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The Arctic Nuclear Challenge






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Preface

This is the third Bellona report on potential sources of radioactive contamination of the Arctic. While the two former reports (1994 and 1996) mainly focused on identifying the sources, this report also present solutions to secure spent nuclear fuel and radioactive waste. In support of the ongoing efforts to safely secure this waste, this report describes various new projects proposed by Bellona in order to solve the problems of further radioactive contamination and the ensuing adverse health effects to the people living in the Arctic areas.

Most of the nuclear safety challenges in the Arctic are related to the legacies of the cold war. The spent nuclear fuel storage sites in Andreyeva Bay and in Gremikha, the laid-up nuclear submarines and the large volume of radioactive waste at the bases and naval yards along the cost of the Kola Peninsula are the legacy left to our generation from the past decades. International co-operation in the work to secure nuclear waste generated during the arms race must replace the earlier mistrust that raged between the nations.

Nuclear safety is not a task solely for officials, state agencies and private business. The civil society plays the most important role in providing public support and establishing the right priorities when projects are discussed and new solutions must be found. As a pragmatic non-governmental organisation, Bellona is searching for solutions to head off the problems of potential Arctic radioactive contamination. It is important to protest against the current radioactive contamination coming from the British reprocessing plant in Sellafield, but it is equally important to propose projects aimed at preventing future contamination coming from the retired nuclear submarines and rundown storage sites for spent nuclear fuel at the Kola Peninsula.

Through our offices in Oslo, Murmansk, St Petersburg, and Washington, D.C., we have worked to establish contacts and mutual understanding between Russian, European and American authorities and corporations. Our offices in Brussels and Washington, D.C. have been working for years to establish a political understanding in the European Union and in the United States as to why it is important to maintain a strong international co-operation with Russia in nuclear safety projects. Today, the political willingness to assist in nuclear waste cleanup projects in Northwest Russia is greater than the ability to implement those projects. Bellona hopes that this report will assist in concretising this ability by carrying out projects such as a new intermediate storage for spent nuclear fuel at the Kola Peninsula.

The contents of this report will be redesigned into a web-friendly version and will be updated continuously. The updates will track all of the developments and changes in the issues described in this report to provide comprehensive up-to-date information for decision-makers and the general public. Check www.bellona.org for updates.

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Oslo, June 13th 2000.

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This report is a part of the Bellona report series on nuclear issues in Russia. The two former reports published in 1994 and 1996 are available on the web:
Report 1-94 "Sources to Radioactive Contamination in Murmansk and Arkhangelsk Counties"
www.bellona.no/1-94/
Report 2-96 "The Russian Northern Fleet – Sources of Radioactive Contamination"
www.bellona.no/2-96/
This report, 3-01 "The Arctic Nuclear Challenge"
www.bellona.no/3-01/

The Bellona Foundation

The Bellona Foundation was founded as anNGO in 1986. The Foundation is a science based environmental organisation whose main objective is to combat problems of environmental degradation, pollution-induced dangers to human health and the ecological impacts of economic development strategies.

Bellona aims to present feasible solutions with the least impact on human activity. Bellona strives to inform the public, and in particular lawmakers, opinion leaders and the media about environmental hazards, and helps draft policy responses to these problems.

Bellona works towards international co-operation and legislation to protect nature and improve the environment, in support of the public's right to enjoy clean air, soil and water, and to guarantee the provision of correct information about the threats against the environment.

Bellona has been involved in environmental questions concerning North-West Russia and the Arctic since 1989. With our reports on nuclear safety issues we hope to contribute to solutions to the challenges and public awerness about the nuclear safety problems in the Arctic. Established in 1994, our branch office in Murmansk has been working intensivly towards this goal.

You will find more information about Bellona Foundation at our web-site www.bellona.org Information in Russian about Bellona Murmansk and St Petersburg is avalible at www.bellona.ru

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List of abbreviations

alfa-particles	two protons and two neutrons
gamma-radiation	high energy electromagnetic radiation
alfa-activity	from radioactive sources emitting a-particles
gamma-activity	gamma-activity, from radioactive sources emitting g-radiation
Bq	becquerel, unit for radioactivity; 1 Bq = 1 disintegration per second
TBq	terabecquerel = 10^{12} Bq
PBq	petabecquerel = 10^{15} Bq
m	metre
km	kilometres, 1,000 meters, 1 km = 0,62 miles
m3	cubicmetres
t	metric tonnes, 1,000 kg
VVER-440	Soviet-design nuclear reactor, pres surised water reactor
RBMK	Soviet-design nuclear reactor, graphite-moderated reactor
AEA Technology	British nuclear company
AMEC	Arctic Military Environmental Co-operation, between Russia, Norway and USA
BNFL	British Nuclear Fuel, British nuclear company
CTR	Co-operative Threat Reduction-programme
DG XI	EU's Directorate-General for Environment, Nuclear Safety and Civil Protection
EPA	Environmental Protection Agency (United States)
EU	European Union
GAN	Gozatomnadzor, Russian radiation protection authority
IAEA	International Atomic Energy Agency
MinAtom	Russian Ministry of Atomic Energy
MSCo	Murmansk Shipping Company
SGN	French nuclear company
SKB	Swedish nuclear company
TACIS	EU's programme for Technical Assistance to the Commonwealth of Independent States
VNIPIET	All-Russia Research Institute for Industrial Technology
SSN	Attack submarine, nuclear powered
SSBN	Strategic ballistic missile submarine, nuclear powered
SMS	Special mission submarines
PWR	Pressurised water reactor
LMCR	Liquid metal cooled reactors

Executive summary

The handling and haphazard storage of radioactive waste and spent nuclear fuel constitute two of the most major environmental and social challenges in the Murmansk and Archangelsk region, both now and in the foreseeable future. Spent nuclear fuel from the Northern Fleet and the civilian nuclear icebreaker fleet has been stored in temporary storage facilities on land or on board various types of vessels since the early 1960s. Less than half of the spent nuclear fuel that has accumulated over the years from naval reactors on the Kola Peninsula has been transported to the Mayak reprocessing facility.

In recent years, Russian methods for the handling, storage, transport and deposition of spent nuclear fuel and radioactive waste have come under increasing criticism throughout Russia and the world. Practices of the Russian military in handling nuclear waste, especially spent nuclear fuel, are particularly criticized. Not only are standard safety measures routinely neglected, but in addition a firm lid of secrecy has blocked any constructive approaches for solving the problems. The consequences are particularly apparent on the Kola Peninsula; indeed there is no other place in the world where such large amounts of spent nuclear fuel are so improperly stored as at the Kola naval bases.

The spent nuclear fuel which is temporarily stored at Andreyeva Bay and Gremikha on the Kola peninsula, as well as the fuel that remains inside the reactors on board retired nuclear submarines or aboard various storage vessels, must be properly secured and moved to a new, environmentally safe storage.

In the Northern Fleet today there are less than 40 nuclear submarines in active service and some 71 retired submarines still containing their spent nuclear fuel. In total there is fuel from about 250 submarine reactors in onshore storage facilities, storage ships or laid-up submarines. The total amount of fuel is around 100 tons. At least 32 nuclear submarines have been dismantled at the five shipyards Nerpa, Zvezdochka, Sevmash, Shkval and Sevmorput. There are at least 35 reactor sections laid up in Sayda Bay, all of which must be properly secured as radioactive waste. In addition comes another 14,000 cubic meters of radioactive waste.

Murmansk Shipping Company (MSCo) currently operates six nuclear icebreakers and one nuclear powered container ship. MSCo also has two laid up nuclear icebreakers. About 20 to 25 nuclear reactor cores are stored on board vessels at MSCo's own base Atomflot. In addition comes radioactive waste from regular operations.

At Kola Nuclear Power Plant (NPP) there are four VVER 440 type reactors currently in operation. The two oldest (Kola 1 & 2) have been identified as some of the world's most risky reactors. On the order of 8,200 cubic meters of solid radioactive waste and 7,000 cubic meters of liquid radioactive waste are currently being stored at Kola NPP in addition to some 1,300 tons of spent nuclear fuel.

Even though around 38,000 TBq of radioactive waste and spent nuclear fuel have been dumped in the Arctic seas, the small radioactive contamination that can be detected today in actual fact originates from other sources. The main sources are the atmospheric nuclear testing in the 1950s and 1960s, the Chernobyl accident in 1986 and the continued releases from the Sellafield reprocessing plant in United Kingdom. It is worth mentioning that the present contamination is low, and the typical level of radioactivity in fish meat is about 0,25 Bq/kg.

To prevent future pollution from the overfilled and rundown storage facilities for radioactive waste and spent nuclear fuel in north-west Russia, Bellona encourages and supports the construction of new waste treatment facilities in the Kola region. These facilities should provide the necessary infrastructure to handle and prepare radioactive waste and spent nuclear fuel for safe storage. The facilities must also include a safe temporary storage for radioactive waste and spent nuclear fuel for the next 50 years.

For a long time, disagreements over taxation and liability issues have led to delays in the development of the various international projects. For example, it remains uncertain who would be responsible in the event of an accident in Russia involving equipment manufactured in another country. Furthermore, the Russian authorities have levied import duties of up to 50% on equipment and services paid for by other countries.

In May 1998, a bilateral framework agreement between Norway and Russia was signed through the Norwegian Plan of Action for Nuclear Safety Issues. This agreement came into being to resolve the taxation and liability issues for a number of specific projects, namely the Lepse project, upgrading nuclear safety at the Kola NPP, upgrade of the Murmansk liquid radioactive waste treatment facility and other projects covered by the framework agreement. But the framework agreement does not encompass multinational projects which were to have been implemented with the participation of other countries. This means that the question of taxation and liability for these projects must be settled separately.

As a follow up to this bilateral agreement, much effort has been put into the Multinational Nuclear Environmental Program for the Russian Federation (MNEPR). The goal of this multinational co-operation would be to obtain a binding, general agreement on legal protection covering all countries willing to participate in the reduction of nuclear dangers in Russia. But so far, no agreement has been signed.

Once signed there should be one less obstacle to start and complete international projects. One of the most pressing projects would be to construct interim storage facilities for spent nuclear fuel and radioactive waste, including necessary infrastructure to handle damaged spent nuclear fuel.


Andreeva-Bay
Malaya Lopatka
Bolshaya Lopatka
Nerpichya
Zaozersk
Ara Bay
Barents Sea
Vidyaevo
Ura-bay
Iceland
Russia
EU
Sayda-Bay
Nerpa
Skalisty
Olenya Bay
Snezhnogorsk
Polyarny
Severomorsk
Roslyakovo
Murmansk
Naval base
Shipyard
Spent-fuel
Radioactive waste
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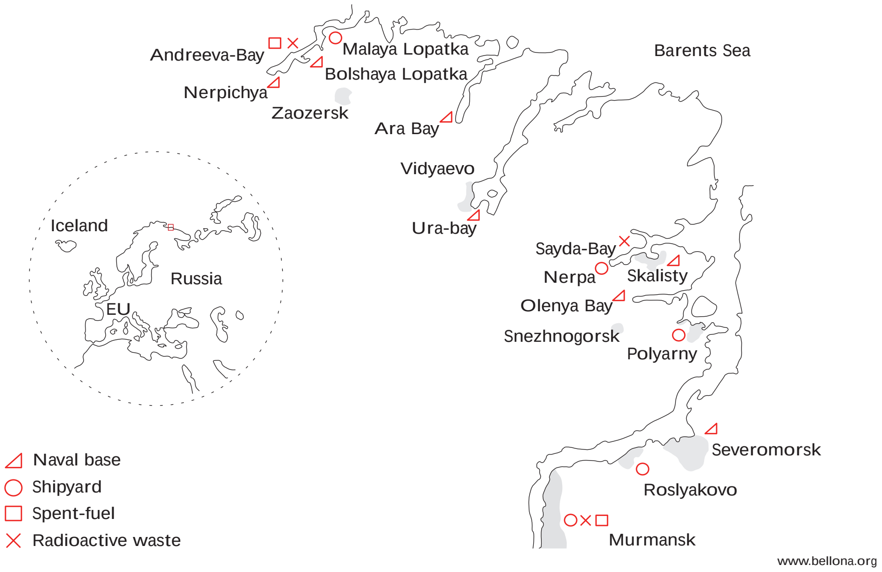
Chapter 1

The Russian Northern Fleet

The Russian Northern Fleet

The Russian Northern Fleet is the largest of the four Russian naval fleets. While there are no nuclear powered vessels in the Baltic and Black Sea fleets, the Pacific Fleet and the Northern Fleet have operated nuclear powered vessels for more than 40 years. Approximately two thirds of all nuclear powered vessels are assigned to the Northern Fleet at the Kola Peninsula and one third were based at Pacific Fleet bases in the Russian Far East.

From the time that the first nuclear powered submarine, Leninsky Komsomol (K-3) first entered service in 1959, the cold war arms race developed far too fast for the Soviet authorities to plan how to dispose of the nuclear waste that would be generated both from the operating vessels, and later, from the decommissioning of the submarines. During the cold war, six new naval bases with nuclear submarine



facilities were created along the ice-free cost of the Kola Peninsula. Over the course of the ensuing years, six naval yards were built or refitted on the Kola Peninsula and in Severodvinsk for the construction and maintenance of nuclear submarines. Most of the spent nuclear fuel and radioactive waste were accumulated at the naval yards and submarine bases, except for the waste which was dumped in the Barents and Kara Seas.

The development of infrastructure for handling and storing spent nuclear fuel and radioactive waste at the bases and naval yards lagged far behind the rate at which the submarines themselves were being built. A certain number of facilities for the handling and treatment of radioactive waste existed only on the drawing board. Construction of many facilities for the treatment and storing of waste was started, but never completed, and of the facilities that actually were built, many have been taken out of service, such as the spent nuclear fuel storage at Andreeva Bay and in Gremikha, for example.

Following the disintegration of the Soviet Union in 1991, the Northern Fleet has undergone significant changes. From the peak in the late 1980s with more than 120 nuclear powered submarines in operation, there are less than 40 submarines in operation in the Northern Fleet in 2001.

The overhanging danger of accidents and radioactive leakage from laid-up nuclear powered submarines and run-down storage sites for spent nuclear fuel and radioactive waste increases from year to year. Both from an environmental and economic perspective, it is important that the decommissioning of the nuclear powered submarines and the securing of storage sites for spent nuclear fuel and radioactive waste is undertaken quickly.

One of the major challenges in the handling of radioactive waste and spent nuclear fuel is the sheer number of the locations where these activities take place. The lack of a central storage and handling facility makes the whole process very ineffective. Below is an overview of the various naval bases and shipyards where spent nuclear fuel and radioactive waste are managed.

Naval bases

Zapadnaya Litsa

- Nerpichya – base point for the Typhoon submarines;
- Bolshaya Lopatka–base point for the Oscar-II and Victor-III submarines; there are at least 10 laid-up sub-marines in this location;
- Malaya Lopatka – repair base with floating workshop;
- Andreeva Bay – main storage site for spent nuclear fuel and radioactive waste.

Vidyaevo

- Ara Bay, Ura Bay - base point for Akula class, Sierra class and Oscar-II class submarines, in addition to at least 17 laid-up submarines.

Gadzhievo

- Skalisty, Olenaya Bay – base point for Delta-III class and Delta-IV class submarines as well as one Yankee class submarine, in addition to at least four laid-up submarines.

Sayda Bay

- storage site for submarine reactor compartments kept afloat at piers, at least 30 reactor compartments.

Severomorsk

– home base for the Northern Fleet – three nuclear powered battle cruisers.

Gremikha

– 17 laid-up submarines and a storage site for spent nuclear fuel and radioactive waste, as well as six reactor cores unloaded from submarines with liquid metal cooled reactors.

Shipyards under the Ministry of Shipbuilding

Severodvinsk

- Sevmash – construction of new submarines and decommissioning of retired submarines; storage facilities for liquid and solid radioactive waste.
- Zvezdochka – repair of submarines and decommissioning of retired submarines; storage facilities for liquid and solid radioactive waste.

Nerpa – repair of submarines and decommissioning of retired submarines.

Northern Fleet shipyards, under the Ministry of Defence

Sevmorput

– repair of submarines and decommissioning of retired submarines.

Roslyakovo

– repair of large submarines.

Shkval

– repair of submarines and decommissioning of retired submarines.

1.1. Nuclear naval vessels

In the period from 1955 till 2001, a total of 248 nuclear powered submarines and five nuclear powered surface ships were built for the Soviet (later Russian) Navy. The nuclear powered submarines can be divided into the following four groups:

Ballistic missile submarines (SSBN)
Guided cruise missile submarines (SSGN)
Torpedo attack submarines (SSN)
Special mission purpose submarines (SMS)

Nuclear submarines were built at four shipyards in the former Soviet Union. These are Sevmash in Severodvinsk, Amursky at Komsomolsk-na-Amur in the Far East, Krasnoye Sormovo in Nizhny Novgorod and at Admiralty shipyard in St Petersburg. Today, construction of nuclear powered submarines is only undertaken at the Sevmash yard in Severodvinsk. One unfinished Akula class submarine is still in the workshop at Amursky shipyard.

The technological development of submarines can be divided into generations. Three generations of nuclear powered submarines have been built, and the first of the upcoming fourth generation is currently under construction at the naval yard in Severodvinsk. All submarines of the first generation have been taken out of service and are awaiting decommissioning. Also, most of the second generation as well as some third generation submarines have also been taken out of operation.

The first generation submarines were built between 1955 and 1966. The second generation submarines were built from 1963 to 1992, and the third generation submarines have been built in the period from 1976 until the present. Construction of the first submarine of the fourth generation began in 1993.

In addition to the three generations of submarines, four prototype submarines and seven attack submarines of the Alfa class with liquid metal cooled reactors have been built. None of them is in active operation today. Three classes of nuclear mini-submarines were also built, but it is unclear whether they remain in operation.

Since 1974 four nuclear powered cruisers, Project 1144 – Kirov class, have been built. These are Admiral Ushakov (1980), Admiral Lasarev (1984), Admiral Nakhimov (1988) and Pyotr Veliky (1995). Today, only Pyotr Veliky is in active service, based in Severomorsk. A nuclear powered communication ship, Project 1941 – Kapusta-class (SSV-33 Ural), was commissioned in 1989 but it was taken out of service shortly after entering service.

Following the development and launching of the different generations of submarines, four generations of submarine reactors were developed, including a number of prototype reactors. The great majority of reactors used in the naval vessel were pressurised water reactors (PWR).

Some of the prototype reactors were cooled with liquid metal. One of these was installed in the hull of a November class vessel. Only one type of the prototype liquid metal cooled reactors (LMCR) went into serial production. This reactor was used in the submarines of Project 705 – Alfa class.

The reactors onboard the surface vessels are similar in design to the PWR-type reactors onboard the civilian nuclear powered icebreakers. The thermal power of Russian submarine reactors varies from 10 MWh for the smaller reactors used in the mini submarines, to 200 MWh

Project	NATO-class	Type	No. built	No. of reactor(s)	Total reactors in class	Vessels still in operation	
						NF	PF
1st generation							
627 A	November	SSN	13	2	26	0	0
658	Hotel	SSBN	8	2	16	0	0
659/675	Echo I/Echo-II	SSGN	34	2	68	0	0
2nd generation							
667 A	Yankee	SSBN	34	2	68	1	0
667 B-BDRM	Delta I-IV	SSBN	43	2	86	10	6
670	Charlie I-II	SSGN	17	2	34	0	0
671 RT/RTM	Viktor I-III	SSN	48	2	96	8	2
3rd generation							
941	Typhoon	SSBN	6	2	12	3	0
949 /A/	Oscar I-II	SSGN	13	2	26	5	5
945	Sierra	SSN	4	1	4	3	0
971	Akula	SSN	13	1	13	6	7
4th generation							
935	Borei	SSBN	Under construction	1		0	0
LMCR							
705	Alfa	SSN	7	1	7	0	0
Prototype							
645 ZhMT	Novemberdesign	SSN	1	2	2	0 (dumped)	0
661	Papa	SSGN	1	1	1	0	0
685	Mike	SSN/SMS	1	1	1	0 (sank)	0
885	Severodvinsk	(unclear)	Under construction	1	1	0	0
Mini submarines							
10831		SMS	1	1	1	?	
1851	X-ray	SMS	1	1	1	?	
1910	Uniform	SMS	3	1	3	?	
Surface vessels							
1144 (Orlan)	Kirov		4	2	8	1	0
1941 (Titan)	Kapusta		1	2	2	0	0
Total			**253**		**475**	**37**[1]	**20**

Table 1.
Nuclear powered vessels built the Soviet Union/Russia in the period 1958-2001

1 **This number does not include SMS submarines.**

for the reactors in the fourth generation submarine(s). The majority of Russian submarines carry two reactors, but the newer submarines are equipped with one single reactor.

The future of Russian nuclear powered submarine forces
Despite the end of the cold war, Russia has clearly stated that the Northern Fleet will remain the most important part of her nuclear strategic arm forces. If Russia fulfils the terms of the START-II treaty, by the year 2007 more than 50 percent of Russia's strategic nuclear warheads will be placed on nuclear submarines, most of them assigned to the Northern Fleet. According to the START-II treaty, a maximum of 1,750 nuclear warheads may be placed on submarines. Most likely, the number will be even less than this by 2007.
It is likely that the Northern Fleet will maintain its fleet of

seven Delta-IV submarines until the new Borei class strategic missile submarines enter service sometime after 2007. In addition, the attack submarines of the Akula class and the Oscar-II class cruise missile submarines will be maintained in active service. The nearest future of the Typhoon submarines is unclear, but most likely the Typhoons will be taken out of active service within the next few years.

1.1.1. First generation submarines

From 1955 to 1966, a total of 57 first generation nuclear submarines were built, of which there were 13 Project 627 A - November class, 8 Project 658 - Hotel class, 5 Project 659 - Echo-I class and 29 Project 675 - Echo-II class vessels. Two prototype submarines were also built which can be referred to as first generation submarines: one Project 645 – November class vessel with a liquid metal cooled reactor and one Project 661 – Papa class submarine.
By 1994, all first generation nuclear submarines had been taken out of active service.[2] One November class submarine, K-8, sank in 1960. The prototype Project 645 – November class vessel with the liquid metal cooled reactor was dumped in the Kara Sea near Novaya Zemlya in 1981. The defuelling and decommissioning of the first generation submarines have been very slow so far. As may be seen in Table 1, only 14 out of the 55 first generation submarines, have been defuelled. As of today, only two have been completely dismantled. Five submarines – two Echo-IIs, one November and two Hotels – have been partially dismantled and placed in Sayda Bay for storage.
The relatively low rate of progress in decommissioning the first generation vessels as compared to the strategic submarines (SSBNs) of the second generation can be explained by the lack of funding and proper infrastructure. The sheer technical difficulties of the undertaking are also a challenge in that some of the submarines have been laid up with spent nuclear fuel in their reactors for more than 15 years.
The decommissioning of SSBNs is primarily funded by the United States through the Cooperative Threat Reduction (CTR) program. The first generation submarines are not included in any CTR programmes since they do not pose a potential threat to American national security.
Five of the first generation submarines are located at Gremikha, the easternmost base at the Kola Peninsula, and 11 submarines are in Vidyaevo base. Neither of these two bases are equipped to defuel submarines. The submarines must be towed to a shipyard to be defuelled, an operation that is made even more complex and difficult by the poor technical condition of the submarines.

1.1.2. Second generation submarines

From 1963 to 1992, a total of 142 second generation submarines were built. There were 77 ballistic missile submarines (SSBNs) including 34 Project 667A – Yankee class vessels, 18 Project 667B – Delta-I class vessels, 4 Project 667BD – Delta-II class vessels, 14 Project BDR – Delta-III class vessels and 7 Project 667BDRM – Delta-IV class vessels. One of the Northern Fleet's Yankee class submarines, K-219, sank in 1986 north of the Bermuda Islands.
48 second generation attack submarines (SSNs) (or, in accordance with Russian classification, general purpose submarines), were built. These included 15 Project 671 – Victor-I class vessels, 7 Project 671RT – Victor-II class vessels, and 26 Project 671RTM – Victor-III class vessels. In addition, 17 second generation cruise missile submarines (SSGN) entered service, including eleven Project 670A – Charlie-I class vessels, and six Project 670M – Charlie-II class vessels. All of the Charlie-I class submarines were assigned to the Pacific Fleet.
Of the 142 second generation submarines built, 114 have been taken out of service, of which 69 belonged to the Northern Fleet. About 93% of the submarines dismantled are SSBNs that were taken out of service in compliance with the START-I treaty.
CTR has up to date funded the dismantling and scrapping of 14 SSBNs, while six SSBNs are being eliminated under CTR with work in progress both in the Northern Fleet and the Pacific Fleet. Two more SSBNs are on contract.
16 SSBNs have been dismantled with Russian funds, but in most cases with the use of CTR's equipment.
Since CTR provides support only for the dismantling of the SSBNs, only two out of 65 second generation attack and cruise missile submarines have been decommissioned so far in the Russian Navy.
Of the second generation SSNs and SSGNs in the

2 All first generation submarines can be classified as general purpose, or SSNs. Hotel class submarines were designed to carry cruise missiles, but in the period from 1977 to 1985 all of them were redesigned, and their missile sections removed in compliance with the SALT-I agreement.

Northern Fleet, 28 are not being defuelled as the Northern Fleet lacks the necessary facilities and equipment to be able to carry out the operation. In 1999-2000, the nuclear support vessel Imandra, operated by the civilian Murmansk Shipping Company (MSCo), defuelled three Victor-II class submarines. However, the engagement of MSCo's nuclear support fleet in the future will be greatly dependent on available funding in the Russian budget, which thus far has been very inadequate.

In the next five years, Russia will remove at least three Delta-III submarines and one Delta-IV vessel from service. Most of the remaining eight Victor-III class vessels will be taken out of service as well.

1.1.3. Third generation submarines

A total of 36 nuclear powered third generation submarines were built in USSR/Russia between 1976 and the present day, including six ballistic missile submarines of Project 941 – Typhoon class; 13 cruise missile submarines including two Project 949 – Oscar-I class and 11 Project 949A – Oscar-II class vessels; and 17 attack submarines including four Project 945 – Sierra class and 11 Project 971 – Akula class vessels. One of the Northern Fleet's Oscar-II class submarines, K-141 (Kursk), sank on August 12, 2000. Unique as they are in type, the seven attack Alfa class submarines equipped with liquid metal cooled reactors cannot strictly speaking be referred to as third generation submarines; however, they are listed here anyway.

The Typhoon class submarine TK-202 arrived in Severodvinsk for decommissioning operations in July 2000. The dismantlement process was to be funded by CTR. In Russia, the plans to decommission this Typhoon have been rather controversial. CTR, however, announced that the Russian Navy had planned to scrap a total of five Typhoons by the year 2001. Other reports suggest that at least three Typhoon submarines will remain in service, assuming that their missile system is upgraded. The precondition to that is available funding. The first submarine of the Typhoon class, TK-208, has been under repairs and upgrading for almost 10 years, but is expected to enter active service again over the course of 2001.

All of the Alfa class submarines have been withdrawn from service, four of which were decommissioned at Sevmash shipyard. Two more Alfa class submarines are laid up at Bolshaya Lopatka in the Zapadnaya Litsa Fjord. The defuelling of these vessels is complicated, as the liquid metal coolant has frozen in their reactors. The facilities at the Gremikha base (located in the eastern part of the Kola Peninsula) must first be repaired before they can be used to remove the fuel from the two submarines. The remaining submarine has been scrapped and its reactor compartment cut out but not defuelled. The reactor compartment is currently being stored on Yagry Island in Severodvinsk.

Two Oscar-I class submarines have been withdrawn from service and are awaiting decommissioning at Severodvinsk shipyards. The remaining 10 Oscar-IIs may remain in service until 2020, assuming that the Granit weapon system installed on them is upgraded. However, funding has not been availalbe to develop the new Granit system, so it is quite probable that the Oscar-IIs may be taken out of service during the coming 10 years. Two more Oscar-II class submarines were to be built, but there is no information as to whether construction has commenced.

All of the Sierra class submarines remain in active service, except for the first submarine, Karp, which was taken out of service in 1998.

Project/Class	Number laid up NF/PF	With fuel NF/P	Without fuel NF/PF	Dismantl NF/PF
627/November	9[3] /4	6/2	2/2	0/0
658/Hotel	6/2	3/1	3/1	0/0
659/Echo-I	0/5	0/5	0/0	0/0
675/Echo-II	15/14	12/10	2/4	1/0
661/Papa	1/0	0/0	0/0	1/0
Total	**31/25**	**21/18**	**7/7**	**2/0**

Table 2.
First generation submarines

The Akula class attack submarines are the most modern submarines in the Russian Navy. A new Akula class, Gepard, is due to enter service in the Northern Fleet in 2001. Two more Akula class submarines are under construction, one in Severodvinsk and one in the Russian Far East.

Project/Class	Number built NF/PF	In service NF/PF	Laid-up NF/PF With fuel	Without fuel	Dismantle NF/PF
667A/Yankee	24[4] /10	1/0	10/10	0/0	11/1
667B/Delta-I	9/9	0/0	2/6	0/0	7/3
667BD/Delta-II	4/0	0/0	0/0	0/0	4/0
667BDR/Delta-III	5/9	3/6	0/0	0/3[5]	2/0
667BDRM/Delta-IV	7/0	7/0	0/0	0/0	0/0
671/Victor-I	12/3	0/0	11/3	0/0	1/0
671RT/Victor-II	7/0	0/0	4/0	3/0	0/0
671RTM/Victor-III	16/10	8/2	8/8	0/0	0/0
670A/Charlie-I	0/11	0/0	0/11	0/0	0/0
670M/Charlie-II	6/0	0/0	5/0	0/0	1/0
Total	**89/52**	**19/8**	**40/38**	**3/3**	**26/4**

Table 3.
Second generation submarines

1.1.4. Nuclear powered surface vessels

Since 1974 four nuclear powered battleships, Project 1144 - Kirov class, have been built and taken into service, namely the Admiral Ushakov, the Admiral Lazarev and the Admiral Nakhimov. In 1999, the fourth one, the Pyotr Veliky, entered active service in the Northern Fleet.

A nuclear powered communication ship of the Project 1941 – Kapusta class (SSV-33 Ural), was based with the Pacific Fleet, but was later laid up because it was too complex for the Navy to operate.

Project/Class	Number built NF/PF	In service NF/PF	Laid-up NF/PF With fuel	Without fuel	Dismantl NF/PF
941/Typhoon	6/0	3/0	3/0	0/0	0/0
949/Oscar-I	2/0	0/0	2/0	0/0	0/0
949A/Oscar-II	6[6] /5	5/5	0/0	0/0	0/0
945(A)/Sierra	4/0	3/0	1/0	0/0	0/0
971/Akula	6/7	6/7	0/0	0/0	0/0
705/Alfa	7/0	0/0	3/0	0/0	4/0
Total	**31/12**	**17/12**	**9/0**	**0/0**	**4/0**

Table 4.
Third generation submarines

The main problem with nuclear powered battle cruisers is the lack of properly equipped naval bases and facilities for servicing their reactors. In addition to the problem of reactor maintenance, the ships' diesel motors are worn out. Hence, virtually none of these ships are operative, and are therefore laid up. Secondly, another serious drawback is the lack of naval base facilities for refuelling the reactors.

Summing it up, the only operational nuclear surface vessel is the battle cruiser Peter the Great. The four others will have to be decommissioned in the coming years. This might

3 November class submarine, K-8, sank in 1960.
4 Yankee class submarine, K-219, sank in 1986.

5 These three SSBNs are being eliminated with work in progress under CTR.
6 The Oscar-II class submarine Kursk, sank on August 12, 2000.

be a challenge for Russia as there is no experience available in decommissioning large nuclear powered vessels.

1.2. State agencies responsibilities

The management of the spent nuclear fuel and radioactive waste that is generated in the course of operation of nuclear powered submarines, as well as the maintenance of laid-up nuclear powered submarines has been the domain of the Russian Navy ever since the first nuclear submarine entered service in 1959.

In the first part of 1990s, the number of submarines retired from active service grew exponentially, becoming a burden for the Navy's scarce budget. The Navy leadership expressed great displeasure with the situation, stressing that

it was not in fact the direct responsibility of the Defence Ministry to manage and secure radioactive waste and retired nuclear submarines.

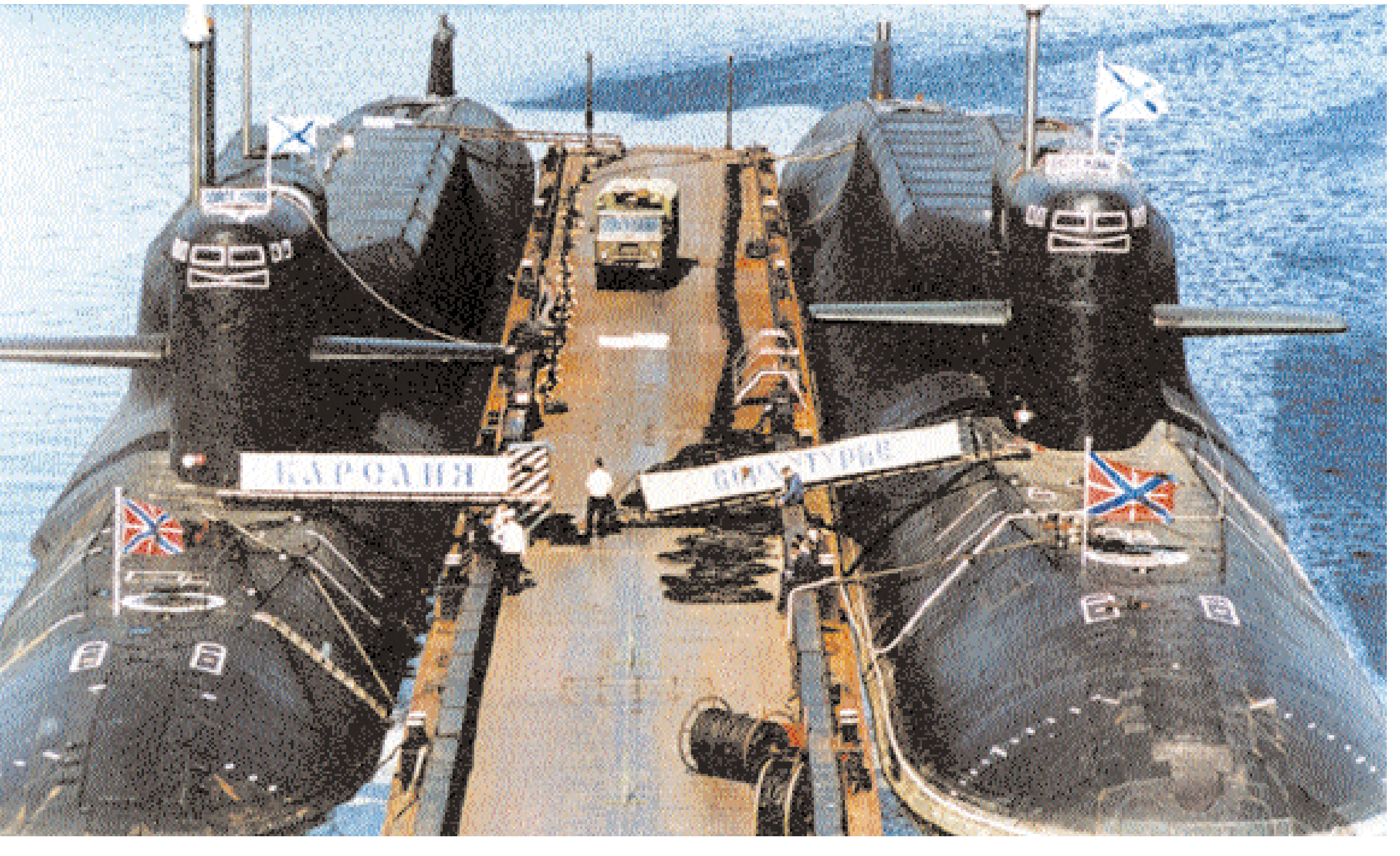
1.2.1. Transfer of Responsibility to Minatom

On May 28, 1998, the Russian government issued Decree No. 518 entitled Concerning Measures to Accelerate the Decommissioning of Nuclear Powered Submarines and Nuclear Powered Surface Vessels Withdrawn from Active Service and the Environmental Remediation of Radioactive Hazardous Sites of the Russian Navy. The decree appointed the Russian Ministry for Nuclear Energy (Minatom) to manage and co-ordinate efforts for decommissioning submarines.[7]

The main function of Minatom is to co-ordinate the decommissioning process, to manage radioactive waste (radwaste) and spent nuclear fuel, to design and to implement the upgrades in infrastructure required to carry out the work. Most of the federal funding specifically earmarked for these issues is managed by Minatom as well.

Minatom is also responsible for developing a master plan to manage radwaste and spent nuclear fuel issues for the entire Russian nuclear complex. This master plan is being developed in compliance with the federal program Nuclear and Radiation Safety in the Russian Federation 2000 - 2006 as approved February 22, 2000 by governmental decree No. 149. The earlier version of this program, decree No. 1030, approved on October 23, 1995 with a time frame from 1996 to 2005 was abandoned. The naval radioactive waste management related issues now form a component of the master plan.

Minatom, however, does not assume full responsibility for



7 Cherneyev, V., Bulletin of Nuclear Energy Information Centre, No.8, 2000.

the retired submarines. The transfer of a retired submarine from the Russian Navy to a shipyard for decommissioning is conducted through the Ministry of Property. After the submarine is defuelled and dismantled, the scrap metal is sold by the shipyard, while the reactor compartment, sometimes filled with radioactive waste, is transferred to a storage place which in the future is expected to fall under the authority of Minatom. In practise, it is still the navy that is responsible for the reactor compartments.[8]

To fulfil the terms of Decree No. 518, Minatom, the Ministry of Defence, and the Ministry of Economy worked out a plan to transfer 125 retired nuclear submarines from the navy to the shipyards where decommissioning procedures were to be carried out. The transfer was set to take place from 1998 to 2000, but at present it lags behind schedule due to unresolved issues involving both the civilian crews at the shipyards who are charged with keeping the retired submarines in safe condition and the lack of proper safety regulations in place. The replacement of military crews with civilian workers may result in greater risks of submarines sinking right at the pier plants due to the shipyards lacking in the necessary experience needed to keep the vessels afloat. Furthermore, the shipyards have no rescue services, whereas the navy at least has the minimum number of ships and infrastructure required to tackle emergencies. The new schedule for the transfer has not yet been announced.

Minatom is also working on taking over storage sites for spent nuclear fuel and radioactive waste which once were under the auspices of the navy. Beginning from 1998, a regional branch of Minatom called SevRAO started working in Murmansk. SevRAO plans to take over the storage sites located in Andreeva Bay and Gremikha on the Kola Peninsula. A similar enterprise has been planned for the Pacific Fleet in the Far East.

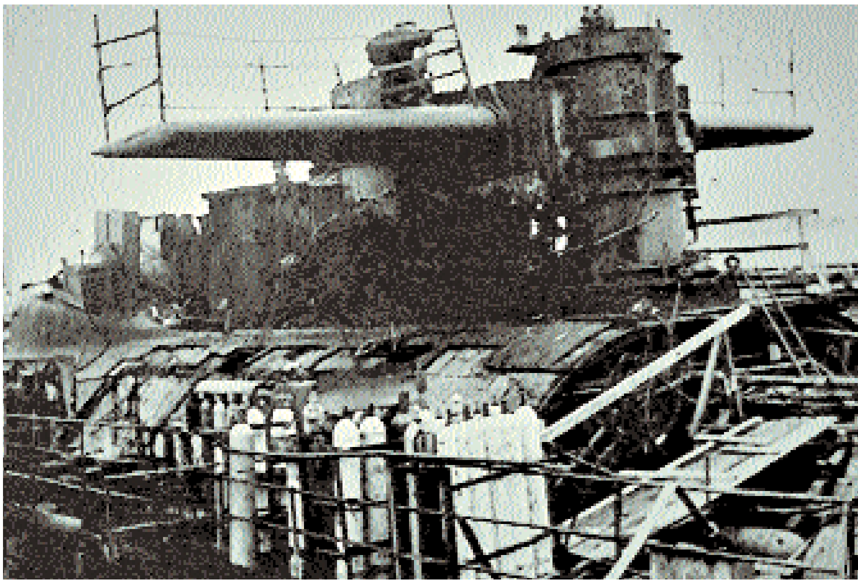
Prior to Decree No. 518, which formally transferred coordinating responsibilities to Minatom, the nuclear ministry was already in charge of the administration of naval radioactive waste to a great degree. To implement the programs already existing at the time, Minatom granted the St Petersburg-based enterprise Nuclide the responsibility to manage navy-related projects in north-west Russia. Nuclide was established in the early 1990s and was primarily engaged in the trade of isotopes manufactured at Minatom's plants. The Russian Nuclear Regulatory, GAN, stated on various occasions that Minatom had no right to contract Nuclide to implement the projects, pointing to Nuclide's lacking competence in this specific area. Consequently, with the creation of SevRAO at the Kola Peninsula which reports directly to Minatom, there is a conflict between those two organisations.[9]

1.2.2. Nuclear Regulatory

The Russian State Nuclear Regulatory Authority, Gosatomnadzor (GAN) was founded after the Chernobyl accident and is responsible for ensuring safety during usage of nuclear energy.

In compliance with the objectives set for it, GAN organises and implements state safety regulations over the usage of nuclear energy, nuclear materials, radioactive substances, and materials containing radioactive substances, both in civilian and military fields of application.

In 1993, through the utilisation of a presidential decree, the Ministry of Defence lobbied to deprive GAN of the right to regulate activities related to development, manufacturing, testing and usage of nuclear weapons and military nuclear power installations. The presidential decree of September 16, 1993, No. 636 Concerning the Partial Amendment of GAN's Set of Rules, in effect handed over the regulatory function over these activities to a division of the Defence Ministry called the State Regulatory Authority for Nuclear and Radiation Safety. Despite the fact that the department was called 'state' it still had a ministerial function in its also being a part of the Defence Ministry. The formal grounds of the decree was the endeavour to avoid transparency of state military programs and to ensure the



safeguarding of state secrets. The stated objective of the decree was merely an excuse in that all GAN inspectors working with military sites are former officers and retired admirals with the same degree of security clearance as the officers from the Ministry of Defence. Neither the Defence Ministry nor Minatom were open to allowing their sites to be inspected by an independent regulatory agency.

In other words, the 1993 presidential decree withdrew the military nuclear installations from a state regulatory authority independent of ministry regulation and control.

In 1995, the utilisation of nuclear energy during the development, testing, operation and decommissioning of nuclear weapons, as well as its usage in military nuclear power installations were all removed from the jurisdiction of the Law on Application of Nuclear Energy.

Thus, activities within a military application of nuclear energy are not only beyond independent state regulation in today's Russia, but also beyond the law. The Law on Application of Nuclear Energy lays the foundation and principles to regulate conditions emerging from the application of nuclear energy, including the provisions directed towards the protection of human life, health, the natural environment. There are no other laws regulating this sphere in Russia.

In 1999, governmental decree No. 1007, pushed through by Minatom and the Defence Ministry, deprived GAN of the right to licence military nuclear-related activities, including

8 Interview with deputy nuclear minister, V. Lebedev, Nuclear Control magazine, no.6, November-December 2000.

9 GAN report submitted to the head of the Ministry for Emergency Situations, 1999.

the decommissioning of nuclear powered submarines. This responsibility was transferred to Minatom.

At present, the Russian government has prepared a bill, initiated by Minatom, which has been sent to the State Duma for a hearing. The bill calls for an amendment to the Law on Application of Nuclear Energy whereby all licensing responsibility is transferred to Minatom.

These limitations of GAN's right to regulate the application of nuclear energy both in the military and civilian context are a matter of great concern. It is an issue, along with problems of nuclear liability that constitutes a serious roadblock to the implementation of international projects.

At present, GAN can still inspect shipyards, which are subjects to the Ministry of Economy, but lacks the authority to licence their nuclear related activities. It is still unclear whether GAN will be permitted access to earlier military nuclear storage sites which are now being gradually transferred to Minatom.

1.3. Decommissioning of nuclear submarines

At this time, 183 submarines have been taken out of service in the Russian Navy. Of these, 113 are located with the Northern Fleet. The rest are in the Pacific Fleet. Only 36 submarines have been dismantled (see Table 5). Most of the dismantled submarines are second generation vessels.

	Retired	Laid-up with fuel	Laid-up without fuel	Dismantled
Northern Fleet	113	71 (130 reactor cores)[10]	10[11]	32
Pacific Fleet	70[12]	56 (101 reactor cores)	10	4[13]
Total	**183**	**127 (231 reactor cores)**	**20**	**36**

Table 5.
Retired nuclear submarines in the Northern and Pacific Fleets.

Since the middle of the 1980s, nuclear submarines have been taken out of service. There is a great shortage of qualified technical facilities coupled with a lack of sufficient funding to carry out decommissioning work. The slow tempo of the decommissioning process has led to nuclear submarines being laid up for up to 15 years with their spent nuclear fuel still remaining inside their reactors. In view of the age of the submarines, there is a risk of their sinking at the piers. In a report prepared by Minatom and titled Nuclear and Radiation Safety in Russia, it was stated that as many as 30 submarines in the Russian Navy may sink, if they are not soon dismantled.[14]

Russian nuclear submarines are being decommissioned for three reasons. Firstly, some of the vessels are more than 25 years old and past their effective operational life. Some of the submarines have undergone serious accidents and are beyond repair. Secondly, the greatly reduced Russian defence budget precludes maintenance and upgrading of the large cold war force of nuclear submarines established by the Soviet Union. Thirdly, international disarmament treaties, such as START-I and START-II aimed at reduction of naval strategic forces require a reduction in the number of submarines.

