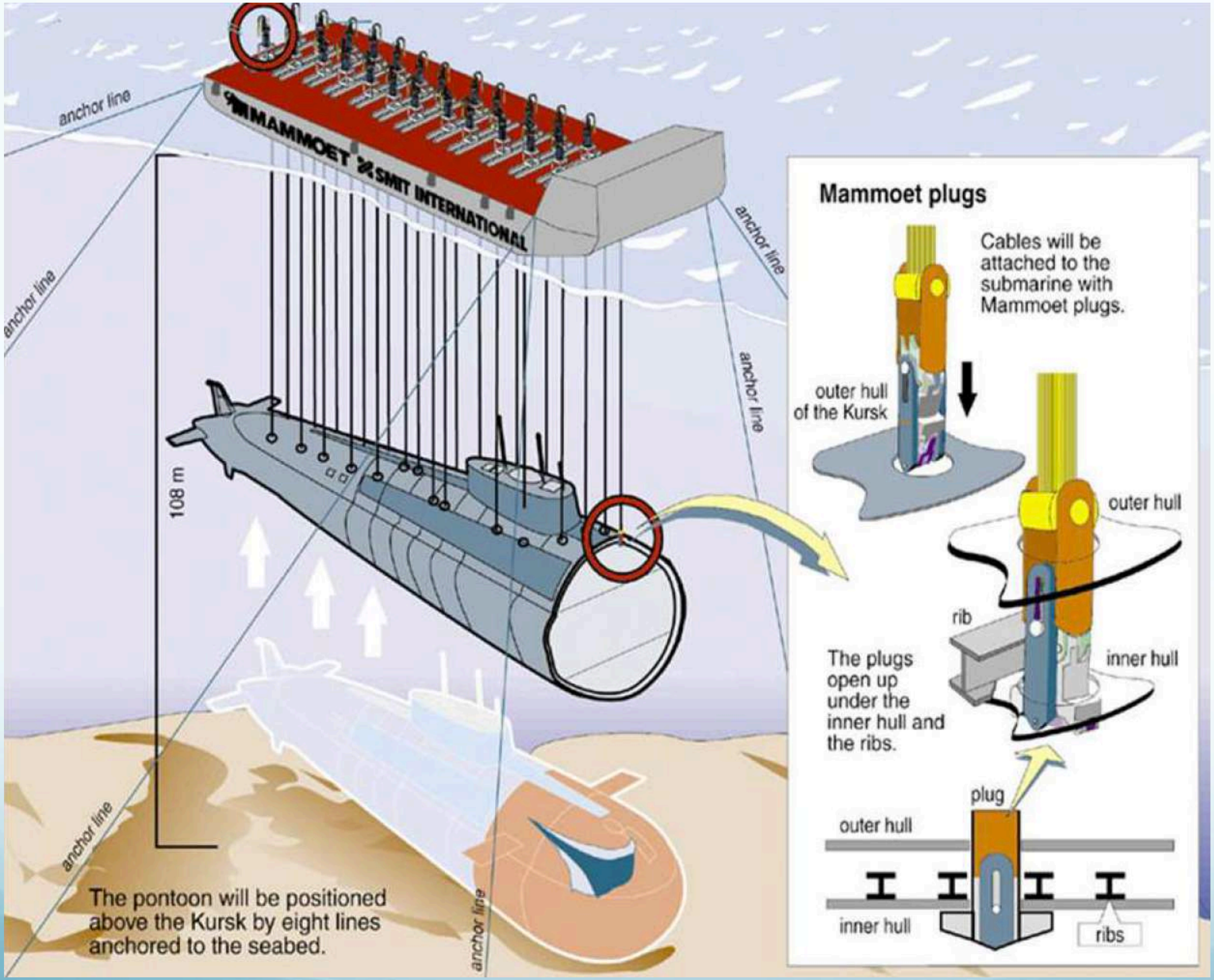


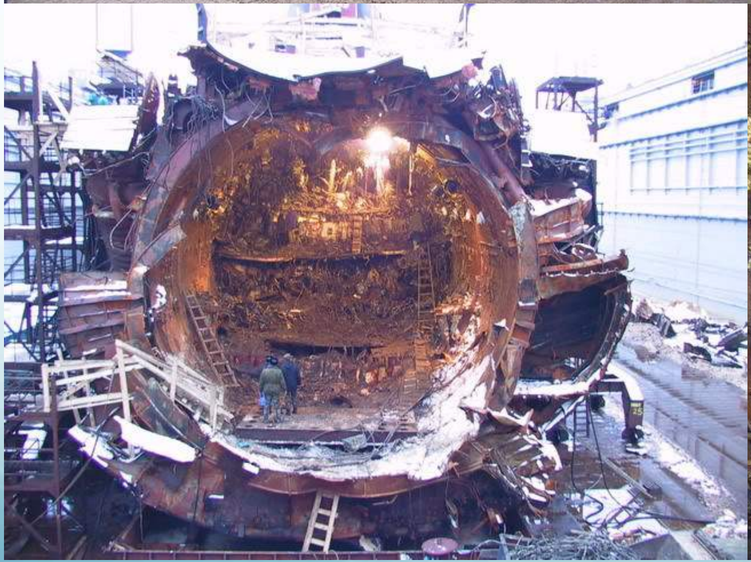

Diagram source: Mammoet Smit International

- 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

# Cruise missiles

This section focuses on Soviet and Russian cruise missiles that have been or currently are deployed on nuclear-powered submarines and/or surface ships.  Not included in this section are several other Soviet and Russian cruise missiles that have been or are deployed only on conventionally-powered vessels, aircraft, and shore installations.

# Cruise missiles deployed on Russian nuclear-powered vessels

| Cruise missile | Years in service (platform) | Weight | Length | Diam (D) / Span (S) | Speed | Range | Guidance | Warhead |
|---|---|---|---|---|---|---|---|---|
| Land attack P-5 Pyatyorka (4K48) (SS-N-3 Shaddock) | 1959 - ?? (Whiskey SSG)<br><br>1961 - 69 (Echo I SSGN) | 5,000 kg | 11.75 m (38.5 ft) | D = 0.98 m (3.21 ft)<br><br>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 (4K88) (SS-N-3A Shaddock) | 1963 – 75<br><br>(Juliett SSG & Echo II SSGN) | 5,000 kg | 10.9 m (35.8 ft) | D = 0.98 m (3.21 ft)<br><br>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 (4K80) (SS-N-12 Sandbox) | 1975 – 95<br><br>(Juliett SSG & Echo II SSGN) | 4,800 kg (10,600 lb) | 11.7 m (38.4 ft) | D = 0.88 m (2.89 ft)<br><br>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 (3M70) (SS-N-12 Mod 2 Sandbox) | 1987 – 95<br><br>(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 (4K66) (SS-N-7 Starbright) | 1968 – 92<br><br>(Charlie I & Papa SSGNs) | 3,650 kg | 7.0 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 |

# Cruise missiles deployed on Russian nuclear-powered vessels

| Cruise missile | Years in service (platform) | Weight | Length | Diam (D) / Span (S) | Speed | Range | Guidance | Warhead |
|---|---|---|---|---|---|---|---|---|
| Anti-ship P-120 Malakhit (4K85) (SS-N-9 Siren) | 1973 - 94<br><br>(Charlie II & Papa SSGNs) | 3,180 kg (7,010 lb) | 8.84 m (29.0 ft) | D = 76.2 cm (30.0 in)<br><br>S = 2.1 m (6.9 ft) | Mach (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 P-750 (Kh-90) Meteorit (3M25) (SS-N-24 Scorpion) | Tested 1983 – 84 on Yankee Sidecar<br><br>Not operationally deployed | 2,800 kg (6,173 lb) | 10.5 m (34.4 ft) | D = 1.2 m (3.94 ft)<br><br>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 (3K45) (SS-N-19, Shipwreck) | 1983 – present<br><br>(Oscar SSGN, Kirov CGN) | 7,000 kg (15,400 lb) | 10 m (33 ft) | D = 0.85 m (33 in)<br><br>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 (3M55) (SS-N-26, Strobile) | 2002 – present<br><br>(Yasen SSN, Oscar II SSGN, Kirov CGN) | 3,000 kg (6,614 lb) | 8.9 m (29.2 ft) | D = 0.7 m (2.3 ft)<br><br>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 |

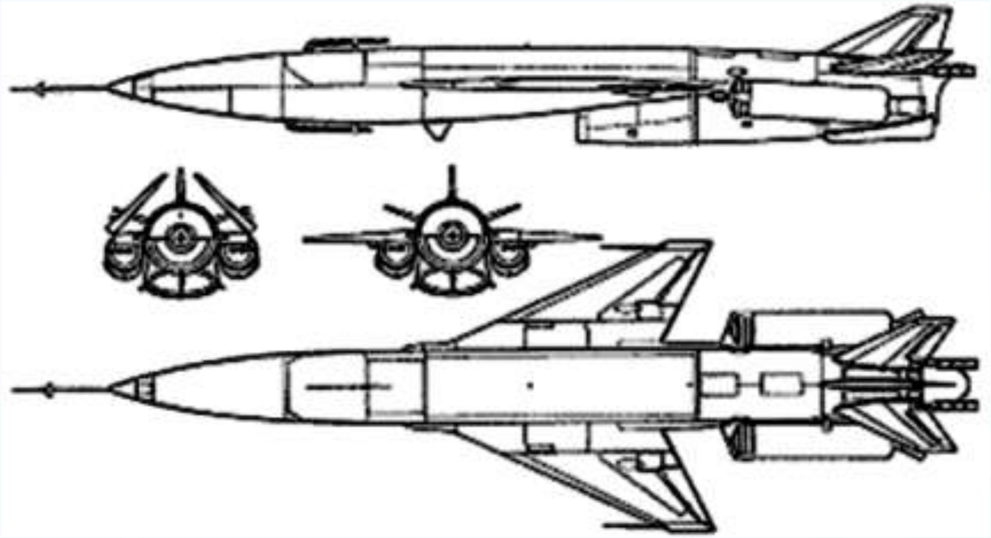
# Cruise missiles deployed on Russian nuclear-powered vessels

| Cruise missile | Years in service (platform) | Weight | Length | Diam (D) / Span (S) | Speed | Range | Guidance | Warhead |
|---|---|---|---|---|---|---|---|---|
| Land-attack RK-55 Granat (3M10) (SS-N-21 Sampson) | 1976 – present<br><br>(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)<br><br>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 be retired)<br><br>Converted to conventional 410 kg (904 lb) HE warheads |
| Anti-ship Kalibr/Klub/ Club (3M54E) (SS-N-27 Sizzler) | 2001 - present<br><br>(Akula, Yasen SSNs; Kirov CGN) | 1,780 kg (3,924 lb) | Club S: 6.2 m (20 ft) | D = 53 cm (21 in) | Subsonic cruise + Mach 2.5 - 2.9 terminal "sprint" | 220 km (137 mi) | Inertial + active radar homing | Conventional, 200 kg (440 lb) HE |
| Land-attack P-900 Kalibr/Klub/ Club (3M14E) (SS-N-30A Sizzler) | 2001 - present<br><br>(Akula & Yasen SSNs; Kirov CGN) | 1,770 kg (3,924 lb) | Club 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 |
| Multi-purpose 3M22 Tsirkon (SS-N-33 Zircon) | 2020 (plan)<br><br>(Updated Oscar II SSGN; Yasen & Husky SSN; Orlan CGN) | TBD | TBD | TBD | Mach 5 to 8 (hyper-sonic) | Function of trajectory flown, est. 250-740 km (155-460 mi) | Inertial + terminal guidance, also possibly command | Conventional, possibly nuclear |

# P-5 / SS-N-3C Shaddock

## Subsonic land-attack cruise missile (aka 4K48)

- 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 US Regulus 1 nuclear-armed, land-attack cruise missile.

# P-6 / SS-N-3A Shaddock

## Supersonic anti-ship cruise missile (aka 4K88)

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 (aka 4K80 & 3M70)

- P-500 Bazalt & P-1000 Vulkan have similar size and planform, and 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 entered service in 1975, deploying 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.

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

# P-70 Ametist / SS-N-7

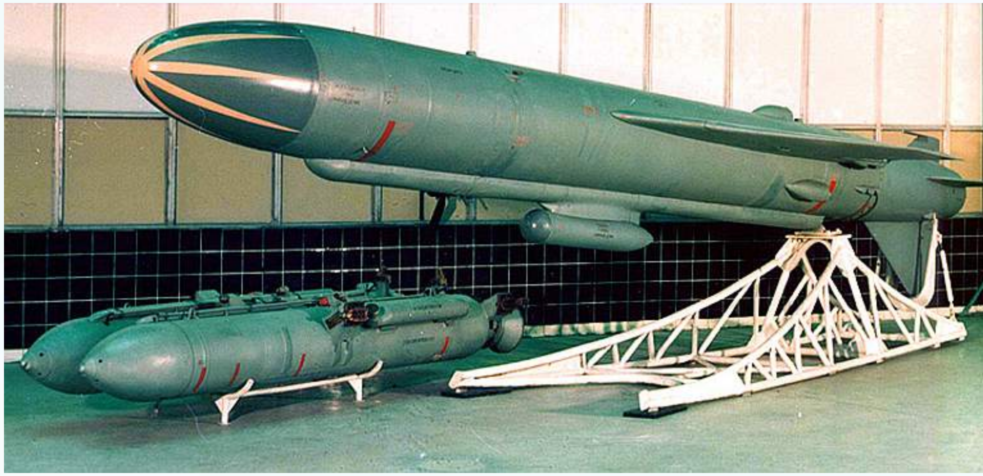
## Subsonic anti-ship cruise missile (aka 4K66)

- 1st Russian cruise missile designed for submerged launch; launch depth 30 - 40 m (98 – 131 ft). Designed by NPO Mashinostroyeniya.
- 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 Malakhit / SS-N-9

## Subsonic anti-ship cruise missile (aka 4K85)




Source, two photos: 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.

# P-750 (Kh-90) Meteorit / SS-N-24

## Supersonic land-attack cruise missile (aka 3M25)

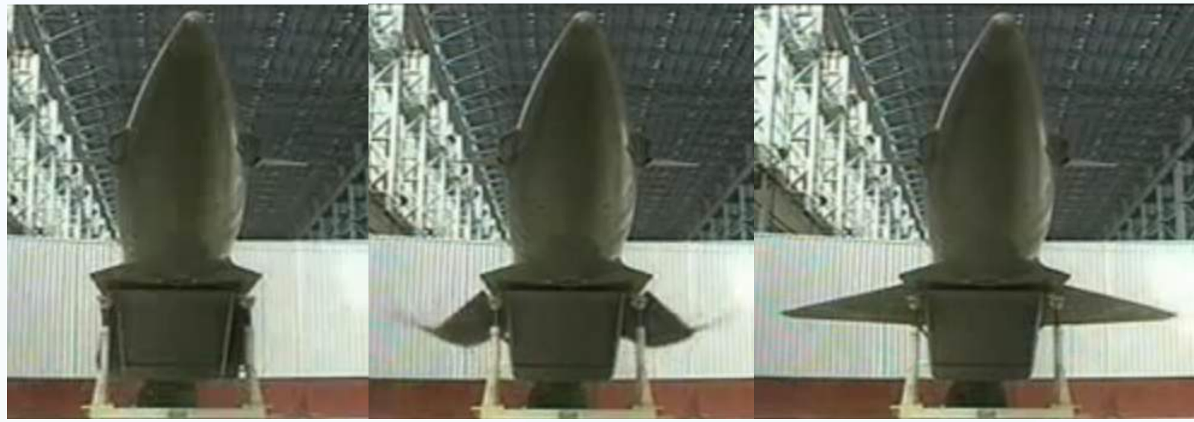
- Russia was developing the Meteorit-M long-range, nuclear-armed, strategic land-attack cruise missile in the mid 1980s.
- Land-, sub-, and air-launched versions were planned.
- Intended to carry 2 x 90 kT nuclear weapons and attack two targets up to 100 km (62 mi) apart.
- Naval deployment was planned 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/

# P-750 (Kh-90) Meteorit / SS-N-24

## Supersonic land-attack cruise missile (aka 3M25)



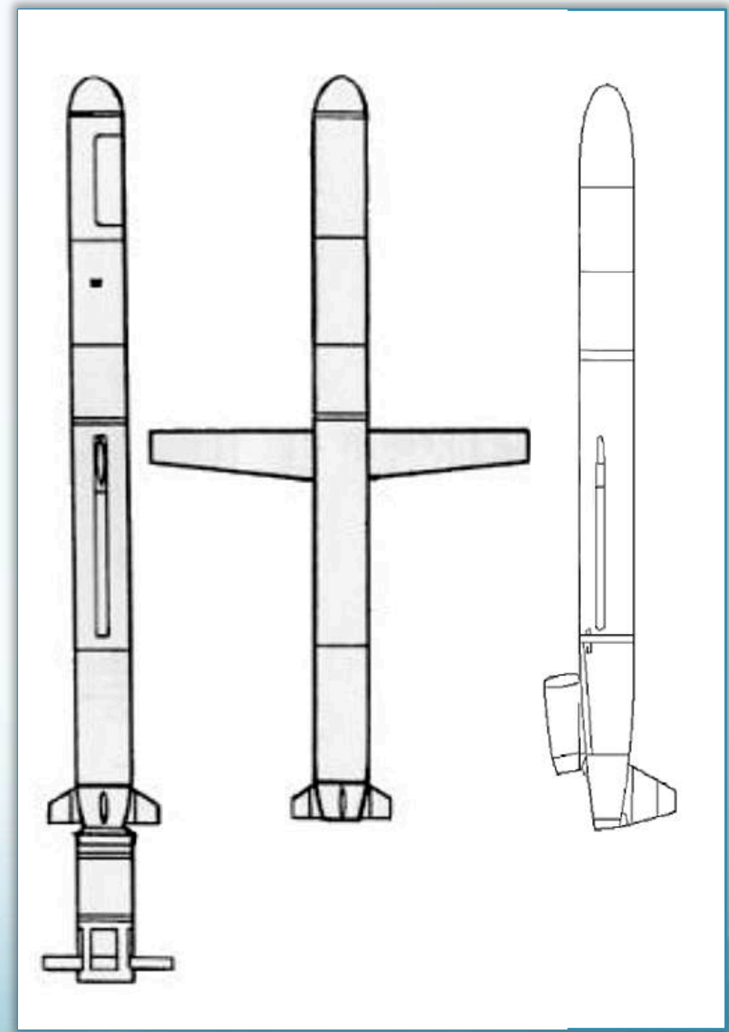
Meteorit A mockup demonstrating the wing deployment sequence following launch.