Until the middle of the 1980s, older nuclear submarines were kept in service as long as possible. Most of the vessels were very run down, and some of them spent up to ten years in ship repair yards, only to be retired shortly afterwards. The only submarines to have been taken out of service were those whose fuel assemblies were so badly damaged that refuelling was impossible. These vessels were laid up, but most of them had their reactor sections cut out and dumped into the Kara Sea. With new reactor sections installed they continued their service. One submarine, K-27 (November class with two liquid metal reactors) was dumped in its entirety in the Kara Sea in 1981.

1.3.1. Laid up submarines environmental risks

The old age of the hulls of laid up submarines increases the risk of the submarines simply sinking at the piers where they are laid up. The consequences of a sunken submarine are aggravated by the fact that most of the oldest first generation submarines still have spent nuclear fuel inside their reactors.

A submarine is kept afloat with the help of ballast tanks, which can be filled with air. These ballast tanks consist of three groups; located in the stern, the bow and the midpart of the submarine.

To reinforce the surface floating capabilities, the ballast tanks located in the mid-part of the submarine have one regular valve and one emergency valve. When diving, the air is pushed out of the mid-part ballast tanks through the regular valve. But air can still escape from the ballast tanks when the valves are sealed if the ballast tanks are leaky or if the valve seal is damaged. Repairs of the ballast tanks system are usually carried out in a dock.

Air from the ballast tanks can be released from a moored submarine in stormy weather. The ballast tanks are being filled with water and the floating capability of the submarine is reduced. All submarines are designed to stay afloat even if one of the compartments or two of the ballast tanks on the starboard or portside are flooded. Most of the first generation submarines have leaky ballast tanks, which increases the risk of sinking.

To keep the submarines afloat the ballast tanks have to be refilled periodically with air from onshore facilities. Each submarine is also designed to have its own high-pressure air to use in emergency situations.

The hull of a submarine has hundreds of external valves, which require regular maintenance. Such maintenance can only be carried out in dock. If the valves are damaged, water can then seep into the submarine's compartment. If the adjacent ballast tanks are also damaged, the submarine can sink.

The sinking of a laid-up submarine with spent nuclear fuel onboard represents a threat to the environment. In order to enhance the nuclear safety of laid up submarines, their primary circuit is secured with a solidifying matter, the electricity cables to the control rods are cut off and the control grid is set to a fixed position.

Those measures can provide nuclear safety in regular situations but in the event of an emergency, such as sinking or capsize, they may prove to be insufficient. It is unclear, for example, whether water can penetrate into the primary circuit, and, hence, into the reactor, as a consequence of the vessel sinking and the ensuing increase of pressure with increasing depth. Should such a situation occur, it could lead to radioactive contamination of the water and greatly complicate defuelling efforts when the submarine is raised.

10 Minatom says 12 more submarines were defuelled in 2000, February 2001.
11 Five first generation submarines have been partially dismantled and placed in Sayda Bay for storage.
12 Minatom says 73 submarines have been taken out of service in the Pacific Fleet, 49 submarines (93 reactor cores) have not been defuelled, October 2000.
13 Minatom says 18 submarines have been dismantled in the Pacific Fleet, October 2000. By the definition of dismantled in this report we understand that a submarine has been defuelled, and the reactor compartment with adjacent two compartments, or with attached pontoons is towed to a storage site. Some of the submarines both in the Northern Fleet and in the Pacific Fleet were defuelled and towed as a whole to a storage site. A submarine in such condition is not considered to be dismantled in this report. For details about individual submarines refer to 'Classification of nuclear powered naval vessels' subchapter.
14 Nuclear and Radiation Safety in Russia, report for the Russian government meeting, Moscow 2000.

Under ordinary circumstances, the probability of an uncontrolled chain reaction is close to zero. But what happens when a submarine capsizes and hits the seabed is hard to predict. The development of an uncontrolled chain reaction is possible in such situation if, for example, the control grid is torn off its fixed position.

Past experience indicates that the most high-risk work is in refuelling or defuelling the reactor. Approximately 50 different technical operations are carried out during the process, 25 percent of which may potentially expose the operators to radiation. The risks are higher during defuelling of first generation submarines, as their reactor installations do not meet any modern safety requirements.

In the 1990s, a safer method was developed for removing spent nuclear fuel from pressurised water reactors on submarines. First, the reactor tank is emptied of the water before the work begins. This water slows the neutrons inside the reactor. By removing the water from the tank, the risk of an uncontrolled chain reaction in the reactor core is reduced. The drawback with this method is that the level of radiation in the reactor compartment increases dramatically because there is no longer any water present to moderate the neutrons. Subsequently, extra measures must be taken to prevent the exposure of the workers to radiation. Hence this method of defuelling can only be carried out on submarines that have been laid up for a number of years whereby the level of radiation has decreased naturally.

1.3.2. Decommissioning process

Until 1986, there were no formal plans for decommissioning obsolete nuclear submarines. In 1986, the Central Committee of the Communist party and the Supreme Soviet ratified Decree No. 095-296 which laid down formal procedures for decommissioning and dismantling inactive nuclear submarines. The decree contained the following main points:

-Weapons and other important equipment to be removed. Vessels to be laid up with reduced crew in suitable locations.

- Fuel elements to be removed from the reactor.
- Decommissioning of vessel by cutting out the reactor compartment. Non-contaminated metal to be reused.
- Sealing and transporting the reactor compartments to suitable locations for long term storage. Storage to be undertaken where radiation safety is maintained and can be verified.

These guidelines have been followed until today. In connection with this, a special decree governing safety routines for laid-up nuclear submarines was ratified in early 1988. It was not until 1991, under the precepts of Resolution No. 714/13/0105, that the Russian Navy adjusted its guidelines for delivering inactive submarines for dismantling.

In July 1992, the Russian government ratified Decree No. 514, which called for the trial decommissioning of nine nuclear powered submarines, including two attack submarines, four ballistic missile submarines and three Alfa class attack submarines with liquid metal cooled reactors. The work was to be done at shipyards, which now fall under the auspices of the Ministry of Economy, but at the time answered to the Ministry of Military Industry. The submarines defuelled by the navy were transferred to the shipyards for the period of the decommission work. The cut out reactor sections, sometimes filled with solid radioactive waste, were returned to the navy, whose responsibility was to provide their safe storage. All the reactor compartments were towed to Sayda Bay at the Kola Peninsula for storage afloat.

The approach rested on the assumption that the shipyards would receive as payment for their work in decommissioning the submarines the proceeds from the sale of scrap metal and even earn some profit. The navy, facing harsh economic times, expressed great displeasure with such an approach, and demanded a part of the profit. The navy also demanded that part of the retired submarines should be transferred back to the shipyards, (which also fell under the auspices of the Defence Ministry), so that they too could also earn money.

The commercial aspect of the decommissioning work soon proved to be futile. The experience with the nine dismantled submarines showed that external funding was required to proceed with decommissioning work, while the sale of scrap metal covered only 20% of expenses.[15]

1.3.3. CTR funding

The Cooperative Threat Reduction program, or CTR, became one of the major (and the only external) contributors to the decommissioning of Russian ballistic missile submarines (SSBNs), which were taken out of service in compliance with the START-I arms reduction treaty (See chapter 'Projects to secure nuclear waste'). Starting in 1992 and proceeding until 1997, five submarines were dismantled in the Russian Navy utilising CTR equipment. After 1997, CTR started to contract directly with the shipyards themselves concerning the dismantling of the SSBNs, Nerpa at the Kola Peninsula, Zvezdochka in Severodvinsk and Zvezda in the Russian Far East.

Six SSBNs are being eliminated under CTR with work in progress both in the Northern Fleet and the Pacific Fleet, including one Typhoon class, three Delta-III class and two Delta-I class vessels in 2001. Two more SSBNs are on contract, including one Delta-I and one Delta-III. CTR has also been notified that one Delta-IV class submarine will soon become available. Discussions are also being held about one Typhoon, two Delta-IIIs and one Delta-I class vessel.[16] Thus, CTR will fund in total the dismantlement of 27 SSBNs assuming that all of the planned contracts are fulfilled. In total, CTR's objective is to dismantle 31 SSBNs. The work will proceed at Zvezdochka shipyard in Severodvinsk and at Zvezda shipyard in the Far East.

In 1998, due to the lack of defuelling capacities and storage space for spent nuclear fuel, US officials granted CTR a waiver of the non-reprocessing policy. It was agreed that CTR would fund shipment of spent nuclear fuel to the Mayak reprocessing plant from 15 SSBNs dismantled on CTR's money.[17]

1.3.4. Minatom's engagement

The funding for nuclear powered submarines from the federal budget was and remains very scarce. In 1998, it was just over 4 USD million. However, starting from 1999, the major part of funding started to come from Minatom in compli-

15 Interview with deputy nuclear minister, V. Lebedev, Nuclear Control magazine, no.6, November-December 2000.
16 Public Affairs Office, the Pentagon, Washington D.C., 2001.
17 Kudrik, I., Jandl, T., CTR foots nuclear shipment bill, Bellona Web, August 4, 1999.

ance with governmental Decree 518 approved in 1998 (See 1.2 'State agencies responsibilities').

The tempo of defuelling activities kept pace with the budet increase. In 1998, four nuclear submarines were defelled in the Northern Fleet, while in 1999, the number increased to six. I n 2000, according to official returns, 14 submarines were defuelled.[18] In 2001, 16 submarines have been earmarked for defuelling, assuming the availability of funding.[19] Minatom also has the responsibility to ensure that no superfluous infrastructure is built. According to Minatom, the number of submarines defuelled per year can easily be increased to 30, but this will require an expansion of a type of infrastructure which will become useless once the spent nuclear fuel is unloaded from all retired submarines. Minatom considers that the optimal solution would be to dismantle 20 to 25 submarines per year. At this rate, the problems revolving around decommissioning would be resolved within six to seven years. The cost would be around 71.4 USD million per year.[22]

	Yankee	Delta-I	Delta-II	Delta-III	Total
Nerpa		2	3		**5**
Zvezdochka		2	1	2	**5**
Zvezda	1	3			**4**
Total	**1**	**7**	**4**	**2**	**14**

Table 6.
Submarines dismantled with CTR funds until 2000.

Funding, $m	1998	1999	2000	2001 (planned)
Federal budget	4.1	6.4	5.1	-
HEU sales[20]	-	13.8	28.2	-
Minatom's budget	-	3.6	6.9	-
Total	**4.1**	**23.8**	**40.2**	**90.7**

Table 7.
Funding for decommissioning nuclear submarines in 1998-2001.[21]

1.3.5. Infrastructure capabilities

There are five shipyards in north-west Russia engaged in the decommissioning of nuclear powered submarines. Nerpa shipyard at the Kola Peninsula and Sevmash and Zvezdochka in Severodvinsk, Arkhangelsk county are under the authority of the Ministry of Economy. Sevmorput located in Murmansk and Shkval situated in Polyarny at the Kola Peninsula are under auspices of the Russian Defence Ministry.

The defuelling of nuclear submarines is primarily carried out by the Northern Fleet's two nuclear support vessels of the Project 2020 – Malina class, and by four Project 326M vessels (See subchapter 1.4.3 'Service ships for spent nuclear fuel'). The Project 326M vessels require overhaul repairs, which is regularly conducted every 10 years.[23] The procedure can take up to two years and costs around 6 USD million for each vessel. Minatom funded maintenance of the Project 326M ships, with the last repairs on the three vessels having been performed in 2000. The vessels have no licence to sail between the various bases due to safety concerns and will consequently become stationary.[24] The spent fuel from these vessels will be collected by Murmansk Shipping Company nuclear support vessels Imandra and Lotta, which will further deliver the spent fuel to Atomflot base in Murmansk where it will be reloaded onto a special train. The spent fuel is then transported by rail to the Mayak reprocessing plant.

In 1998-1999, PM-63, a Malina class nuclear support vessel, stationed in Severodvinsk, was repaired with the use of CTR funds. The fuel unloaded from the submarine reactors in Severodvinsk was transported by rail to the Mayak plant from a fuel transfer point located there.

Murmansk Shipping Company's nuclear support vessel Imandra was also used in both 1999 and 2000 to defuel three Victor-II class submarines at Nerpa shipyard and at

18 Bellona has record of only two Victor-II class submarines that have been defuelled at Polyarny shipyard. The remaining 12 submarines may have been defuelled in Severodvinsk and at Nerpa, although the number is still too high.
19 Strategy for radwaste and spent nuclear fuel management in Murmansk county, Murmansk county administration, Murmansk 2001.
20 Russia's highly enriched uranium sales to the USA are performed in compliance with the HEU-LEU agreement signed by both countries in 1993. Minatom will earn around $12 billion until 2013 by selling 500 tons of HEU. In the period from 1995 and until 2000, Minatom received USD 1.6 billion. The major part of the sum came in 1999 and 2000.20
21 Report for Cabinet meeting. Minatom of the Russian Federation. "Nuclear and Radiation Safety of Russia", Moscow.
22 Interview with deputy nuclear minister, V. Lebedev, Nuclear Control magazine, No.6, November-December 2000.
23 Cherneyev, V., Bulletin of Nuclear Energy Information Centre, No.8, 2000.
24 Strategy for radwaste and spent nuclear fuel management in Murmansk county, Murmansk county administration, Murmansk 2000.

Shkval shipyard in Polyarny. The vessel continues to perform defuelling operations at various shipyards and naval bases.[25]

The Northern Fleet's nuclear support fleet has the capacity to defuel a maximum of eight submarines per year. The Imandra can defuel a maximum of three to four submarines per year.

The Northern Fleet possesses eight sets of equipment which are specially used in the defuelling of first and second generation submarines, all of which require repair. The cost of repairing one set is around 400,000 USD . To manufacture a brand new set will cost one million USD. Repair work on these sets reportedly began in 1999.[26]

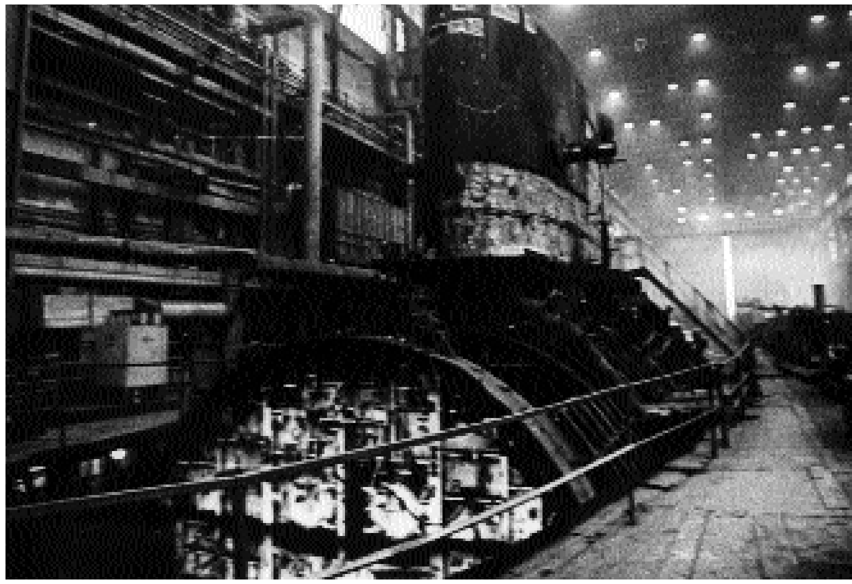
Shipyard No. 85 – Nerpa

Shipyard No. 85 Nerpa is situated innermost of Olenya Bay, and today, falls under the Ministry of Economy. The town of Snezhnogorsk, also known as Vyuzhny or Murmansk-60, is located approximately five kilometres south-west of Nerpa. Nerpa yard's principle task is the service and repair of second generation nuclear submarines. Nerpa has one dry and one floating dock, and it has also a set of equipment for transferring spent fuel to Project 2020 – Malina class ships. One of the Malina class ships, PM-12, is regularly stationed at Nerpa.

The Nerpa shipyard also dismantles second generation nuclear submarines. Per date Nerpa has decommissioned nine submarines, including five submarines funded by CTR. A new land based dry dock has been under construction at Nerpa since 1994. The dock was to be equipped with machinery manufactured in the United States and paid by CTR, including a Hughes Aircraft Systems International plasma torch for cutting tempered steel hull plates, which was commissioned in May, 1997. However, the land-based dry dock is unlikely to be completed in the near future as CTR has abandoned Nerpa and will now focus primarily on the Severodvinsk shipyards.

mantled at Sevmash. The servicing and most of the dismantling work on SSBNs are undertaken at Zvezdochka.

All in all, six submarines have been dismantled at Sevmash shipyard. One Typhoon class submarine is currently stationed at Sevmash, but no clear plans exist as to whether the submarine will be scrapped, upgraded or reconstructed to carry civilian cargoes under the Arctic ice. One Yankee class submarine was dismantled at Sevmash as an experiment to determine whether the yard can handle



such operations. Two Oscar-I class submarines are presently laid up at Sevmash awaiting decommissioning. Of the Alfa class submarines with titanium hulls, there are only two left, and these are stationed at Bolshaya Lopatka, Zapadnaya Litsa waiting to be dismantled. The process has been delayed in that the vessels' liquid metal cooled reactors must first be defuelled, and the facilities at the Gremikha naval base for removing the fuel from such reactors in Gremikha base are currently out of order.

K-no. (Factory no.)	Project/Class	Laid-up/repair period until decommissioning	Date of reactor compartment transfer to Sayda Bay
K-481 (N615)	671 – Victor-I	1994 – 1995	16/08 1995
K-479 (N903)	670M – Charlie-II	1995 – 1996	26/06 1996
K-450 (N312)	667B – Delta-I	1994 –1997	21/11 1997
K-465 (N326)	667B – Delta-I	1995 – 1998	15/09 1999
K-460 (N337)	667B – Delta-I	1998 – 1999	15/01 2000
K-421 (N354)	667BD – Delta-II	1998 – 1999	15/01 2000
K-92 (N342)	667BD – Delta-II	1999 – 2000	31/08 2000
K-182 (N341)	667BD – Delta-II	1999 – 2000	-
K-467 (N803)	671RT – Victor-II	1992 – 2000	-

Table 8.
Submarines decommissioned a Nerpa shipyard.

Severodvinsk shipyards – Zvezdochka and Sevmash

Severodvinsk lies on the White Sea, 35 kilometres west of Arkhangelsk, and has been a closed city ever since it was founded in 1936. Visitors to the town today require a security clearance from the Russian Security Police, the FSB. The town grew up around the two large shipyards Sevmash and Svezdochka which are located on the northern edges of the city and cover an area of 15 square kilometres. These are the largest naval shipyards in Russia and nuclear submarines are both built and serviced here. Both shipyards are subject to the Ministry of Economy. Sevmash is the only shipyard in Russia engaged in the construction of nuclear submarines for the Russian Navy.[27] Submarines with titanium hulls and one Yankee class submarine have been dis-

Zvezdochka has dismantled 17 SSBNs so far, five of which have been dismantled with CTR funds. One more Delta-I is due to be dismantled shortly, also utilising CTR funds. It is expected that Zvezdochka will dismantle 11 Yankee class submarines in the future, and discussions are also being held with CTR concerning the dismantling of one Delta-I and one Delta-IV submarine.

Severodvinsk storage capacity for spent nuclear fuel is limited by the Project 2020 – Malina class nuclear service ship, which can hold around six submarine reactor cores at a time. This explains why the tempo at which decommissioning occurs is largely dependent on the speed at which the fuel is unloaded from the submarines and shipped on to

25 Kudrik, I., Russian Navy contracts civilians to manage spent fuel, Bellona Web, August 31 2000.
26 Cherneyev, V., Bulletin of Nuclear Energy Information Centre, No.8, 2000.

27 Komsomolsk-na-Amur shipyard in the Russian Far East has still one unfinished Akula class submarine in construction berth.

the Mayak plant. CTR is currently funding the construction of a loading point in Severodvinsk to increase the decommissioning capacity in Severodvinsk (See Chapter 5 – 'Projects for securing nuclear waste').

Shipyard No. 10 – Shkval

Navy Yard No. 10 is situated near the town Polyarny outermost of the western side of the Murmansk Fjord. As the

Project/Class	K-no. (Factory no.	Date of reactor compartment transfer to Sayda Bay
667A – Yankee	K-214 (N452)	-
705 – Alfa	K-463 (N915)	1995
	K-316 (N905)	1996
	K-432 (N106)	1998
	K-493 (N107)	1998
661 – Papa	K-222 (N501)	~1998

Table 9.
Submarines decommissioned at Sevmash shipyard.

first nuclear powered submarines were delivered to the Northern Fleet at the end of the 1950s, the yard was modified for the docking and repair of these vessels. Tenders, service ships and dry docks were acquired, including the

Project/Classnono	K-no. (Factory no.)	Date of reactor compartment transfer to Sayda Bay
67A - Yankee	K-216 (N424)	1994
	K-415 (N451)	1994
	K-137 (N420)	~1995
	K-140 (N421)	~1995
	K-210 (N401)	1995-1996
	K-228 (N470)	1995
	K-444 (N461)	1995
	K-241 (N462)	~1996
	K-418 (N418)	1999
	K-32 (N423)	1999
67B - Delta	K-279 (N310)	~1999
	K-385 (N324)	~1999
	K-472 (N338)	1999
	K-475 (N339)	1999
67BD - Delta-II	K-193 (N353)	1999
67BD - Delta III	K-441	-
	K-424	-

Table 10.
Submarines decommissioned at Zvezdochka shipyard.

floating dock PD-63. Around 1970, the yards were reorganised and partially expanded in order to handle the second generation of nuclear submarines.

At the present time, there are two covered floating docks at the yard. The total length of floating and stationary peer plant is 550 m. The yard has a surface area of 41,330 m^2 (446,000 sq. ft.). The yard has also a self-propelled barge with 150 tons payload, two onshore cranes with lifting capacity of 40 tons and 32 tons, two floating cranes with lifting capacity of 30 tons and 25 tons.[28] There are approx. 3,000 employees at the yard. The nearby town of Polyarny has just under 30,000 inhabitants.

At present, Yard No. 10 Shkval is the only Kola-based naval yard capable of accommodating and servicing both second and third generation submarines. Defuelling and refuelling of the submarines is carried out by the Navy's Project 326M ship stationed in Polayrny. In 2000, the civilian nuclear support ship Imandra was working at Polyarny defuelling two Victor-II submarines.

The Shkval yard is capable of processing 3-4 nuclear submarines at the same time. However, the shipyard has not been actively involved in the decommissioning work. The shipyard defuelled and likely dismantled the November class submarine K-5 in 1996. In 1999, the Echo-II class submarine K-172 (K-192) was defuelled and dismantled at Shkval. Some of the first generation submarines were partly dismantled at Shkval and later towed to Sayda Bay for storage. Currently there are four first generation submarines stationed at Shkval: two November class, one Hotel class, and one Echo-II class. Two second generation Victor-II class submarines defuelled by Imandra in 2000 are also stationed here. Shkval has experience and is likely to specialise in dismantling of first generation submarines.

Shipyard No. 35 - Sevmorput

Naval yard No. 35 Sevmorput is also a Northern Fleet naval repair yard located on the Murmansk Fjord in the Rosta district of Murmansk, between the nuclear icebreaker base Atomflot and the merchant harbour.

In addition to several large workshops, the yard operates two large dry docks. Until the end of the 1980s, the yard employed 5,500 workers, but today the number of employees is much smaller.

Sevmorput has been repairing first generation nuclear submarines since the close of the 1960s, and until 1991, the refuelling of nuclear submarines was also undertaken here. Today the shipyard also carries out repairs of second generation submarines. In 1991, county officials prohibited refuelling activities at this yard on the grounds of radiation safety concerns and the fact that the yard is located only a few hundred meters from more populous areas of the city. Defuelling activities were later resumed on the condition that a so-called dry defuelling method is used, whereby the cooling water is pumped out from the reactor. The civilian nuclear service ship Imandra is likely to perform the defuelling operations at the shipyard in the future.

There are presently two first generation Project 675 - Echo-II class and Project 658 - Hotel class submarines in the yard. The Project 658 - Hotel class submarine was defuelled in 1995.

1.4. Spent Nuclear Fuel Management

Spent nuclear fuel unloaded from reactors of nuclear powered submarines and surface vessels contains large amounts of radioactivity. When spent nuclear fuel is taken out of the reactor, one ton of the nuclear fuel contains from 950 kg to 980 kg of ^{238}U, from 5.5 kg to 9.6 kg of plutonium and smaller quantities of alpha-emitting isotopes (neptunium, americium, curium and other transuranium radionuclides).[29] The radioactivity reaches 26,000 Ci/kg in the spent nuclear fuel. According to our data, the average measurement of radioactivity for spent naval nuclear fuel stored at the bases of the Northern Fleet is around 750 Ci/kg.[30]

By the end of 2000, fuel from 118 reactor cores were being stored at onshore bases and nuclear service ships of the Northern Fleet, and a further 130 reactor cores still remained in the retired submarines.[31] A total of 248 reactor cores are stored at the Northern Fleet, corresponding to 99 tons[32] of spent nuclear fuel with radioactivity of 74.5 million Ci.[33]

According to the practice of the 1960s and 1970s for the closed fuel cycle, spent nuclear fuel unloaded from the reactor cores used to be preliminarily stored at pool type

28 Luzgin, V.A., Krukov A.I., Ways of Further Upgrade of Decommissioning Process at Polyarny shipyard, Tekhnologiya Sudoremonta, No. 2 2000.
29 Jaroshinskaya, A.A. 1996. Nuclear encyclopaedia. Moscow, p. 60.
30 Dovgusha, V.V. 2000. "Radiation Situation in North-west of Russia", p. 91.
31 Report for Cabinet meeting. Minatom of the Russian Federation. "Nuclear and Radiation Safety of Russia", Moscow, p. 23, 28.
32 It is assumed here that one submarine reactor contains 400 kg of uranium.
33 Report for Cabinet meeting. Minatom of the Russian Federation. "Nuclear and Radiation Safety of Russia", Moscow, p.22-23, 58-59.

storage facilities for 5 to 10 years. After that it was loaded into special transport casks and shipped by train to the Mayak reprocessing plant, RT-1.

The Northern Fleet used to have two pool storage facilities for spent nuclear fuel, situated at Andreeva Bay and in Gremikha. After these two facilities were taken out of operation, spent nuclear fuel was stored in dry storage facilities and containers in Andreeva Bay, Gremikha, onboard the nuclear support ships and in the reactors of the retired submarines. Six reactor cores unloaded from the liquid metal cooled reactors are stored in Gremikha. These cannot be reprocessed.[35]

1.4.1. Andreeva Bay

Spent fuel from nuclear powered vessels has been collected spanning a period of 40 years. The largest storage for spent nuclear fuel is located in Andreeva Bay, which is situated on the north-western side of the Kola Peninsula. The distance to the Russian-Norwegian boarder is 55 km. Andreeva Bay is part of Zapadnaya Litsa, a tributary fjord to the Motovsky Fjord which flows out into the Barents Sea.

According to the data of Minatom's head design establishment responsible for spent nuclear fuel management, 21,640 spent nuclear fuel assemblies (93 reactor cores)[36] containing 35 tons of fuel materials are stored in Andreeva Bay with a total radioactivity of 26.8 million Ci.[37] Spent nuclear fuel assemblies are stored in dry concrete tanks and in containers placed in the open on a storage pad.

Concrete tanks for dry storage

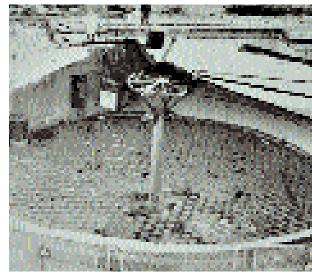
From 1982-1984, it became clear that the pool storage in Building No. 5 was in such poor condition following an accident in February, 1982 that it was no longer possible to continue to use it. Around 3,000 m³ of radioactive cooling water leaked out in the accident. It was decided to construct three concrete tanks for dry storage of the spent nuclear fuel. The spent fuel was transferred from run down temporary storage solutions to the new storage tanks. The present concrete tanks have now been in use for more than 18 years and are 100% filled.

Three 1,000-cubic meter tanks designed for storing and reprocessing high activity liquid waste were rebuilt into dry storage tanks for spent nuclear fuel from Building No. 5. The tanks were given the numbers 2-A, 2-B and 3-A.

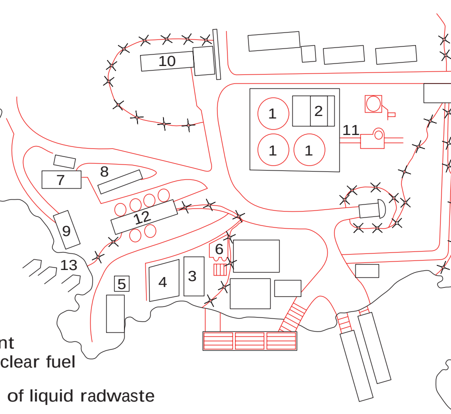
The first of these tanks, 3-A, was taken into use in June, 1983. The tank was used to store 900 assemblies with spent nuclear fuel. The 2-A and 2-B tanks were consequently taken into operation in 1985-1986, and are designed to store 1,200 assemblies with spent nuclear fuel each. In keeping with a decision of the Northern Fleet Technical Department, spent fuel in tanks was to be stored in dry cells specifically designed to hold assemblies with spent nuclear fuel. The dry cells were constructed using 250 to 270 mm diameter pipes, and the space between the pipes was filled with concrete.

The 3-A tank was soon filled to capacity with spent fuel unloaded from the rundown storage facility in Building No. 5. After loading of assemblies with spent nuclear fuel assemblies, the 3-A tank was covered by lead sheets and resin (See drawing). The 2-A and 2-B tanks were used as a working part of the storage until 1999. A part of the fuel was reloaded from the rundown storage to the 2-A and 2-B tanks in 1984. Fuel from both active and retired submarines is stored in these two tanks also.[38]

Each cell of the 2-A and 2-B tanks was closed with a metal lid and metal plates on top of it. The construction was designed to prevent rain and snow from coming inside the cells and assemblies; however, snow and rain still penetrated inside the cells and casks during loading and unloading of the assemblies. Low temperatures caused the water to freeze, and this in turn led to the development of cracks in the external cladding of the assemblies. Although a full examination of the assemblies has never been carried, out, it is believed that most of them are damaged. It is difficult to specify the exact number of damaged assemblies., but



1. Spent nuclear fuel storage tanks, 2-A, 2-B and 3-A
2. Storage pad for TK-6 (TK-11) casks with spent nuclear fuel
3. Site 3 - solid radwaste in concrete bunker
4. Site 7 - solid radwaste in concrete bunker
5. Site 7a - solid radwaste in concrete bunker and open area
6. Site 9 - open storage pad for casks with radwaste (under construction)
7. Site 67 - concrete bunker for high active radwaste
8. Site 67a - concrete bunker for high active radwaste
9. Site 7d - storage for high active filters from reactors
10. Building no.5 - former pool storage for spent nuclear fuel, contains fragments of spent nuclear fuel
11. Storage tanks 3B and 3V, each holding 30m³ of liquid radwaste
12. Building with six tanks which can hold 400m³ of liquid radwast each
13. Five PE-50 type storage tanks, each holding 50m³ of radioactive water, dumped at the costline of Andreeva Bay



Andreeva Bay

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according to different data returns, there are about 300 of them.[39] Bellona Foundation researchers estimate that at least 40-50% of total number of assemblies are is damaged. From a perspective of radiation safety, the process of loading and unloading of the 2-A and 2-B tanks is unsafe. In an attempt to stop the spread of radioactive gases and dust around the whole area of the base covering clothes and skin of the working personnel, an upgraded ventilation installation for the concrete tanks was built. In the 2-A and 2-B concrete tanks a lid was installed at a height of about 2.5 meters and a building to contain the ventilation system was constructed. The lid of each tank was made of metal plates tightly set together, and was placed on metal posts. The ventilators were intended to push the air between the lid and the casks with spent nuclear fuel to the filters and then to the outside, but the lid construction and ventilation system did not perform as intended. Consequently, during its operation many parts of the system broke down and required reparation.

The concrete tanks for dry storage do not meet present nuclear safety requirements (PBYa 06-00-88). Both the storage area and the construction constitute a potential threat to the environment and population living in the immediate area. In the event of an accident, the storage lacks any design to minimise or tackle the consequences.

35 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.
36 It is assumed here that each submarine reactor core contains 233 nuclear fuel assemblies.
37 Contact expert group, October 25, 2000.
38 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.
39 IAEA Contact expert group, October 25, 2000.

Finally, the concrete storage is situated on the slope of the hill 350 meters far from the water line. In case of an accident there would be a high probability for runoff from the storage and into the sea.

Outdoor storage of spent nuclear fuel

Until 1984, the storage pad for containers holding spent nuclear fuel assemblies was located off the coastline of Andreeva Bay next to site No. 3 (See map). In 1984, about 20 containers of spent nuclear fuel assemblies were unloaded onto this storage pad.[40] The rest of them were moved to an outdoor concrete pad where the tanks

utilised for dry storage are located. The concrete surface of the ground becomes deformed because of the friable soil. According to data from Minatom's division for the management of spent nuclear fuel, the outdoor ground site is storing about 220 spent nuclear fuel assemblies from the first generation submarines in TK-6 (TK-11) type containers.[41] Seven spent nuclear fuel assemblies in one of the containers are probably damaged. This was confirmed when one of the containers was being lifted and the plug in its bottom side and a part of an assembly fell out.

The generally poor technical condition of the containers and the lack of a licence authorised by the nuclear regulatory (GAN) preclude any transportation of the containers. Therefore, the unloading of fuel can only be conducted on the site. It is difficult to predict the challenges and problems that can arise during the unloading of the fuel. For example, problems can arise if the fuel elements of the assemblies are not fastened to the top of them. In this case it would be necessary to open the plug in the down side of the container so as to extract the spent nuclear fuel assembly. If the assembly is undamaged, then unloading of the fuel can continue according to the regular steps:

- The container is placed on a horizontal pad;
- The lid of the container is opened;
- The spent nuclear fuel assembly is extracted from the container and reloaded into the transport cask, which then is placed into a shield container;
- The shield container with transport casks is transported to the loading point where it will be placed aboard a nuclear service ship.

Due to the lack of special tools, the operation is conducted manually, using devices allowing the personnel to keep a safe distance from the immediate vicinity to the assemblies.

Defuelling and storage infrastructure at Andreeva Bay

The transportation of spent nuclear fuel from the storage sites in Andreeva Bay is a difficult process, complicated by the lack of a railway to the site. The road from Murmansk to Andreeva Bay does not meet safety requirements and cannot be used for the transportation of spent nuclear fuel. Consequently, spent nuclear fuel has been shipped by sea. There is one stationary quay and two floating piers in Andreeva Bay.

The reinforced concrete floating pier PMK-67 (See map) was used to load and unload spent nuclear fuel from the nuclear service ships. If it should ever be utilised again in the future, a new foundation will have to be constructed. The facility should provide safe access for transport to the pier. The stationary quay sits on reinforced concrete posts and can be utilised for loading spent nuclear fuel from trucks onto the nuclear service ships with the help of a crane. Usage of cranes on the nuclear service ships depends on the technical specifications of the cranes (payload capacity, crane arm's length etc.) and of the nuclear service ships (vessel draught etc). Bellona estimate that only nuclear service ships of Project 2020 - Malina class are capable of loading spent nuclear fuel from the stationary moor plant. It may be that a new ship should be built to provide these kinds of services.

A port crane of KMP-40 class can be used for loading and unloading spent nuclear fuel from the concrete tanks and from the containers placed on the outdoor storage pad. This crane has an arm length of 30 meters and a payload capacity of 40 tons. The crane is in working condition but it is uncertain that it meets safety requirements. The 40-ton cranes can not accommodate loads greater than 35 tons, so the KMP-40 class port crane at Andreeva Bay cannot, for example, be used for 40-ton containers. Besides, use of the cranes can be restricted by weather conditions. The crane cannot be used when wind velocity exceeds 18 meters per second, yet these kinds of weather conditions are typical for this area throughout the wintertime.

The road from the concrete tanks in the dry storage area to the pier where the spent nuclear fuel assemblies are unloaded from the BeLAZ-540 trucks to the nuclear service ship is not safe and needs to be rebuilt. In particular, there is a steep turn on the way to the pier (at about 25 degrees). The BeLAZ-540 truck has a high centre of gravity which compromises its stability and hence fails to meet safety requirements. The centre of gravity becomes even higher when the vehicle is loaded with containers of spent nuclear fuel. Transporting spent nuclear fuel on the BeLAZ-540 truck utilising the road with a 25 degree steep turn is especially dangerous in winter. Furthermore, the truck's technical state of repair is also unsatisfactory.

40 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.

41 IAEA Contact expert group, October 25, 2000.

Conclusions

A sound procedure must be designed and developed for safely unloading spent nuclear fuel from the dry storage tanks and outdoor containers, not to mention a complete overhaul of the entire storage complex at Andreeva Bay.

Only one plan exists for unloading the spent nuclear fuel from the storage facilities: first the fuel cask is lowered into the shield container, then the shield container is placed on a truck which delivers the fuel to the pier. There the transport casks are reloaded onto a nuclear service ship that is fitted for 40-ton containers of the TK-18 type. The loading of the TK-18 containers takes place onboard the ship, whereupon the containers are then transported to a storage site.

To bring such a procedure about in practicality requires that the following measures are taken:

1. Preparation of the concrete tanks for dry storage and positioning of the containers on the storage pad to facilitate the unloading of spent nuclear fuel from them;

- Examination of transport casks and containers;
- Establishment of order and method of unloading spent nuclear fuel assemblies, including damaged assemblies;
- Examination of technical condition and the possibility of using the KMP-40 crane.

2. Construction of new shield containers and loading equipment or repair of the existing ones.

3. Repair and testing of the special ventilation system and also other rooms for dry storage tanks.

4. Acquisition of special tug trucks for transportation of spent nuclear fuel.

5. Repair of the road from the dry storage tanks to the moor plant.

6. Installation of the crane at the moor plant and construction of a bridge connecting the moor plant and the shore.

1.4.2. Gremikha Naval Base

Gremikha (Iokanga) is the second onshore storage site at the Kola Peninsula for spent nuclear fuel from submarines Around 800 elements from pressure water reactors are stored in Gremikha, containing 1.4 tons of nuclear fuel materials. A further six reactor cores from liquid metal reactors are also stored here onshore. Spent nuclear fuel remains in the reactors of all of the 17 submarines laid up at piers at the base.[42]

The Gremikha naval base is the easternmost Northern Fleet base at the Kola Peninsula, located some 350 kilometres east of the mouth of the Murmansk fjord. There is no road or railway connection to the base. Today, there are no active submarines based at Gremikha; only 17 nuclear powered submarines withdrawn from service with their 34 reactors are laid up at the base. The submarines are both first and second generation vessels. There are a total of 14 piers at Gremikha, of which seven floating piers berth the laid up submarines. Most of the piers are in a unsatisfactory condition.[43]

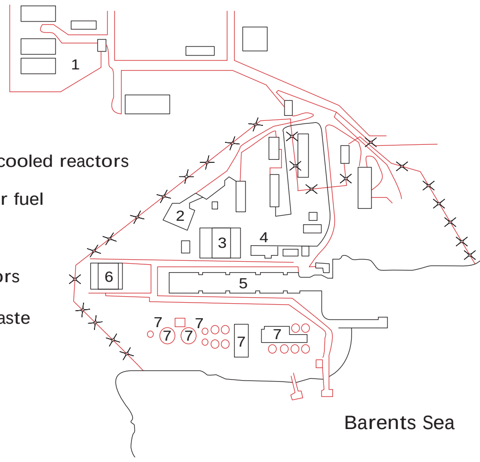
The laid up submarines at Gremikha are as follows:

- Project 627A (November class), 4 units: K-3, K-21, K-60, K-159;
- Project 658 (Hotel-class), 1 unit: K-54;
- Project 671 (Victor-class), 12 units: B-53, B-306, B-323, B-369, B-513, B-517, B-398, B-438, B-367, B-387 and B-370.[44]

The storage sites for spent nuclear fuel and radioactive waste are built around the dry dock SD-10, which was earlier used for refuelling submarine reactors. The dry dock, a floating technical repair base and its surrounding facilities are located in Chervyanaya Bay, near the settlement at the base. Most of the facilities were constructed in the 1950s and 1960s to serve the Northern Fleet's first generation submarines. Then, in the beginning of the 1970s, the base

Germikha costal technical base

1 Barracks settlement
2 Solid radioactive waste area
3 Building for re-charge of liquid metal cooled reactors
4 Pool storage building for spent nuclear fuel
5 Dry-dock SD-10
6 Storage for liquid metal cooled reactors
7 Storage tanks for liquid radioactive waste



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was partly reconstructed to serve strategic submarines of the Project 667 (Yankee-class). In the 1980s, dry dock SD-10 was partly reconstructed, enabling to refuel the reactors and store the reactor cores from liquid metal cool reactors from Project 705 – Alfa class submarines.[45]

At present, no part of the storage site meets the normative requirements for radiation safety. The dry dock SD-10 (142 meters long and 17 meters wide) is not in working condition today. There were plans to repair it assuming the availability of funding. Because of its remote location, much of the work to secure the waste has to be done on site. Also, many of the laid-up submarines at the base are leaking from their ballast tanks, reducing their floating capability and thereby making it too risky to tow them away to another naval yard on the Kola Peninsula or to Severodvinsk for decommissioning.[46]

42 Report from the 9th meeting of the Contact Expert Group, "Strategy for Radwaste and Spent Fuel management in the RF", Helsinki, May 2000.
43 Aagaard, Andreas, Working Paper, 1999.

44 K-numbers were replaced with B-numbers.
45 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.
46 Aagaard, Andreas, Working Paper, 1999.

Pool storage for spent nuclear fuel

Building No. 1 originally contained four water pool storage facilities for spent nuclear fuel from reactors first generation submarines. The four pools have a common shielding around them, while they are separated with concrete walls that are covered with metal on the inside. Each of the four pools was intended to hold two reactor cores, giving a total storage capacity of approximately 1500 spent fuel assemblies, equal to eight reactor cores. Each pool is 68 m^3 in volume and 4.8 m in depth. Construction of the storage pools began in 1960, and they remained in steady use until water leakage was detected in 1984.

The cooling water from one of the pools leaked out to the dry dock SD-10. This leak was caused by a crack in the pool which had come as a result of defective welding in one of the consoles that held the spent fuel elements. The radioactivity of the water leaking to the dry dock was 370 Bq/l. Defects were also found in two of the other pools.

As a consequence of the leakage, three of the water pools were emptied and their spent fuel assemblies were transported away from Gremikha. Simultaneously, all four pools were permitted to dry out. However, pool no. 2 was used to store assemblies that were too damaged to be transported away in normal transport casks.

A total of 95 damaged spent fuel elements are left in pool No. 2. The three other pools have not been decontaminated, although the contaminated soil in the dry dock has been collected and packed into containers and stored at the storage site for solid radioactive waste in Gremikha.[47]

Liquid cooled reactors

In the mid 1960s, the two reactor cores from the prototype submarine Project 645 ZhMT (K-27) were placed in Building 1B, which is the innermost part of the dry-dock SD-10. They had been transported to Gremikha from the naval yard in Severodvinsk where they had been replaced by new ones. Nothing further has been done -- the reactor cores still remain in their concrete containers at this storage site.

In the early 1980s, the storage building 1B was enlarged with the construction of a new storage tank, named 1A. The new tank was built in connection with the decision to phase out liquid metal cooled reactors. In the period between 1988 and 1992, four reactor cores from the liquid metal cooled reactors from submarines of the Project 705 - Alfa class were unloaded in dry dock SD-10. The purpose of Storage 1A was to serve as an temporary storage for liquid metal cooled reactors for a period of two months before the reactor cores were moved on to the other tanks in storage 1B. In 1A the reactor cores had a forced cooling (i.e. cooled by means of fans, as opposed to natural cooling by convection), while the rest of the storage tanks in Facility 1B have natural cooling. The total capacity for storage of liquid metal cooled reactor cores are two cores in Building 1A and 8 cores in Building 1B.

The spent nuclear fuel is placed in special cans filled with a lead-bismuth mixture together with the control rods from the same reactor core, all of them in lowered position. Since the lead-bismuth mixture is "frozen", the entire reactor has to be heated up so that the lead-bismuth mixture melt and the fuel assemblies can be lifted out. On the other side, as long as the lead-bismuth is "frozen", leakage of radioactivity from the fuel elements is very unlikely.

Due to the shifting and settling of the ground, the eastern wall in Building 1B has a crack. Also, the two cranes intended for unloading spent fuel are both in need of repair.

There are plans to unload the reactor cores from the two remaining Project 705 – Alfa class submarines which are currently laid up at the naval base in Zapadnaya Litsa and transfer them to storage in 1B. In addition, the reactor compartment from the submarine K-377 in storage on Yagry Island in Severodvinsk is due to be transferred to Gremikha. A further reactor core remains in the reactor section of an Alfa class submarine currently laid up at Sayda Bay. If all of these reactor cores are transported to Gremikha, there will be a total of ten reactor cores from liquid metal cooled reactors in storage at Gremikha. Ten cores are the current total capacity of the storage 1A and 1B.

The procedure for removing spent nuclear fuel from liquid metal cooled reactors is different to that of removing spent nuclear fuel from pressure water reactors. The submarine is taken into the dry dock SD-10 and a container hoisted out over the open reactor compartment. Then, the reactor core is heated up by steam delivered from a special steam generator beside the dry dock. When the metal coolant has melted the spent nuclear fuel can be lifted out.

Containers with spent nuclear fuel

Spent nuclear fuel from first generation submarines is also stored in containers at the storage site for solid radioactive waste at Gremikha. This storage site is located some 30 meters away from the dry-dock SD-10. The containers used here are of the type TK-6 and TK-11, an old design which today no longer meets normative radiation safety requirements. The containers are in very poor condition, and have been outdoors and exposed to the harsh Arctic climate for nearly 40 years. There are a total of 116 containers at this site, of which 100 contain spent nuclear fuel. In the early 1960s, 91 Type 6 transport containers arrived at Gremikha from the naval yards in Severodvinsk with spent nuclear fuel from some of the first nuclear powered submarines in the Northern Fleet. Later, nine TK-11 type containers, all containing spent fuel, were placed at the same location.

All together, the TK-6 and TK-11 type containers at Gremikha's storage site for solid radioactive waste contain 672 spent fuel assemblies from first generation nuclear submarines,[48] a figure corresponding to nearly three reactor cores.[49]

Conclusion

The Russian authorities view Gremikha as one of the possible locations as a storage site for spent nuclear fuel. The local administrations are also interested in the project as it better the social situation at the base. The main argument against the construction of a permanent storage site in Gremikha is its remoteness and the lack of land-based communications leading to the base.

47 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.
48 Aagaard, Andreas, Working Papers, 1999.
49 Report from the 9th meeting of the Contact Expert Group, "Strategy for Radwaste and Spent Fuel management in the RF", Helsinki, May 2000.

1.4.3. Service ships for spent nuclear fuel

There are approximately 5,040 spent nuclear fuel assemblies or about 22 reactor cores containing 8,8 tons of fuel materials with a total radioactivity of about 6,6 million Ci stored on the nuclear service ships.

At the present, the Northern Fleet operates seven nuclear service ships for the reactor refuelling services and the short-term storage and transportation of nuclear fuel. These vessels are of the Malina class (Project 2020; PM-63 and PM-12), Project 326 and 326M (PM-50, PM-78, PM-124, PM-128).

The four Project 326M vessels were designed at Aisberg design bureau in 1957 and built in Severodvinsk from 1960-1966. The Project 326M service ship of the was used for refuelling first and second generation submarine reactors. Although the nuclear service ships of the Project 326M class were repaired during their operation, all of them are in bad condition and do not fall short of safety requirements.

In view of the inadequate radiation safety provisions in the storage sections, the radiation situation for personnel working onboard the vessels is unfavourable. This factor, combined with the unpleasant conditions onboard the ships and long absences away from family have a negative influence on the morale of the crew and in turn affect the level of nuclear safety during operations. The vessels PM-50, PM-78 and PM-128 are all nuclear service ships that are assigned to Olenya Bay. The nuclear service ship PM-124 is based in the water area of Severodvinsk.

The non-propelled Project 326 type nuclear service ship was used for the refuelling of first generation submarine nuclear reactors. The storage compartments of the Project 326 nuclear service ships are capable of holding 560 spent nuclear fuel assemblies or 2.5 reactor cores each. Spent nuclear fuel assemblies are hung up in storage compartments without being contained in any form of cask. The basic technical specifications of these nuclear service ships are given in Table 6.

The Project 2020 nuclear service ships of were designed in 1980. The feature that sets these vessels apart from the others is that the shape of the hull has no cam surfaces or flat elements. Due to certain design flaws the ship is difficult to trim, and thus it practically always tilts to one side. All ships of this Project were built in Nikolaev. The PM-63 entered service in the Northern Fleet in October 1984, while the PM-12 began in 1991. The PM-12 is permanently based in the water area of Severodvinsk, whereas PM-63 is assigned to Olenya Bay.

There are four storage sections on the Project 2020 nuclear service ships, with each storage section capable of accommodating 51 transport casks. The total capacity is 204 transport casks of spent nuclear fuel or 1,400 spent nuclear fuel assemblies – almost six reactor cores. The ships are equipped with two cranes with a payload capacity of 16 tons to facilitate the reloading of fuel. The basic technical specifications are given in Table 6.

The nuclear service ship Severka was an upgraded vessel of the River-Sea class, Tissa type. It was built in Hungary in 1957. The ship later entered active service with the Northern Fleet. In 1978, Severka was taken out of operation as a Northern Fleet service ship and was rebuilt to transport containers of spent nuclear fuel to Shipyard No. 35 - Sevmorput. Severka was also used to transport spent nuclear fuel from Andreeva Bay to Murmansk prior to transportation to Mayak for reprocessing.

The ship had two storage sections with a total capacity of 88 TK-11 transport casks and was manned by a civilian crew. In 1993, Severka was taken out of active service; her present location is unknown. The fuel was reportedly removed from Severka and the vessel placed in dry dock at one of the shipyards at the Kola Peninsula.[51]

There were also plans to rebuild the Project 1151 tanker Amur to transport spent nuclear fuel, but these have not materialised yet.

Conclusions:

The nuclear service ships of the Northern Fleet hold about 5,040 spent nuclear fuel assemblies or 22 reactor cores containing 8.8 tons of fuel nuclear material with a total radioactivity of not less than 6.6 million Ci.

Bellona considers that storing spent nuclear fuel onboard the nuclear service ships is more dangerous than it would be to allow it to remain in the reactors of the retired submarines. The storage sections of the nuclear service ships are not as tight as the walls of the submarine reactors. Therefore, in the event of flooding or capsize, large volumes of water could be radioactively contaminated.

It would therefore seem reasonable to develop and finance a project aimed at unloading fuel from the nuclear service ships to reduce the treat of radioactive contamination.

Name	PM-50, PM-78, PM-124 PM-128	PM-63, PM-12
Ship class	Nuclear service ship	Nuclear service ship
Project number	326	2020
Number of the vessels in the Northern Fleet	4	2
Displacement		
Empty, ton	3,300	9,700
Loaded, ton	4,000	13,900
Maximum length, m	92	138
Maximum width, m	13.4	21
Draught displacement, m	4.5	7
Maximum speed, knots	Non-propelled	11.5
Maximum travel distance, nm	-	13,000
Main machinery, Hp	-	Diesel energetic installation 2,700
Crew	59	218
Self sustained operation time	15	45
Refuelling capacity	One submarine at a time	One submarine or one surface vessel at a time
Payload capacity and number of cranes, ton	2x12	2x16

Table 11.
Nuclear support vessels in the Northern Fleet[50]

50 Kuzin, V. P., Nokolsky, V. I., USSR Navy from 1945-1991, St Petersburg, 1996.

51 Murmansk GAN inspection, 2001.

1.4.4. Transportation of spent nuclear fuel

In accordance with the "closed cycle" policy of the former Soviet Union, the expectation is that all spent nuclear fuel should be reprocessed and used again. Behind this policy lay the expectation of a uranium shortage in the future. In reprocessing procedures, the spent nuclear fuel assembly is dissolved in an acid solution, and uranium and plutonium is separated from the other elements. This uranium can then be used in the production of new fuel assemblies for RBMK type reactors for nuclear power plants. To that end, a resolution was passed in the middle of the 1960s to build a production facility at the Mayak Chemical Combine for the reprocessing of spent nuclear fuel. This was the beginning of the RT-1 reprocessing facility.

The first technological system for the reprocessing of spent nuclear fuel both from VVER type pressurised water reactors (nuclear power plants) and from naval reactors (nuclear icebreakers and submarines) was started in 1976. Spent fuel assemblies were removed from the reactors and forwarded to the RT-1 reprocessing facility on special railroad cars. In 1973, the first specially modified train from the Northern Fleet consisting of nine cars, ran from Murmansk to Mayak.

Because the storage facilities for spent fuel assemblies located at Andreeva Bay and at Gremikha are not connected to the railway, there were two steps in the process of forwarding spent fuel assemblies from the submarine reactors to the reprocessing facility at Mayak:

- Establishment of a loading area whereby containers of spent nuclear fuel could be transferred from Northern Fleet service ships and transported to the railway;
- Preparation of service ships to carry the containers of spent nuclear fuel by sea from Andreeva Bay and Gremikha to the transfer loading area.

Four locations were considered as possible transfer loading points. The location that was finally selected is situated at Sevmorput shipyard not far from Base 92, and is known today as Atomflot.[52]

Transport containers

TUK ("transport packing container") containers are used to transport spent nuclear fuel. Each TUK consists of two parts: a protective cover (the outward container) and a closed cylinder (internal casing). TUK-11 and TUK-12 containers were used for all reloading of fuel from nuclear vessels until 1993, and in 1994 they were replaced by the TUK-18 container. The TUK-11 and TUK-12 containers were manufactured in 1971-72 by the Uralmash factory in Ekaterinburg. The main difference between the two types of containers is in the height. Each container held one holster in which seven fuel assemblies had been packed. (The cylinders for Murmansk Shipping Company held three to five fuel assemblies). The containers were made of stainless steel, weighed 8,850 kg each and were 327 mm thick. The closed cylinders were also made of stainless steel, and weighed 260 to 300 kg when fully equipped. The TUK-11 and TUK-12 containers were transported on TK-4 railroad cars, each of which could hold four containers. In this way, a special train of nine or ten cars could transport one reactor core; a special train of 18-20 cars could take a maximum of two reactor cores. Before the TUK-11 and TUK-12 type containers were introduced,the earlier model TUK-6 containers were in use.

By 1993, the TUK-11 and TUK-12 containers had become obsolete, and from 1994 onwards, TK-18 (TUK-18) containers have been used exclusively for the transport of spent naval fuel. The TK-18 containers were manufactured by the Izhorsky factory in the city of Kolpino. These too are made of stainless steel, and a single container weighs 40 tons with a thickness of 320 mm. Each TK-18 container holds up to seven closed cylinders, and each cylinder can take five to seven fuel assemblies. In 1989, four special railroad cars of the type TK-VG-18 were built at the Kalininsky Coach Works to transport the TK-18 containers. A TK-VG-18 car can accommodate three TK-18 containers. The Russian Navy has 50 of these containers, half of which are owned by the Northern Fleet. A special train pulling four TK-VG-18 cars with their full capacity of twelve TK-18 containers is capable of transporting two to three reactor cores.[53] The construction of a second set of four TK-VG-18 cars was funded by Norway. Those cars were taken into operation in autumn 2000.

Transport routes

From 1973 to 1984 sea transport of spent nuclear fuel assemblies went over the following routes:
Andreeva Bay-Murmansk;
Gremikha-Murmansk;
Severodvinsk-Murmansk.

Since 1984, as a result of the cessation of activities of the storage facility for spent nuclear fuel from pressurised water reactors at Gremikha, sea transport has taken place only from Andreeva Bay. Until 1978, Barge-4 was used for all sea transport of spent nuclear fuel. In 1979-1980, due to its deteriorated technical condition, Barge-4 was written off from the fleet of service ships. After its decommissioning, it was filled with solid radioactive waste from the Northern Fleet and dumped into the Kara Sea. Beginning in 1979, containers of spent nuclear fuel assemblies were transported on the Northern Fleet service ship Severka. Severka has three cargo holds and a capacity of up to 88 TUK-11 and TUK-12 containers. It is, however, unsuitable for TK-18 con-

52 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.

53 Ibid.

tainers, and has subsequently been laid up.

Until 1993, all rail transport of spent nuclear fuel by rail originated from Murmansk. No less than a third of the spent fuel assemblies originate from Zvezdochka Shipyard in Severodvinsk. These fuel assemblies may be categorised as "cold". In an effort to reduce the number of unnecessary transfers and to accelerate the defuelling of laid-up submarines, it was proposed to transport the spent nuclear fuel directly from Severodvinsk for reprocessing. Loading the containers would take place at sea on board technical service ships of the type 2020-Malina class. The proposal was adopted in December, 1991.

After 1973, the use of transport containers of type TK-11 and TK-12 was forbidden, and the loading area for spent nuclear fuel was moved from Sevmorput shipyard to the civilian nuclear icebreaker base Atomflot. Atomflot already possessed cranes capable of handling the containers for spent nuclear fuel. Atomflot has reconstructed the storage-ship Lotta so that it can accommodate the new TK-18 type containers. Lotta was built in 1961 and has 12 rooms for storing 68 containers with spent nuclear fuel. About half of the spent fuel was from the Northern Fleet, while the other half originated from the nuclear icebreakers at Murmansk Shipping Company.

Reprocessing vs. storage

In the mid to late 1990s, the pace at which spent nuclear fuel is transported and processed has slowed drastically. This is largely due to a sharp increase in the cost of transporting and reprocessing spent nuclear fuel following a change in the billing policy of Mayak Chemical Combine. Starting from January 1, 1991, Mayak Chemical Combine required full coverage of its expenses.

An overview of the number of special transport trains from 1984 to 2000 is given in the list below:[54]

1984: 10 special trains, 586 containers
1985: 9 special trains, 503 containers
1986: 3 special trains, 155 containers
1987: 7 special trains, 386 containers
1988: 6 special trains, 329 containers
1989: 7 special trains, 426 containers
1990: 4 special trains, 235 containers
1991: 3 special trains, 216 containers
1992: 3 special trains, 216 containers
1993: 4 special trains, 280 containers
1994: 1 special train, 12 type TK 18 containers
1995: 4 special trains, 48 type TK 18 containers
1995: 4 special trains, 48 type TK 18 containers
1996: 4 special trains, 48 type TK 18 containers
1997: 2 special trains, 24 type TK 18 containers
1998: 4 special trains, 48 type TK 18 containers
1999: 5 special trains, 60 type TK 18 containers
2000: 7 special trains, 84 type TK 18 containers[55]

As may be seen from the list, there was an increase of shipments in the year 2000. There are several reasons for this. The second train built by Norway was taken into operation, CTR obtained permission from the United States Congress to fund the shipment of fuel from 15 decommissioned SSBNs, and finally Minatom used a part of the profit from its sales in the USA of highly enriched uranium to fund the transportation of spent fuel to the Mayak reprocessing plant.

As stated earlier, there are 248 reactor cores currently stored in the Northern Fleet. Even seven train shipments correspond only to 17.5 reactor cores. Even if they were to be increased to 10 trains per year, it will still take more than 25 years to transport all of the fuel to Mayak. On the other hand, the reprocessing facility at Mayak does not have the capacity to accept such amounts of spent fuel. In 2000, the reprocessing line at Mayak was operational for only 25% of the 400-ton per year capacity it was designed for. These kinds of reprocessing goals can only be attained by overhauling and upgrading the reprocessing line.

In addition to this comes spent nuclear fuel that Mayak Chemical Combine is unable to accept for reprocessing, including:

- All spent nuclear fuel from reactors with liquid metal cooled reactors;
- Damaged and/or defective fuel assemblies, that is, parts that are bent or have broken cladding. This is especially true of the fuel assemblies that are stored in Storage Pool No. 1 at Gremikha and at unshielded locations at Gremikha and Andreeva Bay as well as the three spent fuel storage tanks in Andreeva Bay;
- Furthermore, there are a number of laid-up first generation submarines that may have considerable percentages of damaged spent nuclear fuel within their reactors.
- Spent fuel with zirkonium cladding.

Bellona researchers believe that as much as 40% to 50% of the 21,640 spent fuel assemblies stored in Andreeva Bay are damaged and hence cannot be reprocessed at Mayak. This may also be true of the 52 reactor cores stored onboard first generation submarines.

Bellona considers that an alternative option might be to build a intermediate storage facility for spent nuclear fuel at the Kola Peninsula. This option is discussed at length in Chapter 6 'Regional storage facilities on Kola'.

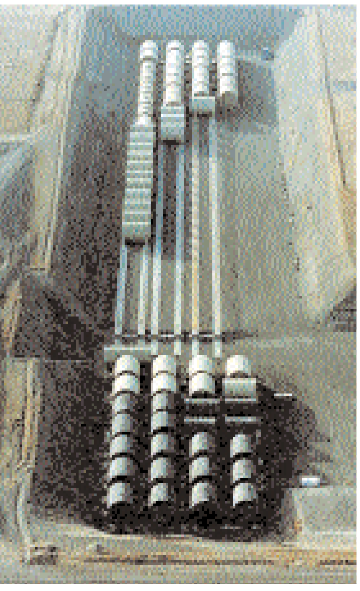
1.5. Management of solid radioactive waste and reactor compartments

The refuelling/defuelling of reactors and repair of nuclear installations, as well as the decommissioning of nuclear powered submarines resulted in the generation of 14,000 m^3 of solid radioactive waste from the Northern Fleet. This waste includes various parts of equipment, packages, filters, garbage, sediments generated during the processing of liquid radioactive waste, contaminated soil etc. The defuelled reactor compartments are also categorised as solid radioactive waste, but due to their large size, they must be handled in very specific ways during processing, transportation and storage.

There are no storage sites for solid radioactive waste and reactor compartments in north-western Russia that would meet current safety requirements. All of the existing sites are filled to capacity and are exposed to harsh weather,

54 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996, and Murmansk Shipping Company, 2001.

55 Shipments from Severodvinsk in 2000 are not included.



with no system in place to collect rain water. The reactor compartments are temporarily stored afloat at the piers in shipyards and in Sayda Bay at the Kola Peninsula.

The radioactivity in the reactor compartment arose from the neutron irradiation of iron and metal components during the operation of the reactor(s). There are also some radioactive corrosion and wear products that have been circulated by the reactor coolant, having become radioactive from exposure to neutrons in the reactor core, and then deposited onto internal piping systems. The reactor design and its operational lifetime vary somewhat between the different classes and individual submarines, and consequently, the radioactivity within the reactor compartments will also vary.

It is not known how much of the piping systems were dried up before the reactor compartments were towed away from the naval yards. It is also possible that some of the reactor compartments contain many more fission products

as a result of different forms of leakage and cracking in the cladding of the fuel elements inside the reactor core. To provide a safe storage for the reactor compartment, it is essential to get a clear picture of the radioactivity inside the reactors before the compartments are prepared for long term storage. Solid radioactive waste is divided in three groups depending on the radioactivity level. The main factor for evaluating activity is the type of radiation that dominates – alfa or beta – and the intensity of the gamma rays on the surface of solid radioactive waste.

The hull and the equipment inside the nuclear reactor, placed inside the biological shield are considered to be high level radioactive waste. Radioactive contamination is generally defined by:

- cobalt-60 (half-life of about 5.3 years), radioactivity high er than $4.8*10^{12}$ Bq/kg;
- serium-144 (half-life of about 264 days), radioactivity higher than $1.0*10^{14}$ Bq/kg;
- caesium-137 (half-life of about 30 years), radioactivity higher than $3.22*10^{12}$ Bq/kg.

High level radioactive waste constitutes around 10% of the total weight of radioactive waste generated during the decommissioning of a nuclear submarine.

The second group consists of medium level radioactive waste. Most of this takes the form of the equipment placed outside the biological shield, including the circulation pumps of the primary circuit, the heat-exchange pipes, metal carcasses and so forth. This equipment has low level exposure radiation and a high degree of surface contamination by radionuclides.

The third group is the low level radioactive waste largely in the form of contaminated systems and equipment. Examples of this would include tanks and other parts of biological protection, pipes and equipment of the third circuit and some other parts. The biological protection equipment makes up for around 50% of the nuclear installation weight.

The total activity of the waste accumulated in the Northern Fleet is around 5,000 Ci. The annual accumulation of waste is around 1,000 tons. Taking into consideration the increased rate at which nuclear submarines are being decommissioned, these numbers could double.[56]

1.5.1. Management of reactor compartments

When the spent nuclear fuel is removed from the reactor(s) of the submarine, the entire reactor compartment must be cut out and separated from the submarine in a dry dock before decommissioning work can continue. This work is mainly carried out at the naval yards in Severodvinsk and at Nerpa shipyard. At present, the reactor compartments are stored afloat at the naval yard or at Sayda Bay to the north-west of Murmansk.

The compartments are either stored as one entity with two attached metal pontoons or with two or more adjacent compartments on both ends.

The practise of keeping the neighbouring compartments together is done to enhance the floating capability. In addition, the lack of specialised enterprises in Russia capable of dismantling radioactively contaminated constructions with the help of remotely controlled robotics, as well as inadequate risk assessments of the work to be carried out prompt towards postponing the dismantling the reactor compartments. In step with this leaning, the whole submarine reactor has to be cut out and stored for about 50 to 70 years. In the United States the storage time is 100 years. After this storage period the compartments will be dismantled and their parts sorted in groups which will be further disposed of as scrap metal or solid radioactive waste.

The storage term from 50 to 70 years reduces radiation levels anywhere from 100 to 1000 times due to the decay of the isotopes, primarily cobalt-60.

At present, there are 35 reactor compartments stored at Sayda Bay in three different variants as described below.

Sayda Bay

Sayda Bay is situated in the western part of the Kola Bay approximately 2.5 kilometres from the submarine base at Gadzhievo (Skalisty). (Gadzhievo is situated in Yagelnaya Bay.) Sayda Bay is approximately ten kilometres long and two to three kilometres wide, with a 100-meter-wide mouth. It is here that the piers holding the reactor compartments are located. Around 35 reactor compartments were moored at the piers here in 2001. This number will

56 Dovgusha V.V. et. al., Radiation Situation in North-Western Russia, p. 90, St Petersburg, 2000.

increase as more submarines are decommissioned.

In the innermost part of the Sayda Bay there is a former fishing village that was annexed as a military area in 1990. The water at the piers in Sayda Bay is 20 meters deep. The oldest pier is over 30 years old, and is in a poor state of repair.[57] According to the available estimates,[58] the reactor compartments could be stored safely at the piers for a period of up to ten years. Today, the storage time for some of the compartments have exceeded this term.

To store the reactors afloat is an unsafe procedure and should only be used as a short-term measure. Both the possibility that the reactor compartment might sink and problems caused by the corrosion of the metal make this way of storing the compartments problematic.

Navy personnel residing at Sayda Bay continually monitor the submarine hulls and the reactor compartments' ability to stay afloat. In case that a hull or reactor compartment sinks, it is the responsibility of these crews to report the event to the Northern Fleet rescue service. In the event of a sinking, the rescue service would then dispatch a tugboat to attempt to pull the reactor compartment up onto land. So far this has not happened.

Monitoring the levels of radiation at the piers is done by the Radiation Safety Service from the Gadzhievo naval base. The maximum permissible level of radiation on the outside of a reactor compartment is 2 microSv/h (200 microR/h).

There are three different categories of reactor compartments stored in Sayda Bay.

- the reactor compartment with two metal pontoons attached on each side;
- the reactor compartment with one or more compartments fore and aft;
- there are also few submarines in Sayda Bay where only the superstructure and missile structures are removed (See photograph).

Some of the reactor compartments stored in Sayda Bay still contain spent nuclear fuel. This is the case for the reactor compartment from the Alfa class submarine, K-463, which has been laid up at Sayda Bay since the early 1990s. It is also possible that the reactor compartments from the oldest first generation submarines (Echo-II, November and Hotel class) contain spent nuclear fuel that has become stuck inside the reactors. Therefore, as many as 50 fuel assemblies have been permitted to remain in the reactor core after its preparation for long-term storage.[59]

Around 50% of the reactor compartments in Sayda Bay are filled with solid radioactive waste. Most of these have come from Severodvinsk shipyards.

The reactor compartments will have to be eventually towed to Nerpa shipyard to be prepared for long term storage onshore.

Planned onshore storage

A current proposal calls for the establishment of a new onshore storage site for reactor compartments at Sayda Bay, close to the current offshore storage site.

Submarine	Reactor installation type	Number of reactors in one compartment	Total compartments	Area occupied by one compartment, m^2	Total area occupied by compartments, m^2
Yankee	OK-700/VM-2-4	2	23	109	2,616
Delta I-IV	OK-700/VM-4B	2	25	109	2,725
Typhoon	OK-650	1	12	100	1,200
Oscar I-II	OK-650B	2	7	126	882
			Total: 67		Total: 7,423 m^2
November	VM-A	2	8	72	576
Echo-II	VM-A	2	15	72	1,080
Hotel	VM-A	2	6	72	432
Charlie II	OK-350/VM-4	1	6	50	300
Victor I-III	OK-300/VM-4	2	35	70	2,450
Sierra	OK-650A/OK-650B	1	4	72	288
Papa	OK-650	2	1	68	68
Akula	OK-650V	1	6	78	468
Alfa	OK-550/BM-40A	1	7	49	343
			Total: 88		Total: 6,005 m^2
X-ray	Unknown	1	1	25	25
Uniform	Unknown	1	3	35	105
"Nurka"	Unknown	1	1	10	10
			Total: 5		Total: 140 m^2
TOTAL			**: 160**		**: 13,568 m^2**

Table 12.
Reactor compartments in the Northern Fleet

Counting all reactor compartments from decommissioned submarines, laid up submarines and submarines still in operation, there is a grand total of 160 reactor compartments, including 120 compartments with two reactors and 40 compartments with one reactor. Most of these reactor compartments are still on laid up submarines or submarines which have not yet been taken out of service but will be retired shortly. They are counted here, because they will be taken out of service within the coming 20 years and should therefore be included in any plans for the long term storage of reactor compartments originating from the Northern Fleet.

The majority of Russian submarines have two reactors which are placed together in the same reactor compartment. The exception is the Typhoon class of submarines which have one reactor compartment in each of their two hulls. In total therefore, there are 280 reactors in 160 reactor compartments, which need to be prepared for long term storage at some time in the future. Except for the reactors from the liquid metal cooled Alfa-class submarines, all Russian naval reactors are pressurised water reactors. The reactor compartments vary considerably in size and component arrangements.

57 Conversations with the controllers of the reactor compartments storage in Sayda Bay, 1995.
58 Nilsen, T., et. al., The Russian Northern Fleet, Oslo, 1996.

59 Shmakov, R. A., Design bureau Malakhit, presentation of the document: Problems of decommissioning nuclear powered submarines and environmental protection in northern areas, pp. 29-30, Severodvinsk, March 15-16, 1995.

As may be seen from Table 7, in order to place 160 reactor sections in storage at Sayda Bay, an area of around 13,600 m² will be required. Thus, keeping in mind the space which will be occupied by various service and infrastructure buildings and facilities, there would be a need for around 500,000 m² (0.5 hectares). Such space is available at Sayda Bay.

Preparation of reactor compartments prior to long-term storage

The present practice for storing reactor compartments at Sayda Bay by no means meet the required safety aspects and will only make final preparations for long term storage

of the reactor compartments more difficult and expensive. The reasons for this are as follows:

- The submarine hulls are not fully decommissioned before they are towed to Sayda Bay;
- Some of the reactor compartments still contain spent fuel, or a fraction of the reactor core (up to 50 fuel elements);
- Some reactor compartments are filled up with solid radioactive waste;
- There is a risk that reactor compartments may sink at the piers.

The most viable solution for dismantling reactor compartments and preparing them for long-term storage is to tow them to Nerpa shipyard. Preparations would include cutting off the supporting compartments or pontoons attached to both sides of reactor compartment, and then sealing them off to ensure safe storage in the harsh Arctic climate for at least 100 years. The remaining spent nuclear fuel inside the compartments should be unloaded. Such operations would require a certain upgrade of Nerpa shipyard infrastructure, but this would still be cheaper than creating the whole set of required facilities at Sayda Bay.

The infrastructure for any long-term storage solution at Sayda Bay should include cranes and transport means to place reactor compartments to the onshore storage site. The storage site should be equipped with drying systems and drainage systems to prevent washout of radioactive water into the surrounding environment.

Sayda Bay is not the only proposed location for a long-term storage facility for the reactor compartments of decommissioned Russian submarines. There is also the option of

using one or more of the 400 meter long tunnels in the Ara Bay on the Kola Peninsula. The precondition for use is that the tunnels are dry. The use of the Ara Bay tunnels as storage has met with criticism from many Russian agencies in that the possibility of flooding in the tunnels could result in radioactive contamination to the sea. The project has been stalled for now.

Another proposed possibility is direct disposal of the waste into the permafrost at Novaya Zemlya. There are proposals to blast 2-3 kilometre long canals inland from the coast. The reactor compartments would then be towed up the canals. Once the canals had been filled with reactor compartments, dams would be built and the remaining water pumped out. Finally the reactor compartments, and possibly other types of radioactive waste, would be covered with sand and rock. This project can be considered as the final disposal site for radioactive waste, if it receives positive response from the international panel of experts who are currently evaluating it.

1.5.2. Solid radioactive waste at naval bases and shipyards

Solid radioactive waste is stored at the following bases in the Northern Fleet: Zapadnaya Litsa, Vidyaevo, Gadzhievo and Gremikha. Vidyaevo, Gadzhievo and the two base points in Zapadnaya Litsa – Bolshaya Lopatka and Nerpichya - have, however, only small temporary storage areas for solid waste. The two major storage sites are located at Andreeva Bay, which is also a part of Zapadnaya Litsa, and Gremikha.

Solid radioactive waste is also stored at the Kola Peninsula shipyards Nerpa, Shkval, and Sevmorput, and at the Severodvinsk shipyards Zvezdochka and Sevmash in Arkhangelsk county.

Andreeva Bay

The storage sites for solid radioactive waste in Andreeva Bay are the largest in the Northern Fleet. There are no data on the amount and the activity of the waste stored there.

At this time, a new storage site for solid radioactive waste has been completed at Andreeva Bay. However, it is still awaiting Minatom's evaluation as to whether it meets safety requirements, and has consequently not yet been commissioned. In addition to the storage sites listed below, there are entire other buildings and areas in Andreeva Bay that are radioactively contaminated and should be treated as radioactive waste during upgrading of the base.

Radioactive waste is stored at the following locations:[60]

- Site 3 – waste stored in concrete bunker;
- Site 7 – waste stored in concrete bunker;
- Site 7a – waste stored both in concrete bunker and in open area;
- Site 9 – open storage area for containers with waste under construction;
- Site 67 – concrete bunker for high activity solid waste, filled to capacity, poor technical condition;
- Site 67a – concrete bunker for high activity solid waste;
- Site 7d – built in the 1990s to store high activity filtering material used in reactors. Seven concrete bunkers are in direct contact with water in the bay. The idea was to reduce the activity of the material by blending it with the seawater. The grids holding the material, which is in the form of small round pellets, have rusted away and the water is washing the pellets out into the bay.

Gremikha

The storage site for solid medium and high level radioactive waste was built in 1963 and consists of a concrete pad surrounded on three sides by a wall of reinforced concrete blocks. The wall is three meter high and 0.4 meter thick. The site is 20 meters long and 15 meters wide. There is no roof over the site, so rainwater, and during the winter, snow, wash out radioactivity from the site into the surrounding environment.

The containers holding spent nuclear fuel occupy half of the storage capacity, while solid radioactive waste is stored in the other half. Some of the waste is packed in rusty metal containers, some is stored in wooden boxes, while some larger contaminated equipment and metallic constructions are stored in the open (See map). Some of the buildings taken out of use at Gremikha are radioactively contaminated and should be treated as radioactive waste during remediation of the base.

The total amount of solid radioactive waste at this site amounts to some 300 m^3, with a weight of 12,891 tons and an estimated radioactivity of 660 Ci.

The following forms of solid radioactive waste are currently stored at the site:

- 20 concrete and leaded containers of spent fuel fragments and high active waste;
- 21 metal containers of spent fuel fragments;
-19 60-liter cans of radioactive garbage (rags etc);
- 26 300-liter cans of tailings;
- 54 containers of solid radioactive waste;
- 300 meters of contaminated pipes with a weight of 10 tons;
- A crane with a weight of five tons;
- Several contaminated trucks.

In addition to the storage site mentioned above, Building No. 19 is the storage for low active solid radioactive waste.

Severodvinsk shipyards

There are four relatively large storage facilities for solid radioactive waste in Severodvinsk. Three of them are located inside the shipyards – Zvezdochka and Sevmash – while the fourth – Mironova Heights - is located outside the city itself.

The following storage sites are located in Severodvinsk:[61]

- Mironova Heights storage for solid radioactive waste located 12 kilometres south-west of the town of Severodvinsk. The storage contains 1,840 m^3 of waste. The facility consists of an underground concrete bunker subdivided into two sections of six rooms. Known as Object 379, the structure is 14.89 meters long and 5.2 meters high. The waste was first stored in this location in 1964. The last batch of waste was delivered in 1976 and then the facility was full. A feasibility study is being made to unload waste from the facility and to remediate the area around. The facility itself is in unsatisfactory condition;

60 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.

61 Cherneyev, V., Bulletin of Nuclear Energy Information Centre, No.8, 2000.23

- Storage site at Sevmash with an area of 2,475 m^2. The facility consists of one closed compartment and an open area where large pieces of contaminated materials are stored. The site is only 25% full since most of the solid waste generated during the decommissioning of nuclear submarines is being packed into defuelled reactor compartments and towed to Sayda Bay at the Kola Peninsula for storage. The safety of the method to store solid waste inside reactor compartments has not been properly researched;

- Partially buried concrete construction (bunker) with a volume of 1,530 m^3 situated at Zvezdochka shipyard. About 55% of the storage capacity has now been used. The storage contains large contaminated reactor components, repair equipment, filters, pipes and protective gear, and gamma sources utilised in the quality control of metals. Some of the waste is packed in containers. The facility is not properly sealed, such that rainwater can enter and wash radioactivity out;

No.	Name	Responsible body	Capacity or area	% of capacity	Condition
1.	Mironova Heights	Sevmash	1,840 m^3	100	Unsatisfactory
2.	Temporary storage	Sevmash	2,475 m^2	25	Normal
3.	Storage bunker	Zvezdochka	1,530 m^3	55	Unsatisfactory
4.	Temporary storage	Zvezdochka	6,658 m^2	Approaching 100%	Unsatisfactory

Table 13.
Overview of the four Severodvinsk storage facilities for solid radioactive waste

- The temporary storage site located next to the concrete bunker at Zvezdochka with an area of 6,685 m^2. This area was taken into use in 1983. The storage site is almost 100% full. Low to medium level waste is stored here, some of it in containers and some as bulk-size equipment. The storage site is unprotected and does not meet safety requirements. A new storage site for solid waste with a storage capacity of 3,000 m^3 is currently under construction.

Shkval, Nerpa and Sevmorput shipyards

Shkval shipyard, or Shipyard No. 10, Nerpa and Sevmorput are all located at the Kola Peninsula.

Shkval shipyard has a storage site where both containers and large pieces of contaminated equipment stored there. The site is full and does not meet safety requirement.

Nerpa has an open air storage site for solid radioactive waste within the shipyard compound. The site has a surface area of 500 m^2.

Sevmorput has an open air storage facility for solid radioactive waste, and low level waste is stored here in containers. There are currently three solid waste storage projects under development for Nerpa and one for Shkval shipyard. The designers of the storage site lean towards placing such a site at Shkval, which has enough of the type of infrastructure required for this purpose. The plans also go as far as to arrange a regional storage and processing centre for solid waste at Shkval shipyard.[62]

1.5.3. Liquid radioactive waste at naval bases, shipyards, special tankers and nuclear support ships

Liquid radioactive waste is generated during various operations on submarines and nuclear installations, as well as during the decommissioning of submarines. At present, around 10,000 m^3 of waste have accumulated, including 300 m^3 of high active waste originating from the Northern Fleet. The amount of radioactivity is around 256 Ci.

From 1993, the Northern Fleet officially declared a halt to the dumping of liquid radioactive waste into the seas. However, it remains an open question as to how to dispose of the liquid waste that continues to be generated given that all of the storage facilities for liquid waste are filled up. Liquid radioactive waste is transferred to special tankers and nuclear support ships, as well as PE-50/PEK-50 type floating tanks. There are also onshore storage facilities at the bases and in the shipyards. Since 1994, the Northern Fleet has been delivering liquid waste to be processed at the treatment facility located in Atomflot nuclear powered icebreakers base. The facility has an annual capacity of 1,200 m^3. This facility is due to be upgraded to treat up to 5,000 m^3 of liquid waste annually, assuming that the ongoing international project to achieve this is completed. A facility for low active liquid waste was completed at Zvezdochka shipyard in Severodvinsk in 2000.

Andreeva Bay[63]

Andreeva Bay has the most unsatisfactory storage conditions for liquid waste:

- The storage tanks 3B and 3V, each holding 30 m3 of liquid waste. The waste is the rain water and snow, which precipitates onto the three spent fuel storage tanks and then collects as radioactive waste into the storage tanks;

-The storage tanks in Building No. 6. After the 1982 accident at Andreeva Bay (See subchapter 'Spent Nuclear Fuel') in Building No. 5, the remaining radioactive water from the spent fuel storage pools was pumped to the tanks of Building No. 6. The total amount of water pumped over was around 1,000 m^3 with an activity of 10-4 to 10-5 Ci/l. Building No. 6 was initially designed to hold highly radioactive material from submarine reactors but had never been utilised for its original purpose. It is almost impossible to achieve control over the temperature and water level in the storage tanks due to design specifications. In 1995, Tank No. 3 developed a leak as a result of steel corrosion of the containers during the wintertime. Around 250 m^3 of liquid waste leaked out. The tank was later repaired;

- On the coast line of Andreeva Bay (See drawing), around

62 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.

63 Ibid.

five PE-50 type storage tanks (each capable of holding 50 m³ of radioactive water) are dumped. Although the tanks were sealed, there is a large probability that the water leaked out as a result of corrosion.

Gremikha[64]

There are 11 storage tanks for liquid radioactive waste at Gremikha, with a total capacity of 3,025 m³. The onshore underground tanks are all located near dry dock SD-10. The storage tanks vary in size. The tanks are made of concrete and are shielded inside with stainless steel. The underground storage tanks were supposed to be a part of the liquid radioactive waste purification plant at Gremikha. The purification plant was never commissioned, although the tanks still contain liquid radioactive waste. A total of 1,960 m³ liquid radioactive waste is stored in the tanks today. Seven of the 11 tanks cannot be filled or unloaded because their pipelines are broken and/or are leaking due to corrosion. Furthermore, these seven tanks are also in very poor technical condition and their carbon steel is completely corroded. An unknown amount of it reportedly cannot be processed at the only operating plant for LRW at Atomflot in Murmansk due to its chemical composition. The LRW has medium activity, around 10^{-5} Ci/l.

In addition to the onshore underground storage tanks there are also several PEK-50 type floating tanks located at Gremikha.

Tank	16AC	16AP	16BP	16BC	18A	18B	18V	20A	20B	23	**Tot**
Capacity (m3)	500	500	500	500	190	190	75	190	190	190	**302**
LRW (m3)	369	483	481	360	50,5	27,9	25	48,7	9,1	106	**196**

Table 14.
Storage tanks for liquid radioa tive waste at Gremikha

Liquid radioactive waste at shipyards

Liquid waste at shipyards has to be regularly collected by special tankers of the Northern Fleet. However, some shipyards have their own onshore storage tanks or floating tanks to hold liquid waste. Most of the liquid waste is generated in Severodvinsk, between 2,000 and 3,000 m³ annually. Only small amounts originate from Sevmash; the greatest part comes from Zvezdochka where the repairs and decommissioning of submarines take place. Today, approximately 3,000 m³ of liquid waste are stored in Severodvinsk.

An overview of the existing liquid waste storage tanks at the shipyards at the Kola Peninsula and Severodvinsk is as follows:[65]

- Shkval shipyard in Polyarny has two floating tanks at the quay. The capacity of the storage is approximately 150 m³;
- Nerpa shipyard has a shore-based storage tank facility with approximately 70 m³ of waste. Nerpa used to have two PEK-50 floating tanks, each of which has a capacity of 50 m³, but now they are decommissioned;
- Sevmash shipyards had five sea-based tanks for storing liquid waste. Three tanks have been taken out of use and should be treated as solid radioactive waste. The two tanks that remain in service each have a capacity of 24.8 m3 of liquid radioactive waste;
- Zvezdochka stores its waste in three land-based tanks also known as Object 159. Object 159 consists of two type A-02 tanks, each with a capacity of 500 m³. The third tank is a type A-04/2 relief tank with a capacity of 100 m³. The two A-02 tanks have been repaired and upgraded as a part of an international project in which the work was completed in 2000 (See the chapter 5 'Projects for securing nuclear waste').

64 Aagaard, Andreas, Working Papers, 1999.
65 Nilsen et. al., The Russian Northern Fleet, Bellona report 2:1996.

Liquid radioactive waste onboard special tankers and nuclear support ships

The Northern Fleet operates specially constructed tankers of the Project 1783A – Vala class to transport and store liquid radioactive waste on the Kola Peninsula. In addition to these comes the Project 11510 – Belyanka class vessel Amur. The rebuilt tanker Osetiya is based in Severodvinsk. Even though the ship still contains liquid radioactive waste, she is no longer in active service.

Project 1783A – Vala class

Number 9

	Northern Fleet	Pacific Fleet	Total
Active	4	4	8
Inactive	1	0	1
Decommissioned	0	0	0

Technical specifications:[66]

Length:	74.4 m
Displacement:	1,080/2,300[67] tons
Beam:	11.5 m
Crew:	33
Draught:	5 m
Speed:	11 knots

The Vala class ships were built in Vyborg and Vladivostok in the period 1966-1971.

Storage capacity

870 m³. Maximum permissible radiation level is 10^{-5} curies per liter.

Individual vessels:

Northern Fleet:

TNT-8 - Retired.

TNT-12 - Ship normally based at naval yard no.10. Shkval in Polyarny.

TNT-19

TNT-25 Ship based in Severodvinsk. It has an increased storage capacity for a total of 950 m³.

TNT-29

Pacific Fleet:

TNT-5 - Ship based at Bolshoy Kamen, Vladivostok. In November 1995, liquid radioactive waste amounting to 800 m³ was transferred to TNT-27.

TNT-17

TNT-27 - Ship based at Bolshoy Kamen, Vladivostok. It is in very poor condition.

TNT-42

66 Kuzin, V. P., Nikolsky, V. I., USSR Navy in 1945-1991, St Petersburg, 1996.
67 Empty/loaded.

Project 11510 - Belyanka class

The two ships of the Belyanka class, Amur and Pinega, were built to receive, transport and store liquid and solid radioactive waste. The ships are equipped with a special filter to reduce the radioactive content of liquid waste. Amur is based with the Norhern Fleet, while Pinega serves with the Pacific Fleet. Both vessels were formerly used to dump radioactive waste at sea.

Technical Specifications:[68]

Length:	122.3 m
Displacement:	6,680/8,250[69] tons
Beam:	17.1 m
Crew:	86
Draught loaded:	6.3 m
Speed:	approximately 16 knots

Storage capacity

Each ship has a storage capacity of 800 m^3 of liquid radioactive waste. The liquid is filtered through a special filtering installation on board the vessel. The design criteria is to reduce the radioactive content by a factor of one thousand. The filter can process 120 tons of liquid waste per day; however, the filter plant has never satisfied the design criteria with regard to reduction of radioactive content and was hardly ever operational. The maximum permissible activity is set at 370 MBq/l-370 kBq/l.

Each vessel also has two holds for the storage of solid radioactive waste. One hold has a capacity of 600 tons of waste loaded in containers; while the other can accommodate 400 tons. The waste may be of varying activity and physical dimensions.

Individual ships

Amur - Commissioned to the Northern Fleet on November 29, 1984. Refitted in 1993/94 at the Nerpa shipyard.

Pinega - Commissioned to the Pacific Fleet on July 17, 1987.

Osetiya

This vessel is a civilian tanker stationed at the Zvezdochka shipyard in Severodvinsk. The tanker was built in 1963. In 1990, her tanks underwent repair, but following an inspection on August 12, 1990, the decision was made to lay her up. She is presently at a permanent mooring.

Capacity: Nine tanks with a total volume of 1,033 m^3.

Project 326 – 326M

Four Project 326 nuclear support barges with storage for spent nuclear fuel – PM-50, PM-78, PM-124 and PM-128 – are based in the Northern Fleet. The vessels contain three storage tanks for liquid waste each. One tank has a volume of 125 m^3 and is intended for waste of medium to low activity. The two remaining tanks of 75 and 30 m^3 respectively, are meant for highly active waste with an activity of 370 MBq/l (10-2 Ci/l).

Project 2020 – Malina class

Two nuclear support Malina class ships – PM-63 and PM-12 - with storage for spent nuclear fuel are based with the Northern Fleet. The vessels are also equipped with storage tanks to hold 450 m^3 of liquid radioactive waste, including 95 m^3 of medium level waste with an activity of up to 3.7 GBq/l (0.1 Ci/l)

Nuclear lighthouses

Along the Russian Arctic cost, more than 150 nuclear lighthouses are located in remote areas. The lighthouses are powered by radioisotope thermal generators (RTGs). RTGs utilize heat from a radioactive source to produce power. These lighthouses have been in operation since the 1960s along the cost of the Kola Peninsula, the White Sea and north to the Kara Sea. The RTGs in lighthouses use a strontium-90 source, a beta-emittor with a dacay time of 28.5 years. Depending on the sice and age, the acitivity are between 1,850 TBq (50 kCi) to 9,620 TBq (260 kCi). This source developes a thermal power of 300 W to 1,700 W in the initial period of operation. By means of a thermoelectrical converter an electric effect ranging from 18 W to 130 W.

The nuclear lighthouses at the Kola Peninsula are owned and operated by the Northern Fleet. In more recent years, much of the maintance of the nuclear lighthouses have been reduced, and by several occations, old strontium-90 sources have been left at the cost. The Environmental Department of Finnmark county in Norway and the Russian Northern Fleet are co-operating in replaceing some of the nuclear lighthouses with lighthouses with solar power.

After the old strontium sources in the nuclear lighthouses are repleaced, they are shipped to a central storage in Mayak.

In May 2001, Four unemployed men in search of scrap metal dismantled generators at a nuclear-powered lighthouse near the town of Kandalakhsa on the White Sea cost, exposing themselves to dangerous doses of radiation. The area around the lighthouse was fenced off because of the radiation after this incident.