Source: screenshots from video, https://www.youtube.com/watch?v=yylJaJDM3aU

# RK-55 Granat / SS-N-21 Sampson

## Subsonic land-attack cruise missile (aka 3M10)

- Originally nuclear-armed.
- All are likely to have been retired or converted to conventionally-armed missiles.
- Analog to the US nuclear-armed Tomahawk cruise missile.
- 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

# P-700 Granit / SS-N-19

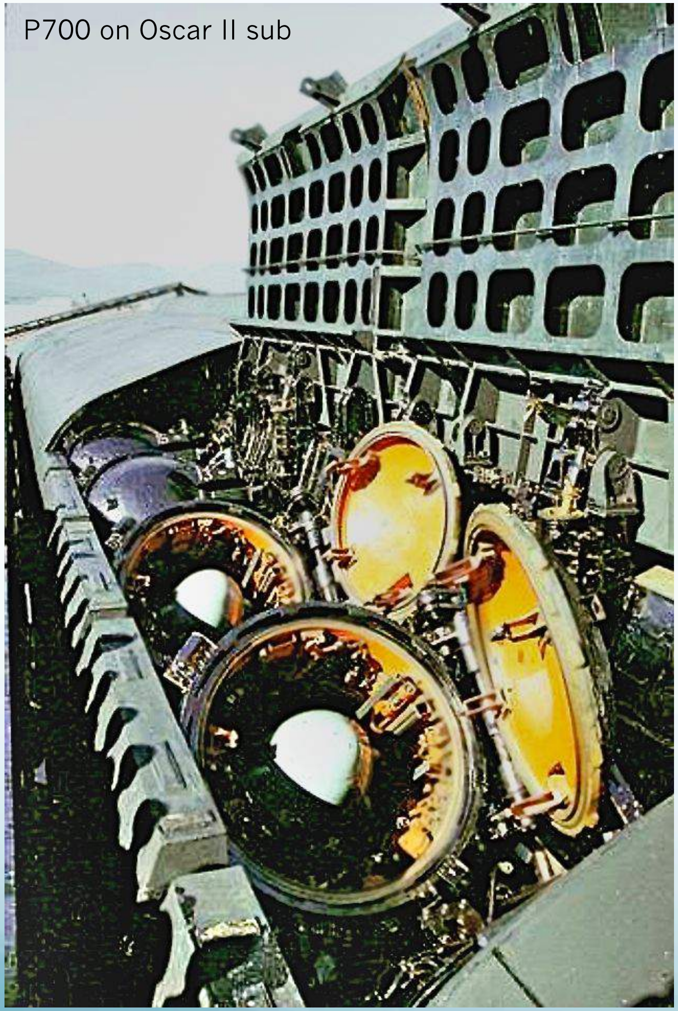
## Supersonic anti-ship cruise missile (aka 3K45)

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

- Designed to be fired in salvos of multiple missiles against a carrier strike 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-700 Granit / SS-N-19

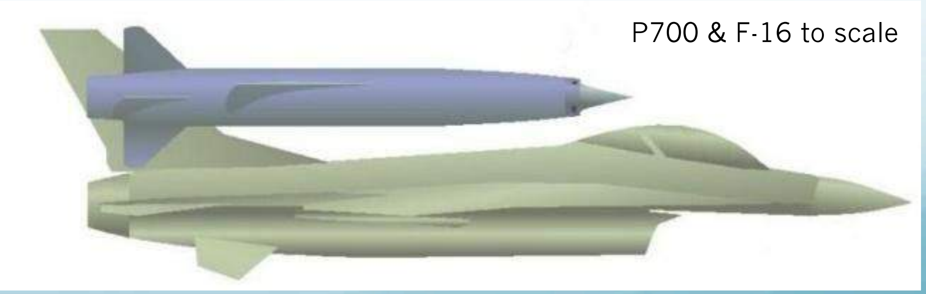
## Supersonic anti-ship cruise missile (aka 3K45)



P700 on Oscar II sub

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

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



P700 & F-16 to scale

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

# P-800 Oniks / SS-N-26

## Supersonic anti-ship cruise missile (aka 3M55)

- Designed by NPO Mashinostroyeniya
- Like the P-700, P-800 is designed to be fired in salvos of multiple missiles against a carrier strike 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.
- Modernizations of Project 949 AM Oscar II-class SSGNs and the Kirov-class *Admiral Nakhimov* CGN are expected to include conversion of each P-700 missile launch tube to carry three P-800 Oniks cruise missiles or similar-sized weapons.

# Kalibr / SS-N-30A Sizzler

## Subsonic land-attack cruise missile (aka 3M14E, Klub, Club, P-900)


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


- Large diameter VLS tubes, each capable of holding 5 x Kalibr cruise missiles, are found on Project 885 Yasen multi-purpose SSNs, Project 949AM modernized Oscar II SSGNs and the Kirov-class *Admiral Nakhimov* CGN.
- Conventional, 450 kg (990 lb) HE warhead.

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

# Kalibr / Club / SS-N-24 Sizzler

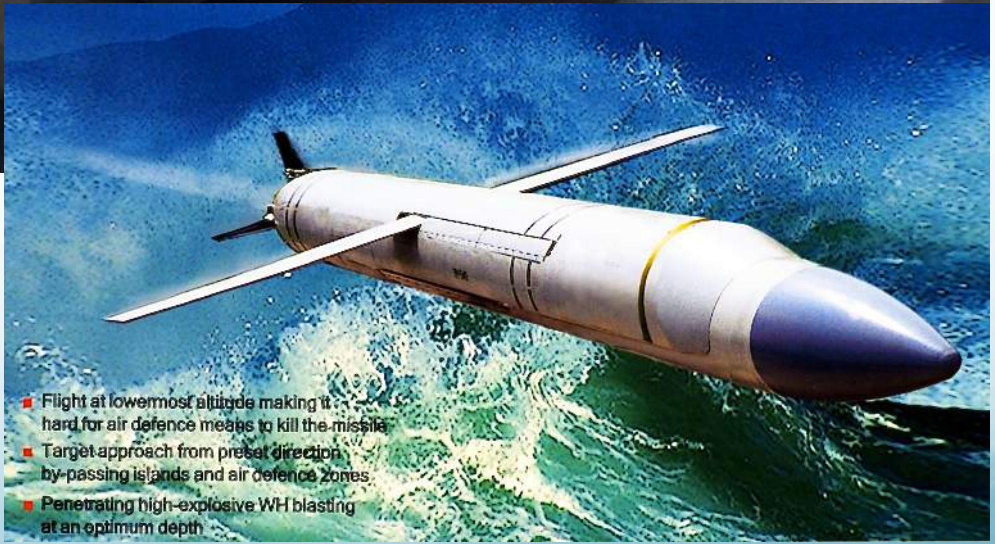
## Subsonic + terminal supersonic anti-ship cruise missile (aka 3M54E)

- The Kalibr 3M54E (aka Club and Klub) is a Russian-developed anti-ship cruise missile that is available in submarine-, surface ship-, and air-launched versions. The missile is used by Russian naval forces and and is available in export versions. China and India are export customers.
- Except in the air-launched version, a 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.
- The 3M54E can be launched from a submarine via a standard 533 mm (21 in) torpedo tube or from VLS launcher at a launch depth of 30 - 40 m (98 – 131 ft).
- The missile carries a penetrating high-explosive warhead.
- Range is about 220 km (137 mi).

# Kalibr / Club / SS-N-24 Sizzler

## Subsonic + terminal supersonic anti-ship cruise missile (aka 3M54E)


Source, above: Allocer via https://commons.wikimedia.org/wiki/File:3M-54E_missile_MAKS2009.jpg

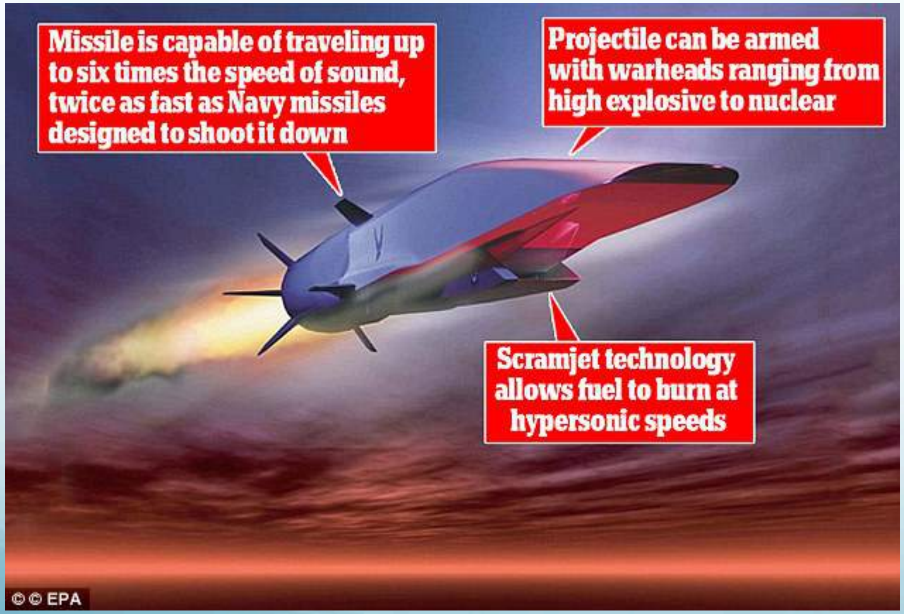



Source: http://www.ausairpower.net/APA-Rus-Cruise-Missile

# Tsirkon / SS-N-33 Zircon

## 3M22 maneuvering, hypersonic cruise missile

- Zircon was designed by NPO Mashinostroyeniya, which also designed the P-70 Amethyst and P-800 Oniks Russian cruise missiles and the BrahMos cruise missiles being developed collaboratively by Russia and India.
- There will be submarine-, surface ship-, land- and air-launched versions of Zircon.
- Prototype testing began in 2012. Development testing of all versions is expected to be completed by 2020.
- A solid-fuel booster rocket launches the weapon and accelerates it to supersonic speed. Then the booster separates and a scramjet (supersonic combustion ramjet) engine powers the missile at hypersonic speed (Mach 5 – 8) to the target.




Source: http://www.dailymail.co.uk/news/

- The Zircon hypersonic vehicle is believed to be have a lift-generating center body & small aerodynamic surfaces.
- Flying characteristics and range of the Zircon are not known. However, the vehicle is believed to be capable of flying a variety of trajectories, including a low-level trajectory that reduces range (est. 250-500 km / 155-311 miles), and a semi-ballistic trajectory that significantly increases range (est. 740 km / 460 miles).

# Tsirkon / SS-N-33 Zircon

## 3M22 maneuvering, hypersonic cruise missile

- The Zircon airframe has been being designed for stealth.
- The missile is expected to have radar and optical terminal homing capabilities.
- A variety of conventional and possibly nuclear warheads can be carried.
- The extremely high speed of Zircon reduces its flight time to a distant target to a matter of minutes, limiting the reaction time available for defense systems. Moreover, existing fleet anti-air / missile defense systems may not be capable of reliably engaging this stealthy incoming hypersonic cruise missile.
- Zircon is designed for use with the universal launch systems currently used for the Onyx and Kaliber / Klub / Club cruise missiles. This will simplify deployment of Zircon on a wide variety of platforms.
- An export version will have a range limit of 300 km (186 miles) to comply with the Missile Control Technology Regime (MCTR).

# Nuclear-powered special operations subs & strategic torpedoes

- Small special operations nuclear submarines
- PLA-carriers (“motherships”)
- Strategic nuclear torpedoes & torpedo carriers

# Small special operations nuclear submarines

# Russian small special operations nuclear submarines

## "Deep-diving nuclear power stations"

| Project # | Class | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|
| 1851 / 18510 | Nelma (X-ray) | 1 | 44 m (144.4 ft) | 3.5 m (11.5 ft) | Not known (surf) 529 (sub) | Possibly NIKIET 10 MWt (est.) * | 2,000 (est.) * | 6 | 1986 | 1986 - present |
| 18511 | Halibut (Paltus) | 2 | 55 m (180.4 ft) | 3.8 m (12.5 ft) | Not known (surf) 730 (sub) | Possibly NIKIET 10 MWt (est.) * | 2,000 (est.) * | 6 | 1994 - 95 | 1994 - present |
| 1910 | Kashalot (Uniform) | 2 *** | 69 m (226.4 ft) | 7 m (23 ft) | 1,390 (surf) 1,580 (sub) | 50 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) | 1,600 (surf) 2,100 (sub) | Possibly Afrikantov E-17 50 MWt (est.) * * | 10,000 (est.) ** | 25 - 30 (est.) ** | 2003 | 2003 - present |
| 09851 | Khabarovsk (Wicket-SMP) | Khabarovsk may be a strategic nuclear torpedo carrier rather than a "deep-diving nuclear power station." See details in the "Russian strategic nuclear torpedo carriers" section. | | | | | | | | |

* Nelma and Halibut both have been cited in various sources as having an 8-10 MWt reactor. If true, such a reactor should be capable of delivering up to 1,900 shp propulsion power.
** Kashalot and Losharik both have been cited by various sources as having 10,000 shp propulsion systems. If true, the corresponding reactor thermal power to deliver that amount of propulsion power would be about 50 MWt. The cited 10,000 shp propulsion power would give these subs a high top speed, greater than a comparably-sized French Rubis/Amethyst SSN.
*** AS-33 is believed to be out of service, leaving two operational Kashalot-class subs.

# Project 1851 Nelma

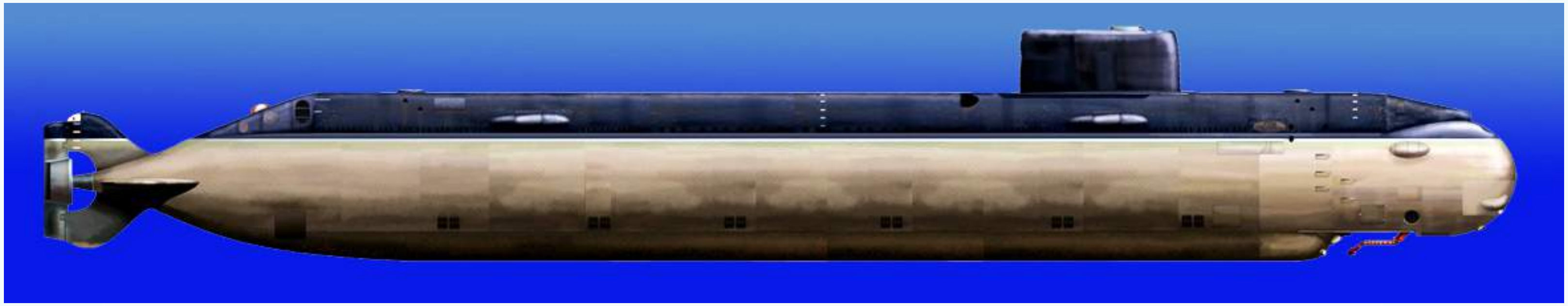
## "Deep diving nuclear power station" (aka Project 678) X-Ray-class research & special operations submarines


Source: www.hisutton.com

- This one-sub class, AS-23, was designed by the Malachite Central Design Bureau, St. Petersburg, and built at the Admiralty Shipyard (then Sudomech).
  - AS-23 was launched in October 1983 and joined the Northern Fleet in December 1986.
- This sub is designed for operation at depths up to about 1,000 meters (3,281 feet) and is equipped with various devices for underwater work. The design is roughly comparable to the US NR-1 small nuclear submarine, but differs in: (a) being double hull, (b) having a diver lock-out capability, and (c) able to be carried by a submarine "mothership" to a distant operating area.
- No armament.  Crew complement: est. 14
- Propulsion:  The reactor likely is a small PWR rated @ 8 - 10 MWt (est.), which some sources attribute to NIKIET.
  - Estimated propulsion power is about 1,900 shp (1.42 MW) delivered to a single shrouded propeller.
  - Small electric auxiliary propulsors (thrusters) provide precise underwater positioning.
- AS-23 may have been modernized in 2011 – 12 under Project 18510M.