68 Kuzin, V. P., Nikolsky, V. I., USSR Navy in 1945-1991, St Petersburg, 1996.

69 Empty/loaded.

Chapter 2

Civilian nuclear vessels

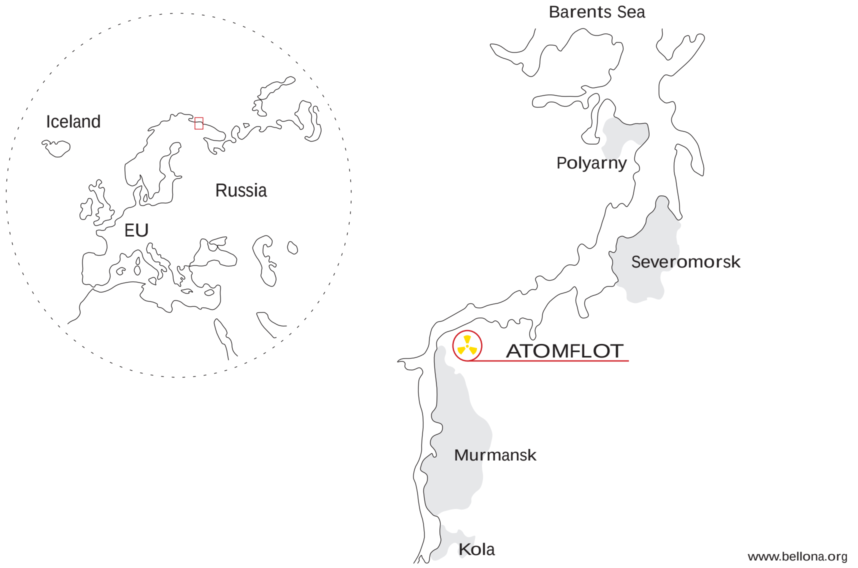
Civilian Nuclear Vessels

From 1959 to 1992, a total of nine civilian nuclear-powered vessels were constructed in the Soviet Union. Of these, eight were nuclear-powered icebreakers and one, Sevmorput, was a nuclear-powered container ship. (See Table 1).

The purpose of the nuclear icebreakers was to contribute to the large-scale development and industrialisation of the northern regions of the Soviet Union, whereby the icebreakers would force through the ice to facilitate the passage of cargo ships. Over the course of the 1960s and 1970s, transport on the northern seaway increased year by year, and the icebreakers were needed to keep open waterways covered by ice for long periods each year.

Operations for a typical nuclear icebreaker mission in the Arctic lasted approximately 6-8 months, but there were some passages that lasted more than 12 months. A nuclear icebreaker can operate for at least four years without having to refuel the reactor.

All of the civilian nuclear vessels are operated by Murmansk Shipping Company (MSCo) and have their home base at Atomflot.



2.1. Atomflot

Atomflot is the service base for the nuclear icebreakers and is located two kilometres from the northern border of city Murmansk, covering an area of 17.2 hectares. Until 1988 the base was called Base 92 and was a structural subdivision of Murmansk Shipping Company. After the privatisation of MSCo, Atomflot remained a federal property under the Ministry of Transportation.

The name Base 92 appeared in the beginning of the 1960s (92 is an atomic number of uranium). During that period the base represented a strip of land of the Kola Bay's coastal zone with a small wooden dock, several wooden block constructions, storage facilities and sheds where the equipment of icebreakers reactor installations was stored. The service base began operations in 1960 as a base for the Admiralty shipbuilding yard in St. Petersburg and was engaged to undertake the servicing of the first nuclear icebreaker Lenin.

The active building of the base started in 1970s when it had already been decided that the nuclear fleet would soon acquire new vessels. It was necessary to build mooring lines, modern workshops and departments as soon as possible.

The buildings and facilities, which make up the base today, were constructed to a design developed by the Soyuzmorniiproekt Institute in Moscow. The initial buildings went into operation in 1981 as part of the basic maintenance service (including maintenance of the nuclear installation, docks, and storage facilities for solid radioactive waste). Over the ensuing years, the construction of the auxiliary objects was expanded: building of special installation for filtering of radioactive water, new docks, a garage, a fire department, an administration building and other objects. Construction of a new land-based waterpool for storage for spent nuclear fuel was also started, but the construction was stopped in 1987.

Atomflot is a place for the ongoing service of nuclear icebreakers and other nuclear vessels; it is also here that the following task are carried out:

-maintenance and repair work on vessel systems and equipment;

-refueling the nuclear reactors;

-preparing spent fuel for transportation by rail;

-receiving and loading fresh nuclear fuel onto service ship Imandra;

-receiving, processing and temporary storing of solid and liquid radioactive waste.

Most maintenance work involving radioactive material is carried out in special departments and workshops.

Servicing of the icebreaker hull is carried out at dry docks in central dock areas close to the center of Murmansk City.

Service and maintenance of the nuclear lighter Sevmorput (length – 260 meter) are done at a Ministry of Defense shipyard in the settlement Roslyakovo (several kilometers north of Murmansk).

In 1995 Atomflot received a floating dock (from Russias Far East), but a lack of financing has delayed the reconstruction for service of nuclear icebreakers and service ships. In more recent years (1996 -2000), the decommissioning of the floating control-dosimetric boat PKDP-5 and the service ship Volodarsky was carried out in this dock.

Atomflot has its own railway connecting the service base to the Murmansk branch of the national railway, which is used for transporting fresh and spent nuclear fuel. To carry out the cargo works, Atomflot has three cranes placed on the mooring line to assist with the loading and unloading of cargo, including a 100-ton crane.

Technological subdivisions currently in operation at the service base include the following:

-maintenance and technology complex including plants for repairing vessel equipment, metalwork, and manufacturing of ship designs;

-special complex for repair of equipment for the nuclear installations;

-storage facility for containers holding solid radioactive waste (volume – 400m^3) complete with a plant for processing of inflammable waste;

-storage facility for high level solid radioactive waste (containers)

holding spent filter materials and emergency cores - 216 cells);
-storage facility for high level equipment (steam generators and so forth - 12 cells);
-storage facility for special containers holding worn reactor parts, three units;
-pilot plant for cleaning liquid radioactive waste. There are two on-shore tanks, (100m^3 in volume) for temporary storage of liquid waste;
-central plant laboratory, environmental protection laboratory, dosimeter control post;
-floating dock;
-important auxiliary units, including a boiler-house, transport department, fire department and so forth;
-technological docks with bridge cranes.

2.2. Nuclear icebreakers

The world's first nuclear icebreaker Lenin was in operation from 1959 until 1989. The second generation of icebreakers including Sibir (taken out of operation in 1993), Arktika, Rossiya, Sovetsky Souyz and Yamal, are the most powerful. The last icebreaker of the second generation, called 50 Let Pobedy, was launched in 1994 at the Baltic shipyard in St. Petersburg; however, the continuing lack of finances indicates that this icebreaker will not be enter operation for the next 3 years.

Table 1.
The main parameters of Russian nuclear-powered vessels

Name of vessel/ (operational since)	Place of Construction	Length max, m	Width max, m	Weight tons	Propulsion power MWt	Reactor capacity, MWt	Type
Lenin (1959)	St. Petersburg, Admiralty shipyard	134,0	27.6	19,420	32,0 (2x159)*	3x90 (OK-900)	OK-150
Arktika (1975)	St. Petersburg, Baltic shipyard	148,0	30.0	23,000	54.0	2x171	OK-900A
Sibir (1978)	St. Petersburg, Baltic shipyard	148,0	30.0	23,000	54.0	2x171	OK-900A
Rossiya (1985)	St. Petersburg, Baltic shipyard	148,0	30.0	23,000	54.0	2x171	OK-900A
Taimyr (1988)	Helsinki, Wartsila Marine and Baltic shipyard	151,8	29.2	21,000	35.0	1x171	KLT-40M
Sevmorput (1988)	Kerch, Zaliv yard	260,1	32.2	61,000	32.5	1x135	KLT-40
Sovetsky Soyuz (1989)	St. Petersburg, Baltic shipyard	148,0	30.0	23,000	54.0	2x171	OK-900A
Vajgach (1990)	Helsinki, Wartsila Marine and Baltic shipyard	151,8	29.2	21,000	35.0	1x171	KLT-40M
Yamal (1992)	St. Petersburg, Baltic shipyard	148,0	30.0	23,000	54.0	2x171	OK-900A

-The first nuclear power plant on board Lenin had 3 reactors; after modernisation in 1970 two new reactors were installed.

Taimyr and Vaigach, belong to the third generation of nuclear icebreakers, and were built in Finland. The reactor plant was installed at the Baltic shipyard in St. Petersburg. The two vessels are used for the northern sea-route, including shallow waters (whereby the waterline gauge is 8.1 meters). However, both vessels are mostly used on the Yenisey River to the river port Dudinka.
The Russian Transport Ministry has begun to plan the construction on a new generation of the massive, powerful nuclear powered icebreakers to be put into operation after 2010.
The nuclear-powered container ship Sevmorput is used to transport barges and containers to the coastline of the northern Siberia, (here the waterline gauge is 10.7 m) and the ship is able to force through ice with a maximum thickness of one meter. The Sevmorput was the first nuclear-powered vessel constructed according to the international convention safety requirements for nuclear cargo ships.
Sevmorput can carry 1,336 standard 20-foot containers or 74 lighters. The lighter is a special type of seagoing transportation vessel that is utilised for loading and unloading operations in areas where the harbour waters are too shallow to accommodate the container ship, thereby necessitating operations in the open sea.
According to the original plans (in Soviet Union times), the container ship was also to be used for international transport, and to that end, Sevmorput did indeed sail a number of voyages to Vietnam in the late 1980s and early 1990s. In the late 1990s the container ship has only been used for journeys between Murmansk and Dudinka. However, in the most recent years, Sevmorput has been laid up at Atomflot. Assuming that refuelling and the repair operations otherwise go according to plan, Sevmorput will be nonetheless still be laid up at Atomflot in 2001 because of financial problems, a situation that is expected to last until 2003.

2.3. Accidents and emergency situations

2.3.1. Nuclear icebreaker Lenin

The first nuclear propulsion unit (OK-150) on Lenin had three identical pressurised water reactors (PWR) with a maximum heat output of 90 MWt. The shaft power was 44 ,000 horsepower. Enriched uranium was used as fuel (the content of U-235 was equivalent 85 kg), and distillate water was used as a moderator and for heat transfer. The reactor core was 1.6 meters high and measured one meter in diameter. The core consisted of 7,704 fuel pins in 219 fuel assemblies.

There have been two accidents onboard the nuclear powered icebreaker Lenin. The first took place in February 1965, when Lenin was undergoing repairs and refuelling. The vessel sustained severe mechanical damages to the fuel assemblies, some of which were broken in two pieces, and were detected during the unloading of fuel from reactor number two. About 95 spent nuclear fuel assemblies were transferred to the nuclear service ship Lepse and unloading was halted after that.

After investigations as to why the spent nuclear fuel assemblies were deformed, it was established that the nuclear reactor operators had made an error that left the reactor core without cooling water. The partial deformation of the fuel assemblies had occurred due to overheating of the reactor core. About 60% of the assemblies were damaged. The decision was made to unload the remaining 124 spent nuclear fuel assemblies together with the neutron absorbing rods and control grid.

A special cask was built onshore to implement this operation. A part of the reactor containing spent nuclear fuel (SNF) was placed into the cask and filled with furfurol-based solidifying matter. This cask was then stored for two years. In 1967, it was reloaded onto a pontoon, towed by a tug to the eastern coast of the Novaya Zemlya Archipelago and dumped in Tsivolki Bay.

The second accident aboard the Lenin took place in 1967, when the pipe system of the third circuit sprung a leak following the loading of fresh nuclear fuel. In this instance it was necessary to open the biological shield of the reactor compartment in order to locate the leakage. This protection was made of concrete mixed with metal shavings and it required the use of sledgehammers to break through the shield. This led to further damage of the reactor installation. Upon later examination, it became clear that it would be impossible to repair the damage incurred to the reactor installation by the sledghammers.

By that time an upgraded model of the reactor installation, OK-900, was almost completed. The failure to repair the cooling system prompted the replacement of the whole reactor installation on the Lenin, and consequently, the whole 3,500-ton reactor compartment including steam generators and pumps was to be cut out.

Since one of the reactors of the damaged OK-150 installation had been recently loaded with fresh fuel, it was decided to remove all of the assemblies and to send the nuclear fuel to the manufacturer. However, both the internal and external surfaces of the assemblies showed significant levels of radioactive contamination; therefore all assemblies were dismantled and the fuel elements were removed (36 fuel elements in one assembly). After that the elements containing fresh nuclear fuel were decontaminated using chemical solutions and carefully wiped clean. Only then they were sent to the manufacturing plant.

The SNF from the two other reactors was also loaded onto the Lepse nuclear service ship. The reactor installation itself was filled with a furfurol-based solidifying matter. Special cuts were made around the reactor installation and in the icebreaker's hull. After that Lenin was towed to Tsivolki Bay (Novaya Zemlya Archipelago). The reactor installation was then prepared for dumping in the bay. Crosspieces fastening the whole construction of the installation were filled with explosives. The explosives were then detonated, and the reactor construction split apart from the icebreaker's hull and sank at the depth of 40 to 50 meters.

The icebreaker was then towed to the Zvezdochka shipyard in Severodvinsk, Archangelsk county, where the vessel remained from December 12, 1967 until May, 1970, while a new OK-900 reactor installation was being installed.

Removal operations of the OK-150 reactor plant were carried out at the Zvezdochka yard in Severodvinsk and took 38 months. The operation included the following two stages:

-dismantling of the generator from April 19 until December 12, 1967. This operation was carried out according to guidelines developed by the central design office Aisberg. The generator with biological shielding was removed through the vessel's bilge directly in a dumping area, (Zivolki Bay, Novaya Zemlya). The total weight of the dumped equipment was 3,500 tons.

-installation and tests of the new OK-900 generator were done from December 12, 1967 until June 20, 1970.

The OK-900 reactor plant had two reactors with four steam generators and four primary circulating pumps. The first OK-900 reactor went into operation on April 22, 1970, with the second reactor starting up on April 23 of the same year. Repair and pre-setting operations lasted until June 20, 1970. The OK-900 reactor plant then remained in operation until Lenin was taken out of service in 1989. The spent nuclear fuel was removed from the reactors in 1990.

During the second half of the 1990s, check-up operations were carried out and steam generator piping in the form of cutting metal samples for testing. The results of these tests will be applied towards developing solutions aimed at prolonging the active use of power plants in nuclear ships.

The nuclear icebreaker Lenin is currently moored in the harbor in Murmansk, which is located 1 km from the centre of the city. In the early months of 2000, a decision was made to create a museum onboard the icebreaker which would be moored in Murmansk Harbour. This project will cost more than 1 million USD; the federal budget for the year 2000 allocated 500 000 roubles for this purpose (equivalent to about 18 000 USD).

2.3.2. Neutron source theft

On July 13, 1999, five persons were arrested trying to sell a strong radiation emitter in St Petersburg. Such material as californium-252 and more than 17 kg of mercury were confiscated. According to the press reports, the level of radiation was around hundred times higher than the background radiation. Two of the arrested persons worked at Murmansk Shipping Company and had served as crew members aboard the nuclear service ship Imandra and the nuclear icebreaker Rossiya.

Californium-252 is a strong neutron emitter and may be used for starting up reactors. The stolen source was stored in a 200-kg container at the Imandra nuclear service ship. A smaller container was used to deliver the source to the reactor room. The theft occurred when a used source was taken out of operation and placed in a container for solid radioactive waste aboard the Imandra in autumn 1998. The thieves managed to steal the material and carry it out of the base territory without being noticed. After their arrest in July 1999, the two thieves were sentenced in May 2000 to imprisonment for 2.5 and 4.5 years in St Petersburg.

2.3.3. 1993 fresh nuclear fuel theft

On the night of November 26, 1993, fresh nuclear fuel (contains uranium) in the form of three fuel rods for nuclear powered submarine reactors of the second generation (Victor-III class) was stolen from a naval storage in the northern part of Murmansk. The storage facility from which the rods were stolen was 50 years old and had no proper alarm system. The lock was easily sawed off from the door of the storage. The break in was not discovered until 2.00 p.m. the following day.

It took more than six months for the police to track down the thieves. About 600 persons were called in for questioning with no result. The criminals were found quite by accident. One of the thieves had divulged his secret with a work mate and this information reached the counter-intelligence service of the Northern Fleet. On June 30, 1994, three persons were arrested: a captain of the second rank, a lieutenant and a retired captain of the third rank. All of them confessed, admitting that their intent had been to find customers for uranium. The fuel assemblies had been stored in a garage of one of the thieves (fresh fuel rods pose little danger to humans and the environment).

In February 1995, the Severomorsk military court reached a verdict. Both of the captains were deprived of their military ranks and sentenced to three years in labor camp. The lieutenant was convicted conditionally.

After this incident the assemblies were shipped to another Northern Fleet storage facility. Military officials claim that stealing assemblies from this facility storage is impossible.

2.4. Handling of radioactive waste

All nuclear vessels have tanks for collecting liquid radioactive waste and storage facilities for temporarily storing containers holding solid radioactive waste. As soon as enough radioactive waste has accumulated, the containers are transferred to the service ships Imandra and Serebryanka, and transported to Atomflot for processing.

Solid waste is sorted by radiation level and divided into categories of "flammable" and "inflammable". At Atomflot there is a flammable solid waste destruction facility with a capacity of 40 t/y. The facility allows for a reduction in volume of the solid waste by a factor of 80. The gases, which are produced in the process are specially filtered. Up to the present day, more than 350m^3 of flammable solid waste has been processed using that installation.

Non-flammable solid waste, spent filter materials, and contaminated equipment are stored in special rooms and on the temporary storage sites at Atomflot, as well as on the service ship Volodarsky. All production sectors of Atomflot entailing work with contaminated equipment are equipped with an air cleaning system from radioactive aerosols.

Liquid waste is transferred for processing at a pilot plant. Radioactive water is passed through a series of filters whereby the content of radionuclides is reduced to an acceptable concentration. The water is then bio-cleaned in the general cleaning system and released into the Kola Bay.

2.4.1. Nuclear service ships

Murmansk Shipping Company operates six nuclear service ships at the present time (see Table 2). They are moored at Atomflot and have the following functions:

-unloading spent nuclear fuel assemblies and refueling nuclear reactors with fresh fuel;
-storing spent and fresh nuclear fuel;
-receiving, transportation and short-term storage of liquid and solid radioactive waste;
-receiving, decontamination, repairs and storing of special equipment for nuclear icebreakers;
-transportation of spent nuclear fuel and radioactive waste;
-supplying nuclear powered vessels with various materials (filter components, evaporator, gaseous nitrogen);
-decontamination of personnel.

Ship	Year of construction	Length (m)	Width (m)	Displacement (ton)	Crew	Vessel Utilisation
Imandra	1981	130	17	9700	100	Floating nuclear service base
Lotta	1960	122	16	7000	60	Floating nuclear service base
Serebryanka	1974	102	12	4300	30	Special nuclear service tanker
Rosta-1	1985	62	12	1650	14	Radiation monitoring barge
Lepse	1936	87	17	5600	40	Floating nuclear service base
Volodarsky	1929	96	16	5500	-	Floating nuclear service base

Table 2.
The main technical parameters of the service-storage ships

From 1961-1986, Murmansk Shipping Company was also operating the following nuclear service vessels:

-The steamer Nikolay Bauman (dumped with solid radioactive waste aboard in Tsivolki Bay at the Novaya Zemlya Archipelago in 1964);
-The barge SB-5 (dumped with solid radioactive waste aboard in Olga Bay, Novaya Zemlya Archipelago);
-Radioactive waste storage barge PSSN- 328 (dumped with solid and liquid radioactive waste aboard in the Kara Sea in 1976);
-Radiation monitoring barge PKDP-5 (decommissioned at Atomflot in 1997).

2.4.2. Imandra

The service/storage ship Imandra was built in 1981 at the Baltic shipyard in St. Petersburg as a special project. Imandra is used to service the nuclear powered ships and for operations involving spent nuclear fuel. Hence the following equipment and facilities may be found on board:

-equipment for removing spent fuel and loading fresh fuel assemblies;
-storage for spent fuel;
-storage of fresh fuel assemblies;
-two ship cranes, each of which has a lifting capacity of 16 tons;
-rooms with specialised equipment for decontamination of equipment and instruments;
-acceptance, storage and transfer of liquid waste as well as filter materials;
-installation for preparing and replacement of the filter materials;
-installation for production of high filtered nitrogen;
-two evaporators for water filtration;
-special laundry for decontamination of clothes;
-sanitary control for personnel and contaminated clothing.

The maintenance of the civilian nuclear naval reactors is normally carried out at the Atomflot quay. If necessary, Imandra has the capability to carry out some operations at other sites that lack specialised equipment.

Imandra can store containers holding spent nuclear fuel assemblies. The Imandra has six separate tanks for storing spent nuclear fuel. The storage is cooled with filtered water, and the temperature is monitored.

Each storage tank has a capacity of 51 containers containing spent fuel assemblies. The containers are fixed into each tank section and closed with a special cover that precludes the possibility of their falling out in the event of an accident (capsizing, for example).

Spent nuclear fuel from the icebreakers is stored in special containers, each of which has a capacity of five assemblies. The total storage capacity of Imandra is at least 1,530 spent fuel assemblies from the reactors of civilian nuclear powered vessels. Containers containing seven spent fuel assemblies from nuclear submarines can also be stored onboard Imandra.

Once removed from the reactor, spent nuclear fuel is a strong radiation source. The 220 mm thick steel plates in the walls provide protection from radiation. The containers are cooled by a water cooling system. A filtration system keeps the water in the cooling system clean. The radioactivity of the cooling water is not permitted to exceed 370 kBq/l (1.0 x 10^{-5} Ci/l).

The fuel assemblies are placed in waterproof containers so as to avoid all contact between the fuel assemblies and the cooling water. This method of "dry" storage of spent nuclear fuel has been practised aboard the Imandra since the mid 1980s. Prior to this common practice was to cool the spent assemblies directly by water. As a consequence, huge quantities of liquid waste were produced aboard the ship. Before the spent fuel for reprocessing is transported to Mayak, the radioactive contaminated water from the containers is transferred to the special tanks.

The temporary storage of spent nuclear fuel aboard the service and storage ships is aimed at lowering the temperature and radioactivity of the spent fuel. This ensures a safer transport by railway to the reprocessing facility at Mayak. The fuel assemblies are stored aboard Imandra and Lotta for at least three years prior to transport to Mayak. The storage time for spent fuel aboard Imandra is approximately three months; after this the fuel is transferred to Lotta for the rest of the storage periode.

In the period from 1981 till 1999, Imandra assisted in the removal of spent nuclear fuel from the civil nuclear powered vessels 32 times and the loading of fresh nuclear fuel aboard them 28 times. In this period there were no more than three refuellings per year, with a total of 7,712 spent nuclear fuel assemblies removed by Imandra throughout this time.

Of the fuel changes facilitated by Imandra, 25 were carried out on civilian nuclear powered vessels. The numbers of changed reactor cores on the different ships are as follows: Lenin: 6, Sibir: 6, Russia: 4, Taimyr: 3, Sovetsky Soyuz: 2, Vaygach: 2, Yamal: 1, the container ship Sevmorput: 1.

From November to December, 1999, Imandra removed spent fuel from a laid-up nuclear submarine for the first time. The fuel was from the two reactors onboard the Northern Fleet's Victor-II submarine (671 RTM, Factory no. 803). Work was carried out at the Nerpa quay (Snezhnogorsk) both by military personnel and by the crew of Imandra. In the autumn of 2000, Imandra participated in another defuelling operation when spent nuclear fuel was unloaded from two Victor-II submarines (factory no. 802 and 804) in Polyarny.

There were a total of 448 spent fuel assemblies to remove, and once the fuel had been removed from the reactors, it was reloaded from Imandra into the transport containers of the Lotta at the Atomflot quay. At the beginning of 2001 the spent fuel was then transported by rail to Mayak for reprocessing.

As of January 1, 2001 Imandra contained 1,290 spent fuel assemblies.

Refuelling a nuclear reactor takes 45 days and entails the following stages:

1. Shutting down the reactor;
2. Waiting for approximately one month for the temperature and level of radioactivity to decrease;
3. Removal of control and protection systems;
4. Removal of reactor cover and installation of equipment to remove used fuel assemblies;
5. Removal of spent assemblies from the naval reactor to Imandra;
6. Cleaning of the first cooling circuit;
7. Loading of fresh fuel into the reactor;
8. Re-installation of reactor cover, control and protection system;
9. Hydraulic tests and restarting the reactor.

The removal of spent fuel (one fuel assembly) is carried out with the use of a shielded transfer-container weighing 12 tons. The container is then transferred to the storage hold in Imandra, where the spent fuel assembly is put into another container. The removal of 241 spent assemblies takes from three to seven days (depending on weather conditions).

Before refuelling or during preliminary operations, the fresh fuel is delivered to Imandra by rail. The fresh fuel is transferred from Imandra to the reactor room of the ship utilising charging cassettes at Atomflot.

During the refuelling of a reactor, the surfaces of rooms, as well as equipment and instruments become contaminated with radioactivity. The level of radioactive contamination is determined by the condition of the cooling agent in the first cooling circuit. Besides, the decontamination of certain elements of the reactor is carried out aboard the Imandra. All service operations to the reactor and the decontamination process itself produce solid and liquid radioactive waste.

The spent assembly is then transferred to a special tank (a cylindrical container with a volume of $1.0 m^3$) and placed onboard Imandra or delivered to Atomflot. High level radioactive waste is transferred to Atomflot in cylindrical containers, which are then sealed upon the conclusion of operations. Most of the equipment is then decontaminated and transferred in special boxes to Atomflot.

Every year, an average of about 20 containers with solid radioactive waste is produced and stored aboard Imandra with a total activity of 1,000 GBq (27 Ci). Between two to three containers of spent filter materials and parts of reactor equipment are produced annually, with a total activity of 1,000 TBq (10,000 Ci).

Table 3.
Function of the service ships

Function	Imandra	Lotta	Serebryanka	Rosta-1	Lepse	Volodarsky
Receiving and storage of SNF	+	+	-	-	+	-
Receiving and storage of fresh fuel assemblies	+	-	-	-	+	-
Equipment for loading SNF to transport containers	-	+	-	-	-	-
Receiving and storage of solid radioactive waste	+	-	-	-	+	+
Receiving and storage of liquid radioactive waste	+	-	+	-	+	-
Filtration of liquid waste	+	-	-	-	-	-
Equipment for decontamination	+	-	-	-	+	-
Preparation of filter materials	+	-	-	-	-	-
Generation of nitrogen	+	-	-	-	-	-
Generation of evaporator	+	-	-	-	+	-
Storage of specialised equipment	+	+	-	-	+	+
Laundry for working clothes	+	-	-	+	+	-

Note: the service /storage ships Lepse and Volodarsky are currently used solely for storing waste, not receiving it. Volodarsky is partly decommissioned.

Tanks of different sizes with a total volume 545 m^3 are used for to temporarily store liquid waste (See Table 4). If the tanks onboard Imandra are full, the waste is transferred to the land-based tanks at Atomflot for cleaning or to the tanker Serebryanka for further storage.

Every year Imandra receives liquid waste with a total activity of 50 GBq (1.5 Ci) from Russian nuclear-powered vessels; in addition there is also the liquid waste from Lotta with a volume of 2 m^3 and an activity of about 370 GBq (10 Ci). As a result of the technological operations and decontamination activities carried out on the Imandra, every year about 100 m^3 of liquid waste with an activity of approximately activity 37 GBq (1 Ci) is produced. Most of this waste is medium level activity – that is, no more than 0,00037 GBq/l (1,0x10-^{5} Ci/l).

Until January 1, 2000 there were 65 m^3 of liquid waste with an activity of 18 GBq (0,5 Ci) and three containers of solid waste on the Imandra.

2.4.3. Lotta

The nuclear service ship Lotta was first designed as a lumber carrier, and was built at the Baltic shipyard in St Petersburg in 1961. Until 1982, she belonged to the Northern Shipping Company (Arkhangelsk) and her first name was Pavlin Vinogradov.

In 1984, the vessel was redesigned as a floating base to store spent nuclear fuel, and was reconstructed at a shipyard in Murmansk, subject to the Ministry of Maritime Transport. The ship was later renamed Lotta and taken into operation as a nuclear service ship at Murmansk Shipping Company (all main functions are given in Table 3).

Lotta is principally used for:

-receiving and further storing of spent nuclear fuel assemblies which have been unloaded from nuclear naval reactors and stored onboard the Imandra service ship for at least three months;

-loading containers of spent nuclear fuel assemblies into transport casks and moving them onshore;

-collecting, storing and transporting solid and liquid radioactive waste generated during main operations and decontamination of equipment and ships. The system for collecting and short-term storage of LRW can receive waste with an activity of not more than $3{,}7\times10^5$ Bq/m^3 (10^{-5} Ci/l)

The vessel has two storage rooms, each of which is divided into six sections. One section can store 68 containers of spent nuclear fuel assemblies. The two storage rooms have a storage capacity of 816 containers, depending on the number of spent nuclear fuel assemblies in the container (There can be anywhere from three to five to seven assemblies in one container). One type of container regularly holds five spent nuclear fuel assemblies, whereas the container for storing fuel from nuclear powered submarines can hold seven assemblies. The storage rooms of Lotta can store up to 16 nuclear powered icebreaker reactor cores. The cooling medium for SNF is the air inside the containers and the containers themselves are cooled by distilled water.

Spent fuel is loaded onto Lotta from the nuclear service ship Imandra or from the Northern Fleet service ship PM-12. These operations are carried out either at Atomflot or where the military service ship is stationed at the given time.

(SNF) is stored aboard Imandra and Lotta for a minimum of three years. This is necessary to reduce the heat emitted by the spent nuclear fuel assemblies to a minimum so as to permit safe shipment of SNF in casks by rail.

Two units in the storage rooms aboard Lotta are dry and free of water at the present time. The utilisation of this completely dry method of storage is used after the discovery that the metal hull of the container develops cracks as a result of long-term storage in water. The contact of the spent nuclear fuel assemblies with cooling water leads to an extra discharge of radioactive elements into the cooling water and hence an increase of both the activity and volume of liquid radioactive waste. The spent fuel in these units has been stored for a long time and does not produce any significant heat. As of January 1, 2000, 594 spent nuclear fuel assemblies were stored in two completely dry units, and it was being considered to prepare a third unit for the same method of dry storage. SNF from Lotta (and earlier, from Lepse) used to be transported in TK-12 casks. This type of cask could only hold one container with five spent nuclear fuel assemblies. TK-12 containers were unloaded from the Lotta and then transported by lorry to a loading point on the railway where flatbed cars were stationed. About 2,370 spent nuclear fuel assemblies (more than 30 trainloads) were transported to Mayak from 1980 to 1990. In 1993, the storage rooms of Lotta were refitted at the Nerpa shipyard in Snezhnogorsk to operate with the new TUK-18 transport containers. Testing of the new system of

No.	Tank name	Use	Volume (m^3)	Protection
1	Tank drain cooling water	Storage of liquid waste	95	biological protection
2	Tank drain cooling water from zone No. 1	Storage of liquid waste from Imandra	52	no protection
3	Tank drain cooling water from zone No.2	Storage of liquid waste from Imandra	50	no protection
4	Tank of decontamination water, acid	Storage of liquid waste from decontamination room	46	biological protection
5	Tank of decontamination water, alkali	Storage of liquid waste from decontamination room	46	biological protection
6	Tank of filtered water No.1	Filtration of liquid waste	72	no protection
7	Tank of filtered water No.2	Filtration of liquid waste	20	no protection
8	Tank of filtered water No.3	Filtration of liquid waste	36	no protection
9	Control tank No.1	Filtration of liquid waste	22	biological protection
10	Control tank No.2	Filtration of liquid waste	24	biological protection
11	Sanitary tank	Water of bath rooms	41	no protection
12	Tank of laundry	Water from laundry	41	no protection
TOTAL			545	

Table 4.
Tanks for temporary storage of liquid waste at Imandra

reloading and transportation of SNF using TUK-18 containers was carried out at the beginning of 1995. In March 1995, the first train of TK-VG-18 train cars and TUK-18 containers of spent nuclear fuel departed from Atomflot bound for the Mayak reprocessing plant. The TUK-18 consists of a TK-18 cask and seven containers for assemblies. Air is the cooling medium inside both the cask and the containers. Lotta can accommodate seven TK-18 casks: six in the storage room and one in the loading room.

After refitting, the Lotta now has:

-a loading room for TK-18 casks;

-a decontamination room for TK-18 casks;

-storage room to store TK-18 casks.

Lotta receives containers of SNF from the Northern Fleet both at Atomflot and at other sites where the service ships of the Northern Fleet are stationed. The Lotta transported SNF originating from Northern Fleet vessels to the Nerpa shipyard on several occasions.

From March 1995 to April 2000, 16 trains carrying SNF from Lotta were shipped. Of this spent nuclear fuel, 75% belongs to the Navy. Compared to the older TK-12 containers, the efficiency of transporting of spent nuclear fuel assemblies utilising the new TUK-18 containers increased by factor of three. The capacity of TK-12 cask was one container holding five spent nuclear fuel assemblies.

Around 3,700 spent nuclear fuel assemblies from the nuclear powered icebreaker reactors were stored onboard Lotta. There were no military spent nuclear fuel assemblies in Lotta's storage rooms.

2.4.4. Serebryanka

The tanker Serebryanka was built in 1974 at the Oka shipyard (located in the town of Navashino, in the Nizhegorodsky region) in 1974. The tanker is used for the following functions: collection, temporary storage, transport and transferral of liquid radioactive waste; and for the collection and transferral of distillate.

Serebryanka has eight tanks with a total capacity of 1,151 m^3 for handling liquid radioactive waste. At present, only six tanks are used for temporary storage of liquid waste (Nos.1-6) with a capacity of 851 m^3, while the remaining two tanks (Nos. 7-8) are used for operations with distillate ($300m^3$). Tanks Nos.1 and 2 have biological shielding made of steel and concrete to increases radiation safety.

Liquid waste is transferred to Serebryanka from the nuclear icebreakers or service ship using temporary pipes. During this operation the level of radioactivity is estimated as well as the levels of salts dissolved in water- that is, a preliminary sorting of liquid waste according to radioactivity and chemical parameters.

Until 1986 the tanker was also used for transporting and processing of liquid radioactive waste to be dumped into Barents Sea. In certain areas of the sea, dumping was carried out after first mixing waste and seawater within the pipe-work. (See Chapter "Dumping radioactive waste"). In 1995, the ship's dumping equipment was removed.

From 1987-1990, onboard testing of the equipment for liquid waste filtration were carried out (the method of filtration is through ion changing). This equipment was a prototype of the similar industrial filtration equipment to be installed at the nuclear icebreaker base Atomflot.

From 1992-1993, Serebryanka was used for several geological expeditions to the areas surrounding the southern tip of Novaya Zemlya, which have been the subject of study as a possible location for the establishment of underground storage facilities for radioactive waste and spent nuclear

fuel.

Since 1996, the ship has been used for collecting and transporting liquid waste from the Northern Fleet's vessels to Atomflot for purification. The total amount of transferred waste is about $2900m^3$, including $720m^3$ from the shipyards located in the town Severodvinsk (Archangelsk region).

2.4.5. Lepse

The building of the 270 foot ship Lepse started in 1934 at the Nikolaevski shipyard in the Ukraine. The vessel was originally intended to be a cargo ship; however, the vessel was never used according to the original plans. During World War Two, the uncompleted vessel was sunk, but after the end of the war she was raised to complete the construction.

In 1961 Lepse was refitted at the Admiralty shipyard in St. Petersburg and taken into service by Murmansk Shipping Company as a service ship for the nuclear icebreakers. Lepse is equipped with storage space for spent nuclear fuel, tanks for collecting and temporarily storing liquid radioactive waste, and rooms for servicing reactor equipment.

Between 1963 and 1981, Lepse provided refuelling services for the Lenin, Arktika and Sibir nuclear icebreakers. After the commissioning of the service ship Imandra, Lepse has only been used for the temporary storage of spent nuclear fuel, radioactive waste, technological equipment and the dumping of radioactive waste.

In the period between 1964 and 1986, Lepse transported radioactive waste to the following dump sites:

-Kara Sea and the bays and inlets of Novaya Zemlya: dumping of solid radioactive waste (in steel containers) and radioactive contaminated equipment;

-Barents Sea: dumping of liquid radioactive waste.

Since 1988, the Lepse has only been used as a storage ship. In the summer of 1999, the Lepse was repaired at the Snezhnogorsk shipyard Nerpa (Murmansk region) where operations were carried out to keep her safely afloat for approximately 10 years more. Currently the Lepse is moored at Atomflot. Of all the service ships at Murmansk Shipping Company, the service ship Lepse has remained in operation the longest.

Spent nuclear fuel storage

The major potential nuclear and radiation danger aboard the Lepse comes of the storage of spent nuclear fuel. Taking into consideration the possibility of accidents following for example collision with another vessel, the sinking of Lepse might lead to an extremely dangerous radiation contamination of the Murmansk local environment.

The storage compartment for the spent nuclear fuel has the following dimensions: length 5.8 m, width 11.5 m and height 6.0 m. The thickness of the biological shielding wall is 380-450 mm. The storage facility consists of two identical tanks with measuring 3.6 m in diameter and 3.4 m in height. Each tank has 366 isolated airtight canisters measuring 67 mm in diameter and four caissons with a diameter of 500 mm. The canisters are designed to store spent fuel assemblies and the caissons for storing filters from the primary circuit. Each storage facility has its own cooling system.

Originally the storage canisters were filled with cooling water. Until the 1990s, the radioactivity of this water had risen to 37 GBq/l (1Ci/l). In the last few years, the storage area has been permitted to dry out (to make the storage more acceptable).

Unlike the storage of fuel assemblies onboard Imandra and Lotta, where fuel assemblies are stored in five-unit containers, onboard Lepse each fuel assembly is placed in a separated section. This section forms a part of the actual storage such that when removing the spent nuclear fuel it can easily be damaged.

Following the reactor accident aboard the nuclear icebreaker Lenin in 1967, some fuel assemblies from the destroyed nuclear reactor core were transferred to one of the storage sections of Lepse. Some of the fuel assemblies did not fit into storage sections because they had expanded and were damaged. During operations of placing the fuel into the storage area, some of the fuel assemblies were additionally damaged. The non-standard and partially damaged fuel assemblies that did not fit into standard sections were placed in the caissons.

Currently there are 639 spent fuel assemblies in storage, including 206 assemblies from the first OK-150 type reactor utilised in the icebreaker Lenin. As of January 1, 2000, the radioactivity of the spent fuel was approximately 28-37 PBq (750,000 Ci - 1million Ci). About 70% of radioactivity emanates from cesium-137 and strontium-90. The total quantity of uranium-235 from the fuel assemblies is 260 kg.

As a result of long term storage in water, the fuel assemblies became prone to corrosion that changed the physical form of the fuel. This change in the fuel makes it difficult to remove the fuel the storage sections. According to a 1988 decree by the USSR Ministry of Industry and Atomic Energy, the fuel assemblies on board the Lepse are considered to be high level solid radioactive waste.

There are high levels of gamma radiation in the compartments where the spent nuclear fuel is stored, ranging from from 0.5 to 10 mSv/h (50-1,000 mR/h). In the adjacent

compartments, the radiation level is from 0.05 mSv/h (5 mR/h) to 5 mSv/h (500 mR/h). In 1991 the space between the storage tanks was filled up with a concrete mixture to ensure additional protection for the engineers.

In 1997, a test was carried out entailing the transfer of two fuel assemblies from Lepse to Imandra. Following the operation, localised radioactive contamination was detected in the storage compartment of Imandra (the inner surfaces of the storage tank and increased radioactivity of the cooling water) and in the areas already under regular monitoring.

Radioactive waste storage

There are 11 tanks for storing liquid radioactive waste onboard Lepse with a total volume of about 650 m^3. The tanks for storing liquid radioactive waste are currently empty; only tank No.1 contains liquid waste with a volume of about 60 m^3 and a total radioactivity of about 67 GBq (1.8 Ci). Contamination and sediments inside the other tanks is solidified by a special concrete mix and polymer covers.

There are also 24 containers of solid low and medium level radioactive waste on board Lepse. They are placed in the storage section for spent fuel and are used for protecting the crew from gamma radiation. There are also about 50 bags of iron-ore concentrate in the storage area which are kept for the same reason.

The Lepse project

A solution for the Lepse problem was included in The Federal program for the handling of radioactive waste and used nuclear materials: their decommissioning and disposal for the years 1993-1995 and with the perspective to the year 2005. According to certain decrees of the Russian Government, the Lepse-problem is included in the list of priorities which is presented in the indicated program. Furthermore, the problem was presented in the working plans of the Euro-Arctic (Barents) region for the years 1994-95.

The technical solution concerning the handling of the Lepse's stored spent nuclear fuel is interesting with respect to the problems of handling the service vessels of the military and civilian atomic fleets and the storage compartments and containers aboard these vessels holding reactor installations in which the nuclear fuel has been damaged.

In 1995, the IAEA founded a consulting committee on the Lepse environmental project in order to co-ordinate the common activities. In 1997, the French firm SGN and the English firm AEA Technology within the TASIS project framework developed a technical solution to remove spent nuclear fuel from the storage tanks. The solution is based on robotics and remote-controlled operations to remove the fuel from storage, and it should dramatically reduce the radiation dose to the workers. Should the work on the other hand be carried out utilising human labour resources only, it would result in about 5,000 workers receiving their annual allowed amount of radiation over the course of a single operation.

The Lepse project has been more or less halted since 1997 due to unresolved issues of liability and tax-exemption status. The question of where to store the spent nuclear fuel once it is removed from Lepse is also unanswered. One solution proposes the use of the Murmansk 80-ton containers that were originally developed for the ship Lotta (See chapter 5.3).

Since the Lepse project has been so delayed and the vessel's crew continue to receive more than the maximum permissible radiation dose, the Bellona Foundation has financed an alternative living and working module for the crew aboard Lepse. The design is based on standard 20 foot industry containers, which are equipped with kitchens, sleeping cabins, laboratories and a radiation control zone with showers. The module is moveable and can be used for other projects in the region at other locales.

2.4.6. Volodarsky

The Volodarsky was built in 1929 at the Baltic Admiralty shipyard in St. Petersburg. The Murmansk Shipping Company took the ship into use in 1969 after reconstructing and refitting the vessel as a service ship to the nuclear icebreakers. At the present time she is the oldest boat in the nuclear icebreaker service.

Up to 1986, Volodarsky was used for transporting solid radioactive waste in containers to an area east of Novaya Zemlya, where the waste was then dumped into the ocean. Containers of used filter materials were also stored onboard, as well as technical equipment for operating the reactor. During the last few years, the ship has been used for storing solid radioactive waste and unused technical equipment.

In July 1997, Volodarsky was docked at Atomflot to in connection with a project developed by Atomenergo (St. Petersburg). During this project, the propeller was removed, all of the outwards holes were sealed, pipes were removed, the tanks were dried, the superstructure was cut off, the storage covers were sealed and equipment from the machine compartment was removed. In this operation 14 containers of solid waste were produced. With a total volume of 20 m^3.

In April 2000, Volodarsky left the dock and was the first service ship to be laid up at Atomflot. Radiation control and hull examination will be carried out from time to time. It is supposed that the boat will be laid up for some years until the problem of how to dispose of solid radioactive waste in the north-west region of Russia is solved. The remaining vessels will then be decommissioned and the waste removed.

At the present time Volodarsky has:

-217 containers of solid waste, with a total activity of more than 400 TBq (10,800 Ci);

-30 containers of used filter materials, with a total activity 6.1 TBq (165 Ci);

-technical equipment in the form of solid radioactive waste weighing more than 2,000 tons.

Chapter 3

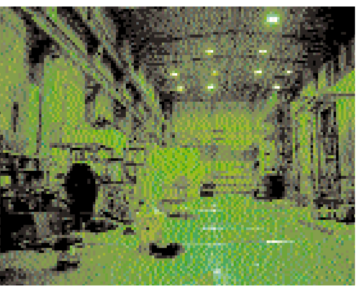
Kola nuclear power plant

Kola Nuclear Power Plant[70]

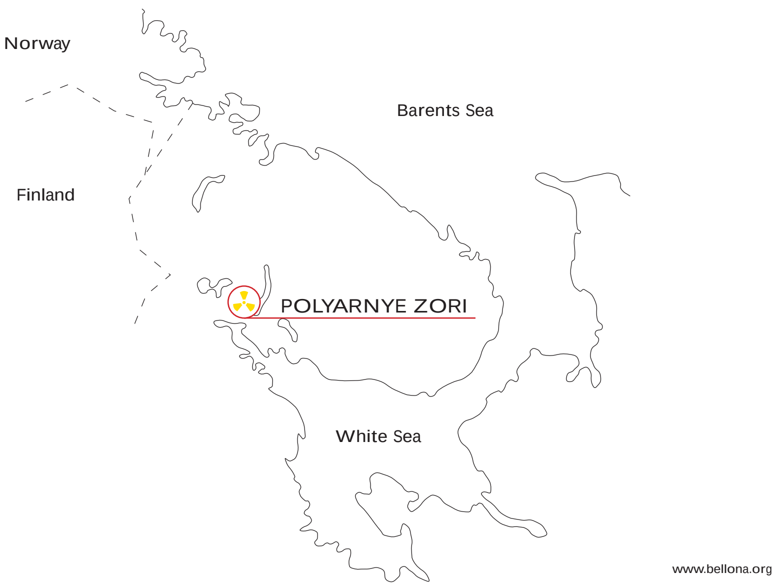
The Kola Nuclear Power Plant (Kola NPP) is the only nuclear power plant in the county of Murmansk, and was the first nuclear power plant in the Soviet Union to be built north of the Polar Circle. The nuclear power plant is centrally situated in relation to the heavy industry on the Kola Peninsula, 15 kilometres west of the town of Polyarnye Zori on the shores of Lake Imandra.

The town of Polyarnye Zori grew up in parallel with the construction of the nuclear power plant. The nuclear power plant is the most important employer in the town, and approximately 6,000 of the towns 21,300 inhabitants work there.[71] The industrial towns of Monchegorsk, Kirovsk, Apatity and Kandalaksha are located within a radius of 120 kilometres of the Kola Nuclear Power Plant. The distance to the Norwegian border is 240 kilometres.