# Project 18511 Halibut

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

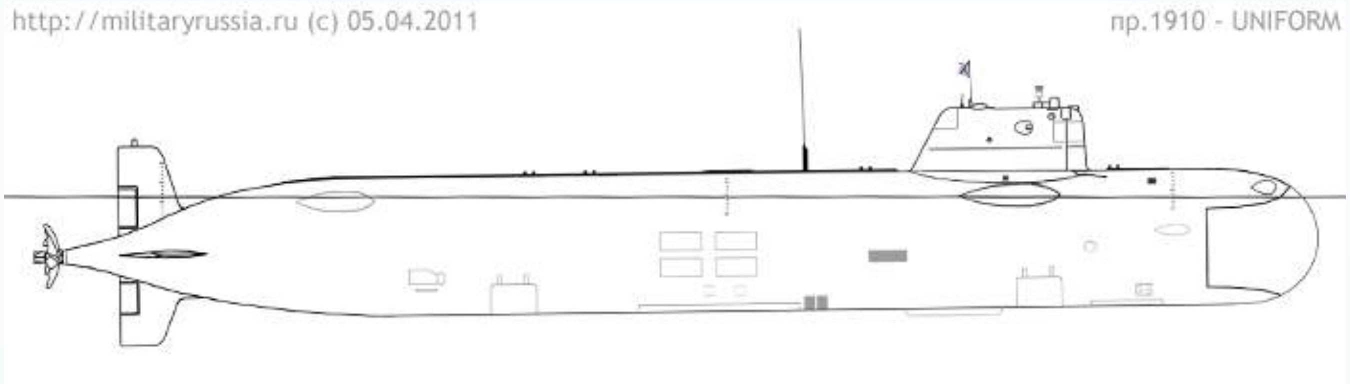


Source: www.hisutton.com

- The two Halibut-class subs, AS-21 and AS-35, were designed by the Malachite Central Design Bureau, St. Petersburg, and were built at the Admiralty Shipyard.
  - AS-21 was launched in Apr 1991 and joined fleet in December 1991; AS-35 was launched in September 1994 and joined the fleet in October 1995.
  - There may be one more unfinished hull.
- The Halibut-class subs are very similar to the Project 1851 Nelma sub.
  - About 10 meters (32.8 feet) longer and have other external differences.
  - Designed for operation at depths up to about 1,000 meters (3,281 feet), equipped with various devices for underwater work.
  - No armament. Crew complement: est. 14
- Propulsion: Believed to be the same propulsion system as on the Nelma sub.
  - The reactor likely is a small PWR rated @ 8 - 10 MWt (est.), which some sources attribute to NIKIET.
  - Estimated propulsion power is about 1,900 shp (1.42 MW) delivered to a single shrouded propeller.
  - Small electric auxiliary propulsors (thrusters) provide precise underwater positioning.
- AS-35 was was modernized 2012.

# 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"
- Three subs in this class were built at the Admiralty shipyard in St. Petersburg.
  - 1st keel laid in 1977, completed as AS-13 in 1986.
  - 2nd keel laid in 1983, completed as AS-15 in 1991.
  - 3rd keel laid in 1988, completed as AS-33 in 1994.
- No armament. Crew complement: est. 36
- Propulsion: Main propulsion power of 10,000 shp (7.46 MW) has been reported by several sources. This would require a reactor rated at about 50 MWt. Propulsion is provided by a single main propeller and six small, retractable auxiliary thrusters for precise underwater positioning.
- Under Project 19102, AS-15 was modernized in 2009 - 2013. There have been reports that AS-33 is no longer in service, and may have been written-off.

# Project 1910 Kashalot

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

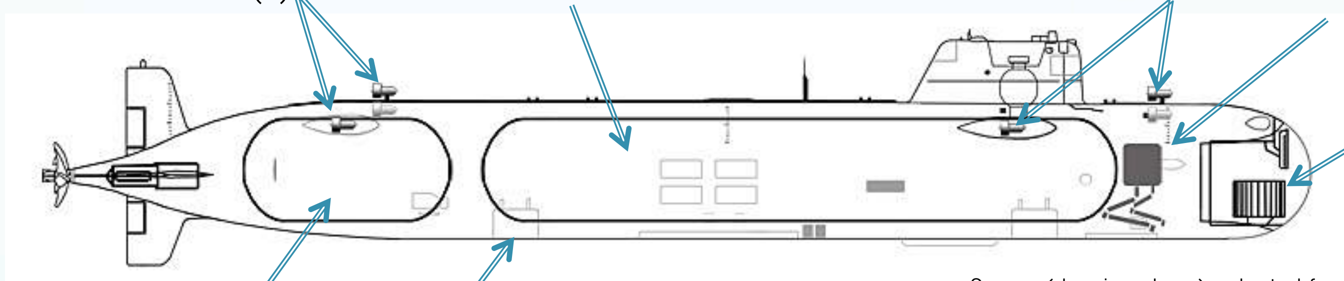
Source: http://forums.airbase.ru/

AS-13 right front thruster in retracted position without cover. Source: http://forums.airbase.ru/

Source: http://www.dodmedia.osd.mil/

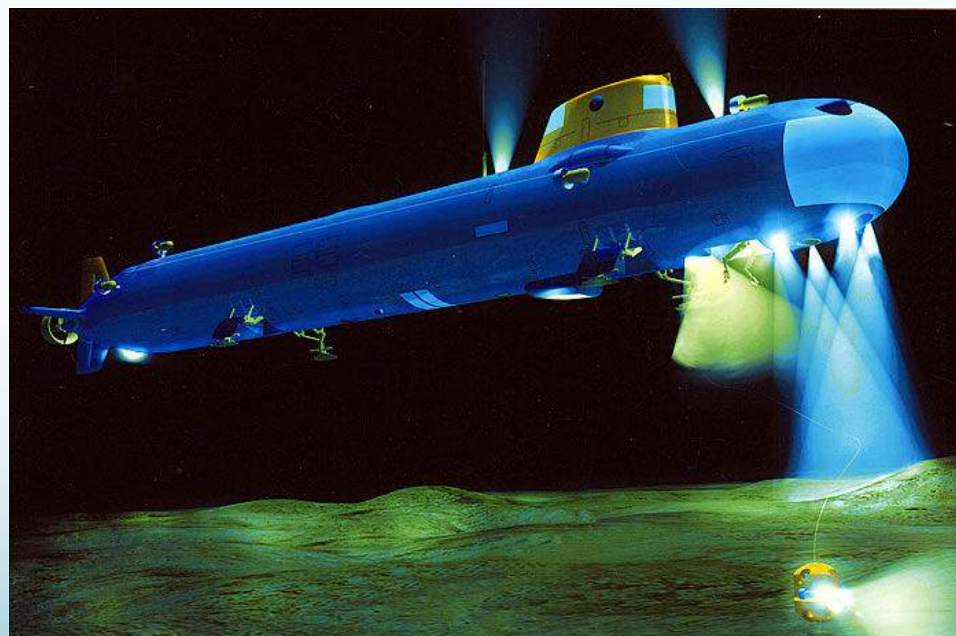
# Project 1910 Kashalot

## “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: http://nvs.rpf.ru/nvs/forum

# Project 10831 Losharik

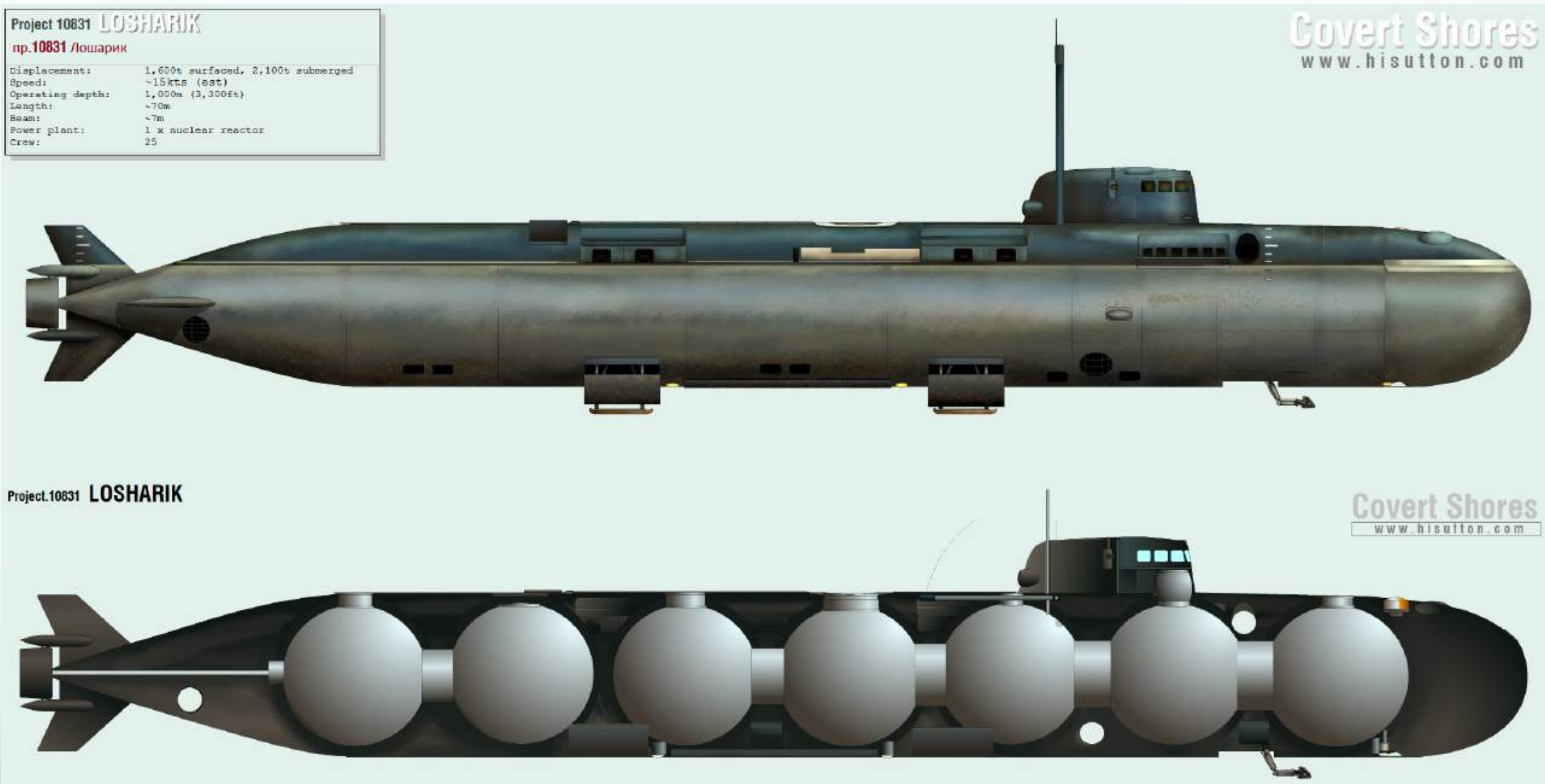
## "Deep diving nuclear power station"
## (aka Kalitka, AC-12, AS-31, NORSUB-5, Project 201)

Source: TopGear

- The sub was designed by the Malakhit Design Bureau. The keel was laid in 1988, but not completed until 15 years later, in 2003 as hull number BN-220. A second hull is believed to exist, but apparently has not been completed.
- The inner hull is 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 is designed to operate at great depth (1000s of meters), 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:
  - Propulsion power of 10,000 shp has been reported in multiple sources. Main propulsion is provided by a single shrouded propeller plus an array of small auxiliary propulsors (thrusters) for precise underwater positioning.
  - The reactor is believed to be an Afrikantov E-17 PWR rated at about 50 MWt. The reactor and main propulsion machinery are located in one or more of the stern spherical hull blocks.

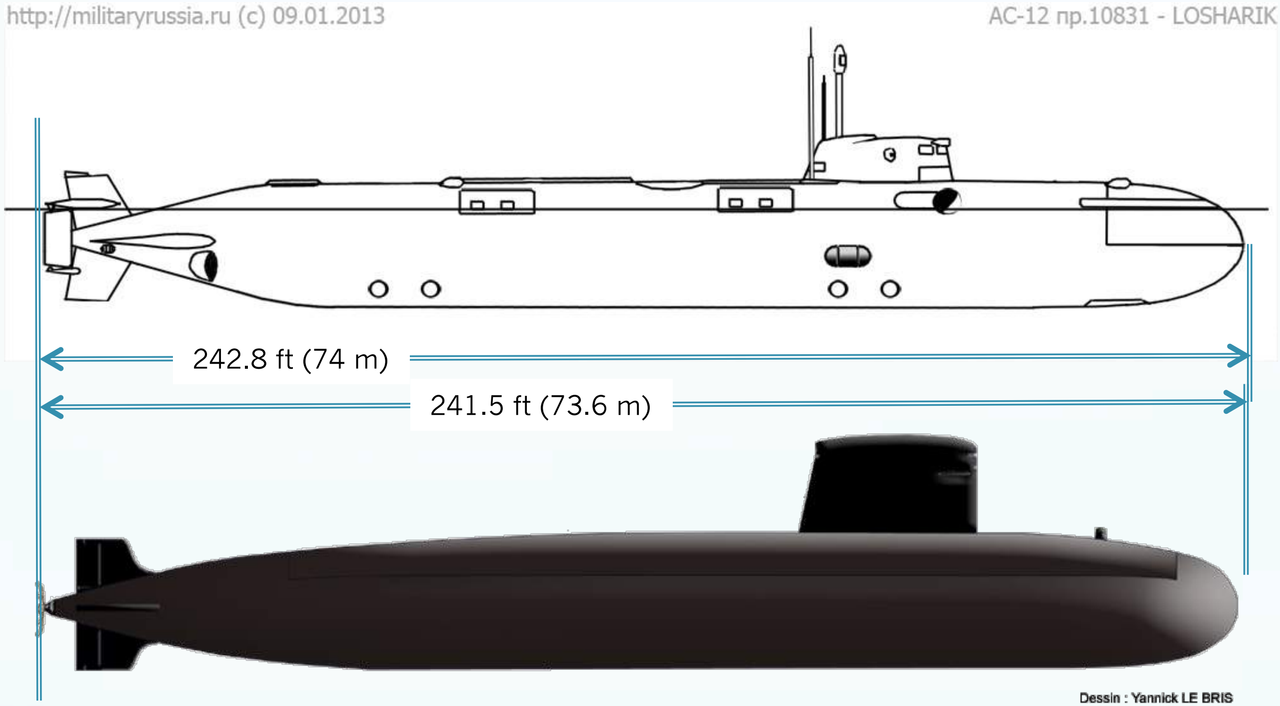
# Project 10831 Losharik

## “Deep diving nuclear power station” notional arrangement




Source: www.hisutton.com

# Comparison of *Losharik* with French Rubis (Améthyste)-class SSN




Source: https://defence.pk/

Losharik:

- Length: 242.8 ft (74 m)
- Hull diameter: 23 ft (7 m)
- Submerged displacement: 2,100 tons
- Propulsion: 10,000 shp cited by several sources
- Reactor: likely Afrikantov E-17 PWR @ about 50 MWt, if cited propulsion shp is true
- Submerged speed: > 25 knots, if cited propulsion shp is true

Rubis (Améthyste)-class SSN:

- Length: 241.5 ft (73.6 m)
- Hull diameter: 24.9 ft (7.6 m)
- Submerged displacement: 2,670 tons
- Propulsion: Turbo-electric, 8,050 shp
- Reactor: CAS-48 PWR @ 48 MWt
- Submerged speed: 25 knots

# PLA-carriers

"Motherships" for the small special operations subs

# Russian PLA-carriers

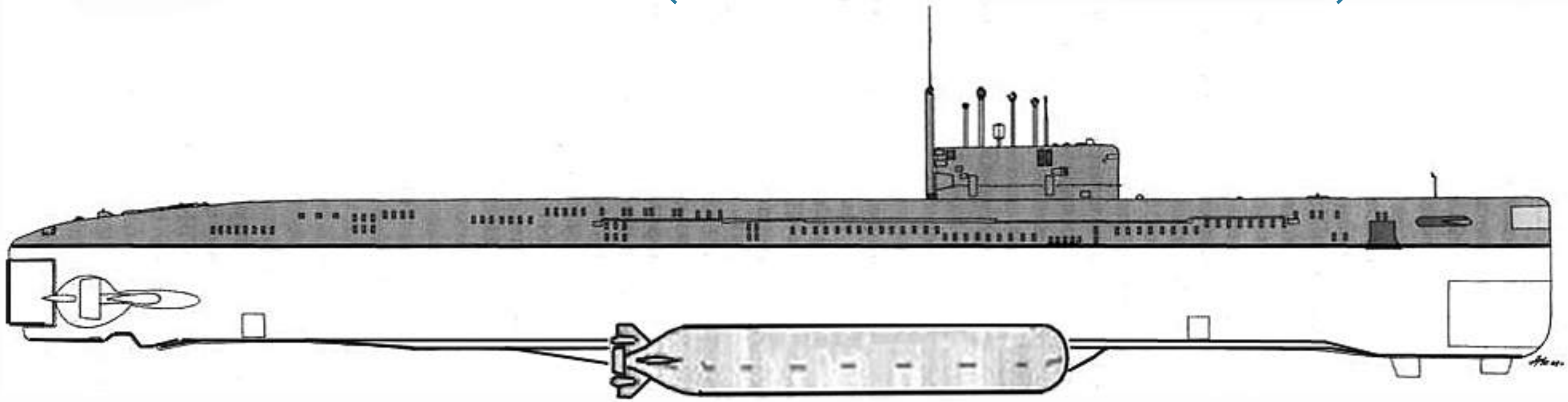
## "Motherships" for the small special operations subs

| 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 I | 160 m (525 ft) | 11.6 m (38 ft) | Not known | OK-700: 2 x VM-4-2 | 34,500 | Not known | 1990 | 1990 - 2009 |
| 09786 | PLA-carrier *Orenburg II* BS-136 | 1 x modified Delta III | 164 m (538 ft) | 12 m (39.4 ft) | Not known | OK-700A: 2 x VM-4 | 60,000 | Not known | 2002 | 2002 - present |
| 09787 | PLA-carrier *Podmoskovye* BS-64 | 1 x modified Delta IV | 167 m (548 ft) | 11.7 m (3984 ft) | 11,700 (surf), 18,200 (sub) | OK-700A: 2 x VM-4SG | 60,000 | Not known | 2016 | 2016 - present |
| 09852 | PLA-carrier *Belgorod* KC-139 * | 1 x modified Oscar II | 184 m (603.6 ft) | Not known | Not known | 2 x OK-650B | 90,000 | Not known | Expected 2018 - 2019 | |

* While *Belgorod* is being overhauled to serve as a PLA "mothership," it also may gain additional operational capabilities as a strategic nuclear torpedo carrier.