There are 17 hydro power plants on the Kola Peninsula. The annually total capacity for the hydro power plants and Kola NPP is 20 TWh. Kola NPP produces annually between 11 to 12 TWh, which is 50 to 60% of the total energy capacity on the Kola peninsula. The main consumer of the energy is the mining industry and the surrounding cities, which consume more than 70% of the energy. Kola NPP itself consumes about 8% of the production. The rest of the production (about 20%) is exported to Karelia, Leningrad and Finland.[72]



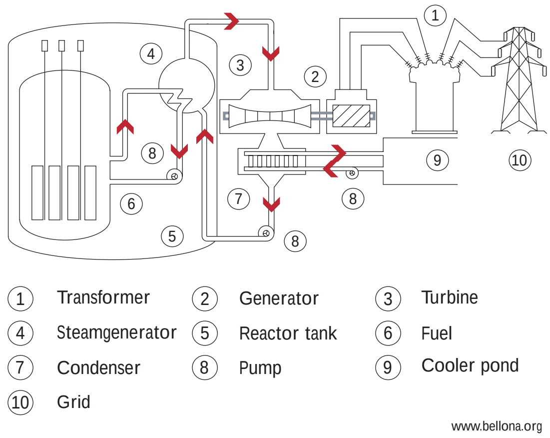
The Finnish company PVO-Group is negotiation with Russia's Rosenergoatom and Kolenergo to increase exports to Finland to 1,5 –2 TWh. This boost in export will require the construction of a new supply line from the Kola Peninsula to the northern part of Finland.



3.1 Technical information

The Kola Power Plant has four reactors in operation. The two oldest reactors (Kola 1 & 2) are of the VVER-440/230 type, and are located in Reactor Room no. 1, while two more recent VVER-440/213 type reactors (Kola 3 & 4) are located in Reactor Room no. 2. Construction of Kola 1 was initiated in 1970, and it went into commercial operation in 1973. The three other reactors went into operation in 1975, 1982, and 1984, respectively[73] Kola 3 is licensed to operate until the year 2011, and Kola 4 is licensed to operate until 2014.[74] The two oldest units may renew their licenses every year until 2003 and 2004, which is set as the maximum. However, Kola Nuclear Power Plant is working on extending the service life with five to seven years beyond 2003.[75]

The VVER-440 reactor is a pressurised water reactor developed from a reactor design based on the first nuclear submarine reactors in the Soviet Union, where demineralized light water is applied as both a cooling agent and for moderating the neutrons. The first version, VVER-440/230, was developed in the 1960s, while the VVER-440/213 was introduced in the early 1980s. Each of the reactors has a power capacity of 440 MWe. The reactor is schematically presented in figure 1.



The reactor core of VVER-440 reactor is 2.9 metres in diameter, 2.5 metres in height, and is enclosed by a cylindrical reactor vessel of steel. The vessel has a diameter of 4.3 metres and a height of 11.8 metres. The total weight is 200 tons. The reactor core contains 312 fuel assemblies and 37 control assemblies. Each fuel assembly consists of 126 fuel pins, which in turn consist of uranium-dioxide pellets. The weight of the uranium content in a single assembly is 121 kg. The total fuel inventory is 43 ton per reactor. The enrichment of ^{235}U in the fuel is 3.5 %. Every year 1/3 of the fuel is replaced by new, non-irradiated fuel assemblies.[76] The spent fuel is stored in a cooling pond beside each reactor for at least 3 years.

The temperature of the cooling water when it enters the reactor is 267ºC, and increases to between 295ºC and 300ºC as it leaves the reactor.[77] Each of the reactors has six independent primary cooling loops. In the secondary cooling circuit, there are six steam generators and two electrical generators. The condensators are cooled by water from Lake Imandra. The four reactors use a total of 1890 million cubic metres of cooling water per year. The cooling water is discharged in Lake Imandra through a one kilometre long canal. Some of the cooling water are used for heating greenhouses and a fish farm situated next to the Kola Nuclear Power Plant.

3.1.1 Insufficincies

The main difference between the VVER-440 reactors and modern reactor designs is the degree of safety containment

70 Nilsen, T, and Bøhmer, N. Sources to radioactive contamination in Murmansk and Archangels counties, 1994.
71 Statisticheskiy yezhegodnik, 1998
72 Bellona-web, http://www.bellona.org/e/russia
73 IAEA, 1993.
74 Murmansk Vestnik, April 25, 2000.
75 Bellona-web, http://www.bellona.no/e/russia
76 World Nuclear Industry Handbook, 1999.
77 Ibid.

surrounding the reactor tank. The airtight safety containment of international nuclear power plants encloses the reactor tank, the primary and secondary circuits, and the steam generators. In the event of a leakage, the safety containment will ensure that the radioactive steam does not escape to the surroundings. By commonly accepted internationally standards, this safety containment is made of prestressed concrete, and is designed to resist a pressure of 4 to 6 bars. Furthermore, there are devices for cooling the steam so as to decrease the pressure in the containment.

The construction surrounding the reactor systems of the VVER-440/230 is too small in volume to relieve the pressure should a breach occur in pipes of more than 32 mm in diameter. The construction is fitted with valves, which are released if the pressure becomes too great. Containment capabilities are improved in the VVER-440/213 reactor. The volume of this reactor type is larger and has a device to cool the steam and reduce the pressure in the event of an accident. This containment is constructed to resist a pressure of approximately 1 bar; however full-scale tests on this type of containment have not been performed. Furthermore this containment represents an improvement compared to the VVER-440/230, it is not on a par with Western standards.

The pressure of the primary circuit in Western pressurised water reactors is 150-170 bars, compared to the 123-124 bars in the VVER-440 reactor. Thus, the temperature of the cooling water must be kept at a lower level. As a result, the reactor is exposed to less strain compared to Western pressurised water reactors. Larger amounts of water are available in the cooling circuits, especially in the secondary circuit. As water has considerable heat capacity, the VVER-440 reactor is relatively resistant to minor disturbances. For example, there are reports of a similar type of reactor in Armenia, which run for six hours without electricity for cooling, without damaging the fuel.[78]

3.1 Insufficiencies of the VVER-440/230 design

In addition to the two VVER-440/230 reactors in operation at the Kola Nuclear Power Plant, there are eight VVER-440/230 reactors in operation in former Eastern Europe and Russia. These are located at the nuclear power plants of Kozloduy in Bulgaria (four reactors), Bohunice in Slovakia (two reactors), and Novovoronezh in Russia (two reactors). Six additional reactors of this type were formerly in operation, but are now shut down. Four reactors used to be in operation at Greifswald nuclear power plant in the former East Germany. After the reunification of Germany the reactors were dismantled due to the lack of security at this type of reactor. There are also two VVER-440/230 type reactors in Armenia, located in an area exposed to earthquakes.[79]

Western experts agree in that of the reactors of the former Soviet Union and Eastern Europe, it is the fifteen RBMK reactors along with the six reactors of the VVER-440/230 type that cause the greatest concern.[80]

The VVER-440/320 reactors deviate in construction from the safety standards of Western reactors. In 1991 the International Atomic Energy Agency (IAEA) performed a safety analysis of the 10 reactors in operation, and found 100 safety points connected to the design and the operation of the plants. More than 60% of these points are of great importance with respect to safety. The main problems with respect to the design of the reactor type are as following:[81]

-Lack of safety containment surrounding the core.
-Deficiencies in the construction with respect to limitation of discharges to the surroundings in the event of breaches in pipes of more than 32 mm in the primary circuit;
-Limited capacity of the cooling system;
-Insufficient backup of the cooling system and safety system;
-Lack of distinction between control systems and safety systems;
-Unsatisfactory procedures and equipment for communication and safety precautions concerning fire;
-Obsolete control room technology.

Neutron irradiation of the reactor tank causes the steel to become brittle, and is therefor a vital safety issue, according to Western experts. The proximity of the fuel assemblies to the steel walls in the VVER-440 reactor tank results in higher neutron irradiation than in other types of reactors, such that the reactor walls to become brittle at a higher pace than normal. The VVER-440 reactor tank is constructed of welded rings. The welded seams are particularly exposed to neutron irradiation. As a remedy, the outermost assemblies of the VVER-440/230 were replaced with steel rods during the late 1980s. The VVER-440/213 is equipped with additional steel lining between the steel wall and the fuel assemblies. The steel may be heated up to 450º to 500ºC over a period of time to stall the embrittlement. This was done at the Kola NPP in 1989.

In 1991 IAEA investigated the safety of the four reactors of Kola NPP, and closely examined reactors of the VVER-440/230-type. The IAEA report concluded that the chance of a serious reactor meltdown at these two reactors was 1 in 180 working years.[82] According to IAEA calculations, the chance of a serious reactor meltdown in the two oldest reactors at Kola Nuclear Power Plant in the course of 23 years is 25%. These two reactors have been in operation for near 30 years, and are expected to remain in operation until 2008 and 2010.[83]

78 "Nucleonics Week", February 1993.
79 IAEA, 1993.
80 Ibid.
81 Ibid.

82 IAEA, 1991.
83 Conversations held with Head of Information at Kola Nuclear Power Plant, A. Danilov, Polyarnyy Zori, August 1993.

Insufficiencies of the VVER-440/213 design

Although some improvements have been made on the VVER-440/213 system, it still fall short of internationally accepted safety standards. Among other things, this type of reactor is fitted with insufficient safety containment around the reactor system, the cooling system and the fire system leave much to be desired, and controls and instrumentation do not meet international standards.[84]

In addition to the two VVER-440/213 reactors at Kola Nuclear Power Plant, there are 12 other such reactors in operation in Eastern Europe and Russia. There are four reactors at Dukovany NPP in the Czech Republic, four reactors at Paks NPP in Hungary, two reactors at Bohunice NPP in Slovakia, and two reactors at South Ukraine NPP in the Ukraine.[85] The pressurised water reactors in operation at the Loviisa NPP in Finland are based on the VVER-440/213 reactors, but the Finish reactors are equipped with a safety containment.

Year	INES 0	INES 1	INES 2
1992	32	6	1
1993	ND	ND	ND
1994	33	4	
1995	16		
1996	16		
1997	6		
1998	10		
1999	9	1	

Table 1.
Incidences according to the INES- scale at Kola NPP 1992-1999.[89]

VVER-440 compared to RBMK

Along with the VVER-440/230, the RBMK reactors are emphasised when it comes to nuclear safety for Russian NPPs. The Chernobyl accident put focus on the RBMK reactor type. The RBMK reactors are water-cooled, but unlike the VVER-440, the RBMK reactor is moderated by graphite. In the Chernobyl accident, the loss of cooling caused an uncontrolled and rapid increase in power production. This increase ignited the graphite in the reactor core. The fire lasted for several days, and caused long life isotopes of a radioactivity of 46,000 TBq (1.2 million Ci) to be discharged to the surroundings.

Like the VVER-440, the RBMK reactor lacks satisfactory safety containment. The RBMK reactor also posseses a built-in positive energy coefficient, that is, the fission process increases as the temperature increases. Hence there may be a greater risk of uncontrolled enlarged power production as the reactor is run down. Furthermore, the abundance of combustible graphite in the core makes it vulnerable to fire following an uncontrolled rise in temperature in the core. Nor is it possible to upgrade RBMK reactors to Western standards.[86]

3.1.2 Disturbances and accidents during operation

Eight instances causing operational disturbances were recorded at Kola Nuclear Power Plant during the period 1987-1991.[87] Each reactor at the power plant has an average of 1-2 emergency stops a year.[88] In 1989, the secondary cooling system of one of the reactors was out of operation for nearly two months. Despite this, the reactor was not shut down, as requested by international and Russian safety regulations.[90] Table 1 shows the incidences reported according to the IAEA International Nuclear Event Scale (INES) during 1992 to 1997 are shown.

The most serious incident so far occurred February 2, 1993, when the oldest reactor was only a short time away from a meltdown accident. As a consequence of the rough weather, the electricity supply broke down, and the external electricity supply was broken off. The two diesel generators used for cooling the oldest reactor would not start, due to poor maintenance. The cooling system of the reactor was consequently without electricity for two and a half-hours, and the reactor was cooled by natural circulation. No reports have been made of any damages of the fuel.[91]

84 Friends of the Earth, 1992.
85 IAEA.
86 Friends of the Earth, 1992.
87 "Finmarken", 27th of April 1992.
88 Backe, S., 1992.
89 Conversations held with the administration of Kola Nuclear Power Plant, September 1992.
90 Rybny Murman, 10th of December, 1993, and NRPA-GAN, 26/-99, and NRPA-GAN annual reports for 1998and 1999.
91 "Nucleonics Week", February 1993.

Another point of great significance in evaluating the safety measures of Kola Nuclear Power Plant, are human factors such as morale and the lack of proper safety culture. One conclusion after an inspection of the power plant by IAEA was that an accident would more likely to occur as a result of human glitch than technical failings. In recent years there have been problems in paying the workers wages. Typically a worker receives his payment 2-3 months later than he should. There have been several strikes and demonstrations at the power plant as well as numerous thefts. The latest incident was reported to the police on May 27, 1999, when parts of the automatic radiation monitor system were removed.[92]

3.1.3 Safety assessments

The IAEA, EU and Norwegian authorities have conducted several inspections to investigate into the safety precautions of the power plant over the last time. In addition, Bellona has examined the conditions at the plant a number of times. During these inspections, several defects at the plant were discovered. IAEA has discovered 1,300 points relating to safety. It is commonly agreed that it is impossible, for all practical purposes, to bring the plant up to Western safety standards and that the VVER-440 reactors along with the RBMK reactors (the Chernobyl type) are the most accident prone.[93]

The group of the world's seven richest countries (G7) has concluded that all reactors of the VVER-440 type should be shut down as soon as possible, as any upgrading to Western safety standards precluded by the reactor construction.[94]

Even the World Bank (IBRD) emphasises the serious safety defects of reactors of this type, rendering any reconstruction unprofitable. From an economic point of view, the IBRD considers nuclear power plants utilising reactors of the Russian VVER-440 type to be the most expensive form of energy for the years to come.[95]

From 1992 to 1997, Norway contributed approximately 8 million ECU to "improve" technical safety at Kola NPP. Improvements were carried out in phases, whith phase one and two including an emergency diesel generator, improved monitoring of water quality and vibration, telecommunication equipment and fire protection. Some of these projects will be continued in the third phase and a new project, Complementary Emergency Feedwater System, is also expected to be initiated.[96]

3.2 Radioactive waste and spent fuel[97]

Low- and medium level radioactive waste is treated and stored at the power plant. There are two compactors for reducing the volume of solid radioactive waste. The volume reduction factor for the compactor located between reactor 1 and 2 is three, and for the compactor located between reactor 3 and 4 the factor is about five. Both compactors have been in operation since 1981. Due to the small compression force (300 kN and 500 kN), metallic waste can not be processed. Kola NPP also has an incinerator. This has been in operation since 1985. The volume reduction factor for the combustible waste processed in the incinerator is about 50. Both the compactors and the incinerator have ineffective ventilation systems and require manual charging and discharging.

Low level solid radioactive waste is stored in a special building (ChSSO) which has a capacity of 12,000 m^3. The storage was taken into use in 1985, and is made of watertight concrete. As of April 1, 1995, ChSSO was filled up to 38% of the total capacity.

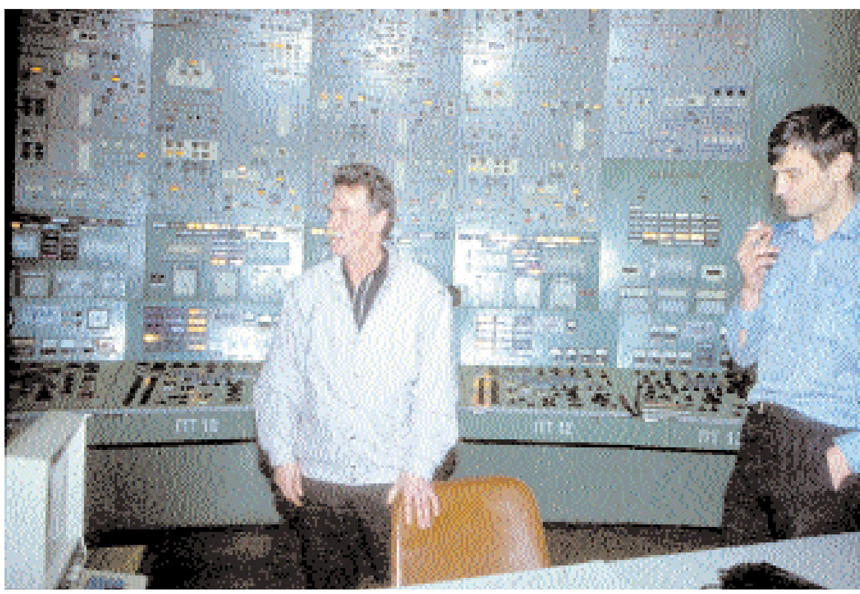
Low and intermediate level solid waste is stored in two storage facilities ChSO-1 and ChSO-2. The ChSO-1 storage facility is located in a special building for reactor 1 and 2, and the ChSO-2 storage is in a special building for reactor 3 and 4. The total storage capacity of ChSO-1 is 1,375 m^3 and the facility was taken into operation in 1973. By 1984, the storage was full. Some of the waste was latter moved to the low level storage facility ChSSO, leaving the storage ChSO-1 filled up to 86% of capacity as of April 1, 1995. The storage facility ChSO-2 was taken into operation in 1982 and has a capacity of 6,098 m^3. As of April 1, 1995, this storage facility was filled up to 12%.

Each of the two reactor halls contains storage space for high level solid radioactive waste. The MZS-1 high level waste storage is located in the central hall of rector 1 and 2, and was taken into use in 1973. The facility has a storage capacity is 144,4 m^3, of which 94 % was used as of April 1, 1995. In addition to high level waste from reactor 1 and 2, there are 292 spent ionising sources from facilities of the Murmansk region stored in MZS-1. The MZS-2 storage is located in the central hall of reactor 3 and 4, and was taken into use in 1982. The total storage capacity is 290,4 m^3, of which 48% had been utilised as of April 1, 1995.

Storage	Start of operation	Waste cat.*	Capacity (m^3)	Status January, 1995 (m^3)	(%),
ChSSO	1985	Short-lived LLW/ILW	12,000	4,444	37
ChSO-1	1973	LLW, ILW	1,375	1,185	86
ChSO-2	1982	LLW, ILW	6,098	753	12
MZS-1	1973	HLW	144,4	134	93
MZS-2	1982	HLW	290,4	139	48

* LLW= Low Level Waste, ILW= Intermediate Level Waste, HLW= High Level Waste.

Table 2.
Solid radioactive waste at Kola NPP.[98]



In total, there was 19,300 tons of waste with a radioactivity on 544 TBq stored at Kola NPP. The location and amount of waste the different solid waste categories are summarised in table 2. According to the Russian Nuclear

92 Bellona-web, http://www.bellona.org/e/russia
93 Backe, S., 1992.
94 Financial Times, July 3, 1992.
95 World Bank, March 1993.
96 NUSAC 1999, Donor report, from NRPA 30/2-99.
97 N. N. Melnikov et al., Inventory of radioactive waste and spent fuel in the Kola Peninsula region of North-West Russia, 1996.
98 Ibid.

Safety Authorities (Gosatomnadzor, GAN) in1998 the total volume of the radioactive waste stored at Kola NPP was 8244 m^3.

Liquid radioactive waste originating from the operation of Kola NPP is defined in three types; salt concentrates resulting from evaporation of liquids, ion-exchange resins and sludges. The liquid radioactive wastes are stored in different types of tanks in two special buildings; SK-1 serving reactor 1 and 2 and SK-2 serving reactor 3 and 4.

The salt concentrates are stored in steel tanks 6.8 meters high, 10 meters in diameter and wall thickness 4 mm. The tanks are in special sections on a 1.5 m thick concrete fundament. Each tank has a storage capacity of 470 m^3. The total storage capacity for salt concentrates in building SK-1 is 2,820 m^3 and in building SK-2 the capacity is 3,160 m^3.

Table 3.
Storage of liquid radioactive waste at Kola NPP[100]

Waste type	Location	Waste category	Capacity (m^3)	Status beginning of 1995 (m^3)	(%)
Salt concentrates	SK-1	ILW	2,820	2,629	93
	SK-2		3,160	2,505	79
Ion-exchange	SK-1	ILW/LLW	990	445	45
	SK-2		800	440	55
Sludges	SK-1	LLW	350	302	86
	SK-2		400	295	74

* LLW= Low Level Waste, ILW= Intermediate Level Waste, HLW= High Level Waste.

Table 4.
Spent nuclear fuel storage at Kola NPP[102]

Location	Capacity (Assemblies)	Status July 1, 1998 (Assemblies)	(%)	(tonuranium)
Kola 1	616	279	45	34
Kola 2	637	188	30	23
Kola 3	662	483	73	58
Kola 4	664	374	56	45

In the beginning of 1995, 93% of the storage capacity in building SK-1 had been used, while SK-2 was 79% filled to capacity.

In buildings SK-1 and SK-2 there are also tanks for storage of ion-exchange resins and sludges. These steel tanks are 6.5 meters in height, 9.01 meters in diameter with a wall thickness of 6 mm. In building SK-1 there are three tanks for the storage of ion-exchange resins with a total capacity of 990 m^3. For storage of sludges , there is one tank with a capacity of 350 m^3. In building SK-2 there are two tanks for storage of ion-exchange resins with a total capacity of 800 m^3. There is also a tank for slugdes with a storage capacity of 400 m^3.

As per January 1, 1995, the total volume of liquid waste stored at Kola NPP was 6,616 m^3, of which 1,004m^3 was low level liquid waste and 5,612 m^3 of intermediate level liquid waste. The location and amount of the different liquid waste types are summarised in Table 3.

According to GAN, the total volume of liquid radioactive waste stored at Kola NPP in 1998 was 7060 m^3. REF

The waste status of the start of 2000 indicates that the solid waste tanks were filled to 42% (6,928 m^3) of the total capacity, and with 80 % (7,211 m^3) correspondingly for liquid waste. With the present handling of solid radioactive waste, the management at Kola NPP calculate that storage capacity for solid radioactive waste will be sufficient for the entire period of operation, including the planned prolongation for Units 1 and 2.[99]

Every year about one third of the fuel (that is, some 117 fuel assemblies) in each reactor is replaced by fresh fuel assemblies[101]. The spent fuel is stored in a cooling pond beside each reactor for at least 3 years, before the ele-

99 Kola NPP web-site, www.kolanpp.ru, February 28, 2001
100 N. N. Melnikov et al., Inventory of radioactive waste and spent fuel in the Kola Peninsula region of North-West Russia, 1996
101 World Nuclear Industry Handbook,1999.
102 IAEA CEG-meeting October 12. 1999.

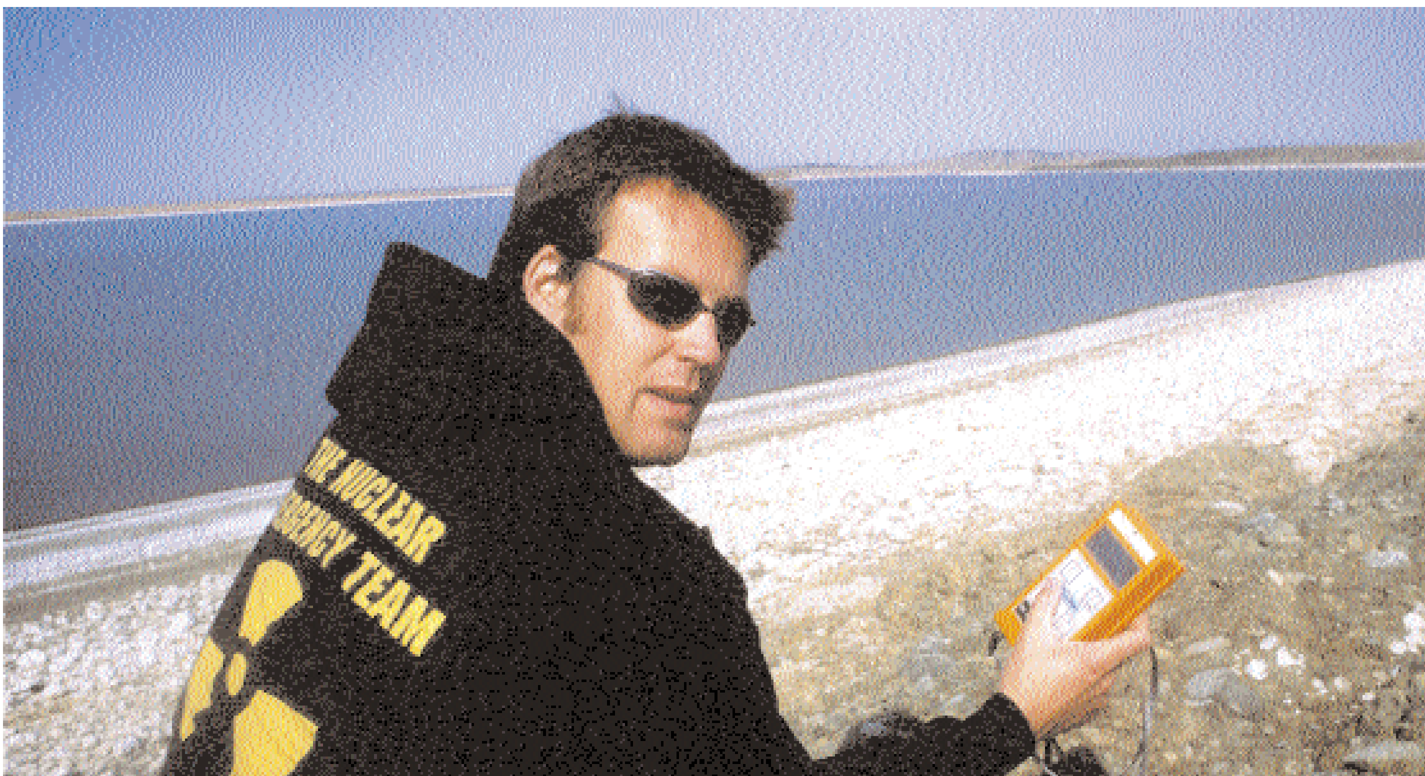
ments are transported to Mayak in South Ural for reprocessing. From 1985 to January 1, 1995, about 35 transports to Mayak have taken place, totalling 6,300 spent fuel assemblies (1,390 t). Transport has been by railroad using the TK-6 transport containers.

As of July 1, 1998, there were 1,324 spent nuclear fuel assemblies with a collective uranium weight of 160 tons being stored close to each reactor at the plant's four water-cooled storage pools. This corresponds to 50% of the total storage capacity for spent fuel at Kola NPP. (See Table 4 for an overview of spent fuel storage in the four pools.) Amidst the stored spent fuel is also a total of 950 failed fuel pins. The failed fuel pins were identified by an increase of radioactivity in the cooling water.

The future decommissioning of Kola NPP will create additional radioactive waste. Although a decommissioning plan for Kola 1 and 2 should have been presented five years before the end of their service life (plans should have been presented in 1998 and respectivly 1999), little information about the decommissioning waste is available. Based on the decommissioning plans for the VVER-440 Loviisa Plant in Finland, it can be calculated the decommissioning waste for Kola 1 and 2 will be 717 tons of high level waste, 3,342 tons intermediate waste and 1,760 tons of low level waste. The total radioactivity of this waste would be 47,700 TBq in 2010.

Chapter 4

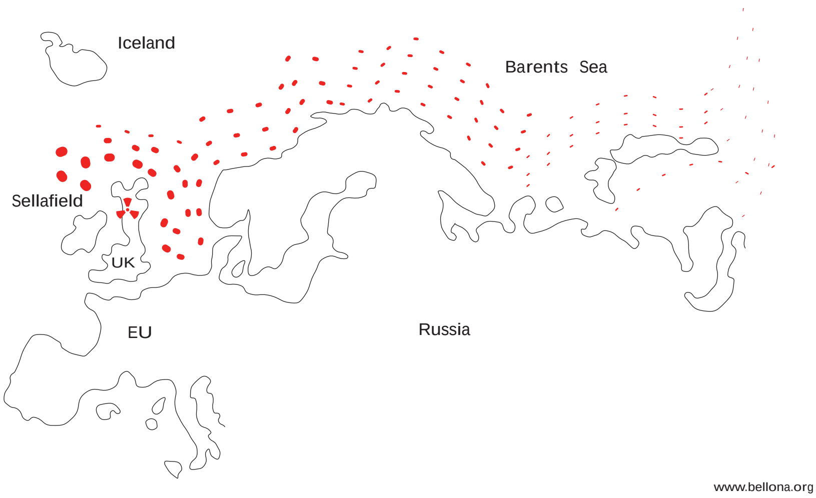
Sources of present Arctic contamination



Sources of present Arctic contamination

During the last decades, several different sources have contributed to a small, but measurable radioactive contamination of the Arctic. These sources are the dumping of radioactive waste and spent nuclear fuel in the Barents and Kara Seas, testing of nuclear weapons, reprocessing of spent nuclear fuel and the Chernobyl accident.

At the present time, radioactive contamination in the Arctic is very low, with the main sources of contamination being events in the past, such as the Chernobyl accident and the European reprocessing industry. So far, there has been no extensive contamination of the Arctic emanating from the unsatisfactory storage of spent nuclear fuel.



4.1 Dumping of radioactive waste and spent nuclear fuel

Since the beginning of the nuclear age in the late 1940s, 13 countries[103] have dumped their radioactive waste and spent nuclear fuel at sea. In total, these countries have dumped waste with a radioactivity at the time of dumping 85,000 TBq. Of this, both the former Soviet Union and Russia are responsible for 38,500 TBq.[104]

The dumping of radioactive waste into the ocean is regulated by both international convention (The London Convention) and by national law. Prior to 1972, the dumping of radioactive waste and spent fuel did not fall under international regulations. The London Convention of 1972 bans the dumping of spent nuclear fuel and limits the dumping of low- and medium level waste from ships. According to the London Convention, the dumping of radioactive waste at sea is restricted to areas outside the continental shelf, at water depths greater than 4,000 meters. The dumping should take place between latitudes of 50º South and 50º North.

The Soviet Union ratified the convention in 1975, and made it effective from January 29, 1976. In 1983, the London Convention instituted a temporary ban on all dumping of radioactive waste. This temporary ban was made permanent from 1993, but Russia has thus not ratified this latest edition of the London Convention.

Although Soviet Union did sign international conventions regulating the dumping of radioactive waste which were also consistent with Soviet law, irregular dumping of radioactive waste and spent nuclear fuel nevertheless continued to take place. The history of dumping in Russian Arctic waters is described in the official White Book No. 3 from 1993, also know as the Yablokov Report.[105] There has been considerable uncertainty in the assessments of the activity of the dumped reactors, and some of the figures for the activity in the dumped reactors have later been recalculated.

4.1.1 Dumping practice of the Northern Fleet and the Murmansk Shipping Company

Since 1959, the Northern Fleet has dumped radioactive waste in the Barents Sea and Kara Sea on a regular basis. All kind of radioactive waste is dumped, including solid radioactive waste, liquid radioactive waste, and nuclear reactors with and without fuel. Radioactive waste from the civilian state-run Murmansk Shipping Company's (MSCo) fleet of nuclear icebreakers has also been dumped in the Barents Sea and Kara Sea. According the most recent estimates the total radioactivity of the dumped material in the Barents and Kara seas is 38,450TBq.[106]

The Russian Navy has also dumped radioactive waste in the Japan Sea, Pacific Ocean, the White Sea and the Baltic Sea.

Liquid radioactive waste

Liquid radioactive cooling water from naval reactors and storage tanks for used fuel assemblies have been dumped at sea since 1959. The last known dumping of liquid radioactive waste took place in November 1991. This practice may be resumed if no alternative solutions are found. According to regulations established by the Soviet Navy in 1968, liquid radioactive waste should have a maximal concentration of radioactivity of 370 Bq/l of long-life radioactive isotopes, and 1850 kBq/l of short-life isotopes.[107] Whether these regulations were observed, is unknown.

Analyses of the dumping history show that liquid waste of the highest radioactive concentration has been dumped in the three dumping sites furthest to the north in the Barents Sea. Radioactive waste with lower level of radioactivity has been dumped outside the shore of the Kola Peninsula. A map of the various dumping sites in the Barents Sea is shown in Map on next page.

In the period from 1959 up to 1991, 3.7 TBq liquid radioactive waste has been dumped in the White Sea, 451 TBq in the Barents Sea, and 315 TBq in the Kara Sea.[108] Furthermore, 430 TBq radioactive water has leaked into the sea following accidents involving storage of fuel assemblies, submarines, and the civil

103 Belgium, France, Germany, Italy, Japan, South-Korea, the Netherlands, New Zealand, Russia, Switzerland, Sweden, Great Britannia and USA.

104 Yablokov, A.V. et al, 1993 and Joint Norwegian-Russian Expert group, 1996.

105 Yablokov, Ibid.

106 Joint Norwegian-Russian Expert group, 1996

107 Yablokov A.V, et al, 1993.

108 Ibid.

nuclear icebreaker Lenin. The total radioactivity of the liquid waste dumped in the Barents Sea, Kara Sea, and White Sea totals 880 TBq (23,771 Ci).

The radiological tanker Amur has been used by the Northern Fleet since 1987. The Amur has cleansing facilities for the radioactive cooling water from submarine reactors. After a cleansing process the cooling water is dumped in the ocean. In the time since Amur went into operation, it has cleansed and dumped 975 tons of radioactive cooling water.[109]

Amur is presently docked at the Northern Fleet's naval shipyard No. 10 Shkval in Pala Bay. Liquid radioactive waste has also been dumped from vessels of the 1783A-type (Vala class) and from the civilian vessel Serebryanka.

Solid radioactive waste

The Northern Fleet and MSCo have dumped a total of 17 ships and barges containing radioactive waste in the Barents and Kara seas. There are different types of radioactive waste of varying levels of radioactivity aboard the ships, consisting mainly of containers with radioactive waste, reactor parts, and other contaminated equipment. The dumped containers were mostly filled with low- and medium radioactive waste, such as contaminated metal parts from the submarines' reactor sections, clothes, and equipment used for work at the reactors. In addition, 155 larger objects such as cooling water pumps from reactors, generators, and different reactor parts have been dumped. Some of these were placed aboard ships and barges before these were sunk.

From 1965 to 1991, solid radioactive waste has been dumped in eight different bays off the eastern coast of Novaya Zemlya, as well as into the Kara Sea. The dumping sites in the Kara Sea are shown on the map. Both the Northern Fleet and the civilian fleet of nuclear icebreakers in Murmansk have dumped radioactive waste in these areas.

According to the Yablokov Report, 6,508 containers of radioactive waste have been dumped directly in the Kara Sea. Of these containers, 4,641 were dumped by the Northern Fleet.[110] In Murmansk Shipping Company archives, the dumping of 11,090 containers into the sea has been recorded. This implies the company has dumped 1,867 individual containers, while the remaining 9,223 containers were placed aboard lighters and ships before they were sunk.

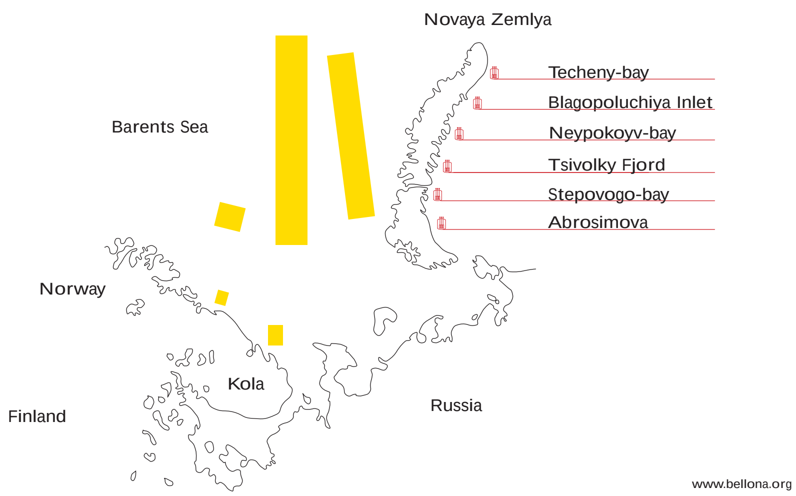
During the earliest dumping missions in the 1960s, many containers did not sink, but remained afloat at the surface. The problem was solved by shooting at the containers with machine guns, causing water to seep in and the containers to sink.[111] This took place in Abrosimova Bay on the south-eastern coast of Novaya Zemlya. Additional, reports tell of repeated finds of containers with radioactive waste floating in the Kara Sea. One container was even found ashore on Novaya Zemlya.[112] The problem was later solved by placing rocks along with the radioactive waste in the containers to make them sink.

In addition to radioactive waste being dumped in bays on the eastern coast of Novaya Zemlya, the ship Nikel was sunk near the island of Kolgoyev in the Barents Sea. The ship was loaded with 18 items with a total volume of 1,100 cubic metres and a total radioactivity of 1.5 TBq.

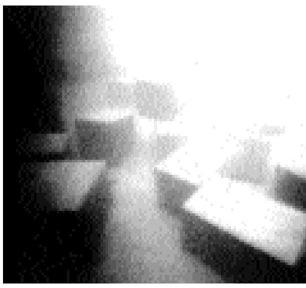
An altogether 31,534 cubic metre of solid radioactive waste with a radioactivity of 570 TBq was dumped, consisting of 6,508 containers, 17 ships, and 155 large objects.

Dumped nuclear reactors

A total of 13 nuclear reactors from submarines have been dumped in the Kara Sea. Six of the submarine reactors were dumped with spent nuclear fuel still aboard. The reactors all came from nuclear submarines that have sustained serious radiation acci-



dents in which on or both reactors were involved. The reactors were so damaged and the radiation so intense that the nuclear fuel was impossible to remove. Consequently the reactors were dumped instead. In addition to the submarine reactors, three reactors from the nuclear icebreaker Lenin have also been dumped.[113]



The dumped reactors had been stored from one to fifteen years from the date of the accident until they were dumped in the Kara Sea. Five of the submarine reactors were filled with a protective material of steel, cement, and polyester to prevent radioactivity from seeping out into the marine environment. According to Russian reactor constructors, this protection can last up to 500 years.[114] Since there is very little technical data on the different nuclear reactors available, there has been a great deal of uncertainty in the assessments of the activity of the dumped reactors. Very rough calculations made by Russian experts based on the information available in the Yablokov Report estimate the total radioactivity to be 85 PBq for the submarine reactors containing fuel.[115] More recent calculations have shown that the activity is closer to 37 PBq.[116]

109 The cleansing of the liquid radioactive waste is done by filtering the waste through special filters, and thereafter mixing it with seawater in a seperate tank. The mixed water is then dumped in the Barents Sea. This cleansing technology is regarded as unsatisfactory by the county authorities in Murmansk. Source: Sovietsky Murman, 17th of October 1992.
110 The figure 6,508 is taken from the Jablokov Report. In file documents from A. Solotkov the total amount of containers of radioactive waste dumped in the Kara Sea is claimed to be 11,090. The difference is probably explained by the fact that nearly 5,000 containers are loaded in some of the ships sunk in the Kara Sea.
111 Polyarnaya Pravda, 25th of September 1991, Murmansk.
112 Ibid.
113 Yablokov A.V, et al, 1993.
114 Ibid.
115 Ibid.
116 Joint Norwegian-Russian Expert group, 1996

4.2 Nuclear weapons testing

Ever since the first nuclear bomb was tested in the United States on July 16, 1945, 2,082 confirmed nuclear explosions have been conducted around the globe. The United States is responsible for about half of these nuclear detonations, with 1,054 nuclear tests. The former Soviet-Union performed 715 nuclear tests, including 115 civilian "peaceful" nuclear explosions. France has detonated 216 nuclear devices, the Peoples Republic of China 45 and the United Kingdom 44. All five of these nuclear powers have stated that they will abide by the Comprehensive Test Ban treaty and will cease testing. In 1998 India and Pakistan started a series of nuclear tests, where India exploded five nuclear devises and Pakistan at least three.[117] It is not clear whether more tests will follow.

Several international agreements have been made in an attempt to limit nuclear testing. The Limited Test Ban Treaty of 1963, banning nuclear explosions in the atmosphere, in space and under water came in the wake of the 1962 Cuban missile crises. This was followed by the Threshold Test Ban Treaty, signed in 1974, which banned underground nuclear weapons tests with an explosive force larger than 150 kilotons of TNT. In 1976, this treaty was extended to also limit the size of civilian nuclear explosions. The next

step was the Comprehensive Test Ban (CTB) which bans all nuclear tests. This United Nations treaty was opened for signatures in 1996.

The Soviet Union performed 715 nuclear weapons tests between 1949 and 1990. Of these, 212 were detonated in the atmosphere between 1949 and 1962. Between 1963 and 1990, 500 underground nuclear tests were performed. Three underwater nuclear tests have been conducted on the western coast of Novaya Zemlya. There were two major sites for nuclear tests in the Soviet Union: Semipalatinsk in Kazakhstan and Novaya Zemlya in the Russian Arctic. In addition, there were three minor nuclear test sites: Azgir and Astrakhan in Kazakhstan, and at Orenburg between the river Volga and the Ural mountains. The 715 nuclear explosions include 115 civilian nuclear explosions, some of which were performed on the Kola Peninsula. For the time being, Novaya Zemlya is the only remaining nuclear test site in Russia; but since the demise of the Soviet Union it has only been used for sub-critical nuclear tests.

Between 1955 and 1990, 132 nuclear bombs were detonated at Novaya Zemlya. At Semipaltinsk, 467 nuclear bombs were detonated. The combined explosive force of all the 715 Soviet nuclear detonations from 1949 to 1990, is approximately 500 megatons of TNT. The combined explosive force of the 132 bombs tested at Novaya Zemlya is 470 megatons of TNT, or 94 % of the combined explosive force of all Soviet nuclear detonations.

4.2.1 Novaya Zemlya[118]

Novaya Zemlya is the northern extension of the Ural Mountains which divide the European and Asian continents. Novaya Zemlya is made up of two islands divided by the Matochin Strait. The two islands are 900 kilometres long in all, and cover approximately 82,179 square kilometres. There are also a number of other small islands, covering a surface of approximately 1,000 square kilometres. Most of the northern, and parts of the southern island, is covered by glaciers. The permafrost reaches down 300 to 600 metres into the ground. The rock of Novaya Zemlya is brittle and has deep crevices.[119] The highest mountain of Novaya Zemlya is 1,547 metres above sea level.

There are two major military settlements on Novaya Zemlya today. There is a town of approximately 2,000 inhabitants at Belochaya Bay. The inhabitants are mostly military personnel employed at the test sites, and their families. Just east of the town lies the 2,400 metre-long Rogachynovo Airport. The other settlement is situated at the Matochkin Strait, where there is a large harbour that also serves vessels of the Northern Fleet. There is also a meteorological station at Matochkin Strait.

Novaya Zemlya is part of the county of Arkhangelsk, but has been under military administration since the establishment test sites in 1954. In 1991, administrational responsibility was, in theory, transferred back to the county authorities of Arkhangelsk¸ however for all practical purposes, it is still the Defence Ministry that remains in command on the archipelago.

The closest area of settlement of any significance on the mainland is the town of Amaderm, 280 kilometres east of the test site. The Norwegian County of Finnmark lies 900 kilometres south-west of Novaya Zemlya.

Two test sites

There are two test sites on Novaya Zemlya, one at Chernaya Bay (southern site) on the southern island, and one by the Matochkin Strait (northern site) dividing the northern and southern islands. All

117 Oklahoma Geological Survey Observatory, gopher://wealaka.okgeosurvey1.gov:70/00/nuke.cat/nuke.cat.under.construction, June 2 1998.

118 Nilsen,T. and Bøhmer, N. Sources of radioactive contamination in Murmansk and Arkhangelsk counties, 1994.

119 The Norwegian geologist Olaf Holtedal borrowed the ship "Fram" from Fridtjof Nansen and undertook examinations on Novaja Zemlja in the company of several other scientists. The geological surveys were published by Holtedal in 1922.

atmospheric nuclear explosions were performed at the northern test site. The southern test site was in use for two years, from 1973 to 1975. The largest geological difference between the southern site and the northern site is the presence of high mountains and deep valleys at the northern site, while the landscape is relatively flat at the southern site.
As previously mentioned, 132 nuclear bombs have been detonated on Novaya Zemlya. Of these 86 were atmospheric tests performed from 1957 to 1962. In addition, 43 underground tests took place from 1963 to 1990. The three underwater tests were performed from 1955 to 1961. At least two of the atmospheric tests were nuclear bombs blasted aboard naval vessels in the Barents Sea west of the Matochkin Strait.