# Project 06754 (675N)

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



Source: oosif.ru

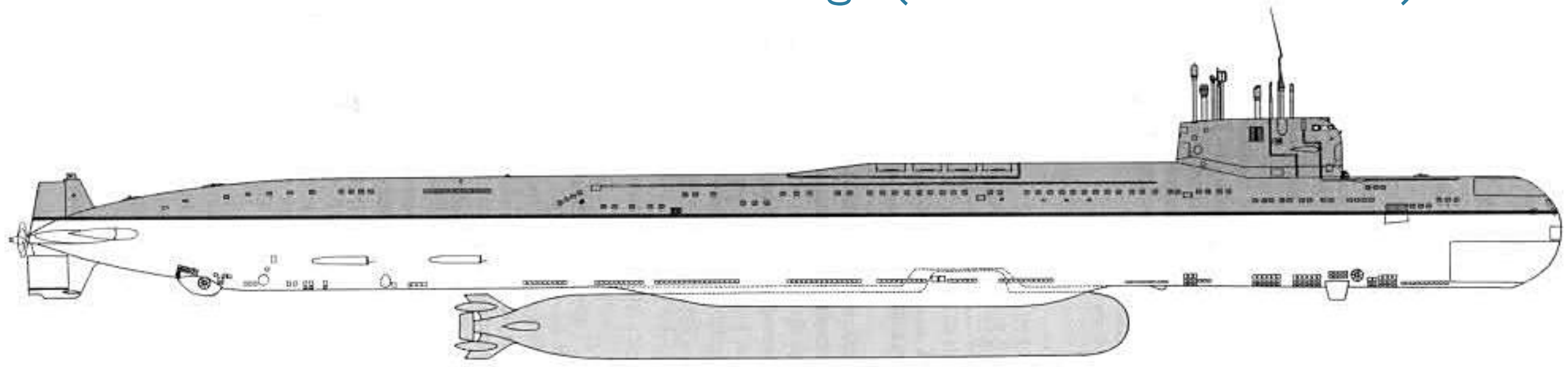
- Echo II K-170 originally launched in August 1963. Re-designated K-86 in 1978.
- Converted to serve as a “mothership” for a Project 1851 / 18511 Nelma / Paltus special operations submarines and renamed KS-86 in April 1985.
- Mission believed to be a combination of oceanographic research, search and 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)



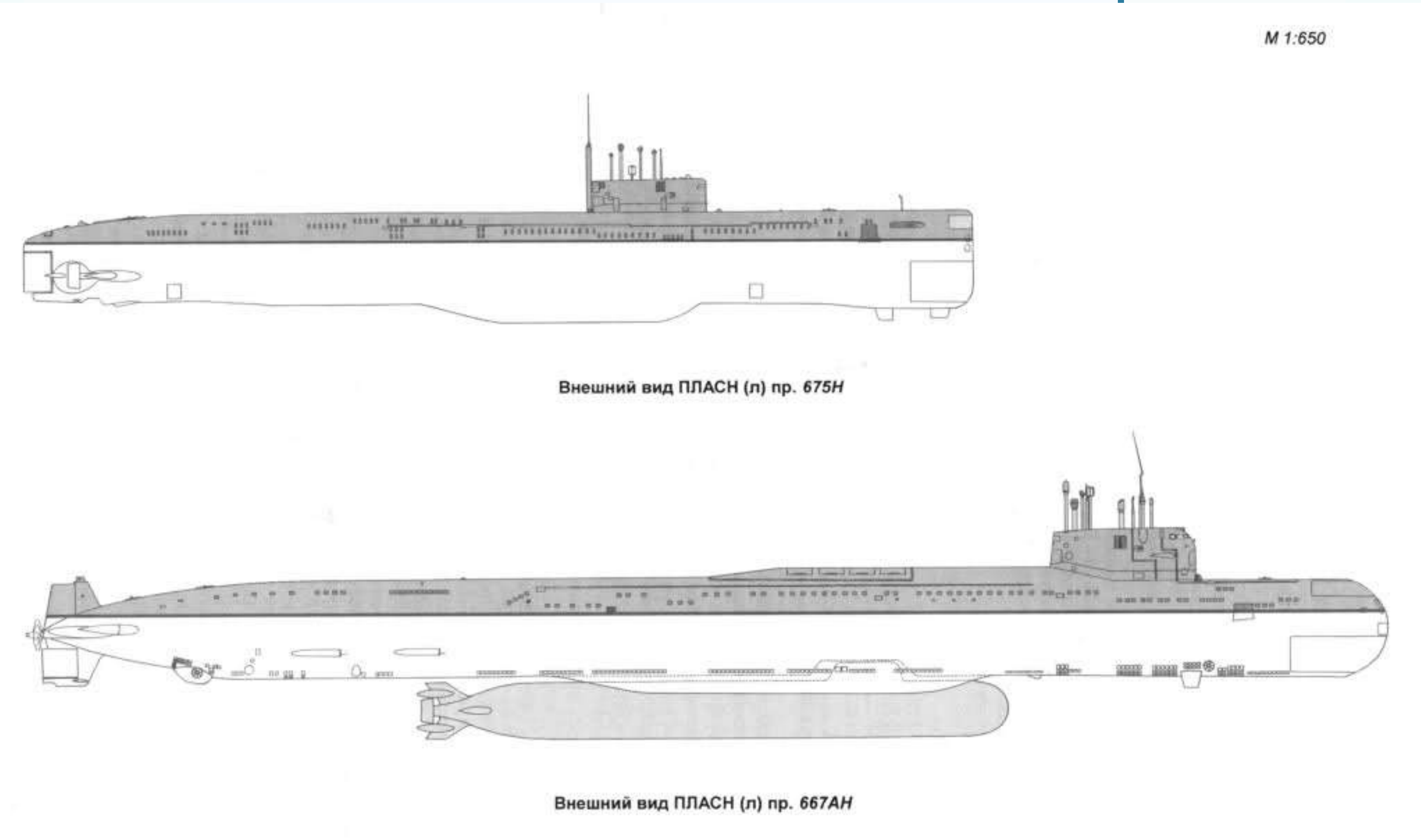
Source: GlobalSecurity.org

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 (525 ft.), 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 was removed for re-use on Delta IV Stretch K-64.

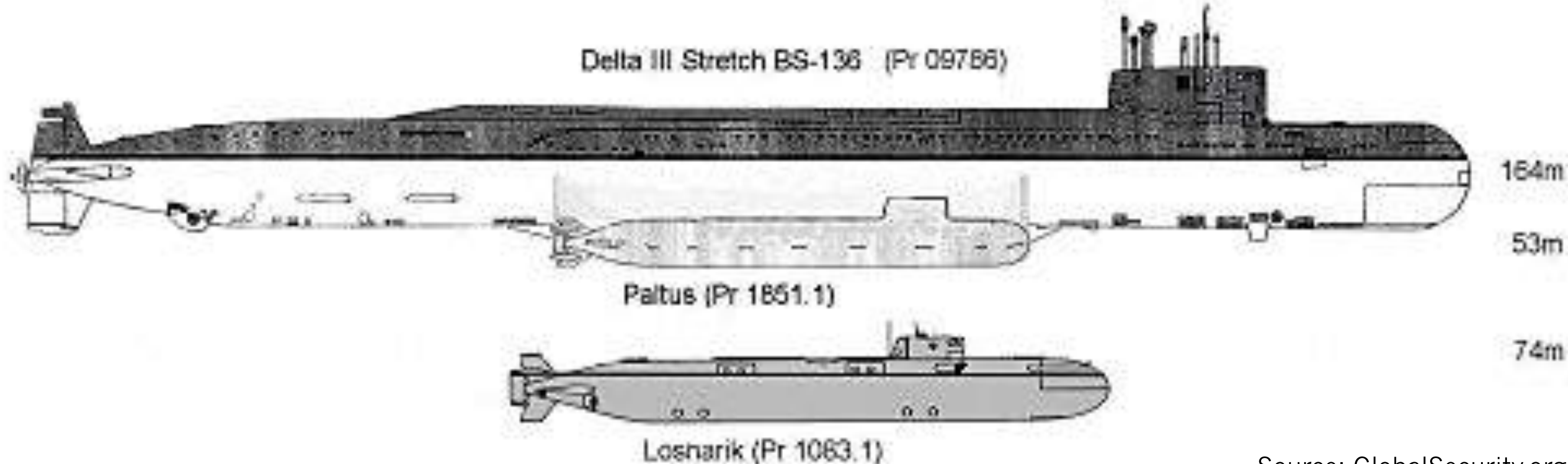
# Comparison of Project 06754 and 09774 “motherships”




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

# Project 09786

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




Source: GlobalSecurity.org

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

# Project 09786

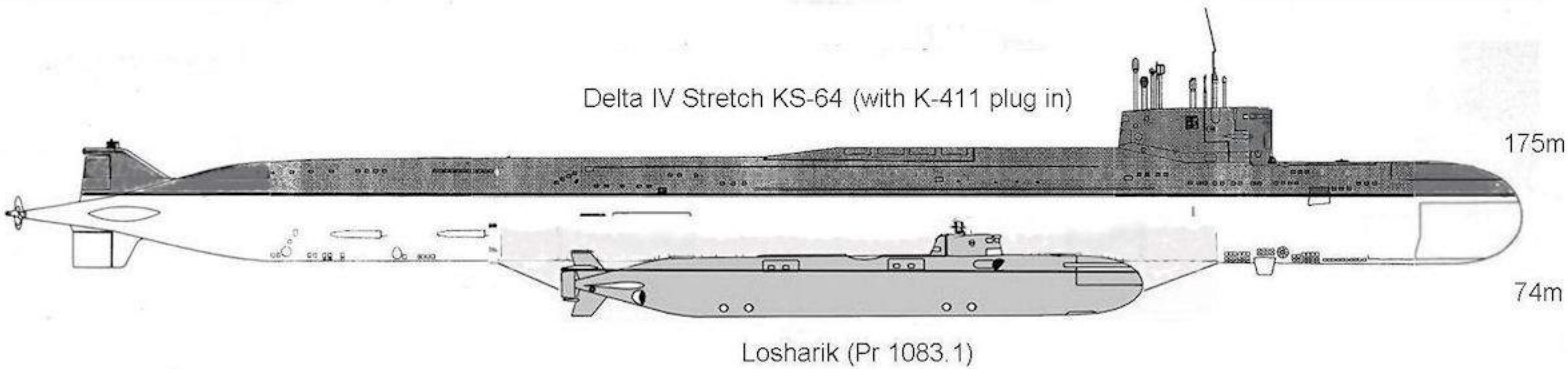
## PLA-carrier BS-136 “Orenburg II” (former Delta III K-129)

In the drydock photo, note the rectangular structure amidships.
Source, two photos above: https://forum.sub-driver.com/

Source, two photos above: http://www.shipmodels.info/

# Project 09787

## PLA-carrier BS-64 *Podmoskovye* (former Delta IV K-64)



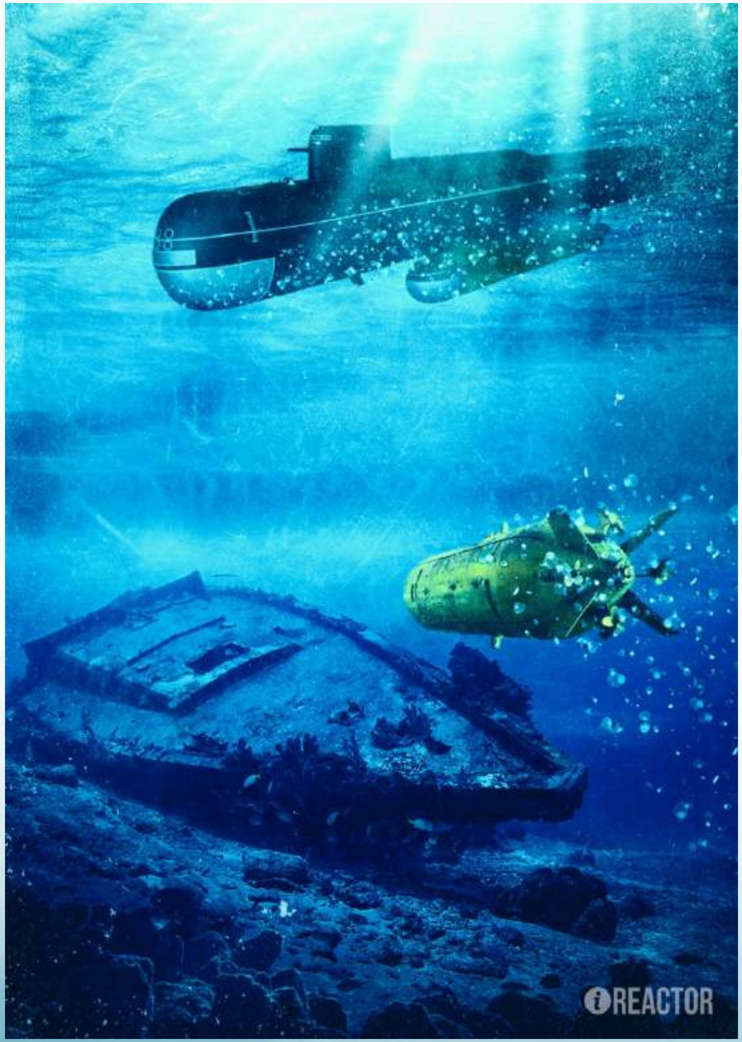

Source, above: GlobalSecurity.org

- “Delta IV Stretch” conversion started in 1999 at the Zvezdochka Shipyard, Severodvinsk. The missile compartment was removed & replaced by an extended hull section taken from retired “Yankee Stretch” KS-411. OA length now 167 m (548 ft).
- Also received updated sonar and underwater communication systems.
- Conversion was completed in 2015 after 16 years in the shipyard.  The sub was delivered to the Russian Navy in December 2016.
- Assigned to the Northern Fleet, based in Olenya Bay, replacing KS-411.

Source, above: http://indiandefence.com/

# Project 09787

## PLA-carrier BS-64 *Podmoskovye* (former Delta IV K-64)




Source: https://russianmilitaryanalysis.wordpress.com/tag/9m730/

- BS-64 serves as a “mothership” to support a small special operations nuclear submarine such as Paltus or Losharik. A recent report indicates that BS-64 also is capable of launching and retrieving a large autonomous underwater vehicle (AUV) like the Harpsichord (aka (Klavesin ).
- The concept drawing shows BS-64 carrying a small special operations nuclear submarine and operating with a Harpsichord UUV (in the foreground).

# Harpsichord-1P and -2R-PM autonomous underwater vehicles

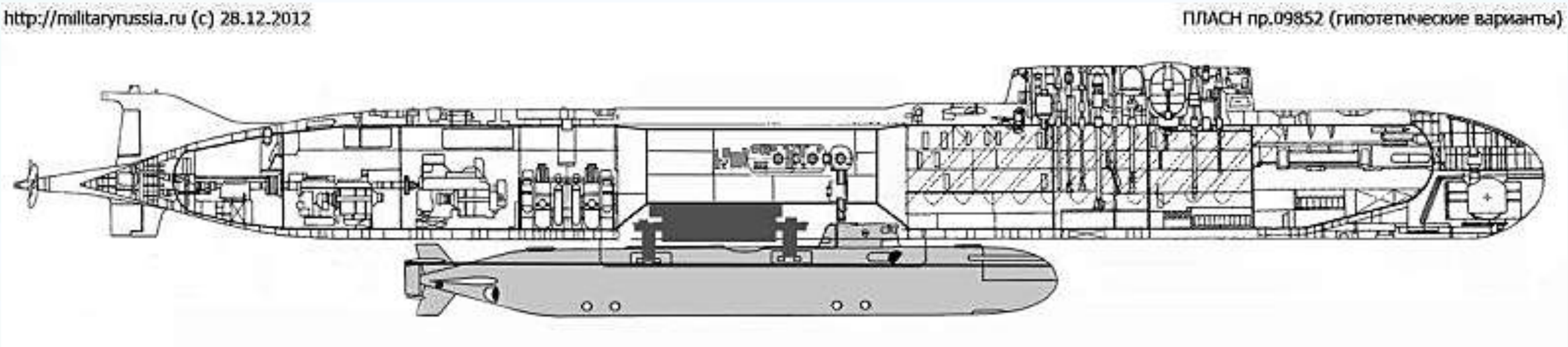
- Developed by Rubin Central Design Bureau, St. Petersburg.
- Length: 6.5 m (21.3 ft)
- Diameter 1 m (3.2 ft)
- Weight: 3,700 kg (8,157 pounds)
- Propulsion: 4 x small podded electric propulsors at the stern plus small ducted thrusters fore and aft for station-keeping.

Harpsichord-2R-PM. Source: http://vpk-news.ru/articles/30962

- Harpsichord-1P autonomy is claimed to be 120 hours, diving depth has been cited variously between 2 to 6 km (6,562 to 19,685 feet), and range about 50 km (31 miles).
- Harpsichord-2R-PM is characterized by greater autonomy and increased diving depth.
- This UUV / AUV can be used for various scientific or military missions, such as: survey the seabed, install, maintain or remove underwater engineering structures.
- Can be carried by PLA "motherships".

# Project 09852

## PLA-carrier KC-139 *Belgorod* (former Oscar II K-139 )




- In December 2012, construction began at the Sevmash shipyard on the Project 09852 submarine, based on the incomplete Project 949A (Oscar II class) submarine K-139, *Belgorod.*
  - The submarine was modified to serve as a "mothership" to carry a small manned submarine, such as the Project 18511 Paltus or the Project 10831 Losharik, or a large autonomous underwater vehicle (AUV) like the Rubin Design Bureau's Harpsichord-1R or the improved Harpsichord-2P-PM.
  - A new 30 meter hull section section was inserted, increasing overall length from 154 to 184 meters (505 to 603.6 ft). The new hull section includes the docking devices designed for the transportation of the small submarine or other devices. Airlock chambers are provided for access to the small submarine and for diver ingress / egress.
- A circa 2012 speculative view of KC-139 configured to carry a small submarine similar to AC-12 (AS-31) *Losharik* is shown above.