4.2.2 Atmospheric testing

The atmospheric testing over Novaya Zemlya were performed during two periods. The first atmospheric testing over Novaya Zemlya took place on September 24, 1957. By October 10 that year, three nuclear explosions had taken place, followed by a further six in February and March 1958. This is the only time nuclear testing has taken place on Novaya Zemlya during the first six months of the year. From

Table 1. Atmospheric tests on Novaya Zemlya

No.	Date	Yield
1.	September 24, 1957	Mt
2.	October 6, 1957	Unknown
3.	October 10, 1957	Small
4.	October 23, 1958	Mt
5.	February 27, 1958	Mt
6.	February 27, 1958	Large
7.	March 14, 1958	>1 Mt
8.	March 20, 1958	Small
9.	March 22, 1958	Medium
10.	September 20, 1958	-
11.	September 30, 1958	Medium
12.	September 30, 1958	Medium
13.	October 2, 1958	Moderate
14.	October 2, 1958	Medium
15.	October 5, 1958	-
16.	October 10, 1958	Large
17.	October 12, 1958	Mt
18.	October 15, 1958	Mt
19.	October 18, 1958	Mt
20.	October 19, 1958	-
21.	October 20, 1958	Mt
22.	October 22, 1958	Mt
23.	October 24, 1958	Mt
24.	October 25, 1958	Large
25.	September 10, 1961	Several Mt
26.	September 10, 1961	Some Kt
27.	September 12,1961	Several Mt
28.	September, 13 1961	Small
29.	September 14, 1961	Several Mt
30.	September 16, 1961	Medium
31.	September 18, 1961	Mt
32.	September 20, 1961	Mt
33.	September 22, 1961	Mt
34.	October, 2 1961	Mt
35.	October 4, 1961	Several Mt
36.	October 6, 1961	Several Mt
37.	October 8, 1961	Small
38.	October 20, 1961	Several Mt
39.	October 23, 1961	25 Mt
40.	October 25, 1961	1 Mt
41.	October 27, 1961	Small
42.	October 30, 1961	58 Mt
43.	October 31, 1961	Several Mt
44.	October 31, 1961	1 Mt
45.	November 2, 1961	Small
46.	November 2, 1961	Small
47.	November 4, 1961	Several Mt
48.	August 5, 1962	30 Mt
49.	August 10, 1962	1 Mt
50.	August 20, 1962	Several Mt
51.	August 22, 1962	Mt
52.	August 25, 1962	Several Mt
53.	August 27, 1962	Several Mt
54.	September 1, 1962	-
55.	September 2, 1962	Mt
56.	September 8, 1962	Mt
57.	September 15, 1962	Several Mt
58.	September 16, 1962	Several Mt
59.	September 18, 1962	A few Mt
60.	September 19, 1962	20 Mt
61.	September 21, 1962	A few Mt
62.	September 25, 1962	25 Mt
63.	September 27, 1962	>30 Mt
64.	October 7, 1962	Medium
65.	October 22, 1962	Several Mt
66.	October 27, 1962	Medium
67.	October 29, 1962	Medium
68.	October 30, 1962	Medium
69.	November 1, 1962	Medium
70.	November 3, 1962	Medium
71.	November 3, 1962	Medium
72.	December 18, 1962	Medium
73.	December 18, 1962	Medium
74.	December 20, 1962	Medium
75.	December 22, 1962	Medium
76.	December 23, 1962	A few Mt
77.	December 24, 1962	Unknown
78.	December 24, 1962	20 Mt
79.	December 25, 1962	A few Mt

Mt=Megaton(s) Kt=kiloton(s)

Source: Soviet Nuclear Weapons Databook, Volume IV

September 20 to October 25, 1958, another 15 nuclear tests took place. After 1958, there was increased resistance to atmospheric tests increased among Russian arms engineers. Andrei Sakharov was one of the most noted opponents of atmospheric tests, claiming that there were no scientific reasons to perform repeated tests of bombs of megaton-sized explosive forces.[120]

No Soviet nuclear tests took place between November 3, 1958 and September 1, 1961. However, due to the tense political relations that developed between the US and the Soviet Union over the course of 1961, the nuclear testing was resumed in 1961. After the summit meeting in Vienna between Nikita Khruschev and John F. Kennedy in June, 1961, the Berlin Wall was built and the international political climate cooled to a considerable degree.

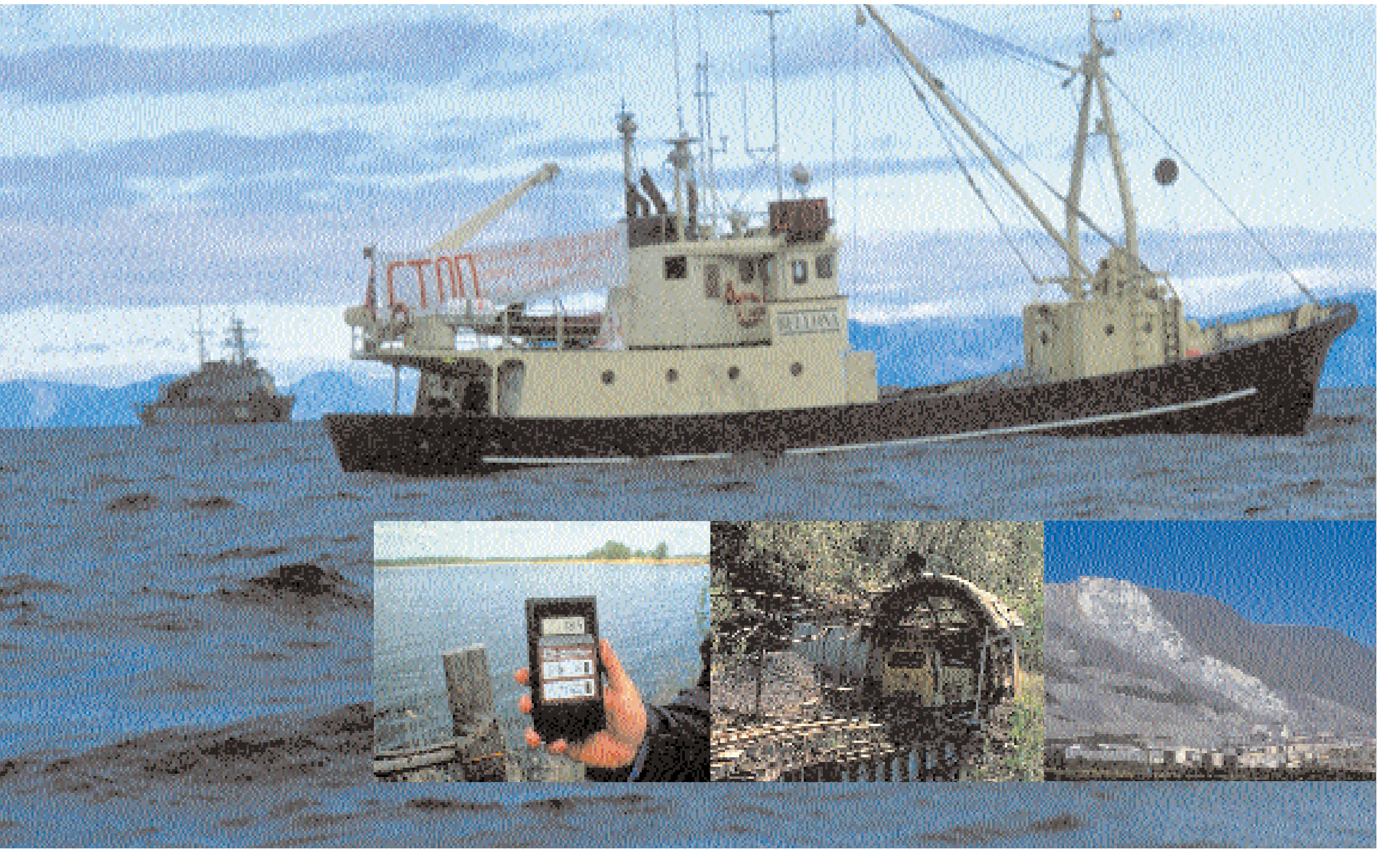
Between September 10 and November 4, 1961, 24 megaton-sized devices were exploded. During this period, nuclear explosions occured almost every second day, the size of the devices ranging from 20 to 30 megatons. The world's most powerful hydrogen bomb was detonated on October 30, 1961. The bomb had an explosive force of 58 megatons, or almost 6,000 times more powerful than the Hiroshima bomb. The bomb was dropped by an aircraft, and detonated 365 metres (1,200 feet) above the surface. The shock wave produced by this bomb was so powerful it went thrice around the earth. The mushroom cloud extended almost 60 kilometres into the atmosphere and the resulting fallout was measured over the entire Northern Hemisphere. A flash of light could be observed all the way to Hopen in the Norwegian Sea, Sør-Varanger in the Norwegian county of Finnmark and by the Inari Lake in Finnish Lappland.[121]

Testing of several bombs of megaton-range continued during the autumn of 1962. Between the August 5 and December 25, 32 bombs were detonated over Novaya Zemlya. Another nine explosions took place during Cuba crisis in October 1962. The Soviet Union, Great Britain and the USA signed the Moscow Treaty on August 5, 1963, which banned nuclear testing in the atmosphere, outer space and under water. The treaty became operational on October 10, 1963. The treaty was created in the wake of the negative effects on both humans and the environment as a results of fallout following the nuclear tests.

Fallout from atmospheric testing

The atmospheric nuclear tests performed by the Soviet Union, the United States, Great Britain, France and China, account for most of the radioactive pollution observed today in the counties of Murmansk and Arkhangelsk. France halted their atmospheric tests in the Pacific in 1980, while China continued until 1984 at Lop Nor.

The radioactive cloud of an atmospheric test explosion can be dispersed over an enormous area before the fallout reaches the ground. To illustrate, there were more fallout following tests on Novaya Zemlya detected on the western coast of Norway, than in



120 **Sakharov, A., 1988.**

121 **Natur og Samfunn, no. 3, 1990**

the county of Finnmark[122], in that there is more rainfall on the western coast than there is in Finnmark. Atmospheric testing over Novaya Zemlya resulted in Norwegians receiving an average radioactive doses corresponding to what they were exposed to following the Chernobyl incident of 1986.[123] Certain sections of the population received considerably higher doses, notably the reindeer-keeping Sami people of Finnmark.

4.2.3 Underground testing

Ever since the signing of the 1963 Moscow agreement which banned atmospheric testing, all ensuing Soviet tests have taken place underground. The first underground test explosion at Novaya Zemlya took place on September 18, 1964 at the Matochkin Strait. Up until the last explosion on October 24, 1990, 43 underground tests had been performed on Novaya Zemlya. in comparison, 343 underground tests have taken place at Semipalatinsk.

The underground explosions that have taken place on Novaya Zemlya tend to be larger than those at Semipalatinsk, as was also the case during the time of atmospheric tests. The most powerful device detonated at Semipalatinsk had an explosive force of 180 kilotons. Underground testing creates significant earth movement, measurable in the same fashion as earthquakes.

As previously mentioned, there were two sites for underground tests at Novaya Zemlya; the northern site at the Matochkin Strait, and the southern site by Chernaya Bay on the south-western tip of Novaya Zemlya.

The southern site was only in use from 1973 to 1975, and only seven tests have been performed here. In contrast to the northern site, at the southern site tunnels were bored vertically into the ground. It was at this site the Soviet Union's most powerful underground test explosion was performed on October 27, 1973. Three nuclear devices were consecutively detonated. The two first bombs had low explosive force, while the third one had an explosive force exceeding three megatons.[124] Another device with an explosive force of two megatons was detonated on November 2, 1974. The last two tests at the southern test site were performed just after each other on October 18, 1975. The southern site has not been in use since.

There are probably two reasons for the closing of the southern site. With only one exemption, underground tests of devices with an explosive force of more than one megaton were always carried out at the southern site. It was discovered that explosions of powerful bombs at the northern site have resulted in some significant landslides on the mountainsides. There are no mountains within proximity of the southern site, and thereby permitting nuclear detonations without the danger of landslides. This indicates that the southern site was especially established for testing powerful bombs. The USA and Soviet Union signed a treaty in July 1974 banning nuclear testing of device with an explosive force of more than 150 kilotons. The treaty became operational from March 31, 1976. The southern site was thus no longer needed.

Another possible reason for closing of the southern site, may be the constant leakage of radioactivity to the atmosphere after the tests. Upon the detonation of the three consecutive devices on October 27, 1973, earth movement caused the rock covering the bombs to shatter apart, resulting in a leakage of radioactive gasses.

No	Date	Yield
1.	September 18, 1964	2 Kt
2.	October 27, 1966	422 Kt
3.	October 21, 1967	93 Kt
4.	November 7, 1968	119 Kt
5.	October14, 1969	140 Kt
6.	September 27, 1971	586 Kt
7.	August 28, 1972	329 Kt
8.	September 12, 1973	2 Mt
9-11.	October 27, 1973	4 Mt (/3)
12.	August 29, 1974	497 Kt
13.	November 2, 1974	2 Mt
14.	August 23, 1974	477 Kt
15.	October 21, 1975	497 Kt
16.	-	70 Kt
17.	October 20, 1976	13 Kt
18.	September 1, 1977	55 Kt
19.	October 9, 1977	4 Kt
20.	August 10, 1978	89 Kt
21.	September 27, 1978	44 Kt
22.	October 18, 1979	70 Kt
23.	October 11, 1980	55 Kt (/2)
24.	October 1, 1981	113 Kt
25.	October 11, 1982	44 Kt
26.	August 18, 1983	89 Kt
27.	September 25, 1983	70 Kt
28.	October 25, 1984	89 Kt
29.	August 2, 1987	70 Kt
30.	May 7, 1988	-
31.	December 4, 1988	-
32.	October 24, 1990	-

Mt= Megaton(s) Kt=kiloton(s) Source: Soviet Nuclear Weapons Databook, Volume

Table 2. Underground test explosior on Novaya-Zemlya

At the northern site, 32 underground tests have been performed. (See map.) Since 1976, the devices tested at the northern site have had an explosive force ranging from 50 to 100 kilotons. From 1976 to 1990 one or two underground tests were performed at Novaya Zemlya each year, with the exception of a 19 month long moratorium from the July 26, 1985 to the February 26, 1987. For the time being, nuclear testing is regulated by the CTB.

Releases of radioactivity from underground tests

As previously mentioned, tests of nuclear bombs are performed underground in order to prevent the discharge of radioactivity into the atmosphere. However, releases of radioactivity from approximatly 100 Soviet underground tests have been detected.[125] This indicates that every fifth underground

122 Hvinden, 1963.
123 Bøhmer, N., 1991.
124 Cochran et al.

125 Hearings berfore the Committee on Foreign Relations United States Senate, June 1986.

test in the Soviet Union has resulted in a discharge of radioactive gases. The discharges result as a consequence of the rock above the bomb cracking up all the way to the surface, thereby allowing radioactive gases to seep out. This is called venting.

A venting occurred following a test at the southern site in 1973. Another probably occurred after a nuclear test on August 2, 1987, when increased levels of radioactivity were observed all over Europe. The highest levels (a measurement of 5,300 microBq. iodine-131 per cubic metre of air) were measured in Ivalo in Finland. At Skibotn in Norway a measurement of 1,370 microBq iodine-131 per cubic metre of air was recorded. In Vadsø in Norway, 15 Bq/l milk was measured.[126] It is assumed that 0.002 to 0.05 per cent of the radioactive material produced during the test explosion, was vented into the atmosphere. The test explosion on October 24, 1990 also led to a venting. Air samples taken at Sundbyberg outside of Stockholm, Sweden, showed concentrations of 10 microBq per cubic metre of air of the radioactive precious gas xenon-133.[127] By tracking meteorological data for this period, the discharge could be traced back to the test explosion of October 24, 1990.

The Moscow Treaty of 1963 bans nuclear tests that may result in fallout outside of the borders of the country performing the test explosion. Several of the tests on Novaya Zemlya have thus resulted in breaches of the Moscow Treaty.[128] In more recent years, several tens of sub-critical nuclear tests have been performed on Novaya Zemlya. These tests include some nuclear material, but not enough to trigger a nuclear explosion.

4.2.4 Underwater testing

Three underwater tests have been performed in the sea surrounding Novaya Zemlya. Two of these were carried out just off the western coast of Novaya Zemlya in September 1955 and September 1957. The third one took place in the eastern part of the Barents Sea during a naval exercise in October 1961.[129]

One of the underwater tests took place at Chernaya Bay south-west of the southern island outside the southern site for underground tests. There are elevated levels of cesium (^{137}Cs) and plutonium (^{239}Pu and ^{241}Pu) in the lower sediments of this area today. Concentration of plutonium in the lower sediments has been measured at approximately 5,500 Bq/kg.[130] This is the highest level of plutonium ever measured in the Barents Sea.

No	Date	Name	Place
1	1971	Globus-2	Near the village Ilinsko-Podomskoye
2	1972	?	The Khibini mountains near Kirovsk
3	1981	Pirit	Kumzhiyskoe
4-5	1984	Dnerp	The Khibini mountains near Kirovsk
6	1984	Kvarts-1	Near the village Ruchi
7	1988	Rubin-1	South-East of the city Kotlas

Table 3.
Civil nuclear explosions in the counties of Murmansk and Arkhangelsk.

126 Haaland, F., 1991.
127 Forsvarets Forskningsanstalt (Defence Institute of Research - Sweden), 1990.
128 Ibid.

4.2.5 Civil nuclear explosions

The enormous explosive force of the nuclear bomb attracted the interest of the planners of Soviet Union at an early stage. From the 1960's and up to 1988, so-called "peaceful" nuclear bombs were actively utilised in the Soviet Union. A total of 115 civil nuclear detonations were performed in the former Soviet Union, with nuclear devices being used for the creation of water- and gas reservoirs, canals, mines, the extinguishing of gas fires and for seismic research. In total, 41 civil nuclear bombs have been detonated in the northern parts of Russia, most of them in Siberia.[131]

On the Kola Peninsula, two civil nuclear explosions were detonated in the Kulpor mine in the Khibini Mountains, 15 kilometres east of the town of Kirovsk. The first nuclear device was detonated in 1972, and the other (Dnerp) in 1984.[132] The bombs' explosive force was approximately 1 kiloton. The aim was to increase the amount of extracted apatite-ore for the production of phosphate, which is used in the production of artificial fertiliser. After the explosion, elevated levels of radioactive contamination were registered in a river flowing just below the mine.[133] The attempt to utilise nuclear bombs to increase the extraction of ore has not been considered successful, and the mine is now closed.

In the Arkhangelsk County, four civil nuclear devices have been exploded. Three of these explosions took place as part of a seismic investigation of the earth's crust. These explosions took place in Ilinsk-Podomskoye (1971), Ruchi (1984) and Kotlas (1988). In 1981, a nuclear explosion was used in the Nenets Autonomous Region in an unsuccessful effort to extinguish a blow-out from a gas well at Kuhzhinskoye.

4.3 Reprocessing industry

The activity from the reprocessing plants in Russia, France and the United Kingdom has discharged large quantities of radioactivity to the environment. Some of the radioactivity has been transported to the Arctic Seas by rivers and ocean currents. So far, discharges from the reprocessing industry in Europe constitute one of the main sources of the radioactive contamination in the Arctic.

4.3.1 Reprocessing in Siberia

Operation of the reprocessing plants Mayak Chemical Combine (Ozersk), Siberian Chemical Combine (Seversk) and Mining and Chemical Combine (Zheleznogorsk) in Siberia has resulted in the discharges of large amounts of radioactivity into the Ob and Yenisey river system. Some of the discharges have been part routine operations, and some are the results of accidents. The rivers also transport sediments contaminated by the global fallout from nuclear atmospheric testing.

The largest routine discharges to the Ob river system occurred in the period 1948 –1951 at Mayak Chemical Combine at a time when high- and medi-

129 EcoNord Inform, No. 1, Apatity-Svanvik 1993.27 Conversations held with participants of the test detonation, "Anna Akmatova", August 1993.
130 Matishov et al.
131 EcoNord Inform, No.1, Apatity-Svanvik 1993
132 Conversations held in Kirovsk, August 1991.
133 Yemeljanenkov, A. & Popov, V., Moscow-Berlin, 1992.

um level waste was routinely dumped directly into the river Techa, which runs out in to the Ob River. Discharges of low- and medium level waste continued after 1953, when high level radioactive waste was dumped in Lake Karachai. A total of 100 PBq of liquid radioactive waste has been discharged into the river Techa. About 25% of this is radioactivity from ^{90}Sr and ^{137}Cs. The radioactive content of Lake Karachai is about 185 PBq. The groundwater beneath the lake is also contaminated.

The river system has also been affected by other contaminating sources, such as the Kysthym accident in 1957 when a tank containing radioactive waste exploded. The release from that accident was 74 PBq. The radioactive contamination of the Yenisey river system is discharges from the nuclear reactors at Mining and Chemical Combine in Zhelznogorsk.[134]

Accurate information is lacking concerning the discharges from Mayak from 1948 to 1951 and it is difficult to model the transport of radioactive isotopes in the rivers. Consequensently, the estimates of actual discharges to the Kara Sea vary between 1,8 and 12 PBq. Since ^{137}Cs settles easily into the sediments, the radioactivity is mainly associated with ^{90}Sr.[135]

4.3.2 European reprocessing

Discharges from the European reprocessing plants (mainly La Hague, France, and Sellafield, United Kingdom) constitute some of the main contributors to today's contamination of the Barents and Kara Seas. The transport time from Sellafield to the Barents Sea is estimated to be four to six years. Discharges from the European reprocessing industry were at a maximum during the 1970s, especially for Sellafield where the maximum discharges occurred in 1974-1978. This corresponds to the rise in radioactive contamination in the Barents and Kara Seas detected in the early 1980s. At that time, the concentration of ^{137}Cs in the southern Barents Sea was 30 Bq/m^3.[136]

Estimates indicate that that 8,4 PBq of ^{137}Cs and 2 PBq of ^{90}Sr have ended up in the Barents Sea, contamination originating from the European reprocessing industry, and from Sellafield in particular.[137] In mid 1990s there has been an increase in the releases from ^{99}Tc from Seallafield and increased ^{99}Tc levels have been measured along the coastline of Norway.

4.4 Contamination

In general, the radioactive contamination of the Arctic is low. Most of the present radioactivity is related to previous activities such as atmospheric testing in the 1950s and 1960s, releases from reprocessing in 1970s and the Chernobyl accident in 1986. But there are still some areas today where there is an increasing degree of contamination, as for example in areas close to some of the dumped material and at some of the naval bases. The level of radioactivity in fish in the Barents Sea is very low compared to for example the North Sea and the Baltic Sea.

4.4.1 Contamination in the Barents and Kara Seas

Radioactive contamination in seawater in the Barents and Kara Seas has been measured since 1963 when the first measurements of ^{90}Sr began. There have been fluctuations in the levels of contamination throughout. The maximum concentration was measured in 1963-1964 after the extensive atmospheric testing in the Northern Hemisphere. At this time the levels of ^{90}Sr in the Barents Sea were 20 Bq/m^3, and in the Kara Sea 40 Bq/m^3. For ^{137}Cs the corresponding figures were 30 Bq/m^3 and 60/m^3. Due to the large releases from the reprocessing facilities in the United Kingdom and France in the 1970'ies, a maximum level of ^{137}Cs at 50 Bq/m^3 was reached in the early 1980'ies in the Barents Sea. Since then the activity has decreased, and the levels of ^{137}Cs in fish meat is typically 0,25 Bq/kg.[138]

For most of the Arctic seas the average ^{137}Cs contamination in sediments are below 10 Bq/kg. Due to unusual sedimentation rates or sediment characteristics, some areas in the Norwegian Sea and the Kara Sea show contamination up to 100 Bq/kg.[139]

At some sites, a much higher contamination can be

Source	Cs	Sr
Nuclear test	2.1	1.
Chernobyl	1-5	-
Sellafield	8.2	1.

Values shown in PBq.

Table 4.
Historic sources of contamination of the Barents Sea

found. In particular these sites are Chernay Bay at Novaya Zemliya, sites within the proximity of dumped material in the Kara Sea, close to certain military naval bases, and close to the nuclear icebreaker service base Atomflot. Some of the measurements are summarised in Table 5.

At Chernay Bay, there were three underwater nuclear explosions in 1955 and 1957. In October 1961 a nuclear test was performed in connection with a naval exercise in the Barents Sea, just outside Chernay Bay.[140] Elevated contamination of the following isotopes has been measured: ^{239,240}Pu (8,500 Bq/kg), ^{241}Am (430 Bq/kg), ^{137}Cs (160 Bq/kg) and ^{60}Co (90 Bq/kg). Even if some radioactive water was dumped in the same area, it is quite clear from the isotopic ratios that the main source of the contamination was the three nuclear underwater tests.[141]

Elevated levels of radioactive contamination have

134 Bøhmer, N. and Nilsen, T., 1995.
135 Joint Russian-Norwegian Expert Group for Investigation of Radioactive Contamination in the Northern Seas, 1993.
136 Ibid.
137 Ibid.
138 AMAP, 1998 and Joint Expert Group, 1996
139 AMAP, 1998.

140 Bøhmer, N. and Nilsen, T., 1995
141 AMAP,1998.

also been measured at some of the dumping sites for radioactive waste in the Kara Sea. Two of the most contaminated sites are Abrosimov and Stepovogo Fjords. During three joint Norwegian-Russian expeditions in 1994-1994, the dumping sites were extensively investigated and monitored. The results from these expeditions showed enhanced levels of ^{137}Cs, ^{90}Sr, ^{60}Co and Pu-isotopes in sediments close to the sites in these two fjords where materials has been dumped. The results are shown in Table 1. Most of the contamination was found in the upper 5 cm of the sediments. In addition, traces of ^{60}Co in Tsvolky Fjord have also been measured, in the sediments, an indication of leakage from the dumped material. So far, the only place where increased levels of radioactivity in seawater have been measured is in the Stepovogo Fjord, where ^{90}Sr levels up to 26 Bq/m^3 have been measured.[142]

	Chernay Bay	Abrosimov Fjord	Stepovogo Fjord	Close to Komsomolets	Litsa Fjord	Outside Atomflot
^{239,240}Pu	8.500	1-18	<0,8-28	1,16	5,4-8,7	0,8
^{241}Am	430	ND	ND	0,2	ND	ND
^{137}Cs	160	23-31.000	14-109.000	7,1	114	8,4-630
^{60}Co	90	0,4-180	0,1-3.150	ND	5,8	<0,4-14,9
^{90}Sr	ND	4-88.500	1-310	ND	ND	ND

ND = No Data

Table 5.
Elevated radioactive contamination at selected sites[143]

4.4.2 Land contamination

The main sources of contamination of land areas in the Arctic take the form of fallout from the nuclear testing in the 1950s and 1960s and the 1986 Chernobyl accident. There are some local areas showing elevated levels of radiation close to some of the nuclear test sites at Novaya Zemlya and close to some of the storage of spent nuclear fuel.

There is little concrete information and reliable measurements available for the actual fall out at the Kola and Arkhangelsk areas following nuclear testing in the 1950' and 1960's. Calculations based on precipitation data have shown that in 1995 the levels of ^{137}Cs because of the fall out were between 1 to 2,5 kBq/m^2.[144] However, these calculations are estimates only, and local variations can occur.

At the test sites on Novaya Zemlya, the fall out was of course higher. Actual measurements show that the highest fall out was over the southern test site at Chernaya Bay. At this site several square kilometres are contaminated with ^{137}Cs level up to 1110 kBq/m^2 and ^{90}Sr levels up to 500 kBq/m^2. The dose rate at some of the craters is between 10-150 microGy/h. These values are about 10-100 times higher than the levels that can be measured at the Northern test site at Matochkin Strait. The mean levels of radioactive contamination at the test sites at Novaya Zemlya are 3 kBq/m^2 for ^{137}Cs and 2 kBq/m^2 for ^{90}Sr.[145]

The impact of contamination after the Chernobyl accident on the Arctic was smaller than the fallout from the nuclear testing. On the Kola Peninsula the concentration of ^{137}Cs in 1986 was up to 1 kBq/m^2 and farther east in the Arkhangelsk county, about 220 Bq/m^2.[146]

142 AMAP 1998.
143 AMAP, 1998, Joint Expert Group, 1996, Nikitin, A.I. et al., 1999, Mathishov, G.G. et al. 199
144AMAP, 1998.
145 Ibid.
146 Ibid.

Chapter 5

Projects for securing nuclear waste

Projects for securing nuclear waste

A number of the proposals for securing nuclear fuel and radioactive waste are co-operative ventures in which various countries contribute both economically and with technical expertise. The momentum for some of these projects has been slowed, mostly due to unresolved questions of responsibility on the Russian side. Hopefully the momentum can be regained again when the multilateral agreement Multilateral Environment Nuclear Programme for Russia (MNEPR) is signed.

The total estimate for establishing the necessary infrastructure for the management of radioactive waste, spent nuclear fuel and decommissioning nuclear powered submarines as well as remediation of contaminated areas at the Kola Peninsula and Arkhangelsk county is around $2 billion.

There are two pilot projects that in effect have the aim of improving the handling of radioactive waste and spent nuclear fuel on the Kola Peninsula. One of them is a Russian-American-Norwegian co-operative effort to treat low level liquid waste; the other is the multi-national Lepse project. These two pilot projects will be invaluable not only for the exchange of information and technology between the involved parties, but also because they will serve to reduce the risk of radioactive contamination.

Besides these two pilot projects, there is also the trilateral military co-operation between the Ministries of Defence of Russia, the United States and Norway, the so-called Arctic Military Environmental Co-operation (AMEC). This consists of several individual projects, some of them aimed at properly securing military nuclear waste. One of projects within the AMEC programme is the development and testing of a combined storage and transport container for spent nuclear fuel from decommissioned nuclear submarines.

There are also plans for additional projects with contributions made by other parties. For example, it is envisioned to empty the storage ship Lotta of its spent nuclear fuel. This particular project has been supported by the United States Environmental Protection Agency (EPA) and the Co-operative Threat Reduction (CTR), also known as the Nunn-Lugar Programme after the two United States senators who initiated it.

Although not having direct environmental relevance, CTR has been the most successful program so far. Five ballistic missile submarines (SSBNs) have been dismantled with the help of CTR's equipment, while the decommissioning of another 14 SSBNs have been directly funded by the program. CTR has also taken an active role in upgrading the existing infrastructure to ensure SSBN dismantlement.

147 Plan of Action for Nuclear Problems- Overwiew over Efforts and projects, Norwegian Ministry of Foreign Affairs, May 2001.

There is also the Norwegian-Russian framework agreement to secure radioactive waste and spent fuel. This agreement opens for the possibility of utilising Norwegian economic assistance to handle naval spent nuclear fuel. Four railroad cars paid by Norway were taken into operation in 2000.

5.1. Norway's plan of action

Norway is taking part in most of the projects carried out by EU countries as well as within the AMEC initiative. In May, 1998, Norway signed a bilateral agreement with Russia in which the joint projects were specified. The agreement defined Norway's dominant role in the initiatives listed below. A precondition for implementation of the projects is the signing of a framework agreement between Norway and Russia to regulate taxation and liability matters. The five projects listed below have either been implemented by Norway or else Norwegian companies have been engaged to carry them out. From 1995 to 2000 Norway allotted 65.3 million USD for the project. Of that sum, only 38.8 million USD have been spent, leaving a balance of 26.5 million USD in unused funds. All the projects are funded by Norwegian Ministry of Foreign Affairs.

The five projects are as follows:[147]

1. Emptying and closing of the storage facility for spent nuclear fuel at Andreeva Bay, and a comprehensive study of methods for the handling of this fuel; planning, building and operating of a facility for temporary storage of solid radioactive waste at Andreeva Bay;
2. Planning, construction and operation of a special ship for the transport of spent nuclear fuel;
3. Construction and operation of four special railroad cars for the transport of spent nuclear fuel;
4. Modernisation and operation of a facility for temporary storage of liquid radioactive waste at Zvezdochka shipyard in Severodvinsk.
5. Replacement of strontium-batteries at Russian lighthouses in northern regions with conventional or solar cells.

The experience thus far with these projects has been mixed; a status report for the different projects is presented below:

Project 1

Implementation of Project 1 was hampered by the reluctance of the Russian Defence Ministry to permit international experts access to Andreeva Bay. Nevertheless, Norway has launched a subproject providing 817,000 USD to divert a small river that runs through a spent fuel facility and into the Litsa Fjord on the Kola Peninsula. The idea was simple: a trench was dug around the storage facility (Building no. 5). The project was completed in September 1999. Russia supervised all the work on the site. Upon completion, Norway received pictures of the completed work.

Future plans, which might be implemented the same way, envision the construction of a roof over the spent fuel storage tank in Andreeva Bay.

Project 2

Discussions on supplying the Russian Navy with a support vessel to transport spent nuclear fuel began in 1995. The Norwegian concern Kværner Moss Technology conducted a study and drafted the design of the vessel The work was funded by the Norwegian Foreign Ministry which provided 423,000 USD. In 2001 the project will be put out for tender. Norway earmarks 13.3 million USD for the project. Great Britain may come in as a co-financier.

Project 3

In Project 3, Norway allotted 3.1 million USD to build four TK-VG-18-type railroad cars to ship maritime spent fuel from the Northern and Pacific fleets to the Mayak plant for reprocessing. Russia has four such railroad cars, which is far from sufficient.The project was completed in autumn 2000, and the railroad cars put in operation.

Project 4

This project entails upgrading the so-called 'Object 159' at Zvezdochka shipyard in Severodvinsk.The object consists of two type A-02 tanks for low level liquid radioactive waste, each with a capacity of 500 cubic meters. The tanks are located near the planned liquid waste processing facility and will serve as a buffer.The upgrade began in May 1998 and was completed in 2000. Norway spent 4.3 million USD on the project.

Project 5

There are more than one hundred strontium-powered lighthouses on the Kola Peninsula and Novaya Zemlya. Project 5 started in 1996 and entails the replacement of strontium batteries with either conventional of solar cells. To date, eight lighthouses are now powered with solar cells. The ninth lighthouse will be powered with solar cells over the course of 2001.

5.2. The Industrial Group

In 1997, an international industrial group was created for the purpose of working on nuclear waste management projects in Russia, among them the spent fuel storage at Mayak. The group was composed of SKB (Sweden), BNFL (United Kingdom), Kvaerner Maritime (Norway) and SGN (France). Kvaerner Maritime was replaced by the Norwegian company Storvik & Co. in 2000.

The Industrial Group completed a study, which concluded that the most viable option was to build a new dry storage facility for naval spent fuel at Mayak. Such a facility could be built at a cost of 50 million Euros and would be financed by the Nordic countries and the EU. However, Minatom, which operates Mayak, stated clearly that a dry storage was not on its agenda, and that is would rather complete the partially built wet storage instead. Disagreement between Minatom and the Industrial Group over technology resulted in the halt of the spent fuel storage project in 1998.

At a meeting in Moscow in early 2000, Minatom seemed to realise that there would be no western funding for the wet storage. Consequently, after that meeting, the Industrial Group and Minatom developed a concept entitled Federal Environment Spent Fuel Store in Northwest Russia; however, Minatom have lately begun to advocate a dry storage in Mayak. As a result, the plans for a dry storage in Northwest Russia are once more in limbo. The Industrial Group and Minatom have so far agreed to build a storage pad for 50 AMEC-type containers for spent nuclear fuel.

A question mark still remains with respect to Norway's position. Even if it has never been stated officially, it is clear that Norwegian officials are not very happy about Minatom's change in position. Between the lines, Norway's hope has been to ship nuclear waste as far away from the Norwegian border as possible.

5.3. Murmansk 80-ton Cask Project/The Lotta Project

In January 1998 at the Barents Council, United States Deputy Secretary of State Strobe Talbott proposed the development of an 80-ton cask to store spent fuel. The initiative was a response to problems associated with Murmansk Shipping Company's support vessel Lotta, which stores 3,130 zirconium-clad spent nuclear fuel assemblies that cannot be sent to Mayak for reprocessing.[148]

An international effort to empty Lotta from spent nuclear fuel has been initiated with the participation of the United States, Norway, Sweden, Finland, the United Kingdom, the European Union and the Nordic Environmental Finance Corporation. In the United States, the effort is led by the EPA's Office for International Activities.

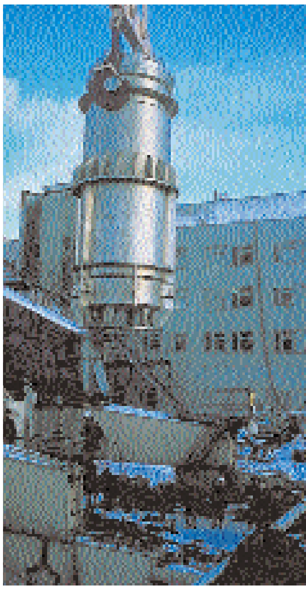
The project will design, fabricate, test and certify the cask; design, construct and commission a storage pad for the cask; and design, fabricate and license equipment for the handling of the cask. Approximately 2.5 million USD have been committed by the international parties for the cask and storage facility[149]. The United States, Norway and Sweden have each supplied 500,000 USD; Finland and the European Union have committed 250,000 USD each[150].

Initial engineering surveys were completed in May 2000;- completion of the final cask demonstration testing is scheduled for November 2001[151]. The location of the storage pad for the cask is not been determined. One of the candidates is the Atomflot nuclear icebreakers base in Murmansk.

The European Commission's Directorate General for Environment and Nuclear Safety (DG-XI) will assist in the completion of the project and ensure the availability of one or two containers for possible use in storing spent fuel from the Lepse (See "Lepse pilot project").

The 80-ton casks, while making economic sense, are difficult to manage at naval bases; which is why the 40-ton cask concept is in parallel development through AMEC. The casks will initially be licensed for a period of 10 years with the possibility of extending the useful life time by another 10 to 15 years.[152]

It is unclear what will happen to Lotta once the vessel has been emptied. The United States argues that the ship should be decommissioned, whereas MSCo maintains that Lotta should be utilised in the ongoing effort to defuel decommissioned submarines. Of the two alternatives, the latter appears to be the most probable outcome, as it represents an opportunity for MSCo to continue earning income from the vessel.



5.4. Russian Minatom proposals

Projects proposed from the Russian side fall in line with the overall master plan developed by Minatom. These concretise the ongoing international described above, most of which are also implemented consistent to the strategy declared by Minatom.

148 Measures for securing radioactive waste and spent nuclear fuel in Murmansk and Archangelsk counties, Bellona Working Paper No. 1:99
149 Environmental Protection Agency, Note to the author, June 22, 2000.

150 Norwegian Plan of Action, Norwegian Ministry of Foreign Affairs, , January, 1999
151 Ibid.
152 Barents Council Meeting, Luleå, January 1998

Spent nuclear fuel management

In keeping with Russia's traditional approach, spent nuclear fuel is shipped from Murmansk and Arkhangelsk counties to the reprocessing plant at Mayak. The new shift in strategy calls not for the immediate reprocessing of spent fuel but rather for dry storage in metal-concrete casks (TK-108) for a period of at least 50 years. The Mayak reprocessing plant still remains the prioritised location; however, proposals have been made, to build intermediate storage pads for fuel casks in Murmansk and Arkhangelsk counties. To this effect, the following projects were proposed[153]:

1. The building of an intermediate spent fuel cask storage pad at Atomflot base in Murmansk to accelerate the tempo of fuel shipment to the Mayak reprocessing plant;
2. Completion of an intermediate spent fuel cask storage pad at Zvezdochka shipyard in Severodvinsk to accelerate the tempo of fuel shipment to the Mayak reprocessing plant;

3. The building of an intermediate spent fuel cask storage pad at Nerpa shipyard and at Shkval shipyard to speed up defuelling of the retired submarines;
4. Upgrading of the infrastructure at Atomflot so as to accommodate the 80-ton size casks to be used for zirconium-clad fuel currently stored onboard the Lotta, as well as for the damaged fuel stored onboard the Lepse.
5. Upgrading of the infrastructure at Gremikha naval base to facilitate the defuelling of submarines with PWR type reactors; also repair of the SD-10 dry dock to permit defuelling of the two remaining Alfa class submarines with liquid metal cooled reactors. The dry dock can also be used to defuel the PWR submarines stationed there, which are also in an extremely poor state of repair;
6. The building of cask transport vessels to transport fuel, specifically, from Andreeva Bay and Gremikha;
7. Defuelling the Lepse.

The list of projects does not include the remediation repairs at Andreeva Bay and Gremikha. Such projects would require enormous funding not available as per the time of writing. Norway has been trying to push through with Andreeva Bay project but this has been hampered by problems of access -- Andreeva Bay is situated just across from the Northern Fleet operational submarine base. The access problem is not so acute for Gremikha, however. At this time, there are no existing remediation plans, neither for Andreeva Bay nor for the base at Gremikha.

Defuelled reactor sections

All defuelled reactor sections from dismantled nuclear submarines are towed to Sayda Bay on the Kola Peninsula, where they are moored to the pier and remain afloat. This practice constitutes the only form of temporary storage in the absence of a long-term storage facility for reactor compartments.

The immediate plans call for the building of a temporary storage pad for reactor sections at Nerpa shipyard. Further plans suggest building an onshore storage site at Sayda Bay. The feasibility study of the project was completed in 2001, with a project cost estimate at around 85 million USD. The storage site is designed to store reactor sections for 50-70 years[154].

Another proposed option suggests digging canals from the sea in the vicinity of the nuclear testing site at Novaya Zemlya, into which the reactor compartments could be towed. Gradually, as the canals fill up, the water would be pumped out so that the reactor compartments are left sitting on dry ground. They could then be covered with sand and gravel, or else remain exposed until radioactivity levels had dropped sufficiently to allow dismantlement and burial of the metal as solid radioactive waste.

Radioactive waste

Murmansk county lacks the infrastructure and facilities for the processing, packing and transportation of solid radioactive waste. The situation with liquid radioactive waste is somewhat better in that one treatment plant is operational at Atomflot and is being upgraded (see "Murmansk Initiative"). Also, another project exists to design and build a mobile liquid waste treatment plant (See "AMEC projects").

Russia suggests building a solid waste treatment plant and container storage site at Shkval shipyard in Polyarny. This site would receive all of the solid waste, including that generated in the processing of liquid radioactive waste. The storage site would be designed to store containers with low-and medium level radioactive waste for 50 to 70 years. This project is estimated to cost 85 million USD.

Both Andreeva Bay and Gremikha will be challenging projects with respect to radioactive waste management, as both sites require full remediation. A summary of the radioactive waste management projects therefore is as follows:

1. Completion of the upgrade of the radioactive waste treatment plant at Atomflot;
2. Design and construction of mobile plant for liquid radioactive waste;
3. Construction of containers for solid radioactive waste;
4. Construction of the regional centre was radioactive waste processing at Shkval shipyard in Polyarny.
5. Remediation of Andreeva Bay storage site;
6. Remediation of Gremikha storage site.

Repository[155]

For several years, plans have existed for the establishment of a repository for low and medium level waste in Northwest Russia. Many different locations have been proposed, but the most concrete option appears to be the building a repository at the former nuclear test site at Bashamachny Bay in the south-western part of Novaya Zemlya. This plan was developed by VNIPIPromtechnologii with support from Minatom, the Northern Fleet, Kola Nuclear Power Plant and the Murmansk Shipping Company. Numerous geological surveys of the area were made over the course of the 1990s, and two wells with a depth of 130 m and 233 m were drilled; however, the

153 Radwaste and spent fuel management in Murmansk county, Murmansk county administration, February 27, 2001.
154 Ibid.

155 Nilsen & N. Bøhmer, Source of radioactive contamination in Murmansk and Arkhangelsk counties, 1994.
156 Lopatin, V.V. et al. Environmental safe disposal of radioactive waste accumulated in the NW region of Russia in a pilot-repository in the permafrost of Novaya Zemlya, 1998.

results from these surveys are not known[156].

The repository will be located underground at a depth of 15 m in a permafrost area. According to Russian scientists from VNIPIPromtechnologii, the permafrost will act as an extra barrier, helping to prevent any leakage from the repository.

The radioactive waste will be transported by sea from the mainland to Novaya Zemlya. Due to the harsh climatic conditions in the area and the lack of daylight in the long Arctic winter, it would only be possible to deliver waste to the repository in the period from May to October. The annual capacity during the first five years is calculated to be 2,000 m^2.[157]

A repository for high level radioactive waste is planned in the same area. This repository will be able to receive both solid transuranic radioactive waste and spent nuclear fuel, although this option hasnot yet been sufficiently researched. A number of other locations at the Kola Peninsula have also been proposed for the building of a storage repository Should the repository project start in the near future, both options must be evaluated on an equal level.

5.5. Arctic Military Environmental Cooperation

The Arctic Military Environmental Cooperation (AMEC) program was formally established by the defence ministers of the United States, Russia and Norway on September 26, 1996, to provide a platform for these three countries to address military-related environmental problems in the fragile Arctic region.

The underlying philosophy is that it should be easier to discuss military environmental problems through a military co-operative effort than through civilian channels. AMEC's primary mission was to fill the gaps in the CTR program on issues of direct relevance to environmental protection. The program emphasises the need to leave behind infrastructure for Russia to use after co-operative programs have come to an end.

The AMEC program currently includes a number of specific activities that fall into the cooperative areas indicated above. These activities address both nuclear and non-nuclear environmental security concerns in Russia and complement related projects that are underway in Russia pursuant to the objectives of CTR (See previous section). All present radiological AMEC projects in Russia are conducted in support of the CTR program and governed by the CTR Implementing Agreement. A synopsis of these projects is presented below:

AMEC 1.1 Development of a dual-purpose prototype transport and storage cask for naval spent fuel. The design, fabrication and the majority of the testing of the cask were completed by May 2000. Certification of the cask by the Russian civilian nuclear inspection agency has not yet been granted. The cask has a design life of 50 years and holds up to 49 submarine fuel assemblies[158]. CTR will purchase upwards of 100 casks, under the condition that they are certified. Project 1.1. was commenced under the CTR Umbrella Agreement and is managed by the EPA for the DOD[159].

The prototype cask may not reflect the safety standards for the casks in serial production at the Izhora plant, and because of this, The Russian nuclear regulator, GAN, has held back from participating in the project. The lack of GAN's representative signature during testing constitutes a violation of Russian safety requirements, and hence civilian certification of the cask is uncertain. To correct the violation, Minatom and the Russian Defence Ministry lobbied through a governmental decree in 2000 which transferred the licensing of the military-related products to Minatom. In 2000, the Izhora plant manufactured 48 storage casks.. The contract for the year 2001 to manufacture 25 casks was granted to Sevmash shipyard in Severodvinsk. According to available estimates, the Russian Navy has a need for 200 casks.

AMEC 1.1-1 covers the design, licensing and construction of a storage pad for the 40-ton cask[160].

AMEC 1.2. Development of mobile technology for the treatment at remote sites of liquid radioactive waste associated with the decommissioning of nuclear submarines. The appropriate expertise and operational experience exists in Russia, with input also coming from the United States, Norway and Finland. The project is now under way, with completion planned for December 2001[161].