# Project 09852

## PLA-carrier KC-139 *Belgorod* (former Oscar II K-139 )

- A 2018 speculative view by naval analyst H. I. Sutton shows KC-139 configured to carry six Poseidon (Status 6 / Kanyon) strategic nuclear torpedoes in place of the inclined cruise missile launch tubes outside the pressure hull, is shown below. This diagram also shows a small special operations submarine and a Harpsichord large AUV.


Source: www.hisutton.com

# Strategic nuclear torpedoes & torpedo carriers

# Russian strategic nuclear torpedoes

| Weapon | Years in service | Weight | Length | Diam | Speed / Propulsion | Range / guidance | Warhead |
|---|---|---|---|---|---|---|---|
| T-15 | Early development work only, circa 1951 - 1954 | 40 tons (reported), likely closer to 50 tons for neutral buoyancy | 23.5 m (77.1 ft) | 1.55 m (5.1 ft) | 29 kts<br><br>Battery & electric motor | 30 - 40 km (19 - 25 miles)<br><br>Guidance: likely just a gyroscope | Very large nuclear warhead (58 – 100 MT based on Tsar bomb) |
| Poseidon (formerly Status-6, Kanyon) | Under development | 50 tons (est.) | 24 m (78.7 ft) (est.) | 1.6 m (5.25 ft) (est.) | > 50 kts (est.)<br><br>Nuclear reactor driving a propulsion turbine & pumpjet | Up to 10,000 km (6,200 miles)<br><br>Guidance: TBD | Nuclear, possibly up to 100 MT with cobalt shell, or conventional |

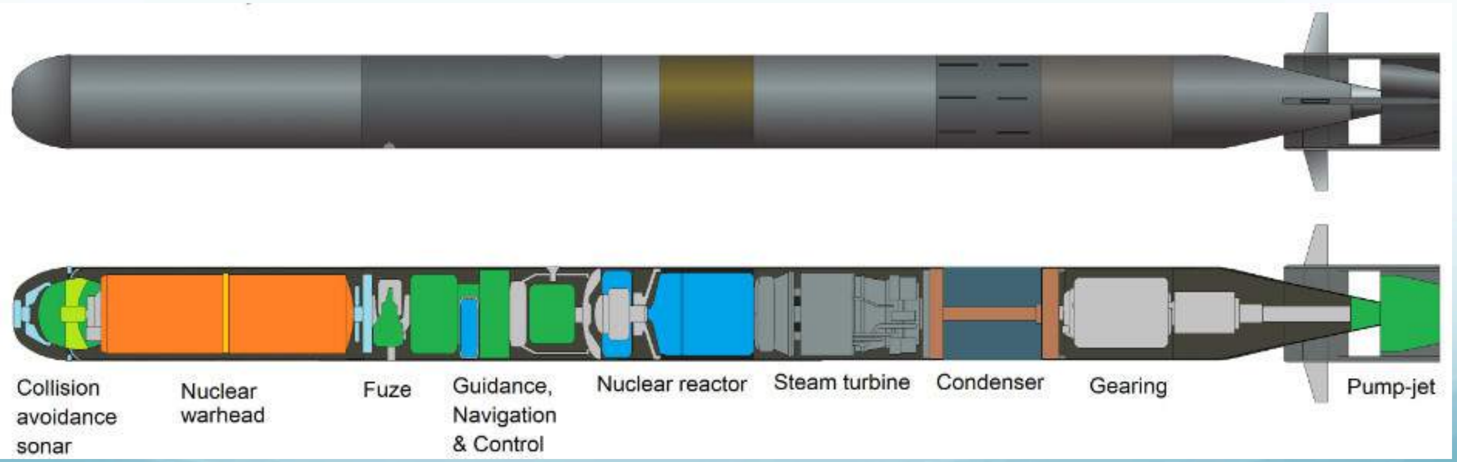
Note: The immense physical size of the Poseidon strategic nuclear torpedo is very similar to the T-15 strategic nuclear torpedo that the Soviet Union considered developing in the early 1950s. In the size comparison chart below, the Bulava is the Russian submarine launched ballistic missile (SLBM) carried on Borei-class SSBNs. The UGST torpedo is representative of a typical torpedo launched from a 533 mm (21 inch) torpedo tube, which is found on the majority of submarines in the world.


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

# Poseidon (Status-6, Kanyon)

## Strategic nuclear-powered, nuclear-armed torpedo

- Poseidon (formerly know as Status-6 and Kanyon) is a large, nuclear-powered, autonomous underwater vehicle (AUV) that functionally is a giant, long-range torpedo. It is capable of delivering a very large nuclear warhead (perhaps up to 100 MT) underwater to the immediate proximity of an enemy's key economic and military facilities in coastal areas.
  - It was first revealed on Russian TV in November 2015.
  - It is a weapon of unprecedented destructive power and it is not subject to any existing nuclear arms limitation treaties. However, its development would give Russia leverage in future nuclear arms limitation talks.
  - Use of such weapons would create coastal tidal waves and vast radioactive contamination zones that would economically cripple any of Russia's enemies. There have been reports that the warhead could be "salted" with natural cobalt (Co-59), which would produce the highly-radioactive, long-lived (5.26 year half-life), gamma-emitting isotope Co-60 when the nuclear weapon is detonated. Contaminated areas would be off-limits to humanity for long periods of time.




Poseidon / Status-6 /Kanyon torpedo notional cross-section. Source: http://www.hisutton.com/

# Poseidon (Status-6, Kanyon)

## Strategic nuclear-powered, nuclear-armed torpedo

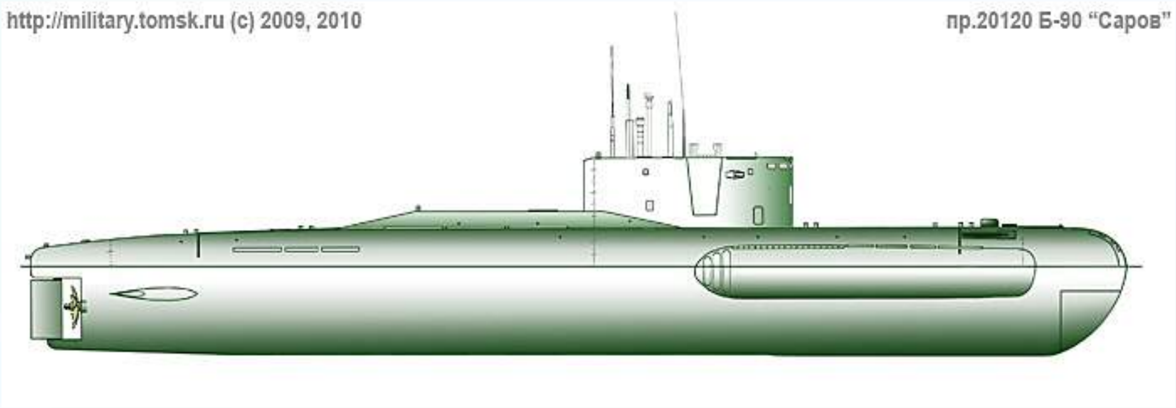
- The Poseidon AUV was designed by Rubin Central Design Bureau for Marine Engineering (SKB-18), St. Petersburg. It was formally named Poseidon in March 2018.
- Basic Poseidon physical parameters are summarized in a preceding table. Here are some additional details.
  - Torpedo weight is not known, but a neutrally-buoyant cylinder of the same size would displace about 50 tons of seawater.
  - Operating depth is reported to be up to 1,000 m (3,300 ft), which is below the operating depth of most torpedoes that could be deployed to attack a Poseidon strategic torpedo.
- Propulsion: A nuclear reactor provides the power to drive the torpedo.
  - Details on the reactor and the power rating of the propulsion plant are not known.
  - In December 2017, President Putin announced that Russian scientists had successfully completed testing of "an innovative nuclear power unit" 100 times smaller than existing submarine reactors, yet more powerful and capable of reaching maximum capacity 200 times faster. Perhaps this is the reactor for the Poseidon torpedo.
  - Another candidate might be a development of the Nikiet VAU-6 Auxiliary Nuclear Power Plant (ANPP), which is packaged as a compact, “hermitic” unit that is believed to contain a small boiling water reactor (BWR) operating in a direct cycle with a steam turbine-generator.
    - In the late 1980s, a version of the VAU-6 installed on the Project 651E Juliett-class submarine B-68, *Nerka*, was reported to deliver 600 kWe (about 805 hp).
    - A current version of an ANPP is believed to be installed on the modern submarine B-90, *Sarov*, which coincidently appears to be serving as a testbed for the Poseidon torpedo.
    - The ANPP could be adapted primarily for propulsion by replacing the turbine-generator with a main propulsion turbine and a small generator to supply “house loads” on the torpedo.

# Russian strategic nuclear torpedo carriers

| Project # | Class | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|
| 627 | This was an early 1950s concept for the November-class nuclear sub. For details, see the "Nuclear-powered fast attack submarines (SSN)" section. | | | | | | | | | |
| 20120 | *Sarov* B-90 | 1 | 98 m (322 ft.) (est.) | 9.9 m (32.5 ft.) | 2,300 (surf) 3,950 (sub) | VAU-6 hermitic ANPP @ 600 kWe | 5,500 (est.) | 17 | 2008 | 2008 - present |
| 09852 | PLA-carrier *Belgorod* KC-139 | 1 x modified Oscar II | 184 m (603.6 ft) (est.) | Not known | >14,700 (surf) >19,400 (sub) | 2 x OK-650B | 90,000 | > 20 | Expected 2018 or later | |
| 09851 | *Khabarovsk* | 1 | 120 m (394 ft) (est.) | 13-16 m (42.6-52.5 ft) (est.) | 10,000 (surf) (est.) | Not known; but likely 1 x OK-650 | Not known | > 20 | Expected 2020 or later | |

# Project 20120 *Sarov*

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




Source: www.hisutton.com

- Designed by Rubin Central Design Bureau; *Sarov* may be based on a Project 877 Kilo-class diesel-electric sub with the addition an auxiliary nuclear power plant (ANPP).
  - Stated mission: Test and develop new technologies and new weaponry.
  - Accepted by the Russian Navy in 2008
- Propulsion: Assume a standard Kilo-class diesel-electric propulsion plant with 2 x 1000 kW diesel generators and 1 x 5,500 shp main propulsion electric motor. Battery power is supplemented by a NIKIET VAU-6 hermitic auxiliary nuclear power plant (ANPP).
  - VAU-6 supplements the diesel-electric propulsion system by serving as a reliable source of electric power: about 600 kWe (800 hp)
  - Power generated by the reactor greatly extends the underwater endurance of the submarine and gives a diesel-electric sub the capability to operate independently under the Arctic ice.
- Armament: One large horizontal launcher in the bow, outside the submarine pressure hull.
  - The launcher is believed to be large enough for a Poseidon (formerly known as Status-6 or Kanyon) strategic, nuclear-propelled, nuclear-armed torpedo. *Sarov* appears to be the testbed for this torpedo.

# Project 09851 Khabarovsk

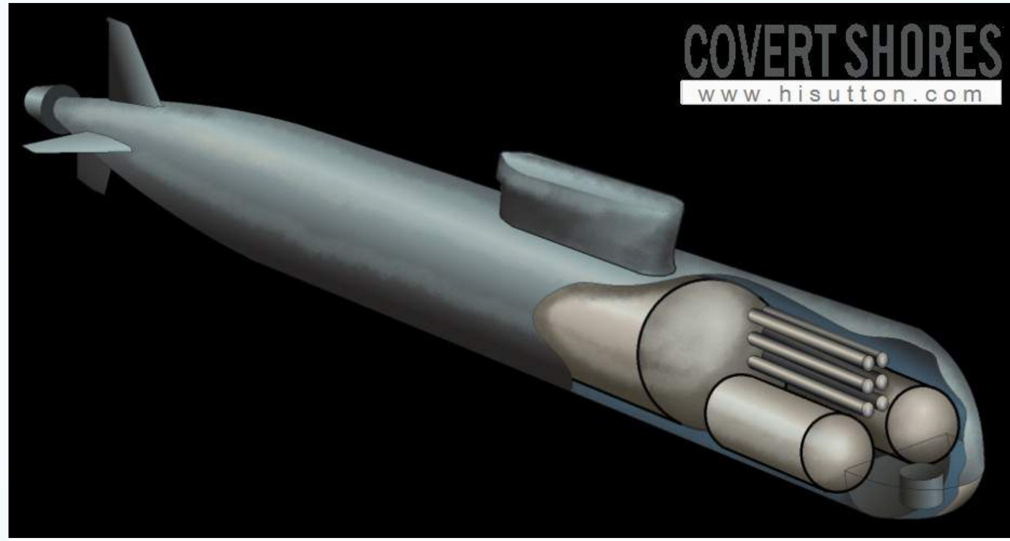
## Strategic nuclear torpedo carrier

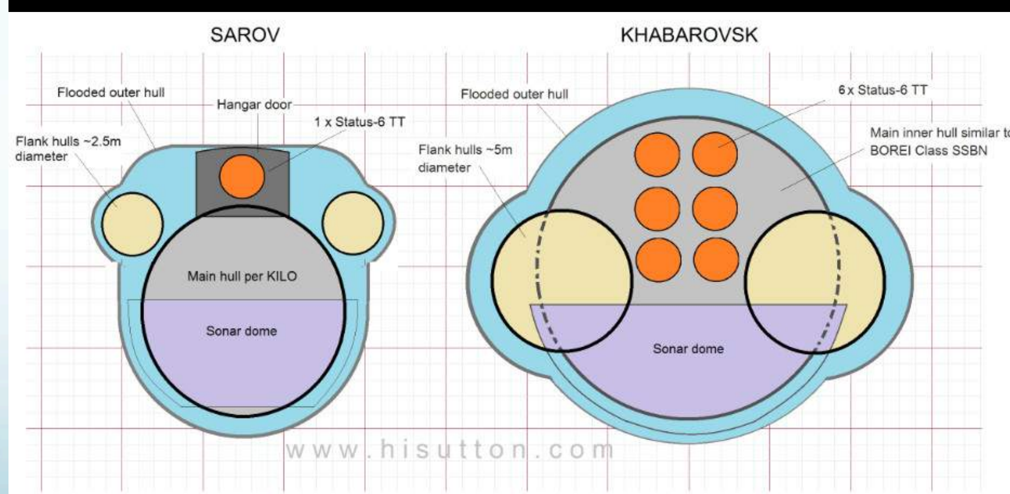

- A 2014 contract between Sevmash shipyard and Rubin Central Design Bureau reported was for designing the Project 09851 submarine.
- Russia has not stated a purpose for *Khabarovsk*. However, naval analyst H. I. Sutton has developed a persuasive case for *Khabarovsk* being the first submarine specifically designed as an operational platform for the Poseidon (Status-6 / Kanyon) strategic nuclear torpedo.
- The notional design, above, is speculative. The relative sizes of a Poseidon strategic nuclear torpedo and a typical 533 mm (21 inch) diameter torpedo are shown in this diagram.
- Propulsion: The reactor is likely to be an Afrikantov OK-650 modular PWR, which currently is being employed on new-construction Yasen-class SSNs and Borei-class SSBNs.
- *Khabarovsk* is expected to be completed by about 2020.

# Project 09851 Khabarovsk

## Strategic nuclear torpedo carrier

- The two small pressure hulls at the bow create a storage space in the free-flood area for six Poseidon (Status-6 / Kanyon) strategic nuclear torpedoes.
- The main section of the hull is about 13 meters (42.6 feet) in diameter, similar to that of a Borei SSBN.
- Toward the bow, the hull widens to a beam of about 16 m (52.5 ft).
- The cross-section diagrams show the likely internal arrangement of *Sarov* and *Khabarovsk*, focusing on the locations of the Poseidon strategic nuclear torpedoes in free-flood areas outside the submarine pressure hull.




Source, both graphics: www.hisutton.com

# Other special-purpose nuclear-powered submarines

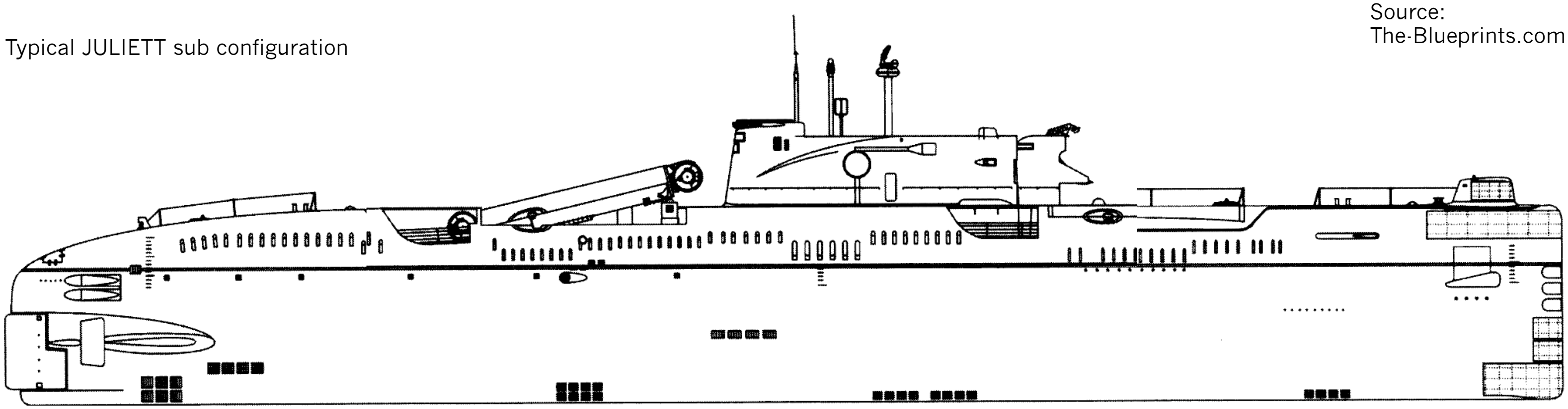
# Russian other special-purpose nuclear-powered subs

| Project # | Class | # in Class | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Years delivered | Years in service |
|---|---|---|---|---|---|---|---|---|---|---|
| 651E | Nerka | 1 | 90 m (295 ft.) | 10 m (32.8 ft.) | 3225 (surf) 4200 (sub) | VAU-6 hermitic ANPP | 600 kWe (800 hp) from ANPP | 18 | 1985 | 1985 - 1990 |
| 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 |
| | Seismic survey sub | 1 (concept) | 135.5 m (446 ft) | 14.4 m (46.3 ft) | 13,820 (sub) | Not known | Not KNown | 12.6 | | |

# Project 651E Nerka

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

Typical JULIETT sub configuration



Source: The-Blueprints.com

- Submarine B-68 started life as K-68, a Project 651 Juliett-class diesel-electric SSG designed by Lazurite Central Design Bureau. From September 1976 - December 1985, B-68 was overhauled at Krasnoe Sormovo shipyard in Nizhny Novgorod (Gorky) and received a small auxiliary nuclear power plant (ANPP) installed under the aft compartment (compartment 8).
- Propulsion: Standard Juliett-class diesel-electric (2 x 3,000 kWe and 1 x 1,300 kWe diesel generators, 2 x 3,000 shp main propulsion motors and 2 x 500 shp "creeper" motors) supplemented by electric power generated by a NIKIET VAU-6 "hermitic" ANPP.
  - The VAU-6 ANPP is believed to be a compact boiling water reactor (BWR) + turbo-generator package producing about 600 kWe of electric power (about 805 hp).
  - A prototype VAU-6 was built in 1971 and a second was built in 1986.