AMEC 1.3. Review and implementation of technology for reduction in the volume of solid radioactive waste. Volume reduction reduces overall storage costs. The project aims to facilitate the disposal of solid waste from strategic and general purpose submarines. A technology assessment was completed in 1999 and the manufacture of a mobile treatment facility is planned. The remaining task, a metal decontamination unit, has not yet been approved. Originally, Project 1.3 was scheduled for completion in September of 2002.

AMEC 1.4. Advanced interim storage technologies for solid radioactive waste. Poorly designed Russian storage facilities for radioactive materials have caused local contamination. This project aims at building capabilities within the Russian Federation to design and build appropriate storage facilities without further outside assistance. A total of 22 American-made solid radioactive waste containers have been delivered to Russia and are being tested for certification. Another 100 steel containers were produced in Russia and are now being certified. The manufacture of lower-cost concrete containers has also begun. The project is scheduled for completion in October 2002 with the delivery of the concrete waste containers.

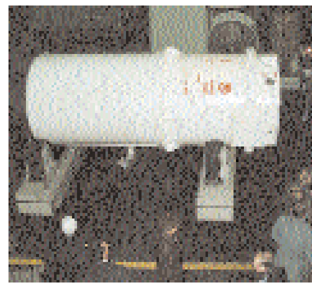


Table 1.
AMEC Program US Fundi
in 1,000 USD

Project	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	Total
AMEC 1.1.	200	2,000	1,600	800	0	0	4,600
AMEC 1.2.	0	200	800	500	200	0	1,700
AMEC 1.3.	727	600	400	1,600	1,200	800	5,327
AMEC 1.4.	250	1,250	850	1,600	900	600	5,450
AMEC 1.5.	150	700	750	300	300	0	2,200

Source: AMEC

AMEC 1.5. Cooperation in radiation monitoring and environmental safety. The project aims to assist in in the identification of risk levels during various stages of decommissioning, the determination of safety monitoring equipment needs and the provision of safety equipment and operator training. Originally scheduled for completion in July 1999, the most recently issued timeline foresees project completion in September 2001.[162]

AMEC 2.1. and 2.2. are non-nuclear programs.

5.6 Murmansk Initiative

During the 1993 negotiations of the London Convention, which bans ocean dumping of radioactive materials, Russia declared it did not have the capacity to manage its low-level liquid radioactive waste (LLRW), especially when adhering to START-prescribed submarine reduction levels, without ocean dumping. Consequently, Russia ceased ocean dumping, yet without signing on to the amendments to London Convention banning radioactive waste dumping. Through the Murmansk Initiative, the United States, Norway and Russia cooperate in enhancing the capacity and the treat-

157 Ibid.
158 U.S. EPA. Note to the author, June 22, 2000.
159 Department of Defense, AMEC Information Sheet, April 2000.
160 U.S. EPA, Note to the author, June 22, 2000.
161 Ibid.
162 U.S. DoD, AMEC Information Sheet, April 2000.

ment capabilities of the LLRW treatment facility at the Atomflot base in Murmansk from 1,500 cubic meters annually to 5,000 cubic meters[163]. The US project manager in the form of the Environmental Protection Agency's Office of International Activities, coordinates funding from DoE, DoE and the United States Agency for International Development.

The project is expected to cost 5.2 million USD, and it will use Russian technology in treating the liquid waste from MSCo and the Northern Fleet. These technologies will be automated through the use of a US supplied computer system. The treatment process is based on the use of filters, electrolysis and sorbent technologies. These filters are back washable while the sorbents become contaminated and must be stored as radioactive waste. Solids generated from the treatment process will be stored in cement at Atomflot. The construction phase was completed in January 2000. Operational testing has continued and the plant is currently in the process of treating 50 cubic meters of LLRW as an initial test run for the facility. The hydro-unloading system of sorbents, one of the plant's main technical challenges, has been surmounted[164].

5.7. United States projects

Even after the collapse of the Soviet Union, the United States saw that the end of the Cold War did not bring with it an end to the threat to national security imposed by Soviet, now Russian weapons. The threat, however, had shifted in nature from one of deliberate and intentional attack to an unsettling potential for nuclear proliferation and the environmental consequences of a disintegrating command and control system and severely under funded-protection and storage facilities for fissile materials and other hazardous substances.

The recognition of new proliferation and environmental threats also sparked the creation of a number of threat reduction assistance programs through which the United States has engaged Russia in a co-operative manner. Mainly aimed at reducing the risk of proliferation through the elimination of weapon systems, safeguarding of fissile materials and funding research programs to keep nuclear scientists from selling secrets or defecting, the American programs also have an environmental security component. In some cases, the latter is a more ancillary aspect, while in other programs it is the main aim of US assistance.

Reflecting the focus Congress has placed on national security, the leadership roles for various nuclear assistance projects rest with the Departments of Defence, Energy and State. The Environmental Protection Agency (EPA) and other federal agencies play a role in support of the three aforementioned departments, but do not draw direct funding from Congress for Russian nuclear assistance work.

5.7.1 Cooperative Threat Reduction (CTR)

In 1991, following the collapse of the Soviet Union, the United States established the Cooperative Threat Reduction (CTR) program to reduce the threat posed to US national security by weapons of mass destruction in the former Soviet Union (FSU). The program is also known as the Nunn-Lugar program[165].

The CTR program has focused primarily on 1) the destruction of nuclear delivery systems (missiles), their launchers (silos and submarines), and associated facilities as well as chemical weapons; and 2) on securing former Soviet Union (FSU) nuclear weapons and their components[166]. More recently, the CTR program has begun to include projects to reduce threats from FSU biological weapons, materials and prevent spreading of knowledge associated with these materials. To date, the United States Congress has provided the Department of Defence with more than 3.1 billion USD through fiscal year 2000 for the CTR program[167].

During the early stages of the CTR program, the scope of threat reduction activities did not exclude projects with a direct environmental focus. In 1993, for example, under the auspices of CTR, a project was launched for the "study, assessment, and identification of nuclear waste disposal by the former Soviet Union in the Arctic region"[168]. Starting in 1996, however, the US Congress added amendments to funding bills to limit CTR's authority in assisting with environmental restoration projects and has continued to include prohibitive language in defence authorisation bills[169].

Despite the congressional restriction on environmental expenditures by the CTR program, a number of projects initiated over the years have had or will have some environmental and safety benefits. In NW Russia, CTR projects associated with submarine dismantlement, spent fuel storage and disposition, radioactive waste processing and fissile materials management partly fall into this category. Table 2 illustrates funding trends since the mid-1990s of CTR program components, including environmentally relevant projects. These projects are discussed below.

Table 2.
Funding Trends in 1000 000 USD.Selected CTR Programs – Russia.

Fiscal Year	Strategic Offensive Arms Elimination (Includes Submarine Dismantlement in NW Russia)	Mayak Fissile Material Storage Facility	Submarine Dismantlement (Far East)
FY 1994	51.3	55.0	-
FY 1995*	32.0	-	-
FY 1996	74.0	29.0	-
FY 1997	59.8	66.0	-
FY 1998	77.9	57.7	-
FY 1999	142.4	60.9	-
FY 2000	157.3	64.5	25.0+
FY 2001 Request	152.8	57.4	-

* Drop reflects transfer of MPC&A program to the Department of Energy
+Money transferred from chemical weapons destruction facility budget for defueling and dismantlement of SSBNs at Zvezda shipyard.

Sources: Nuclear Successor States of the Soviet Union, Monterey Institute of International Studies, March 1998 (FY 94-98); and Russian-American Nuclear Security Advisory Council, www.ransac.org, (FY99-01)

5.7.2 Strategic Offensive Arms Elimination (SOAE)

As part of the CTR program's efforts to eliminate Russian strategic offensive arms, projects are underway to support the dismantlement of Russian strategic ballistic missile submarines (SSBNs). While conducted pursuant to US national security objectives, SSBN dismantlement could be relevant to environmental concerns in NW Russia. The submarines contain radioactive materials, including spent fuel and contaminated reactor compartments, yet they are poorly maintained and deteriorating in several Russian ports. The dismantlement of Russian SSBNs and the disposition of their parts will remove from these ports radioactive materials that might otherwise be dispersed in northern waters.

163 U.S. EPA, – EPA Goal 5, Objective/Sub-objective 1.5, March 7, 2000.
164 Bellona web, www.bellon.org, 11/1 2001
165 CTR home page in the Internet.
166 GAO, Weapons of Mass Destruction: U.S. Efforts to Reduce Threats From the Former Soviet Union, March 6, 2000.
167 FY2000 Defense Appropriations, CTR, FY 2000 Budget Conference Report (HR 106-371) and GOA, Weapons of Mass Destruction: Effort to Reduce Russian Arsenals May Cost More, Achieve Less Than Planned, April 13, 1999.
168 FY93 DoD Appropriations Act, Public Law 102-396, October 6, 1992.
169 The Kasich Amendment.

SSBN dismantlement activities in NW Russia and elsewhere generate radioactive by-products, namely liquid radioactive waste, spent fuel, and reactor compartments. CTR funds projects that mitigate the potential detrimental impacts associated with the dismantlement activities. These projects include the development and maintenance of infrastructure that can be used for storage and processing of radioactive materials removed from the submarines, thereby ensuring that the materials are properly managed. Environmentally relevant activities within the SSBN dismantlement program are discussed below:

SLBM Launcher/SSBN Elimination

Under the "SLBM Launcher Elimination/SSBN Dismantlement" project, the CTR program is assisting in the dismantlement of SSBNs to meet Russia's Strategic Arms Reduction Treaty (START I) commitments. Program goals include the dismantlement of all START I-designated SSBNs by 2003.

Early CTR support of submarine dismantlement focused on the provision of relevant technology to three shipyards designated by Russia in START I for dismantlement activity: Nerpa in Murmansk, Zvezdochka in Severodvinsk, and Zvezda in Bolshoi Kamen (Far East). Equipment provided to these shipyards included cranes with magnetic lifting devices, cutting tools, excavators with shears for dismantlement, guillotine shears, cable choppers, plasma cutters, portable filter and ventilation systems, balers, electric forklifts, gantry cranes, tractors, trailers, radio communication equipment, air compressors, and oxy-acetylene torches[170]. Beginning i 1997, with the goal of speeding SSBN dismantlement rates and improving the process, CTR program officials shifted the focus of dismantlement assistance from providing equipment to awarding direct contracts to Russian shipyards on a "deliverables" basis[171]. As of Spring 2000, contracts had been awarded to four Russian shipyards (the three START I shipyards and Sevmash in Severodvinsk, designated by Russia as a START I facility) for complete dismantlement of 17 SSBNs[172]. In 1999, a contract was approved to begin the process of eliminating one of the six Typhoon-class missile boats, the world's largest submarines, at Sevmash[173]. CTR hope that five Typhoons can be slated for elimination under CTR[174]. Future SSBN dismantlement support will be accomplished through direct contracting with the Russian designated shipyards, yielding a total of 31 SSBNs dismantled in this manner (17 from the Northern Fleet and 14 from the Pacific Fleet), at a cost of $455 million USD.

Spent Naval Fuel Disposition

Under the CTR program, a project has been initiated to assist in the disposition of spent naval fuel removed from Russian SSBNs at Zvezda (Bolshoy Kamen), Zvezdochka (Severodvinsk), and Nerpa (Murmansk). Nerpa shipyard dropped out later, however, as CTR decided to focus on Severodvinsk to provide decommissioning of SSBNs in north-west Russia. The project consists of four major elements[175], which will be carried out by appropriate Russian entities through direct contracts[176]:

-Reprocessing of spent nuclear fuel at Mayak from up to 15 SSBNs eliminated under the CTR program;

-Storage of uranium and plutonium end products from the spent fuel reprocessing;

-Construction of pad for interim storage for spent nuclear fuel containers;

-Procurement of 40-ton containers for transport and interim storage of spent nuclear fuel[177].

As of January 2000, the schedule for the above activities called for the issuance during FY 2000 of contracts for reprocessing of fuel from the first six SSBNs, procurement of transportation containers, and the design of a pad for interim storage of spent nuclear fuel containers[178]. The procurement of the casks was projected to be by direct contract to the Izhora plant outside of St Petersburg. The Izhora plant received a contract first for 12 and then for 36

170 SLBM Launcher/SSBN Elimination, CTR web site, http://www.dtra.mil/ctr/07frame.html.
171 James Clay Moltz, Spring 2000, op. cit.
172 Ibid.
173 Senator Richard Lugar, December 13, 1999.
174 Capt. Kenneth Trass, Program Manager, SOAE Russia, Bellona IWG Conference, Washington, March 1-2, 2000.
175 Spent Naval Fuel Disposition, CTR Project Plan, October 8, 1999.
176 Jim Reid, CTR Program Official, Personal Communication, June 23, 2000.
177 The containers were developed in conjunction with the AMEC program.
178 Spent Naval Fuel Disposition, Russia Country Book, CTR Program, January 2000.

40-ton casks (TUK-108) in 2000. The contract for manufacturing an additional 25 casks in 2001 was granted to Sevmash shipyard in Severodvinsk[179].

In addition to cask procurement, an assessment of the potential locations for situating storage pads intended to support the casks, as well as the design of the pads, has been performed, and final construction of the pads will ultimately be undertaken by direct contract with Russian companies[180].

The spent fuel transfer point funded by CTR in north-west Russia will be located at Zvezdochka shipyard in Severodvinsk. The infrastructure will be optimised and will include a storage pad for 15 TK-18 or TUK-108 casks[181].

Volume Reduction of Low Level Radioactive Waste

To facilitate dismantlement of SSBNs, a low-level radioactive waste (LLRW) volume reduction project was approved for implementation in 1998. Lockheed Martin Energy Technologies was awarded a contract in a competitive procurement process to design, procure and install LLRW volume reduction systems at two Russian, START-designated elimination facilities, Zvezdochka and Zvezda. In addition comes the construction of an interim storage facility for 1,500 cubic meters of processed LLRW at Zvezda[182].

While the waste reduction and storage systems was turned over to the shipyards for their operation in 2000, CTR may exercise options to provide technical service and logistics support through the end of fiscal year 2002 or until the waste from at least 31 SSBNs with SLBM launchers is eliminated[183]. The LLRW infrastructure associated with the submarine dismantlement under the CTR program is important in that once all SSBNs are dismantled, the remaining infrastructure could be used to support dismantlement of non-strategic decommissioned, deteriorating nuclear submarines that are currently moored in naval bases and shipyards in NW Russia[184].

179 RBC new agency, April 18, 2001.
180 Spent Naval Fuel Disposition, CTR Project Plan, op. cit.
181 Expert evaluation of the feasibility study on building an infrastructure to defuel retired submarines at Zvezdochka shipyard, 2000.
182 Volume Reduction of LLRW, CTR Project Plan, Defense Threat Reduction Agency, October 1999.
183 Volume Reduction of LLRW, op. cit.
184 U.S. DoD, AMEC Program Plan and Report on Proposed Obligations for FY 1999.

5.7.3 Safeguarding Nuclear Materials

In addition to dismantlement, cleanup and storage efforts and the supporting infrastructure development, the United States is actively assisting the Russian Federation in accounting for its nuclear materials and assuring their safe storage. The lead program that addresses the facilities in which materials are stored is the Material Protection, Control and Accounting (MPC&A) program. Designed with non-proliferation objectives in mind, MPC&A has considerable environmental benefits, as poor accounting and management of fissile materials could engender major environmental problems in the future.

The majority of MPC&A sites are Russian and NIS (Newly Independent States) civilian sites and Russian Navy sites. By 2000, the MPC&A program had installed equipment at Northern Fleet Site 49 (fresh fuel storage), on the Malina class PM-63 naval refuelling ships and on the icebreaker fleet service ship Imandra[185]. In the Russian Far East, equipment was installed at Pacific Fleet Site 34 (fresh fuel storage) and aboard the Malina class naval refuelling ship PM-74[186]. Other sites in NW Russia include various nuclear research and nuclear weapons related centres in Russia..

5.7.4 Future Issues

While the CTR program tends to have the support of both major parties in the US legislature, and budgets have correspondingly risen over the years, the program is not without criticism. Over the years of the program's existence, Congress, the General Accounting Office, and private experts have found fault with it for a number of reasons, including poor accountability and reporting practices[187], support of projects that fall outside of the scope of US national security interests[188], excessive cost growth for certain projects without clear national security benefits[189], and indirectly supporting Russian rearmament and weapons modernisation[190]. Thus, despite CTR's considerable all-around support, any future expansion of the pro-

185 Department of State, U.S. Government Assistance to and Cooperation with the New Independent States of the Former Soviet Union: FY 1999 Annual Report, January 2000.
186 Ibid.
187 U.S. GAO, Weapons of Mass Destruction: DOD Reporting on Cooperative Threat Reduction Assistance Can Be Improved, September 29, 1995.
188 Prohibition on Use of Funds for Specified Purposes, op. cit.
189 U.S. GAO, Weapons of Mass Destruction: Effort to Reduce Russian Arsenals May Cost More, Achieve Less Than Planned, op. cit.
190 Rich Kelly, The Nunn-Lugar Act: A Wasteful and Dangerous Illusion, Foreign Policy Briefing #39, The Cato Institute, March 18, 1999.

gram's scope requires careful justification by supporters in the Administration and the Congress in light of the above and related criticisms. The Bush Administration have stated that they will perform a comprehensive review of all American aid programs to Russia that were set up to stop the spread of nuclear weapons[191].

It is against this backdrop of both renewal and criticism that DoD and DoE have undertaken a joint analysis of a Russian request to assist in the safe dismantlement of general purpose submarines (SSN and SSGN). The general purpose submarine assessment analyses the US national security interest in scrapping what would be called attack and cruise missile submarines in the West. Russia and European countries sees in these old and rusting vessels, frequently still with spent nuclear fuel on board, primarily a high environmental risk. At present, the approach to the SSN issue that enjoys most political support is that the United States should support the dismantlement of vessels capable of carrying cruise missiles (about 35) based on a national security interest, while leaving the remaining vessels (around 110) to Russia or its environmentally more concerned European neighbours[192].

Steps in the direction of SSNs dismantlement were taken by the US when President Bill Clinton signed the law entitled the "Cross-Border Cooperation and Environmen tal Safety in Northern Europe Act of 2000." The bill was authored by Sam Gejdenson (D-CT), Senior Democrat on the House International Relations Committee. The legislation passed the House in May and the Senate in July 2000, and seeks to strengthen co-operation in the Baltic area and to combat the environmental and security threats posed by laid up nuclear submarines in Murmansk and Arkhangelsk counties. The main objective of the bill is to secure Russian general purpose nuclear submarines[193].

Whether US funding for general purpose submarine dismantlement is approved or not, CTR is already building the necessary infrastructure for Russia to utilise in this effort at a later time. CTR has signed a contract with the shipyards at Zvezdochka and Zvezda for the construction of onshore defueling facilities which, while not essential to SSBN dismantlement, will be helpful in defueling the large number of SSNs to be dismantled[194].

5.8 The European Union and the Lepse project

From 1962 until 1981, Lepse was used as a service ship at the nuclear icebreaker base Atomflot (See chapter 2.4.5). Today, 639 spent fuel assemblies are stored on board the Lepse under highly unsatisfactory conditions. The fuel has become partially jammed in the holding tubes and is thus extremely difficult to remove.

Experts generally agree that the spent nuclear fuel aboard Lepse should be removed from the vessel and properly disposed of. In addition, the vessel itself should be dismantled to allow processing and disposal of radioactive contaminated parts.

Bellona has been discussing the Lepse-project with the Murmansk Shipping Company since 1992. At first it was important to ascertain the overall condition of the vessel and to find out just exactly what was being stored on board. Different solutions were discussed with MSCo. Russian calculations had shown that without access to remote control equipment, the work to remove the spent nuclear fuel would subject 5,000 workers to the maximum permitted doses of radiation. Since this equipment was too expensive for MSCo, the company presented an alternative option of towing the vessel to Novaya Zemlya for deposing it.

As a counter to these proposals, in the fall of 1994 Bellona presented an alternative approach whereby the spent fuel from the Lepse would be removed with the help of remote control technology. This solution would engender a significant reduction in the radiation doses to which workers would be exposed, but it would also be more costly. Indeed, in view of the greater cost, MSCo's response to the plan was sceptical.

In the autumn of 1994, following an environmental conference organised by Bellona and MSCo, an expert panel was formed by the European Union (EU), consisting of representatives from EU's TACIS-programme, DG XI and Norway. Upon the recommendation of the EU expert group, 18.5 million USD were appropriated for a technical solution. The technical feasibility study was financed by the TACIS programme.

The objective of the feasibility study was to investigate how spent nuclear fuel could be safely removed from Lepse and, once removed, how to manage it properly. Bids were invited for the feasibility study from the European nuclear industry. The British AEA Technology and French SGN won the tender. An international advisory group consisting of government representatives from Norway, France, the EU, the United States and Russia was established to monitor the work on the Lepse project.

For the time being, the scope of the international Lepse project consists only of removing the assemblies stored in the ship's storage tanks. No formal agreement could be reached for removing the most damaged fuel, which lies in pieces in "caissons", special storage containers for fuel that is longer than standard fuel. Nor is it clear what will happen to the spent nuclear fuel once it has been extracted from the Lepse. Lastly, there is no plan as to how the Lepse herself is to be dismantled and treated.

The project has been stalled in the lack of a tax exemption and liability agreement from Russia. In 2000 the law on tax-exemption for technical aid was adopted. In addition, the Russian side informed their western partners in 1998 that the Lepse project must fit Russian specifications. The EU, Sweden and Norway have agreed to fund the preparation of regulatory procedures for Lepse's decommissioning by the Russian nuclear regulator GAN.

Due to the stalling of the Lepse project, Bellona Foundation have financed the Lepse Village project, which will reduce the radiation doses to the crew and workers on Lepse with 50 %. The Lepse Village will allow the workers to limit their time onboard Lepse, and will also provide the Lepse crew an alternative place to live onshore. When the Lepse is emptied of spent nuclear fuel, the Lepse Village can be utilised another places.

191 New York Times, www.nytimes.com, March 29, 2001
192 Communication with Ken Myers, Office of Sen. Richard Lugar, March 2000.
193 Statement by the President of the United States of America, Office of the Press Secretary, August 3, 2000.
194 Capt. Kenneth Trass, Program Manager, SOAE Russia, Bellona IGWG Conference, Washington, March 1-2, 2000.

Chapter 6

Regional storage facilities on Kola

Regional storage facilities on Kola

In view of the serious problems with the storage of radioactive waste and spent nuclear fuel discussed in the previous chapters, measures are needed in order to ameliorate the situation. Matters are particularly pressing with respect to storing spent nuclear fuel, for the existing facilities not only are filled beyond capacity, but they are also in very poor condition. Furthermore, there is an increasing need to upgrade the facilities used for storing radioactive waste.

A first positive move would be the funding and construction of a intermediate storage facility for spent nuclear fuel and radioactive waste on the Kola Peninsula, where the waste keeps accumulating. Construction of a storage facility for spent nuclear fuel on the Kola Peninsula will cost the same as it would at the reprocessing facility in Mayak; however, locating the facilities at Kola as opposed to Mayak

would also have the effect of saving money spent on transportation to a distant intermediate storage facility, thereby reducing the safety risks associated with transportation and eliminating the risks of proliferation that might arise from reprocessing. Since a Kola location would be close to the probable location of any final repository, the Bellona recommendation also significantly reduces the costs and risks associated with transportation from a temporary site to the final repository site later on.

This regional handling facility for radioactive waste and spent nuclear fuel would be constructed in keeping with the criteria presented later in this chapter. These criteria would ensure the selection of the best possible location and would guarantee independent inspection and monitoring of the facilities.

The facilities would also have to fulfil Russian and international requirements for safety and the environment. Hence a group of independent experts should be appointed to ensure that the handling of radioactive waste and spent nuclear fuel is undertaken in accordance with international requirements and recommendations. This would secure both international and local level support for the realisation of the project. It will be very important to include local authorities in shaping the project, not to mention keeping the local population updated, so as to avoid that an unacceptable solution is forced on a resentful population.

Given that the proposed solutions are only temporary in nature, thorough studies of possible permanent solutions to the problem of radioactive waste and spent nuclear fuel should begin as soon as possible. In any event, a repository will be needed for spent nuclear fuel which cannot be reprocessed. This repository would have to comply with international guidelines. While there is some international experience in the design and construction of repositories for radioactive waste, there is still a great need for further development. Through widespread international co-operation, further developments in this field could be made as cost-efficient and time-saving as possible. Russian experts would have much to contribute to this international co-operative effort. In the short term, wide-reaching economic assistance from other countries is needed in order to ensure that radioactive waste and spent nuclear fuel are properly handled and stored. In the longer run, once the economic situation has improved, Russia will progressively have to foot a larger part of the bill.

A study should be conducted of the consequences of continuing reprocessing activities in which particular emphasis is directed towards economics, security policy and the environment. It is entirely possible that such an analysis will indicate that it would be better for both the environment and the Russian economy if all spent nuclear fuel were to be intermediately stored, as it is, for example, in Sweden, Finland and the United States.

A local storage facility would furthermore alleviate Western concerns over inadvertently assisting the Russian nuclear fleet in refuelling its active submarines. Bellona supports modular dry storage facilities to be tailored to accommodate exactly the quantity of nuclear waste to be stored in a certain facility, such as for example, the Lepse storage ship. Thus, the module would be full when a certain project is completed. No additional waste could be placed in the module without the knowledge of the contributors. Meanwhile, due to the modular character of the storage facilities, they could be expanded as funding is made available and as new projects are identified.

There would be a need to clean up the existing storage sites after they have been emptied. This would be most urgent for the storage sites in Andreeva Bay and Gremikha, which constitute the two main stoppage points for spent nuclear fuel today. In Gremikha there would be the additional problem of the liquid cooled reactors.

6.1 Transport of spent nuclear fuel to Mayak

Russia has adopted what is known as a "closed cycle" for the removal of spent fuel from submarines equipped with pressurised water reactors and nuclear powered civilian vessels. The fuel is simply sent to the Mayak plant for reprocessing. Russia has eight IAEA certified TK-VG-18 type railroad cars, which can ship about two reactor cores at a time. Russia has 51 stainless steel TUK-18 transport containers designed to fit the TK-VG-18 railway cars. One TUK-18 transport container can hold a maximum of 49 spent fuel assemblies. The total capacity for the 51 TUK-18 containers will be 2,500 assemblies. Hence there is still an insufficient number of containers and storage space both in the Northern Fleet and Mayak since only the Russian Northern Fleet, excluding the Pacific Fleet, has to find a proper storage for around 58,000 fuel assemblies. Murmansk Shipping Company has regularly around 5,000 spent nuclear fuel assemblies onboard nuclear service ships. More than 1/3 of the spent fuel in the Northern Fleet and Murmansk Shipping Company cannot be reprocessed at Mayak and must be dealt with in other specific ways.[195]

Russia has started to manufacture special casks for the storage of submarine spent nuclear fuel, a development that might end shipments to the Mayak plant for reprocessing. This 40-ton metal-concrete cask is a part of the AMEC program, the acronym for Arctic Military Environmental Co-operation. Each cask has a price tag of 150,000 USD and a lifetime of 50 years. Between four to twelve casks are required to defuel one submarine.[196]

6.2 Spent nuclear fuel management

Any treatment facility for spent nuclear fuel should also contain a receiving facility where the spent fuel is removed from the transport containers. Here, any damaged fuel could be repackaged into new containers. A production facility for new containers would also be needed for the damaged spent nuclear fuel assemblies.

The spent nuclear fuel should be stored in a modular dry storage facility, with a passive air cooling system. The storage area for spent nuclear fuel should be located within the immediate vicinity of the receiving facility. Spent nuclear fuel from liquid metal cooled reactors and badly damaged fuel will probably have to be transported and stored in specifically designated containers. These containers should be stored on a specially adapted concrete pad in the vicinity.

A large fraction of the spent nuclear fuel is in poor condition as a result of its having been improperly stored for such a long time. It will be necessary to encapsulate the majority of the spent fuel in new, approved and specially modified containers. In order to carry out the work properly, "hot cells" will be needed (under negative air pressure in order to preclude any possible release of radioactivity to the environment). Waste handling could be accomplished using remotely controlled equipment, thereby shielding the operators from radiation.

The new storage facility must not only have the capacity to accept the amount of spent nuclear fuel that is already in the region, but it must also be dimensioned so as to receive the spent nuclear fuel that will be added in the future as more and more inactive nuclear submarines and icebreakers are decommissioned. As may be seen in Table 1, a minimum of 75,000 spent fuel assemblies from naval reactors must be properly stored over the course of the next decade. As of today, 75% of this spent nuclear fuel may be found in land-based storage, aboard unseaworthy storage ships or inactive naval vessels.

Russian officials have made available only limited technical descriptions of the different storage facilities and storage ships for spent nuclear fuel. Information on the actual condition of the spent nuclear fuel is also lacking. Consequently, any suggestion for establishing a new temporary storage facility must necessarily carry a number of provisos.

195 Murmansk Shipping Co., Radiation Safety Department, 1 March, 1999.
196 Bellona Web, www.bellona.org, 27/10 1999.

6.3 Radioactive waste storage

There is great need for a comprehensive plan of action with respect to the handling of radioactive waste in the Murmansk and Arkhangelsk region. A regional treatment facility/temporary storage for solid radioactive waste will be an important element. This facility should be placed close to the spent nuclear fuel facility. In addition to this temporary solution, the basis for a permanent repository must also be established.

The regional handling facility for radioactive waste will consist of several parts. First of all, the waste that arrives at the facility must be sorted according to type and origin. In all probability, some of the radioactive waste will have to be repackaged into approved containers. Based on experience from the United States, for example, much of the oldest waste will not have been particularly well sorted as compared to current international practice.[198] The identification, classification, and sorting of the waste will therefore be

	In land-based storage and on storage ships	Aboard inactive vessels	Minimum increase by 2010[197]	Total
Northern Fleet	27,500	30,500	17,000	75,000
MSCO	5,000	-	2,200	7,200
Total	**32,500**	**30,500**	**19,200**	**82,200**

Table1.
Overview of the number of sp nuclear fuel assemblies on the Kola Peninsula and in Severodvinsk, today and 10 yea into the future.

an important first link in the facility. This part of the facility will consist of equipment to aid in identifying the waste, such as gamma detectors and x-ray equipment.

Because a high volume of waste must be repackaged, a large number of containers will be needed. Ideally, these containers should be built in close proximity to the treatment facility. These containers will have to satisfy international standards for the storing of radioactive waste. Some of the containers should be constructed in such a way that they can be used for the safe transportation of radioactive waste from the various storage facilities. To reduce the

number of containers needed, a so called compactor should be installed. This can reduce the volume of the waste with a factor up to 20.

Until a permanent repository for radioactive waste can be constructed, the existing waste must be properly stored in the interim. This will require that as the containers are

197 Based on the assumption that spent fuel is removed from those vessels in operation today, 37, including three nuclear powered surface vessels, at the Northern Fleet and seven at MSCOo.
198 Fact Sheet, Hanford.

stored, they are protected from any outward stresses or strains. This could be accomplished in either warehouses or underground facilities. Enlarging the storage area should remain an option, in case the establishment of a permanent repository is delayed until far into the future.

With respect to more permanent solutions for storing low and medium level radioactive waste, there are several approaches. In Sweden, for example, large underground facilities have been built 50 m beneath the Baltic Sea, where all low and medium level waste is stored. The repository has a capacity of 60,000 m^3, but may be enlarged to twice that size. A repository such as this one must be secure from leakage for 500 to 1,000 years after it is sealed.

With regards to high level solid waste and transuranic waste, a storage facility should be constructed with sufficient safety criteria. The criteria for the high level waste storage would be more secure than those for the facility for the low and medium level waste. In addition, a permanent repository for this waste category would require much more security, as the activity level in this waste would constitute a threat to mankind and the environment for the next hundredthousand years. At present , the best solution is to build an underground repository at a depth of 500-1,000 m below the surface in stable geological formations.

6.4 Criteria for storage of spent nuclear fuel

There is a great deal of uncertainty about the technical conditions of the spent nuclear fuel. However, regardless of the technical condition, Bellona recommends the following basic criteria that should serve as guidelines for establishing a new temporary storage facility at the Kola Peninsula:

Civilian monitoring

One of the main obstacles that has hampered the development of international projects for securing naval waste has been the lack of civilian and independent monitoring. In view of this concern, the new storage facility should be established outside the military naval bases or other closed military areas.

The future handling of spent nuclear fuel is not a natural area of jurisdiction for the Navy. Civilian Russian authorities (such as the local government and GAN) and international agencies such as IAEA should have full inspection rights, both during the construction of the facility and at any later point during operations. Furthermore, donor countries have need of an independent controlling body which can guarantee that the money is spent in a proper way.

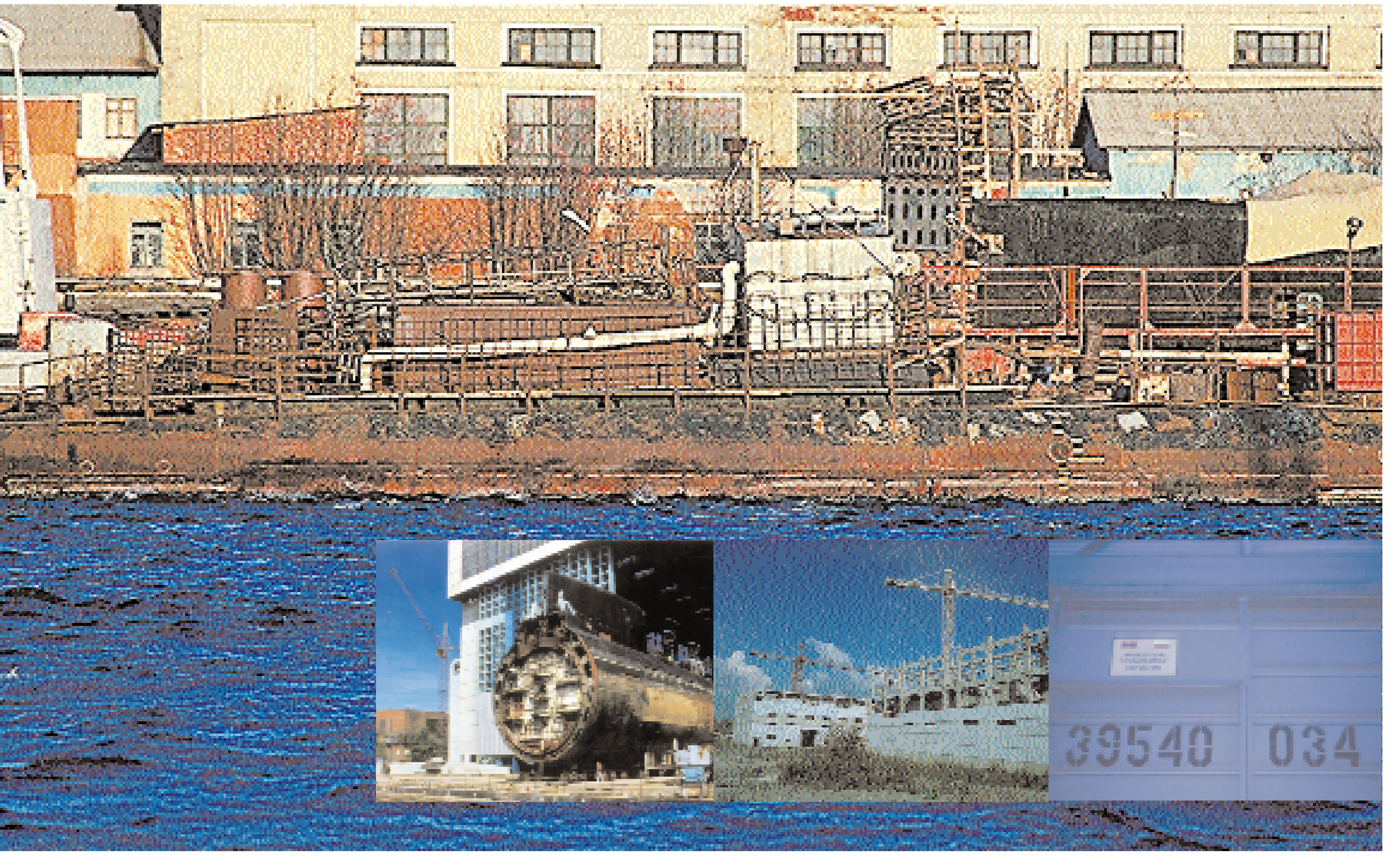
Security

Every stage in the operation of the facility should comply with Russian and international safety requirements. In practice, this means, for instance, that the Russian civilian nuclear authority, GAN, can require the operator(s) to follow set rules, or as a last resort, that these bodies have the authority to veto further operation of the facility.

Both environmental safety aspects and security against terrorism must form the backbone of any storage facility project. It is essential that spent nuclear fuel is secured against theft to minimise the risk of proliferation.

Time perspective

The storage facility should provide safe storage for a defined period of time. This length of time should be long enough to permit the development and construction of a



final repository for the waste, or else to find alternative solutions. On the other hand, the operational life span should not be too long, since this could make the construction more expensive.
Based on these criteria, the storage facility should be constructed with a maximum operational life of 50 years. The technical construction of the facility should be such that the spent fuel may be removed and transferred relatively easily at a later date.

Storage method

The method of storage of spent nuclear fuel in water pools, so called wet storage, has been used for several decades by the nuclear industry. The experience with this method of storage has been problematic due to problems of corrosion of the stored fuel. A wet storage requires more monitoring and maintainance. The international inclination today is to move away from storing spent nuclear fuel in wet storage to dry storage.
In view of the problems associated with the wet storage of spent nuclear fuel, the new storage facility on Kola should be constructed as a dry storage with passive air cooling. This would both minimise the risk of corrosion problems and reduce running expenses.

Utilisation of existing infrastructure

The storage facility should be built at a location whereby the existing infrastructure can be utilised. Such infrastructure might include piers, roads, access to the railroad and cranes with enough lifting capacity. It would also be good if local labour forces could be used. The cost of establishing the necessary infrastructure at the new location could turn out to be far more expensive than the actual storage facility itself.
There is also the question as tohow much of the existing infrastructure could be utilised without extensive rebuilding. The available information about the technical condition for the naval installations indicates a huge need for rebuilding and modernisation.

Construction in stages

Given the pressing nuclear fuel situation in the region, the facility should be built in stages to bring the individual parts into operation as soon as possible. It would also be possible to address the most pressing problems first, and then at a latter stage, solve the smaller and not so pressing problems.
Another benefit in building the facility in stages would be that it would be easier to ensurethat the spent nuclear fuel coming in to stored originates from retired submarines and not vessels in active service.

Legal agreements

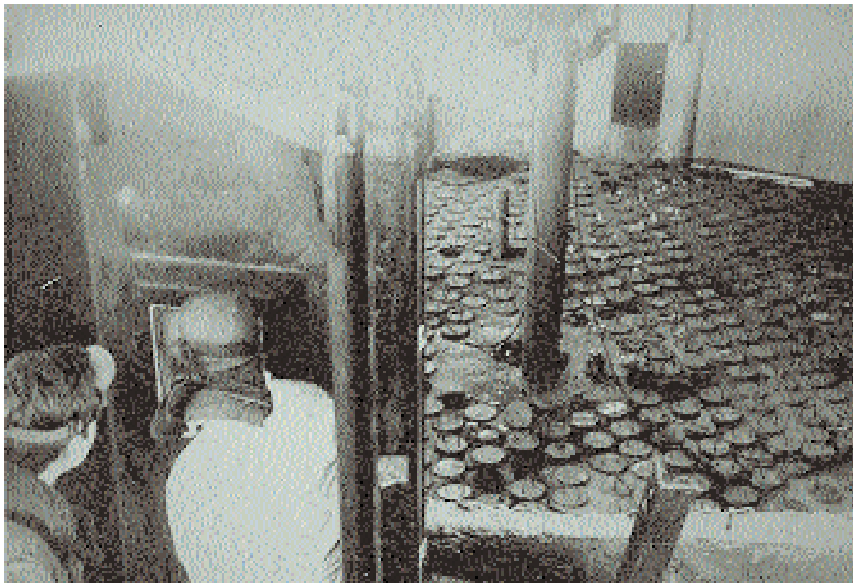
Russia must make legal agreements with the donor countries covering issues such as tax exemption and nuclear liability. The present situation, where each donor country has to sign separate agreements with Russia, is not satisfactory. Bellona fully supports the international efforts being made to create an multinational agreement to cover these issues.. Russia must adhere to the international practice that each country fully accepts responsibility for nuclear accidents in their own country. All foreign assistance and technical equipment must be exempt from taxes and import duties.

Active submarines

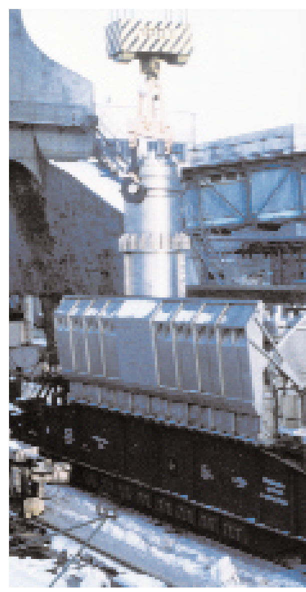
The temporary storage facility financed by other countries may only be used for the storage of spent fuel from decommissioned submarines. Under no circumstances must it contribute to sustaining the operation of active Russian military nuclear submarines. Any storage for the fuel from active submarines must be paid for by Russia.

6.4.1 Location of the storage facilities

The debate over where to place the temporary regional storage facility will be important in the near future. Many



parties will participate in the discussion, from local residents to Minatom. As it is today, radioactive waste and spent nuclear fuel fall under the jurisdiction of various authorities, with different departments in charge of different types of waste.
In order to simplify the discussion, it is important to establish a number of criteria for selecting the location of the future storage facility. The most important criteria are:



Transportation requirements

Today, spent nuclear fuel is stored at numerous locations, from Zapadnaya Litsa in the west to Severodvinsk in the east. To minimise the need for transport an analysis of the transport requirements for the different potential locations needs to be performed. A reduction in transportation will bring benefits, both in terms of economy and ecology. From a safety point of view, it is important that the spent fuel be moved as little as possible to minimise the risk of accidents.
The method of transportation should also be analysed. Until the present, transport of spent fuel at Kola has been accomplished primarily by ship and train. Some locations might have special requirements with respect to issues of transportation,such as, for example, Gremikha where spent nuclear fuel and radioactive waste can only be performed by ship. Other locations also lack the option of transport by rail.

Distance from civilian population

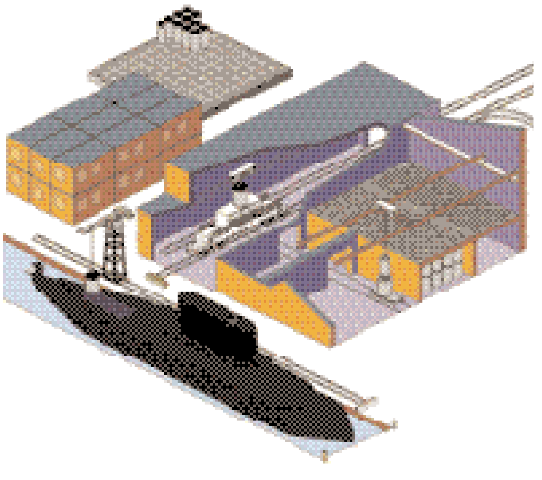
In the event of an accident resulting in releases of radioactivity, the proximity to the nearest population would be one major part in determining the consequences. From a safety perspective, it is crucial that the storage facility is not built near densely inhabited areas such as Murmansk, a city of 360,000 inhabitants.

Size

Both the storage facility and the auxiliary technical support will require considerable area. In calculating the capacity for the storage, future decommissioned submarines should also be taken into consideration. Before selecting a location, enough information about the total waste amount must be available. If such information is not available a location should be selected whereby expansion of the facility is possible.

Technical expertise

The operation of the storage facility will require a great deal of specialised expertise. Particularly operations such as re-packing damaged spent fuel will require special attention. In view of this, it would be to great advantage if the storage facility were located within range of already existing technical expertise in the handling of spent fuel and radioactive waste.



6.4.2 Possible locations

There are numerous sites on the Kola Peninsula that might be suitable as a prospective location for a temporary storage facility. It is probable that in any future debate over the location of the facility, the "not-in-my-backyard" syndrome will come into play. Consequently, it is important that local authorities and inhabitants be included in discussions over the various alternatives. Two proposed locations are presented below, but there could of course be other alternatives. One such alternative could be Nerpichya, but this site is a military area and the railroad to Nerpichya needs to be upgraded.

Atomflot[199]

Spent nuclear fuel is also being stored on board the two operational service ships Lotta and Imandra just north of Murmansk at the Murmansk Shipping Company's nuclear icebreaker base Atomflot. MSCo is organised as a joint-stock company. The nuclear icebreakers constitute federal property.

A maximum of around 6,500 spent nuclear fuel assemblies can be stored on board Lotta and Imandra. A further 639 spent fuel assemblies are stored aboard Lepse. In 1995, at least 744 m^3 of solid waste with a radioactivity of at least 730,000 TBq and 446.5 m^3 of liquid radioactive waste were stored at Atomflot. Of the available storage capacity for liquid radioactive waste, about 30% has been filled up, as is the case with a treatment facility for liquid waste with an annual capacity of 1,200 m^3. In addition, 75 tons of ion exchange resin with a radioactivity of 740 TBq were also stored at Atomflot in 1995. This is just over 70% of the storage capacity. The annual generation of such waste is about 2-3 tons,[200] and the facility was filled up over the course of 1998.

There is still no land-based storage facility for spent nuclear fuel at Atomflot, even though construction on a planned storage building at the base has begun.