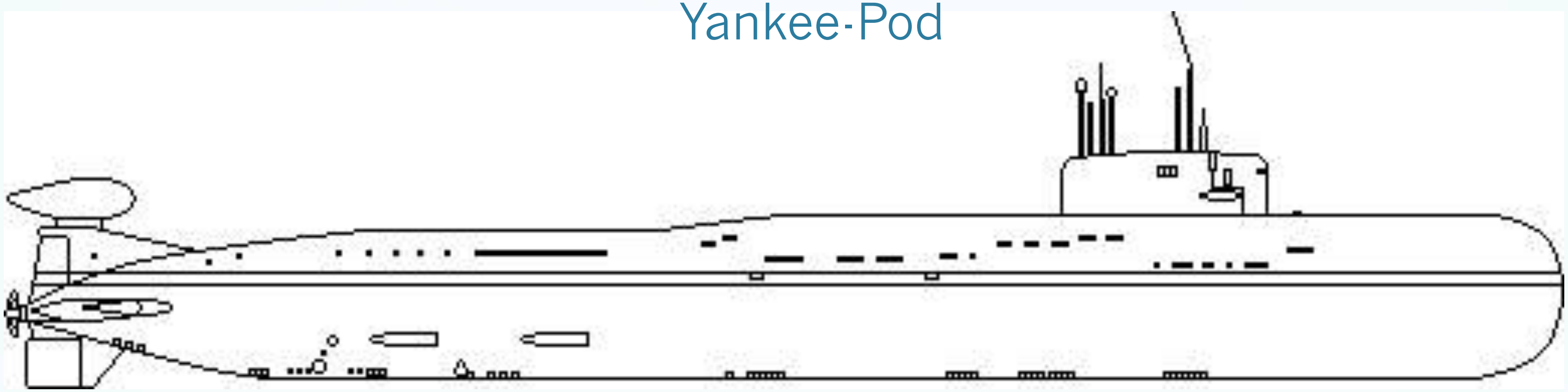
# Project 651E Nerka

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

- Armament: If standard Juliett SSG armament was retained, then B-68 would have had the following armament:
  - 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 were launched with the sub on the surface.
  - 6 x 533 mm bow torpedo tubes
  - 4 x 400 mm stern torpedo tubes
- Operational matters:
  - B-68 operational testing took place in the Black Sea.
  - The continuous submerged range of B-68 is reported to have increased from 350 miles (563 km) at an economic speed of 2.8 knots using storage batteries alone to almost 7,000 miles (11,265 km) at an economic speed of 4 knots using the ANPP.
  - B-68 was decommissioned in 1990.

# Project 667AK Akson-1

## Yankee-Pod

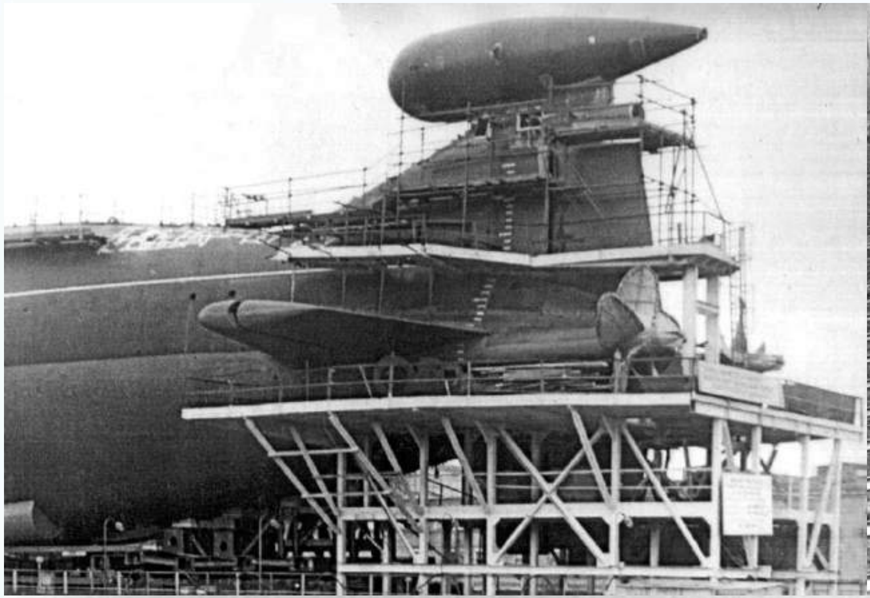
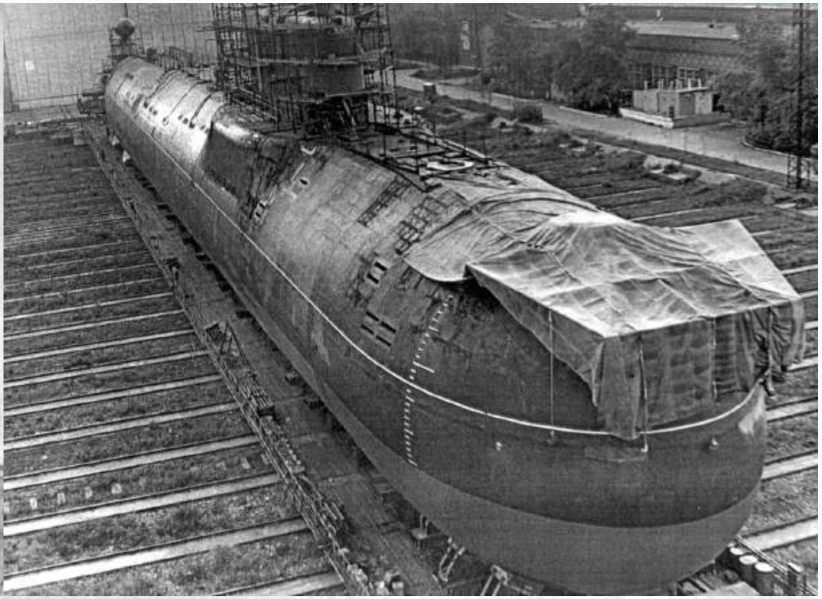
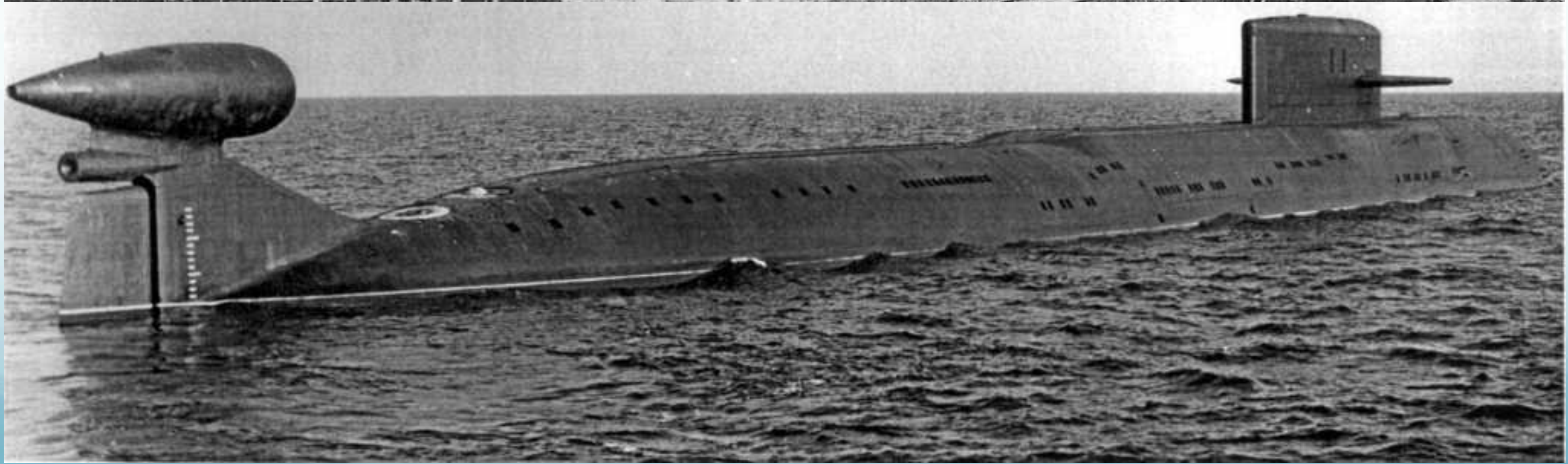


Source: http://www.okretywojenne.mil.pl/index.php?go=542

- Yankee Pod was a conversion of Yankee I K-403 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.
  - This type of pod was first operationally deployed on Victor III-class SSNs, and later deployed on many Russian submarine classes.
- 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
  - Two independent secondary power trains, each with 2 x main turbines and a reduction gear driving a single shaft and propeller. The two trains have a combined rating of about 34,500 shp.

# Project 667AK Akson-1

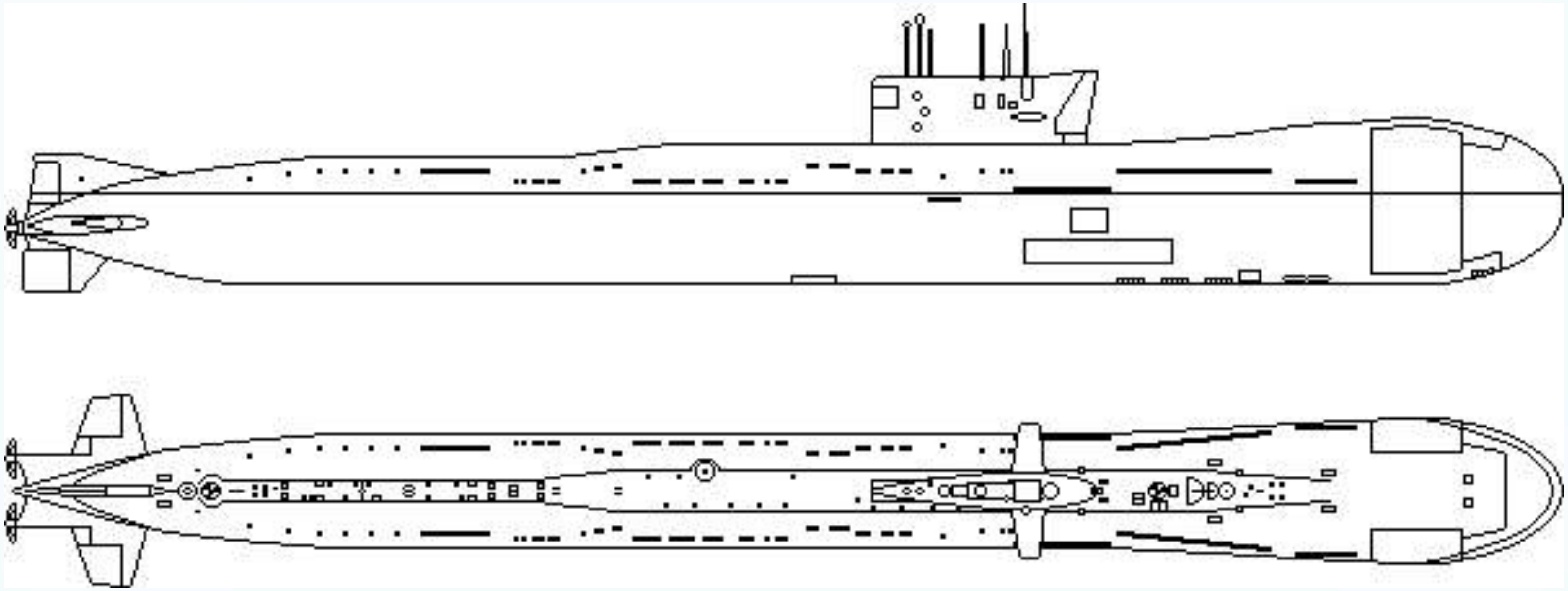
## Yankee-Pod

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
  - Two independent secondary power trains, each with 2 x main turbines and a reduction gear driving a single shaft and propeller. The two trains have a combined rating of about 34,500 shp.

# Project 09780 Akson-2

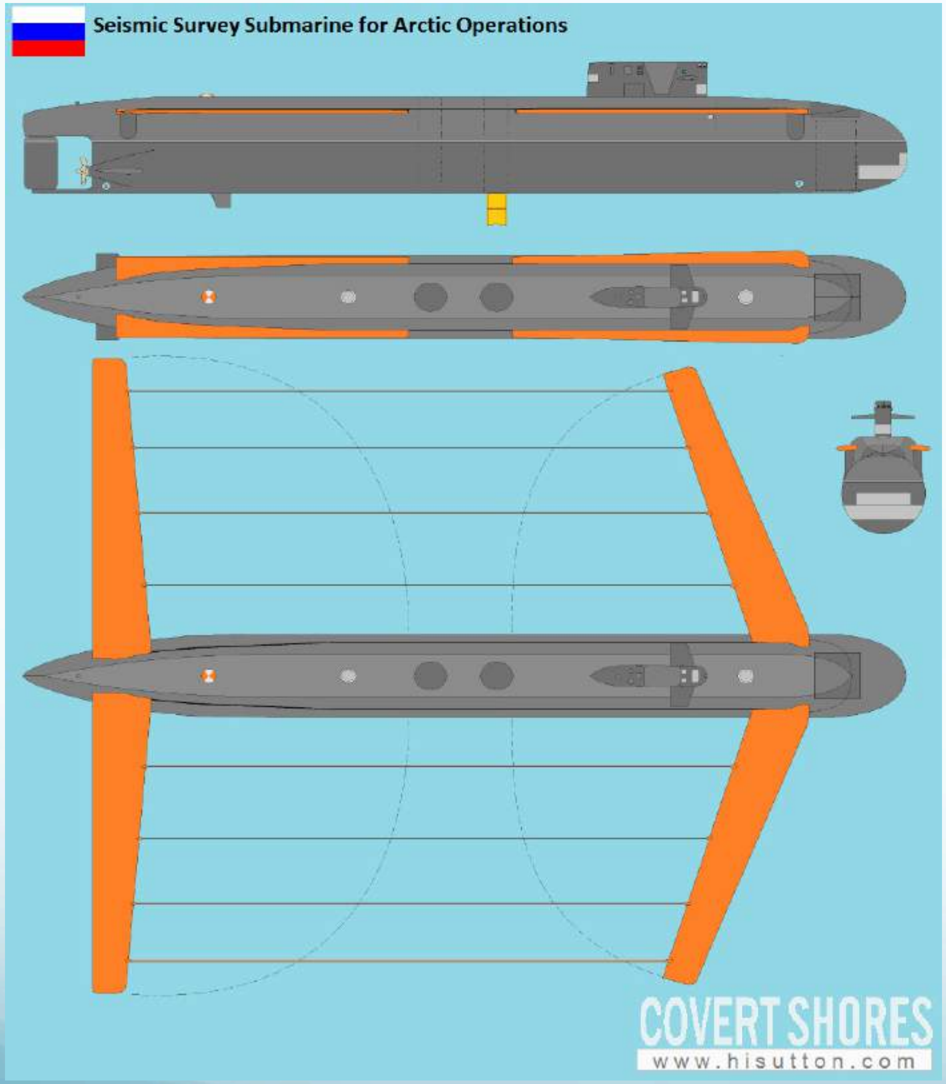
## Yankee Bignose

- 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.
  - Originally five Sierra III boats were planned but construction started on only one in 1991. It was scrapped in 1993.
- 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.
- The Yankee Bignose sail appears similar to that on the Borei-class SSBN.

Source, above: www.shipmodels.info

SJC "*Irtysh-Amphora*" spherical sonar array used on Project 09780, Akson-2 and also used on Project 885 Yasen SSNs.
Source: http://paralay.com via http://militaryrussia.ru/blog/topic-339.html

# Seismic survey submarine




Source: H. I Sutton at http://www.hisutton.com/Seismic_Survey_Sub.html

- In 2017, naval analyst H.I Sutton reported on a large, non-military, nuclear-powered seismic survey submarine being developed by the Rubin Central Design Bureau for use in the Arctic.
- The submarine is designed to conduct sub-bottom surveys using very low frequency active sonar which can penetrate the sea floor. The receivers for this sonar are mounted on distinctive, deployable wing-like structures, which extend from the sides of the submarine for a total deployed "wingspan" of about 100 meters (330 feet).
- Length: 135.5 meters (446 feet)
- Beam: 14.4 meters (47 feet)
- Max. speed: 12.6 knots; survey speed: 3 knots.
- Construction is expected to start in 2020.
- For Sutton's analysis of this survey sub, refer to the *Covert Shores* website at: http://www.hisutton.com

# Examples of unbuilt nuclear submarine projects

# Unbuilt nuclear submarines

| Project # | Description | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Year of concept |
|---|---|---|---|---|---|---|---|---|
| 653 | November SSN adapted as an SSGN for P-20 strategic cruise missiles | 107.4 m (352.4 ft) | 7.9 m (25.9 ft) | 3,665 (surf) 5,350 (sub) | 2 x VM-A | 27,000 | > 20 | 1956 |
| 667 | Original Project 667 design armed with three Beriev P-100 strategic cruise missiles | Not known | Not known | Not known | Not known | Not known | Not known | Early 1960s |
| 667 | Later iteration of Project 667 armed with eight R-21 SLBMs | Not known | Not known | Not known | Not known | Not known | Not known | Early 1960s |
| 673 | Sail-less SSN | Not known | Not known | 1,500 (sub) | Not known. 190 – 200 MWt required (est.) | 40,000 | 35 - 40 | Early 1960s |
| 748 | Dual-role mine-layer and amphibious assault ship | 159.0 m (521.5 ft) | Not known | > 10,000 (est.) | 2 x OK-300 | 30,000 | Not known | Mid-1960s |
| 679 | Victor I SSN adapted as an SSBN armed with R-27 SLBMs | Not known | 10 m (32.8 ft) | > 3,500 (surf) > 4,750 (sub) | OK-300: 2 x VM-4 | 31,000 | > 20 | Late 1960s |
| 667V | Yankee SSBN re-armed with R-27K anti-ship ballistic missiles | 132 m (433 ft) | 11.6 m (38 ft) | 7,700 (surf) 9,300 (sub) | OK-700: 2 x VM-4-2 | 34,500 | 27 | Early 1970s |
| 687 | Alfa SSN adapted as an SSBN armed with R-27 SLBMs or R-27K anti-ship ballistic missiles | Not known | 9.5 m (31 ft) | 4,200 (surf) | 1 x OK-550 or 1 x BM-40A | 40,000 | > 20 | Mid-1970s |

# Unbuilt nuclear submarines

| Project # | Description | Length | Beam | Displacement (tons) | Reactor | Shaft hp | Max speed (kts) | Year of concept |
|---|---|---|---|---|---|---|---|---|
| 705A | Alfa SSN adapted as an SSGN armed with P-70 Ametist anti-ship cruise missiles | 81.4 m (267 ft) | 9.5 m (31 ft) | 2,385 (surf) | 1 x OK-550 or 1 x BM-40A | 40,000 | > 30 | Mid-1970s |
| 667BDR variant | Delta III SSBN adapted for Arctic cable-laying | 166 m (544.6 ft) | 12 m (39.4 ft) | Similar to SSBN: 13,500 (surf) 18,200 (sub) | 2 x OK-700A | 34,500 | > 20 | 1990s |
| 941 variant | Typhoon SSBN adapted for Arctic cable-laying | 175 m (574.1 ft) | 23 m (75.5) | Similar to SSBN: 23,200 (surf) 33,800 (sub) | 2 x OK-650 | 99,200 | > 20 | 1990s |
| | Multifunctional Underwater Station - Ministry of Industry and Trade design | 115 m (377 feet) | 11 m (36 feet) | 5,800 (surf) | Not specified | | 12 | 2010 |
| | Multifunctional Underwater Station – Lazurite design | 117 m (384 ft) | 15 m (49 ft) | | Not specified | | 13 | 2012 - 2015 |

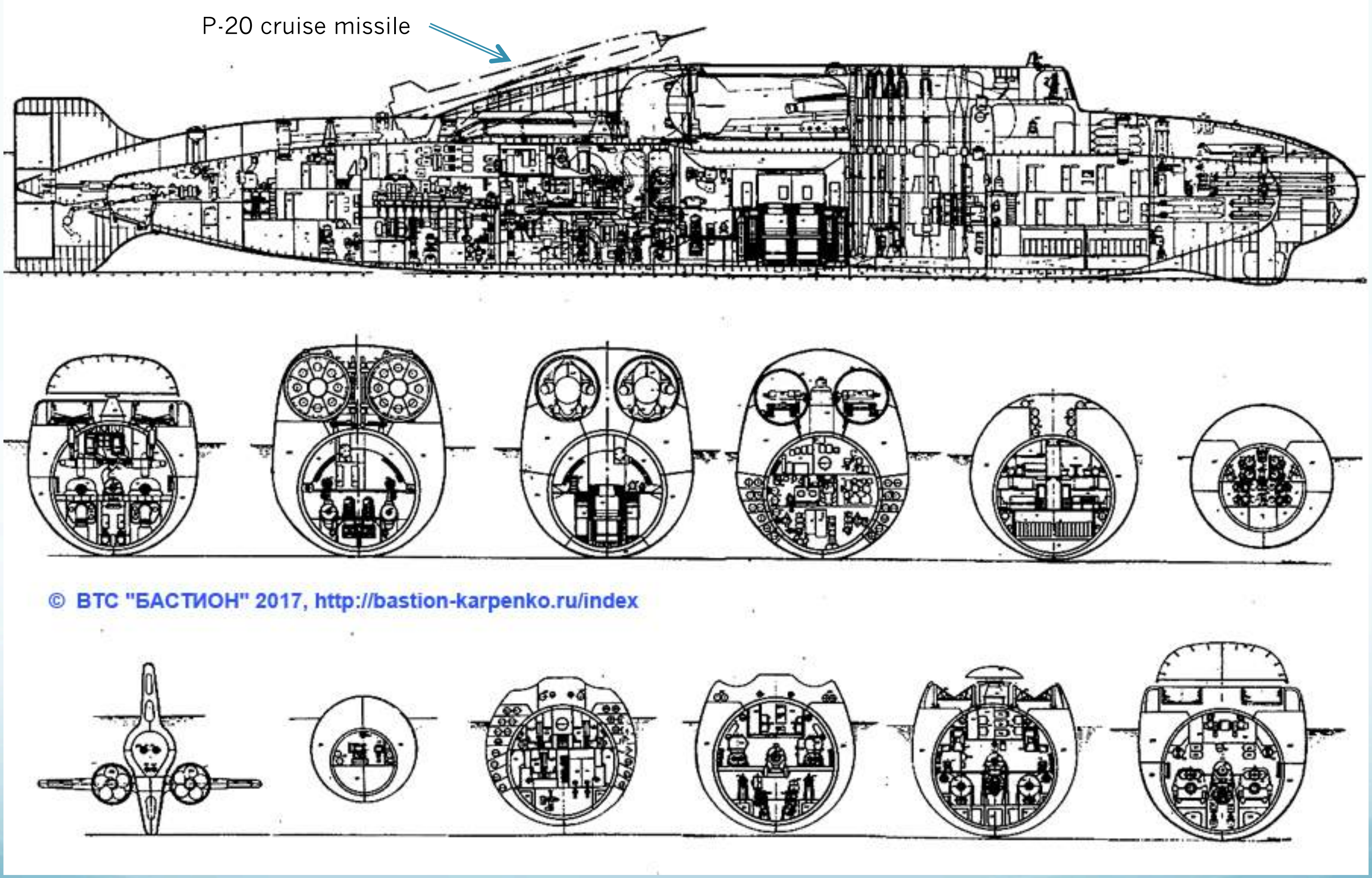
# Project 653

## Strategic cruise missile (SSGN) variant of the Project 627A SSN

- Beginning in 1956, SKB-143 (later Malachit Central Design Bureau, St. Petersburg) was responsible for the Project 653 submarine, which was to be a strategic cruise-missile carrying variant of the Project 627A November-class SSN.
  - Modified to carry two, very large, side-by-side, watertight, horizontal cylinders aft of the sail, each containing one P-20 strategic cruise missile.
  - With the submarine on the surface, the cylinders would be raised to launch the missiles.
  - The cruise missile features added at least 600 tons to the submarine's displacement.
- Development of the P-20 strategic cruise missile, designed by OKB-240, began before submarine-launched strategic ballistic missiles became practical weapons. Basic cruise missile operational parameters were:
  - Cruise altitude: 20 km (65,616 feet)
  - Cruise speed: 3,000 to 3,200 kph (1,864 to 1,988 mph)
  - Range: 2,000 to 3,000 km (1,243 to 1,864 miles)
- The P-20 proved to be too ambitious a project and it was never was flown. The Project 653 submarine was cancelled.

# Project 653

## Strategic cruise missile (SSGN) variant of the Project 627A SSN




Source: bastion-karpenko via, http://modernwartech.blog.hu/2017/07/03/a_projekt_705_k_lira_alfa_osztalyu_vadasztengeralattjaro

# Project 667

## Strategic cruise missile launcher (SSGN)

- The original Project 667 submarine design was to be armed with three very large Beriev P-100 strategic cruise missiles. This submarine design was cancelled by 1961. Project 667 continued with the development of an SSBN design armed with eight R-21 SLBMs before evolving into Project 667A, which became the Yankee I-class SSBN armed with R-27 SLBMs.
- The P-100 was Beriev's entry in a Soviet long-range cruise missile competition in 1960. The missile was to be be adaptable for launch from fixed silos, aircraft, surface ships, and submarines. The missile project was scheduled for completion in 1965, but was cancelled in 1961 while still in the design phase.
- P-100 specs for the smaller "attack" version:
  - Missile gross mass: 60,000 kg (132,000 lb)
  - Length: 11.4 m (37.4 ft)
  - Diameter: 1.24 m (4.1 ft)
  - Wingspan: 2.3 m (7.5 ft)
  - Maximum range: 2,000 km (1,243 miles)
  - Cruise altitude: 25 to 30 km (15.5 to 18.6 miles)
  - Speed: 3,500 to 4,000 kph (2,175 to 2,485 mph)
  - Boost propulsion: 4 x solid rockets
  - Cruise propulsion: 1 x ramjet
  - Single nuclear warhead

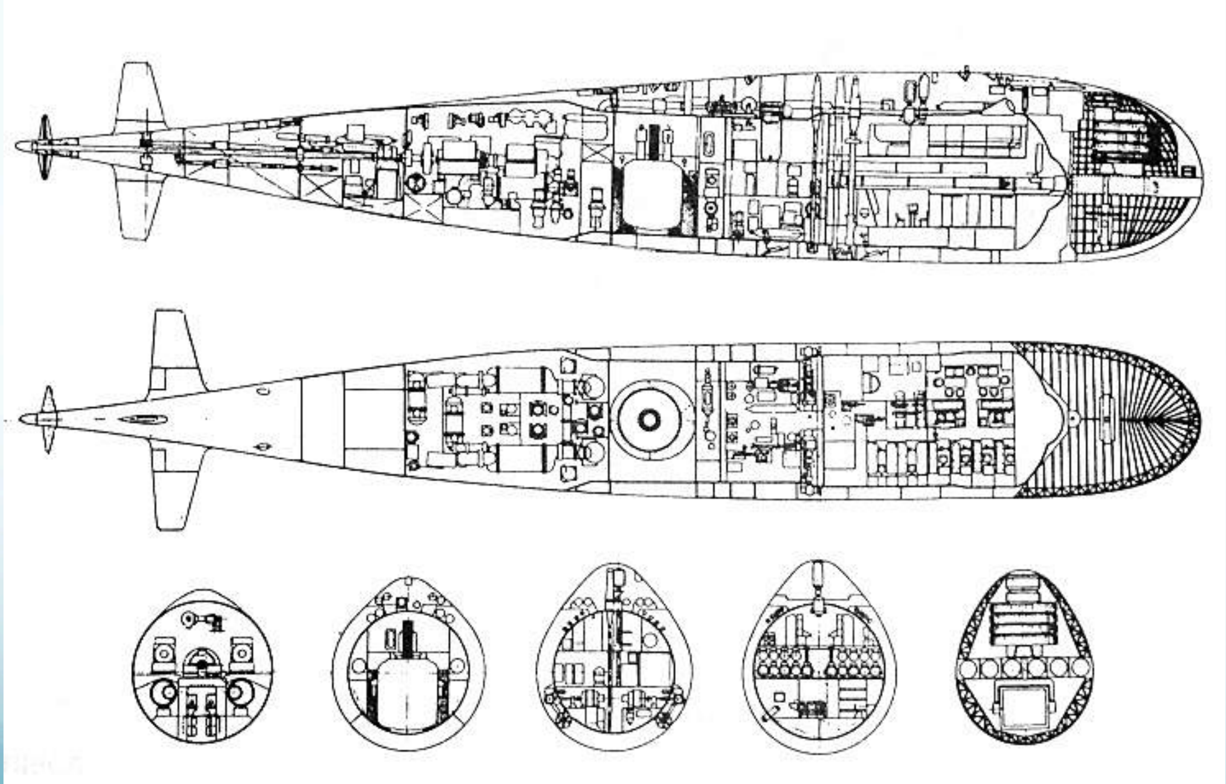
Beriev ramjet-powered P-100 strategic cruise missile with two large booster rockets.

Graphic source: Mark Wade via, http://www.astronautix.com/p/p-100.html

# Project 673

## Sail-less SSN

- The Project 673 SSN was designed by Lazurite in 1960 as a small (~1,500 tons surfaced) and fast (35 - 40 knots) SSN. To maximize speed, the sail was removed and a single-reactor, 40,000 shp propulsion plant was planned. Without a sail, this submarine would have been the most maneuverable submarine ever. In the early 1960s, the Soviets had no single submarine reactor capable of delivering the required power.
- In concept, the Project 673 SSN was similar to the US CONFORM SSN proposed in the late 1960s.

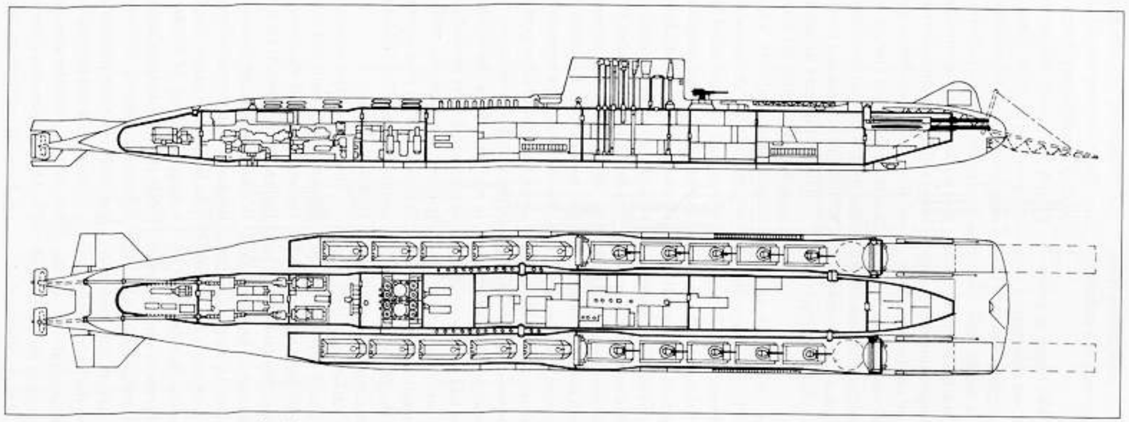


Source: adapted from https://www.reddit.com/r/ImaginaryWarships/

- The Afrikantov OK-550 liquid metal cooled reactor, which was introduced in 1971, was the first Soviet submarine reactor to deliver 40,000 shp.
- The Afrikantov OK-650 PWR, which was introduced in 1981, was the first Soviet water-cooled submarine reactor to deliver 40,000 shp.

# Projects 748

## Nuclear-powered mine-layer & amphibious assault sub



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

Source: Figure from Norman Polmar & Kenneth J. Moore; "Cold War Submarines, The Design and Construction of US and Soviet Submarines"; Brassey's, Inc.; 2004, p. 234

- Project 748 is one example of several very large nuclear-powered transport submarines that were designed in the Soviet Union during the 1960s.
- Project 748 originally was conceived as a dual-role mine-layer and amphibious assault landing ship.

- The keel for the Project 748 sub was laid in 1964 at Soviet Shipyard No. 402 (now SEVMASH), Severodvinsk. Construction was stopped in November 1966; the sub was not completed.
- The submarine pressure hull was flanked by two long, watertight cylinders designed to transport 1,166 tons of cargo; for example: a landing force of 500 troops or a combination of troops, vehicles, equipment and supplies. Each cargo cylinder was comprised of two compartments, each with access to the main hull of the submarine.
- Propulsion: 2 x OK-300 PWRs driving 2 x main turbines delivering a combined 30,000 shp to two shafts with fixed-pitch propellers.
- For more information on "unbuilt giants," refer to Norman Polmar & Kenneth J. Moore; "Cold War Submarine, The Design and Construction of US and Soviet Submarines," Brassey's, Inc., 2004

# Projects 679 & 687

## SSBN variants of SSNs

- Projects 679 and 687 were two attempts by Malakhit Central Design Bureau, St. Petersburg, to develop an SSBN based on their SSN designs.
  - The Project 679 SSBN was a concept based on the Project 671 Victor I SSN, which entered service in 1967. The SSBN version would have been modified to carry R-27 SLBMs.
  - The Project 687 SSBN was a concept based on the Project 705 Alfa SSN, which entered service in 1971. The SSBN version would have been modified to carry the R-27 strategic SLBM or the R-27K anti-ship ballistic missile.
- These projects were cancelled during the preliminary design phases and Soviet SSBN development was focused on the Project 667A Yankee I SSBN designed by the Rubin Central Design Bureau.
- The interest in adapting an SSN design to an SSBN role is similar to the approach taken by the US, which used the Skipjack-class SSN design as the basis for the George-Washington-class SSBNs. Manufacturing and construction work already accomplished on the early Skipjack-class SSNs was redirected to constructing the SSBNs.

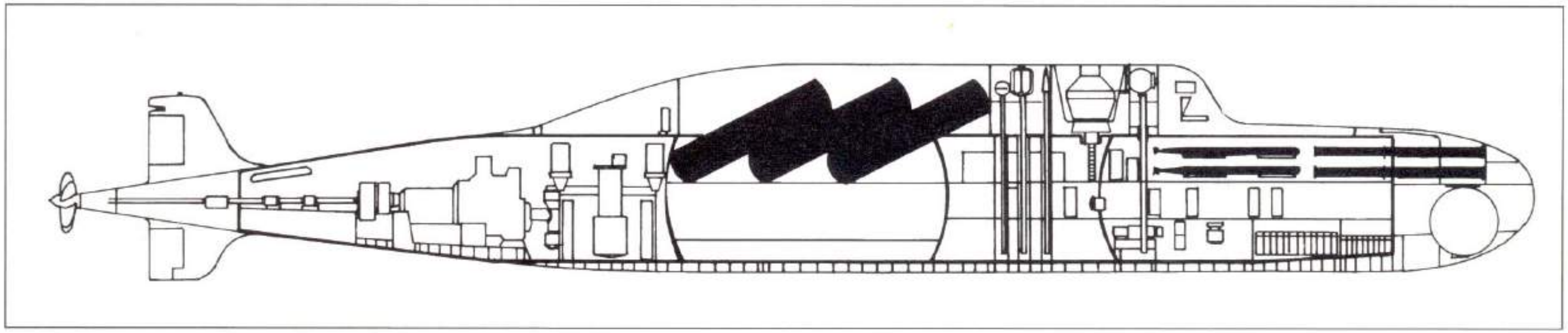
# Project 667V

## Yankee SSBN re-armed with anti-ship ballistic missiles

- A concept was developed under Project 667V for a Yankee SSBN variant armed with R-27K anti-ship ballistic missiles and equipped with with the D-5K launch system.  This Yankee SSBN variant was not developed.
    - While the R-27K could fit in the launch tubes of the Project 667A and 667AU Yankee SSBNs, these subs lacked the necessary fire control system to target and launch the R-27K anti-ship version of the R-27 SLBM.
- The R-27K missile was developed and tested on the Project 605 Golf IV SSB from 1972 - 1975. While the R-27K was accepted for service on 15 August 1975, it never became operational, primarily because every launch tube used for an R-27K counted as a strategic missile under the SALT strategic arms agreement.  The strategic warheads on the R-27 & R-27U SLBMs were more important than the R-27K's unique anti-ship capability.
    - See the "Submarine-launched ballistic missiles (SLBM)" section for more information on the R-27K missile.

# Project 705A

## A cruise missile (SSGN) variant of the Project 705 SSN



*Project 705A/Alfa cruise missile variant.* (©A.D. Baker, III)

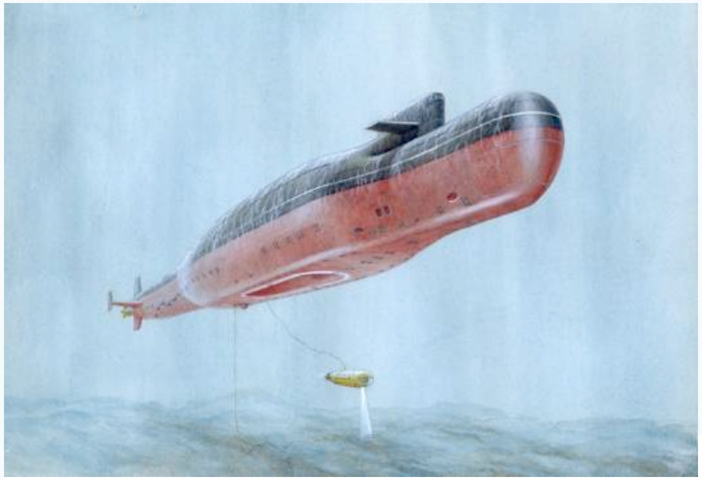
Source: Figure from Norman Polmar & Kenneth J. Moore; "Cold War Submarines, The Design and Construction of US and Soviet Submarines"; Brassey's, Inc.; 2004, p. 163.

- The Project 705 Alfa-class SSN was designed by the Malakhit Central Design Bureau, St. Petersburg. The first Alfa SSN entered service in 1971. The Project 705A SSGN was a mid-1970s adaptation of this basic design:
  - Modified to carry two rows of three large, watertight, inclined cylinders aft of the sail, each containing one P-70 Amethist / SS-N-7 anti-ship cruise missile. This was the first Soviet cruise missile designed for submerged launch; launch depth was 30 - 40 m (98 – 131 ft).
  - The cruise missile features increased the Alfa sub's surfaced displacement from 2,264 tons to 2,385 tons.
- Project 705A was not developed. The P-70 Ametist anti-ship cruise missile was deployed on Charlie I-class SSGNs starting in 1968 and on the single Papa SSGN in 1969.

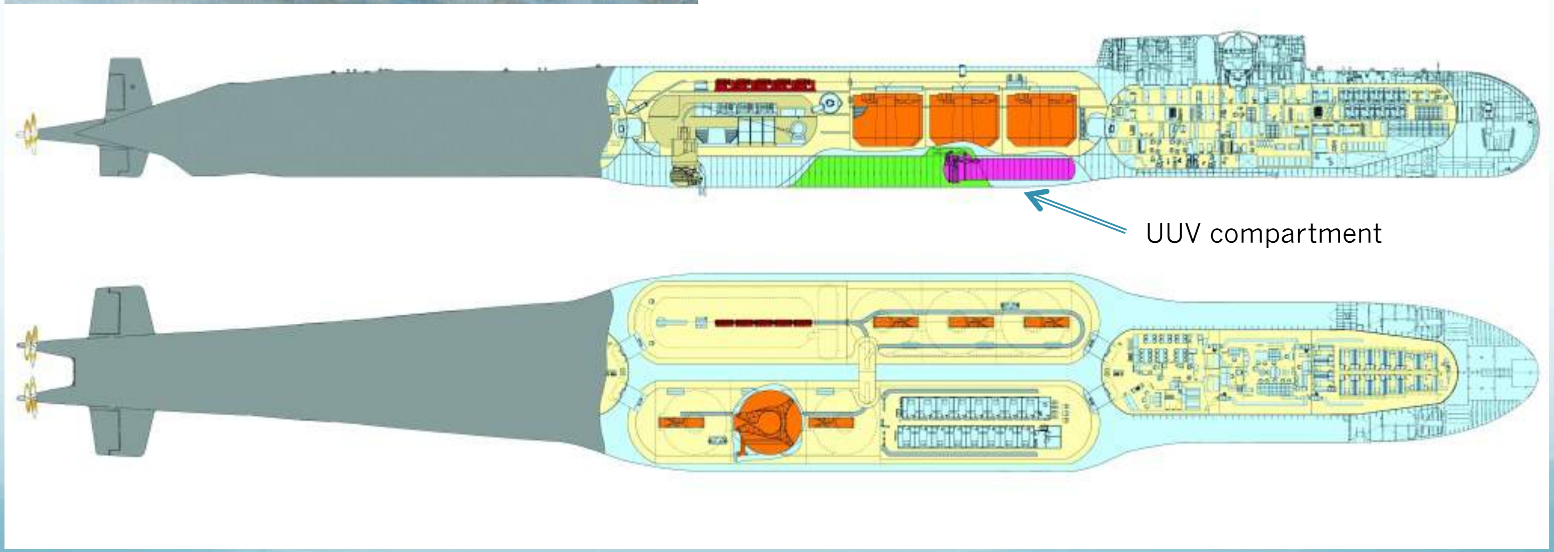
# Nuclear-powered cable-laying submarine

- In the 1990s, the Ministry of Communications of the Russian Federation commissioned Rubin Central Design Bureau for Marine Engineering, St. Petersburg, to study the feasibility of an underwater vehicle to be used for cable laying and maintenance under the Arctic ice pack.
- Rubin proposed using decommissioned Project 941 (Typhoon SSBN), Project 667 BDR (Delta III SSBN) and Project 949 A (Oscar II SSGN) missile submarines for this purpose. This approach made efficient use the empty missile compartment space inside the pressure hull of the SSBNs.
- Rubin engineers adapted existing cable laying technology from surface cable vessels to the unique environment of a submarine cable-laying vessel.

# Delta III SSBN adapted for Arctic cable-laying

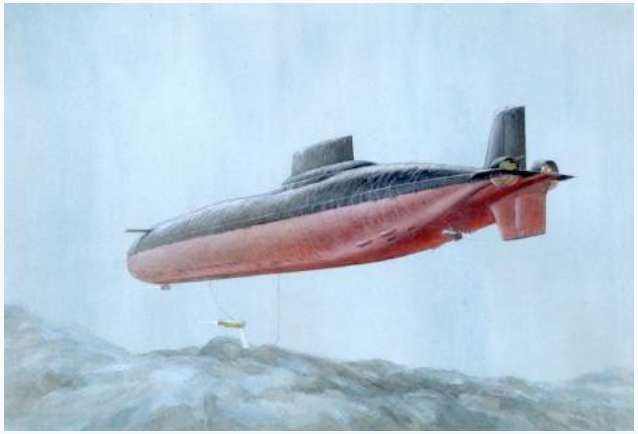


- The original Delta III missile compartment would be replaced by parallel hull sections containing cable storage, cable-laying gear, and facilities for storing and operating an unmanned underwater vehicle (UUV) to assist in cable-laying operations. The UUV is shown in the accompanying diagram (left).
- The original bow and engineering compartments would be retained.

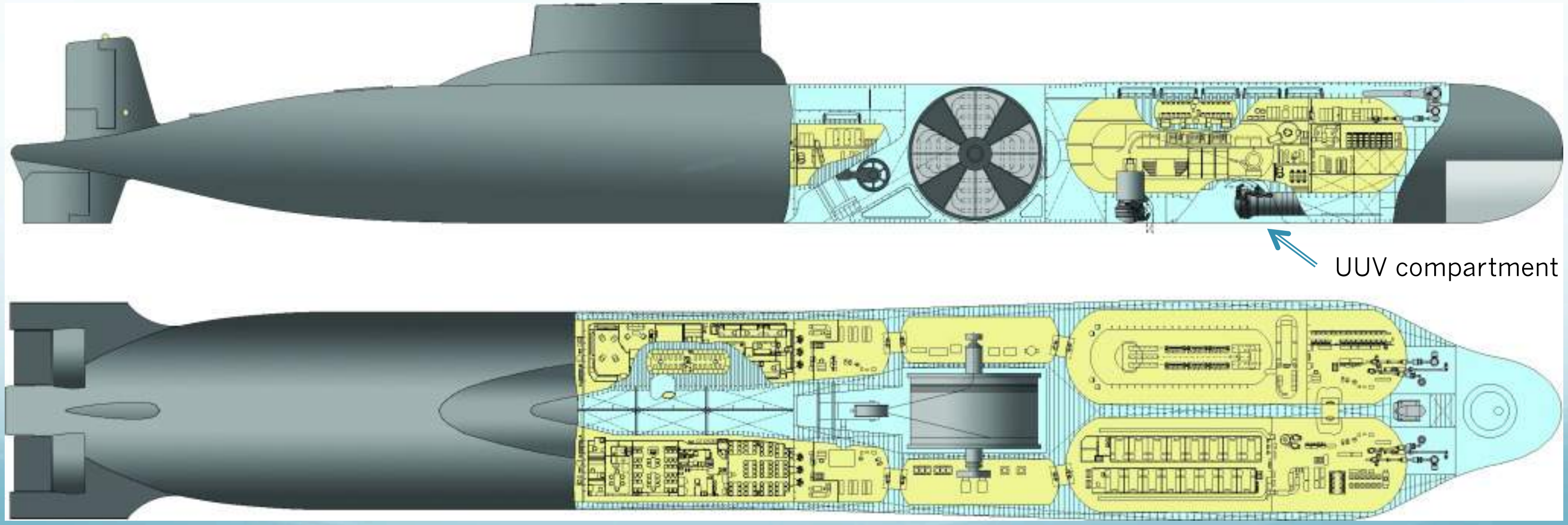



Source: http://ckb-rubin.ru/en/projects/other_projects/underwater_cable_laying_ship/

# Typhoon SSBN adapted for Arctic cable-laying

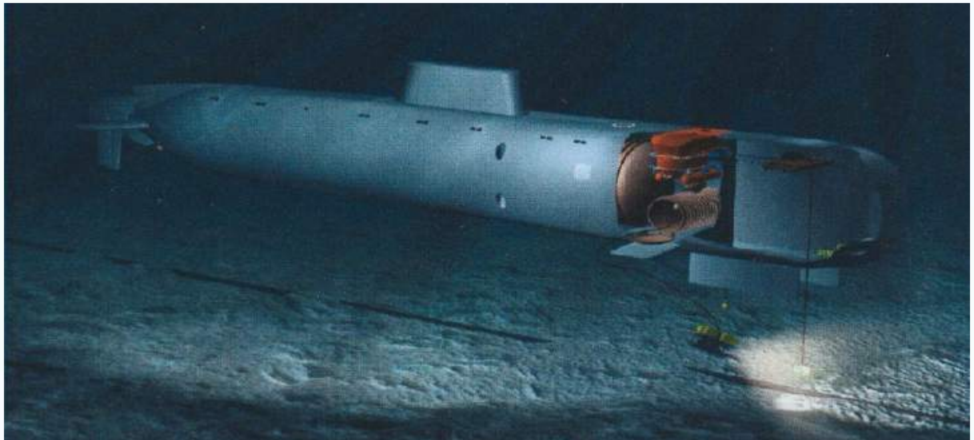


- Major redesign of the entire forward half of the Typhoon sub to accommodate cable storage, cable-laying gear, and facilities for storing and operating an unmanned underwater vehicle (UUV) to assist in cable-laying operations. The UUV is shown in the accompanying diagram (left).
- The aft half of the Typhoon sub would be retained, including the engineering compartments.




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

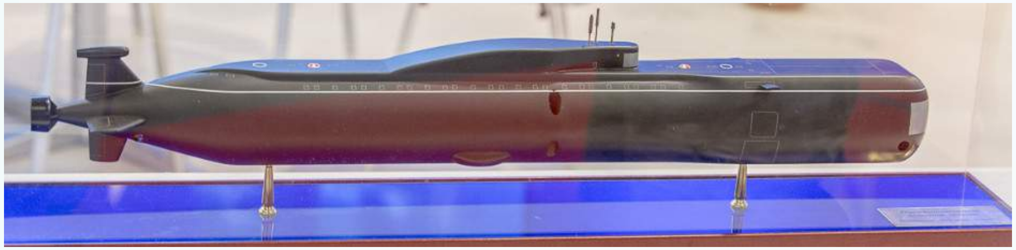
# Multifunctional underwater station (MPS), circa 2010



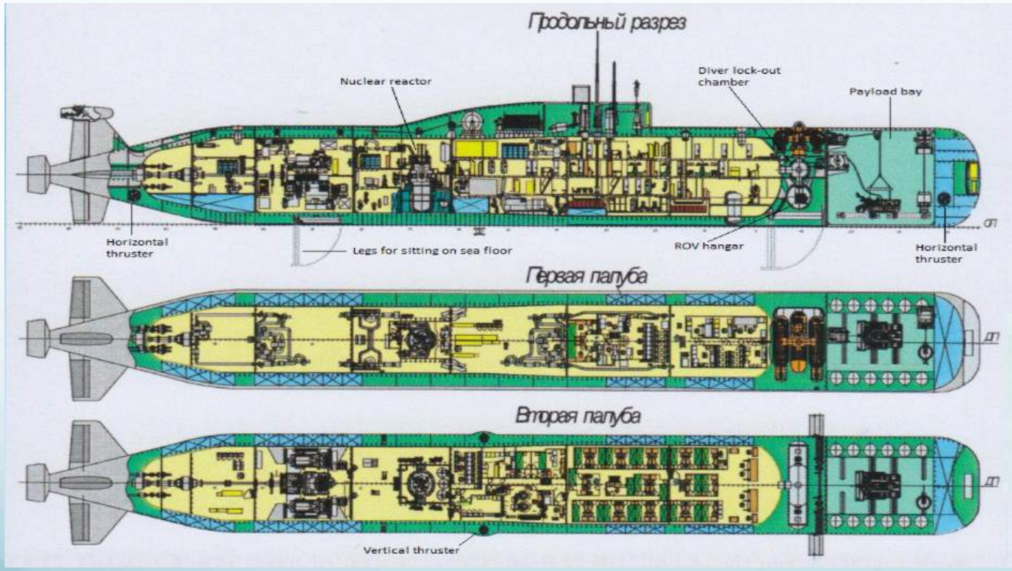

Source, both graphics: http://www.hisutton.com/Unbuilt_Russian_Spy_Subs.html

- Proposed by the Russian Ministry of Industry and Trade in 2010.
- Length: 115 m (377 feet)
- Beam: 11 m (36 feet)
- Displacement: 5,800 tons surfaced
- Speed: 12 knots
- Operating depth: 400 m (1,312 feet)
- The bow structure included a massive 1,060 cubic meter (37,434 $ft^3$) integral payload bay (about as large as a three story house) allowing the sub to place or retrieve large items on the sea floor.
- Capable of operating multiple unmanned underwater vehicles (UUVs) and divers.
- Unspecified nuclear reactor driving a single main pumpjet propulsor and auxiliary thrusters.

# Multifunctional underwater station (MPS), circa 2012 - 2015



Lazurite's MPS display at the Naval Show in St. Petersburg, 2015




Source, photo and graphic:
http://www.hisutton.com/Unbuilt_Russian_Spy_Subs.html

- In 2012, Lazurite Central Design Bureau proposed a similar MPS design.
- Length: 117 m (384 feet)
- Beam: 15 m (49 feet)
- Speed: 13 knots
- Operating depth: 400 m (1,312 feet)
- The bow structure included a massive integral payload bay with bottom access to the sea floor and doors on top to facilitate dockside loading and unloading.
- Capable of operating multiple unmanned underwater vehicles (UUVs) and divers.
- Unspecified nuclear reactor driving a single main pumpjet propulsor and auxiliary thrusters.