A concrete pad for the storage of the new 80-ton casks is under construction at Atomflot. The pad would be capable of holding a maximum of 50 casks. The casks will be primarily used to secure the spent fuel stored today onboard service vessels such as Lotta and Lepse, and can also take non-standard size cylinders in order to store damaged fuel from the service ship Lepse. The cost of an 80-ton cask is estimated to be 320,000 USD. Opposition to this project takes the form of local resistance in Murmansk where the Mayor has expressed strong opposition to any long-term interim spent fuel storage within the city borders.

Nerpa[201]

The naval shipyard Nerpa lies innermost at Olenya Bay, a few kilometres west of Polyarny. At this time, Nerpa falls under the jurisdiction of the Department of the Economy and thus lies beyond the authority of the Northern Fleet. The naval yard's main task has been repair and maintenance work on second generation nuclear submarines, although earlier on, the yard was also responsible for the removal of control rods and preparing reactors for the loading of new nuclear fuel. Nowadays, the yard is utilised almost exclusively for dismantling second generation submarines.

A new land-based dry dock utilising special equipment for dismantling submarines is now under construction at Nerpa naval yard. This dock is being supplied with equipment from the American company Hughes Aircraft Systems International, including a large plasma torch for cutting tempered steel. The dock should have been completed in 1996, but has been delayed several years.

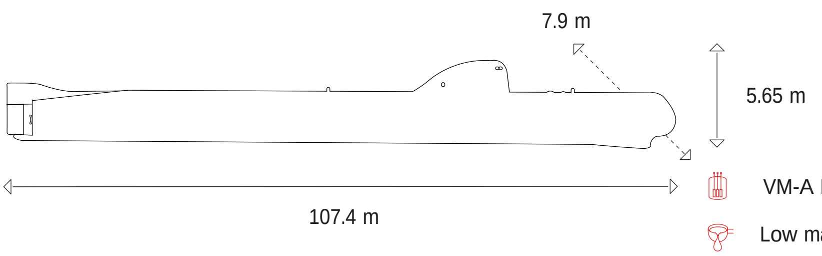
At this time, Nerpa probably has the best-equipped infrastructure within the region for handling spent nuclear fuel and solid radioactive waste. There is a facility to remove spent fuel assemblies from decommissioned nuclear submarines as well as a storage facility for solid radioactive waste, but this has been filled to capacity.

CTR also gives financial support to the decommissioning work underway at the Nerpa shipyard at Kola. So far, it has not yet been finally decided how many casks are to be placed in Severodvinsk and how many are to be stored at

199 T. Nilsen & N. Bøhmer, Sources of radioactive contamination in Murmansk and Arkhangelsk counties, 1994.
200 Ibid.
201 Ibid.

the Nerpa shipyard at Kola. Discussions have been underway regarding the need for a storage pad at Nerpa, but this seems unlikely in the event that the Polyarny shipyard gets one. Polyarny is in the neighbouring bay to Nerpa.

At the same time, Nerpa is considered to be one of the most suitable locations for the new modular dry storage, or the so-called Federal Environmental Spent Fuel Store. Nerpa has much of the needed infrastructure, such as a good harbour and equipment for removing spent nuclear fuel from submarine reactors and service vessels. Finally, and, perhaps most importantly, Nerpa has many employees with knowledge of nuclear safety and experience in handling spent nuclear fuel.



VM-A PWR

Low magnetic steel

2x70 MWt (2x17,500 hp)

3,065/4,750 tons

9

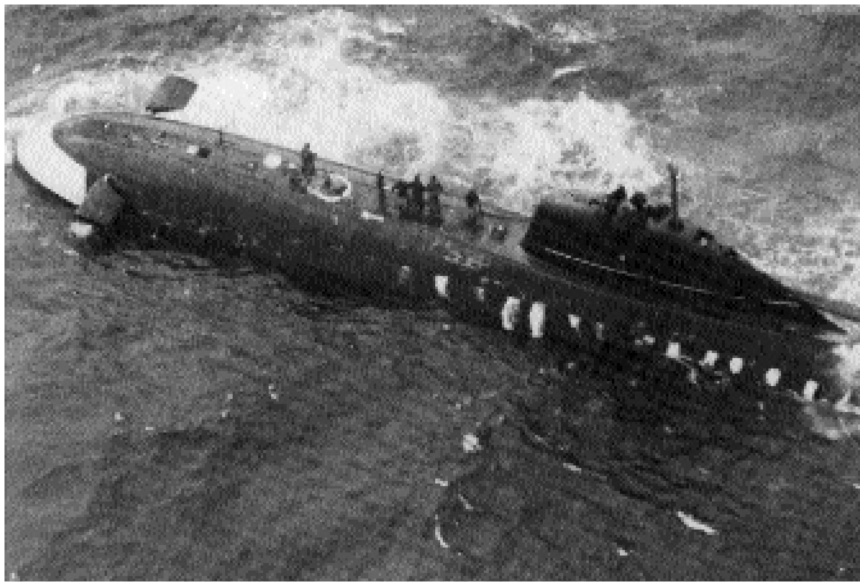
Project 627, 627A (Kit) -November Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs
K-3 (N254)	Sevmash 24/09 1955 09/08 1957	17/01 1959 1988	1963-65: Overhaul repairs. Reactor compartment replaced 1970-71: Repairs 1977-81: Overhaul repairs
K-5 (N260)	Sevmash 13/08 1956 01/09 1958	27/12 1959 1990	1960-62: Repairs and upgrade 1965-68: Repairs. Reactor compartment replaced 1971-73: Repairs 1979-80: Repairs
K-8 (N261)	Sevmash 9/09 1957 31/05 1959	31/12 1959 sank in 1970	No data
K-52 (N283)	Sevmash 15/10 1959 28/08 1960	10/12 1960 1987	1962: Emergency Repairs 1965 –67: Repairs 1969 -72: Overhaul repairs
K-21 (N284)	Sevmash 02/04 1960 18/06 1961	31/10 1961 1991	1973-75: Repairs 1975: Refuelling 1983-85: Overhaul repairs 1963-64: Repairs 1964-68: Reactor compartment replaced
K-11 (N285)	Sevmash 31/10 1960 1/09 1961	30/12 1961 1990	1971-74: Overhaul repairs and upgrade 1982: Repairs 1967-68: Repairs and refuelling
K-181 (N278)	Sevmash 15/11 1961 7/09 1962	27/12 1962 1987	1971-74: Repairs 1984-87: Overhaul repairs, stopped until taken out of service
K-159 (N289)	Sevmash 15/08 1962 06/06 1963	9/10 1963 1989	1967-68: Steam generators replaced 1970-72: Repairs and refuelling 1979-80: Repairs 1967-68: Repairs
K-50 (K-60) (N291)	Sevmash 14/02 1963 16/12 1963	17/07 1964 1991	1973-75: Overhaul repairs and refuelling

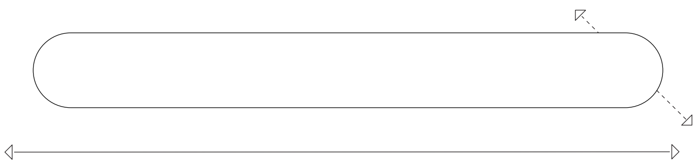
1 The reactor compartment with nuclear fuel was dumped in Abrosimov Bay, the Kara Sea, at the depth of 20m in 1965.
Nuclear fuel was unloaded from the reactors. The reactor compartment was dumped in Abrosimov Bay, the Kara Sea, at the depth of 20m in 1966.
2 Ibid.
3 Kudrik, I. "Decommissioning of nuclear submarines at Polyarny." Bellona Web 19/02 1997.
The reactor compartment (one of the reactors with nuclear fuel) was dumped in Abrosimov Bay, the Kara Sea, at the depth of 20m in 1965.

	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	6	2	8
- defuelled	2	2	4
Dismantled	0	0	0
Sunk	1	0	1
Number	9	4	13

Of the 8 inactive November class submarines in the Northern Fleet, 4 are laid up at Gremikha, 1 in Sayda Bay and 3 at the Shkval shipyard, Polyarny.



Operation intensity **-Covered miles** **-Hours (years)**	**Accidents**	**Present condition**
128,443 nm 14,115 h (1.6)	1958: Break of cooling circuit and radioactive discharges[1] 1962: Fuel elements cladding cracks, radioactive discharges 08/09 1967: Fire, 39 people died Feb 1975: Fire Jan 1981: Fire	Laid-up in Gremikha; Reactors not defuelled; Port-side reactor primary cooling circuit has cracks; Main ballast tanks no. 4, 7, 8, 9, 11, 12, 13 are leaky; Last refuelling believed in 1981.
198,975 nm 33,407 h (3.9)	1965: Fuel elements cladding cracks. Reactor compartment cut out and replaced[6]	Reactors defuelled at Shkval shipyad in Poyarny [3] in November 1996; No data whether the submarine is dismantled.
No data	12/04 1970: Two fires started simultaneously in both the third [2] (central) and eighth compartments. The submarine sank in the Bay of Biscay at a depth of 4,680. 52 people died	No data
236,804 nm 23,666 h (2.7)	1962: Radiation discharge in steam generator 18/06 1969: Flooding of reactor compartment 1962: Radiation discharge in steam generator	Laid-up at Shkval shipyard in Polyarny; Reactors not defuelled; Last refuelling believed in 1972.
190,831 nm 22,932 h (2.6)	No data	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 1, 2, 3, 4, 5, 7 (starboard), 13 (portside) are leaky; Last refuelling believed in 1985.
220,179 nm 29,560 h (3.4)	1964: Fuel elements cladding cracks 12/02 1965: Nuclear accident, uncontrolled chain reaction during refuelling. Reactor compartment cut out and replaced[9]	Laid-up at Shkval shipyard in Polyarny; Reactors not defuelled; Last refuelling believed in 1982.
185,641 nm 20,773 h (2.4)	18/12 1976: Seawater intake when submerged 1979: Malfunction in primary circuit support systems	Partly dismantled and laid-up at Sayda Bay since 1991-92; Reactors defuelled;
212,618 nm 25,364 h (2.9)	02/03 1965: Accident with discharges in steam generators	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 1, 3, 4, 5, 9, 13 (starbord) and 2, 8 (portside) are leaky; Last refuelling believed in 1972.
171,456 nm 24,760 h (2.8)	No data	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 5, 6, 7, 11, 12 are leaky; Last refuelling believed in 1975.



VM-A PWR

Low magnetic steel

2x70 MWt (2x17,500 hp)

4,039/5,000 tons

10

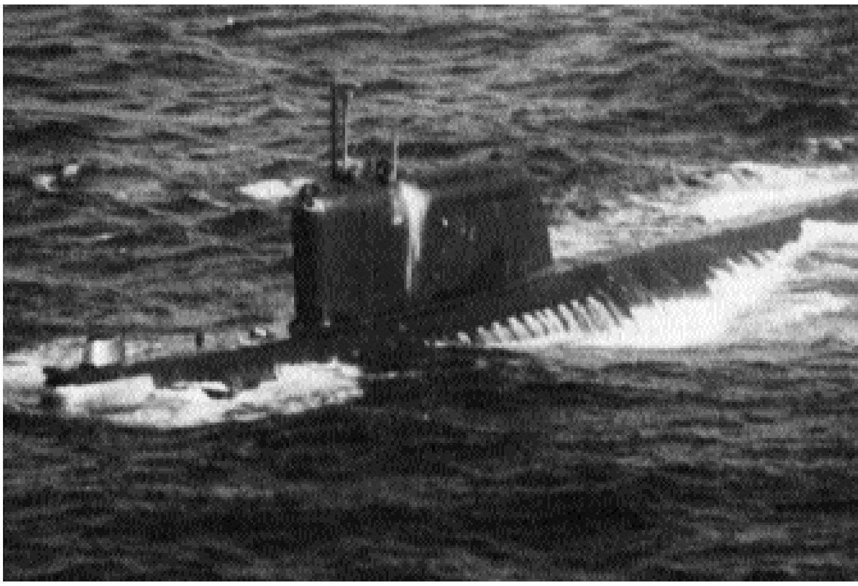
Project 658, 658 M, 658 , 701 -Hotel Class

K-no. **(factory no.)**	**Ship yard** **-Laid down** **-Launched**	**Active service** **-Start date** **-End date**	**Repairs**
K-19 (KS-19) (N901)	Sevmash 17/10 1958 11/10 1959	12/11 1960 1991	1962: Repairs after nuclear accident. Reactor compartment replaced[1] 1967-68: Repairs and upgrade 1972: Repairs after fire accident 1973: Refuelling 1976-79: Overhaul repairs
K-33 (K-54) (N902)	Sevmash 09/02 1959 06/08 1960	24/12 1960 1987	1962-64: Repairs 1965: Refuelled 1968: Refuelled 1969-71: Overhaul repairs and upgrade, refuelling 1976: Refuelled 1978-83: Overhaul repairs
K-40 (N904)	Sevmash 06/12 1959 18/06 1961	27/12 1961 1987	1963: Repairs 1966-67: Overhaul repairs and upgrade 1971-72: Repairs 1975: Refuelled
K-16 (N905)	Sevmash 05/05 1960 31/07 1961	28/12 1961 1988	1963: Repairs 1968-70: Repairs and upgrade 1982-85: Refuelling 1987: Repairs until retirement
K-145 (N906)	Sevmash 21/01 1961 30/05 1962	23/10 1962 1989	1965: Repairs and upgrade 1970-72: Overhaul repairs 1979: Refuelled
K-149 (N907)	Sevmash 12/04 1961 20/07 1962	27/10 1962 1991	1964-65: Overhaul repairs and upgrade 1968-70: Refuelling and repairs 1984-87: Overhaul repairs

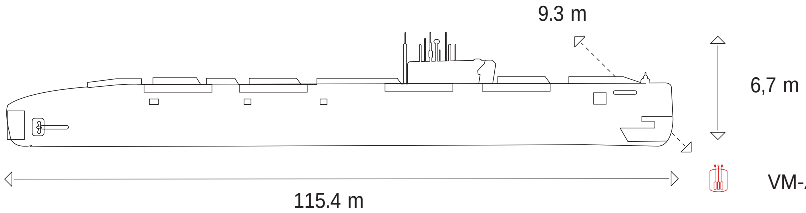
1 The reactor compartment with nuclear fuel was dumped in Abrosimov Bay, the Kara Sea, at the depth of 20m in 1965.
2 Nilsen et. al., Russian Northern Fleet – Sources to Radioactive Contamination, Bellona report No.2:1996.
3 bid.

	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	3	1	4
- defuelled	3	1	4
Dismantled	0	0	0
Number	6	2	8

Of the 6 inactive Hotel class submarines in the northern fleet, 1 is laid up at Olenya Bay, 2 in Sayda Bay,1 in Gremikha, 1 in Shkval shipyard, Polyarny and 1 at the Sevmorput shipyard.



Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
332,396 nm 20,223 h (2.3)	03/07 1961: Nuclear accident. Break down of the primary circuit, radioactivity discharge. 8 people died. 15/11 1969: Collision with American nuclear submarine, the Barents Sea 24/02 1972: Fire, 30 people died 15/11 1978: Fire 17/08 1982: Fire	Laid-up at Shkval shipyard in Polyarny; Reactors not defuelled; Last refuelling believed in 1973.
131,918 nm 19,349 h (2.2)	11/04 1963: Fire 1965: Fuel elements cladding cracks, refuelled 1968: Fuel elements cladding cracks, refuelled	Laid-up in Gremikha; Reactors not defuelled; Portside reactor primary cooling circuit has cracks; Main ballast tanks no. 1, 2, 3, 4, 7 (starb.), 8, 10 (port.) are Last refuelling believed in 1976. Laid-up at Sayda Bay since 1990;
181,877 nm 23,576 h (2.7)	No data	Submarine partly dismantled in 1989; Reactors defuelled.
208,352 nm 25,770 h (2.9)	1966: Cracks in primary circuit. Power limit set to 30% until reactor core is burnt out. 22/05 1986: Torpedo section flooded during loading of torpedoes	Laid-up at Sayda Bay since 1990-92. Reactors defuelled.
83,170 nm 11,796 h (1.3)	No data	Laid-up at Sevmorput shipyard in Murmansk;[2] Reactors defuelled in autumn 1995; Last refuelling believed in 1979.
176,978 nm 20,730 h (2.4)	1975: Portside reactor primary circuit pressure drop 21/12 1977: Fire 03/03 1978: Fire	Laid-up at Olenya Bay; [3] Reactors not defuelled; Last refuelling believed in 1968.



VM-A PWR

Low magnetic steel

2x70 MWt (2x17,500 hp)

4,450/5,760 tons

10

Project 675, 675 M, 675 MU, 675 MKV - Echo-II Class

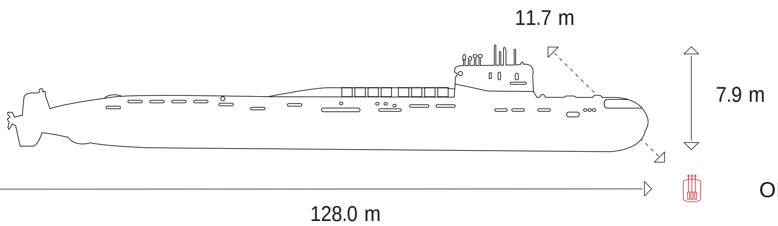
K-no. (factory)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs
K-166 (K-71) (N530)	Sevmash 30/05 1961 06/09 1962	31/10 1963 1989	1967-68: Repairs 1969: Refuelled 1976-81: Overhaul repairs, put on reserve until 1983
K-170 (K-86, KS-86) (N532)	Sevmash 16/05 1962 04/08 1963	26/12 1963 1991	1966-67: Repairs 1973-1980: Repairs and upgrade
K-47 (B-47) (N534)	Sevmash 07/08 1962 10/02 1964	31/08 1964 1994-95	1970-72: Repairs 1976: Refuelled 1984-90: Overhaul repairs and refuelling
K-172 (K-192) (N533)	Sevmash 08/08 1962 25/12 1963	30/07 1964 1990	1968-71: Repairs, steam generator replaced 1974: Refuelled 1981-85: Overhaul repairs
K-1 (N535)	Sevmash 11/01 1963 30/04 1964	30/09 1964 1992	1987: Refuelled
K-28 (K-428) (N536)	Sevmash 26/04 1963 30/06 1964	16/12 1964 1990	1968-70: Repairs and refuelling 1977: Refuelled 1981-85: Overhaul repairs and upgrade 1968-77: Repairs and upgrade
K-74 (N537)	Sevmash 23/07 1963 30/09 1964	30/07 1964 1992	1970-73: Overhaul repairs 1975: Refuelled 1982-83: Repairs
K-22 (B-22) (N538)	Sevmash 14/10 1963 29/11 1964	07/08 1965 1994	1970-73: Overhaul repairs 1975: Refuelled 1985-90: Overhaul repairs and upgrade, refuelling
K-35 (N539)	Sevmash 06/01 1964 27/01 1965	30/06 1965 1993	1969-73: Overhaul repairs 1981: Refuelled 1984-87: Overhaul repairs and upgrade
K-90 (K-111) (N540)	Sevmash 29/02 1964 17/04 1965	25/09 1965 1989	1970-73: Repairs 1978: Refuelled 1986-87: Repairs
K-104 (N531)	Sevmash 11/01 1962 16/06 1963	15/12 1963 1990	1967-69: Repairs 1972: Refuelled 1973: Primary circuit pipe system replaced 1976-81: Overhaul repairs and upgrade
K-125 (N542)	Sevmash 01/09 1964 11/09 1965	18/12 1965 1991	1970-1974: Overhaul repairs and upgrade 1974: Refuelled 1983-87: Repairs and refuelling
K-128 (K-62) (N543)	Sevmash 29/10 1964 30/12 1965	25/08 1966 1990	1977-81: Overhaul repairs and upgrade 1982: Refuelled
K-131 (B-131) (N544)	Sevmash 31/12 1964 06/06 1966	30/09 1966 1994	1972-1976: Overhaul repairs 1984-1989: Overhaul repairs and refuelling
K-135 (K-235) (N545)	Sevmash 27/02 1965 27/07 1966	25/11 1966 1988	1974-78: Overhaul repairs and refuelling 1984-85: Repairs of malfunction in starboard reactor

1 Maritime Nuclear Installations Inspection of the Russian Nuclear Regulatory (GAN), Murmansk, March 2001.

	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	12	10	22
- defuelled	2	4	6
Dismantled	1	0	1
Number	15	14	29

Of the 15 inactive Echo-II class submarines in the Northern Fleet, 11 are laid up at Vidyaevo, 3 in Sayda Bay and 1 at the Sevmorput shipyard.

Operation intensity -Covered miles -Hours (years)	**Accidents**	**Present condition**
101,947 nm 12,746 h (1.5)	1969: Fuel elements cladding cracks 10/12 1970: High pressure air tanks explosion	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1969.
175,728 nm ~20,000 h (2.2)	Aug 88: Starboard turbine malfunction	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1973-80.
183,983 nm 22,164 h (2.5)	24/09 1976: Fire, 3 people died 24/09 1984: Third circuit leakage	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling in 1989-90.
295,833 nm 34,597 h (3.9)	March-Apr 1968: Mercury contamination 1975: Primary circuit leakage 1978: Steam generator malfunction 15/06-26/06 1989: Portside reactor primary circuit leakage. Starboard reactor primary circuit leakage and rapture. Starboard reactor meltdown	Reactors defuelled at Shkval shipyard in Polyarny in summer-autumn 2000. [1] Reactor section cut out and towed to Sayda Bay.
317,040 nm 32,562 h (3.7)	20/08 1973: Collided with underwater rock in the Caribbean Sea 08/08 1978: Seawater penetration into reactor system. Both reactors shutdown. Submarine towed to home base	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1977.
189,951 nm 20,698 h (2.4)	No data	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1977.
227,803 nm 47,126 h (5.4)	No data	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1975.
233,108 nm 26,834 h (3.1)	08/08 1976: Water intake 28/08 1977: Collided with American frigate	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1986.
171,646 nm 19,543 h (2.2)	07/12 1975: Explosion in battery section	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1981.
285,357 nm 22,772 (2.6)	1979: Primary circuit leakage	Laid-up at Sayda Bay since 1993; Submarine partly dismantled in 1992; Reactors defuelled.
175,341 nm 18,753 h (2.1)	No data	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling believed in 1972.
251,498 nm 28,584 (3.3)	10/04 1976: Fire	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling in 1985-86.
286,129 nm 26,750 h (3.1)	May 1968: Seawater intake 1989: 70% power limit set for starboard reactor	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling in 1982.
248,038 nm 29,894 h (3.4)	19/06 1972: Collision with another submarine. Serious damages 28/09 1982: Fire. 2 people died 18/06 1984: Fire. 13 people died 1993: Power limit for reactor installation	Laid-up at Sayda Bay; Submarine is partly dismantled; Reactors defuelled.
227,562 nm 27,775 h (3.2)	No data	Laid-up at a base in the Northern Fleet; Reactors not defuelled; Last refuelling in 1977.



OK-700 (VM 2-4type) PWR

Low magnetic steel

2x89.2 MWt (2x26,000 hp)

7.760/11.500 tons

10

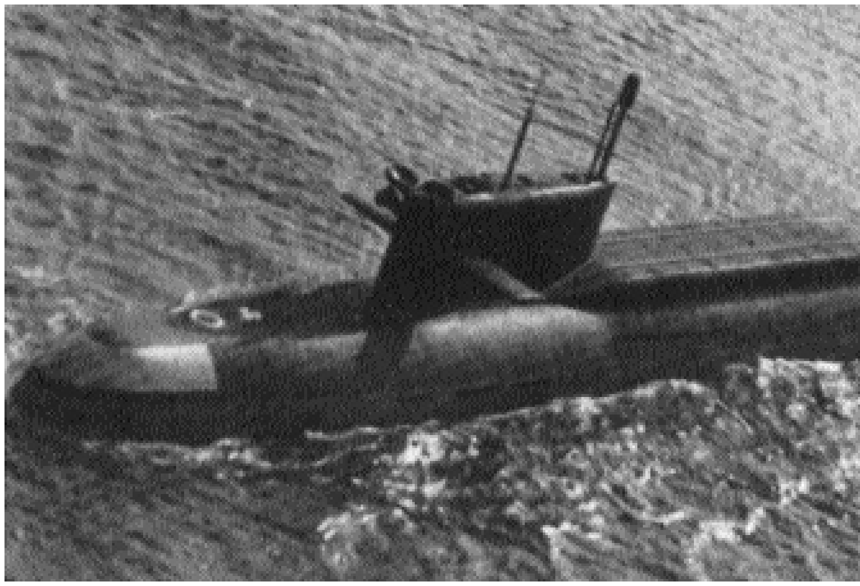
Project 667A (Nalim, Navaga) – Yankee Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs
K-137 (N420)	Sevmash 09/11 1964-28/08 1966	05/11 1967 1980s	No data
K-140 (N421)	Sevmash -/-	30/12 1967 1980s	No data
K-26 (N422)	Sevmash -/-	03/09 1968 1980s	No data
K-32 (N423)	Sevmash -/-	26/10 1968 1980s	No data
K-216 (N424)	Sevmash -/-	27/12 1968 1980s	No data
K-207 (N400)	Sevmash -/-	30/12 1968 1980s	No data
K-210 (N401)	Sevmash -/-	06/08 1969 1980s	No data
K-249 (N402)	Sevmash -/-	27/09 1969 1980s	No data
K-253 (N414)	Sevmash -/-	28/10 1969 1993	No data
K-395 (N415)	Sevmash 08/09 1967-28/07 1969	5/12 1969 in service	No data
K-411 (N430)	Sevmash -/-	31/08 1970 1980s	No data
K-418 (N431)	Sevmash -/-	22/09 1970 1980s	No data
K-420 (N432)	Sevmash -/-	29/10 1970 1994	No data
K-426 (N440)	Sevmash -/-	22/12 1970 1980s	No data
K-403 (N441)	Sevmash -/-	20/08 1971 1980s	No data
K-423 (N442)	Sevmash -/-	13/11 1971 1994	No data
K-245 (N450)	Sevmash -/-	16/12 1971 1980s	No data
K-415 (N451)	Sevmash -/-	30/12 1971 1980s	No data
K-214 (N452)	Sevmash -/-	31/12 1971 1980s	1998-91: Upgrade and repairs at Sevmash shipyard, Project 667AT;
K-219 (N460)	Sevmash -/-	31/12 1971 sank	No data
K-444 (N461)	Sevmash -/-	09/12 1972 1980s	No data
K-241 (N462)	Sevmash -/-	23/12 1972 1980s	No data
K-228 (N470)	Sevmash -/-	31/12 1972 1980s	No data

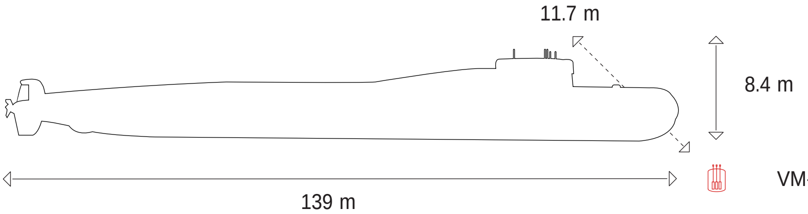
1 Reactor section (one reactor with fuel) was cut out and dumped in the Kara Sea in 1972.
2 Severny Rabochy, 03.02.00.
3 Nilsen et. al., Russian Northern Fleet – Sources to Radioactive Contamination, Bellona report No.2:1996.
4 Ibid.

	Northern Fleet	Pacific Fleet	Total
In service	1	0	1
Inactive			
- with fuel	10	10	20
- defuelled	0	0	0
Dismantled	11	1	12
Sunk	1	0	1
Number	23	11	34

Of the 22 Yankee class submarines in the Northern Fleet, 11(reactor compartments) are laid up in Sayda Bay, 7 in Severodvinsk and 4 (including 3 laid up) in Gadzhievo.



Operation intensity -Covered miles -Hours (years)	**Accidents**	**Present condition**
No data	No data	Dismantled at Zvezdochka shipyard in Severodvinsk. Reactor section towed to Sayda Bay.
No data	27/08 1968: Uncontrolled reactor start-up[2].	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section towed to Sayda Bay.
No data	No data	No data
No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section towed to Sayda Bay in 1999[3].
No data	1984: Leaky steam generator	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section (8-compartment block) towed to Sayda Bay in 1994[4].
No data	No data	No data
No data	1984: Leaky steam generator	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section towed to Sayda Bay in 1995-96[5].
No data	No data	No data
No data	No data	Laid-up in Gadzhievo.
No data	No data	Based in Gadzhievo
No data	No data	No data
No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section towed to Sayda Bay in 1999.
No data	No data	Laid-up in Gadzhievo.
No data	No data	No data
No data	No data	No data
No data	No data	Laid-up in Gadzhievo.
No data	No data	No data
No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section (3-compartment block) towed to Sayda Bay in 1994.
No data	No data	Dismantled at Sevmash shipyard in Severodnisk in 1999.
No data	6/10 1986: Sank in Atlantic Ocean, north of Bermuda Islands, 4 people died	No data
No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section (3-(8)-compartment block) towed to Sayda Bay in 1995.
No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section (3 –compartment block) towed to Sayda Bay.
No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk. Reactor section (3 –compartment block) towed to Sayda Bay in 1995.



VM-4B PWR(OK-700)

Low magnetic steel

2x90 MWt (2x26,000 hp)

8,900/13,700 tons

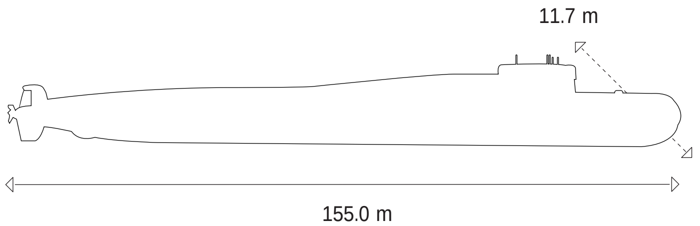
10

	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	2	6	7
- defuelled	0	0	0
Dismantled	7	3	11
Number	9	9	18

Of the 9 inactive Delta-I class submarines in the Northern Fleet, 7 (reactor compartments) are laid up in Sayda Bay and 2 in Severodvinsk.

Project 667B (Murena) – Delta-I Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-279 (N310)	Sevmash 1971 1972	22/12 1972 1993	No data	No data	1984: Collision with iceberg 1984: Leaky steam generator Dec. 1986: Fire	Dismantled at Zvezdochka shipyard in Severodvinsk in 1998. Reactor section towed to Sayda Bay.
K-447 (N311)	Sevmash - -	1973 ~1998	No data	No data	1985: Leaky steam generator	The submarine was in service in 1997. Discussions are being held with CTR to fund dismantlement.
K-450 (N312)	Sevmash - -	1973 ~1994	No data	No data	No data	Dismantled at Nerpa shipyard in 1997. Reactor section towed to Sayda Bay on 21/11 1997.
K-385 (N324)	Sevmash - -	1974 ~1995	No data	No data	No data	Dismantled at Zvezdochka shipyard in Severodvinsk in 1998.
K-457 (N325)	Sevmash - -	1974 ~1996	No data	No data	No data	Laid-up at Severodvinsk, to be dismantled shortly with CTR funds.
K-465 (N326)	Sevmash - -	1974 ~1995	No data	No data	No data	Dismantled at Nerpa shipyard with CTR funds in 1998. Reactor section towed to Sayda Bay on 15/09 1999.
K-460 (N337)	Sevmash - -	1975 ~1998	No data	No data	No data	Dismantled at Nerpa shipyard with CTR funds in 1999. Reactor section towed to Sayda Bay on 15/01 2000.
K-472 (N338)	Sevmash - -	1975 ~1997	No data	No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk with CTR funds. Reactor section (3-compartment block) towed to Sayda Bay in 1999.
K-475 (N339)	Sevmash - -	1975 ~1997	No data	No data	1984: Compartment flooded	Dismantled at Zvezdochka shipyard in Severodnisk with CTR funds. Reactor section (3-compartment block) towed to Sayda Bay in 1999.



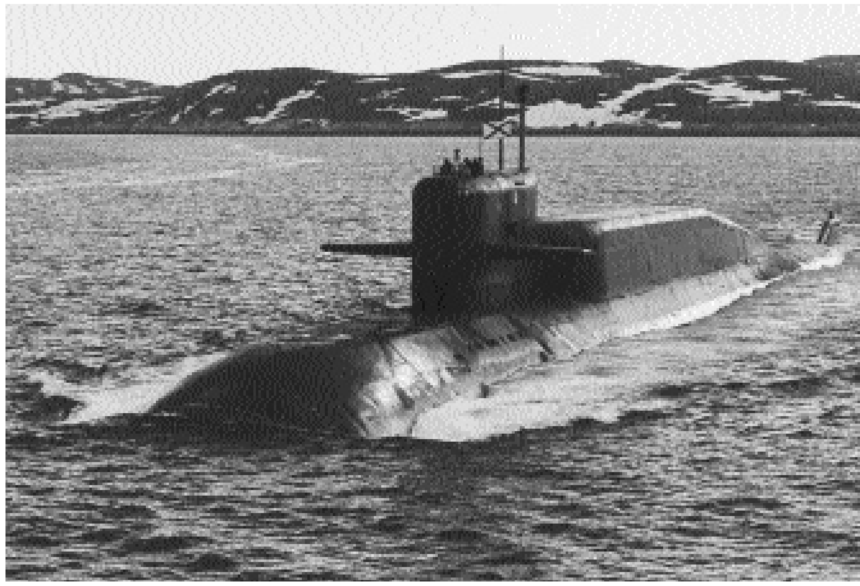
VM-4 PWR (OK-700)

Low magnetic steel

2x90 MWt (2x27.500 hp)

10.500/15.750[1] m3/tonnes

11



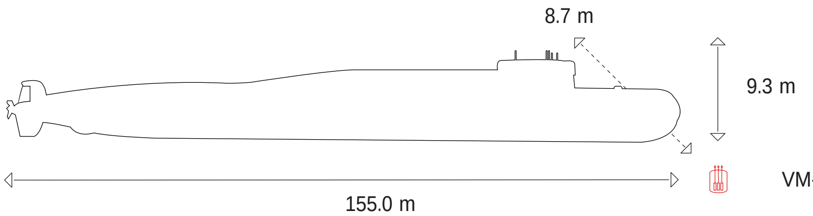
	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	0	0	0
- defuelled	0	0	0
Dismantled	4	0	4
Number	4	0	4

The 4 (reactor compartments) inactive Delta-II class submarines in the Northern Fleet are laid up in Sayda Bay.

Project 667BD (Murena M) – Delta-II Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Ship yard -Laid down -Launched	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-182 (N341)	Sevmash Apr 1973 Jan 1975	30/09 1975 1999	No data	No data	No data	Dismantled at Nerpa shipyard with CTR funds in 2000. Reactor section t be towed to Sayda Bay[2].
K-92 (N342)	Sevmash 1973 1975	17/12 1975 1999	No data	No data	No data	Dismantled at Nerpa shipyard with CTR funds in 2000. Reactor sectio towed to Sayda Bay on 31/08 2000[3].
K-193 (N353)	Sevmash 1974 1975	30/12 1975 ~1996	No data	No data	No data	Dismantled at Zvezdochka shipyard in Severodnisk with CTR funds 1998. Reactor section (3-compartment block) towed to Sayda Bay in 199
K-421 (N354)	Sevmash 1974 1975	30/12 1975 1998	No data	No data	No data	Dismantled at Nerpa shipyard with CTR funds in 1999. Reactor sectio towed to Sayda Bay on 15/01 2000[4].

1 Surface/submerged.
2 Murmansk GAN inspection, 2001.
3 Ibid.
4 Ibid.



VM-4S PWR(OK-700A)

Low magnetic steel

2x90 MWt (2x30,00 hp)

10,600/16,000 tonnes

11

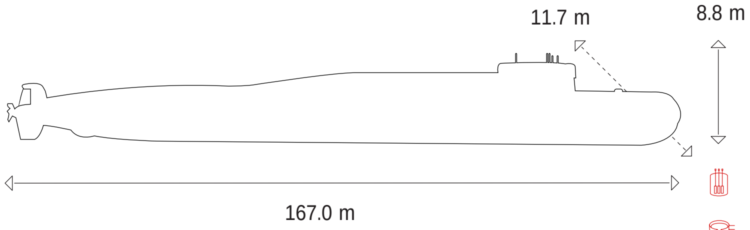
	Northern Fleet	Pacific Fleet	Total
In service[1]	3	6	9
Inactive			
- with fuel	0	0	0
- defuelled	0	3[2]	3
Dismantled	2	0	2
Number	5	9	14

Of the 5 Delta-III class submarines in the Northern Fleet, 3 are based in Gadzhievo and 2 (reactor compartments) in Sayda Bay.

Project 667BDR (Kalmar) – Delta-III Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-441 (N-)	Sevmash 1975 30/12 1975	09/06 1976 1996	No data	No data	No data	Dismantled at Zvezdochka shipyard in Severodvinsk with CTR funds in 1994[4].
K-424 (N-)	Sevmash - -	1977 1996	No data	No data	No data	Dismantled at Zvezdochka shipyard in Severodvinsk with CTR funds in 1999[5].
K-487 (N-)	Sevmash - -	1978 in service	No data	No data	No data	Based in Gadzhievo.
K-44 (N-)	Sevmash - -	1979 in service	No data	No data	No data	Based in Gadzhievo.
K-496 (N-)	Sevmash - -	1979 in service	No data	No data	No data	Based in Gadzhievo.

1 CTR plans to eliminate 2 Delta-III in the Northern Fleet starting in 2002 and until 2005, and 9 Delta-III in the Pacific Fleet stating in 2001 and until 2007.
2 CTR is in progress of dismantling 3 Delta-III in the Pacific Fleet.
3 Surface/submerged.
4 Presentation by CDR Mark A. Baker, CTR project manager, 2000.
5 Ibid.



VM-4SG(OK-700)

Low magnetic steel

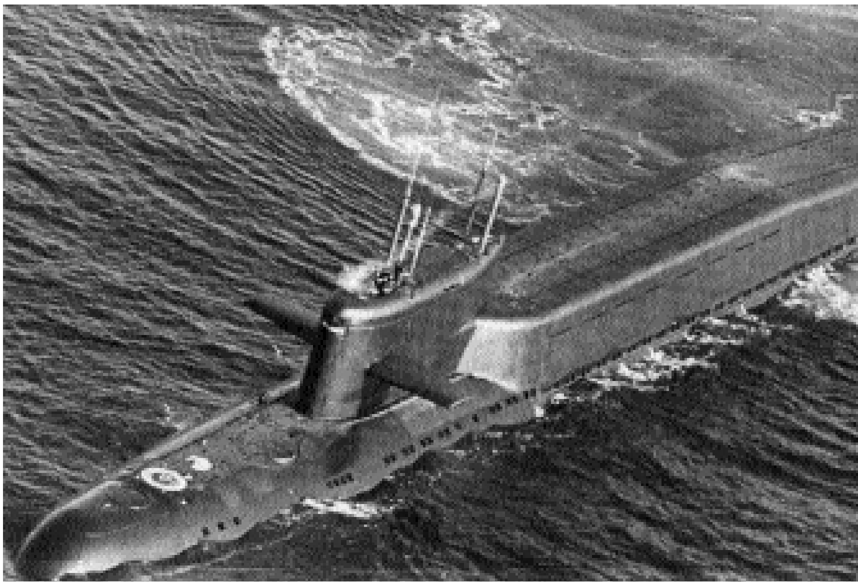
2x90 MWt (2x30.000 hp)

11,740/18,200 tons

10

	Northern Fleet	Pacific Fleet	Total
In service	7[1]	0	7
Inactive		0	
- with fuel	0	0	0
- defuelled	0	0	0
Dismantled	0	0	0
Number	7	0	7

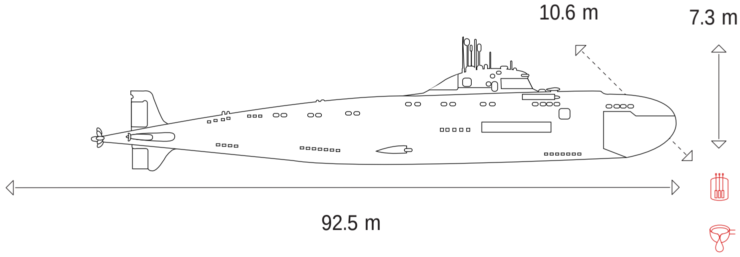
The 7 Delta-IV class submarines in the Northern Fleet are based in Gadzhievo.



Project 667BDRM (Delfin) – Delta-IV Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-51 (Verkhoturye)	Sevmash 23/02 1981 Jan 1975	29/12 1985 in service	No data	No data	No data	Based in Gadzhievo; 1993-99: Overhaul repairs at Zvezdochka shipyard, Severodvinsk[3].
K-84 (Yekaterinburg)	Sevmash Nov 1985 Dec 1985	Feb. 1986 in service	No data	No data	No data	Based in Gadzhievo.
K-64 (N-)	Sevmash Nov 1985 Dec 1986	Feb. 1988 in service	No data	No data	No data	Based in Gadzhievo.
K-114 (Tula)	Sevmash Dec 1986 Sep 1987	Jan. 1989 in service	No data	No data	No data	Based in Gadzhievo.
K-117 (Bryansk)	Sevmash Sep 1987 Sep 1988	Mar. 1990 in service	No data	No data	No data	Based in Gadzhievo.
K-18 (Karelia)	Sevmash Sep 1988 Nov 1989	Sep. 1991 In service	No data	No data	No data	Based in Gadzhievo.
K-407 (Novomoskovsk)	Sevmash Nov 1989 Jan 1991	20/02 1992 in service	No data	No data	No data	Based in Gadzhievo.

1 CTR was notified that one Delta-IV (fabric N381) will become available. Public Affairs Office, The Pentagon, Washington D.C., 2001.
2 Pravda Severa, 03.01.00.



VM-4 PWR (OK-300)

4.250/6.085 tons

2x75 MWt (2x31,000 hp)

Low magnetic steel

7

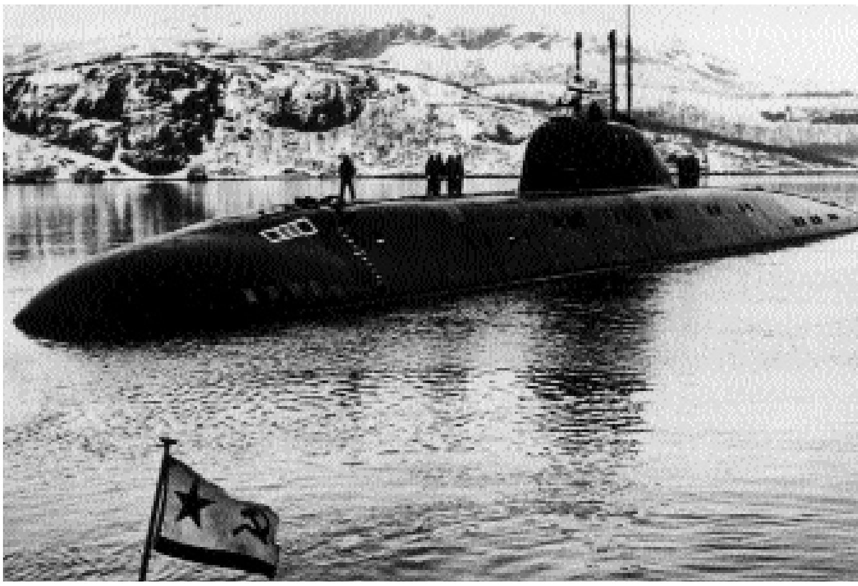
Project 671, 671 V, 671 K (Yersh) - Victor -I Class

K-no. (factory)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs
K-38 (N600)	Admiralty Shipyard 12/04 1963 28/07 1966	05/11 1967 1991	No data
K-69 (N601)	Admiralty Shipyard 31/01 1964 22/09 1967	06/11 1968 1991	No data
K-147 (N602)	Admiralty Shipyard 16/09 1964 17/06 1968	25/12 1968 1996	No data
K-53 (N603)	Admiralty Shipyard 16/12 1964 15/03 1969	30/09 1969 1993	No data
K-306 (N604)	Admiralty Shipyard 20/03 1968 04/06 1969	04/12 1969 1991	No data
K-323 (N605)	Admiralty Shipyard 05/07 1968 15/03 1970	29/10 1970 1993	No data
K-370 (N606)	Admiralty Shipyard 19/06 1969 26/06 1970	04/12 1970 1993	No data
K-367 (N609)	Admiralty Shipyard 14/04 1970 02/07 1971	05/12 1971 1995	No data
K-438 (N608)	Admiralty Shipyard 13/06 1970 23/03 1971	16/09 1971 1995	No data
K-398 (N611)	Admiralty Shipyard 22/04 1971 02/08 1972	15/12 1972 1995	No data
K-462 (N01613)	Admiralty Shipyard 03/07 1972 01/09 1973	30/12 1973 1996	No data
K-481 (N01615)	Admiralty Shipyard 27/09 1973 08/09 1974	27/12 1974 ~1991	No data

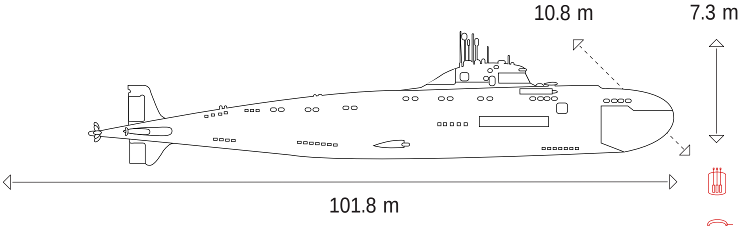
1 Information on submarines laid-up in Gremikha from AS Andreas Aagaard Working Papers, 1999.

	Northern Fleet	Pacific Fleet	Total
In service	0	0	7
Inactive			
- with fuel	11	3	14
- defuelled	0	0	0
Dismantled	1	0	1
Number	12	3	15

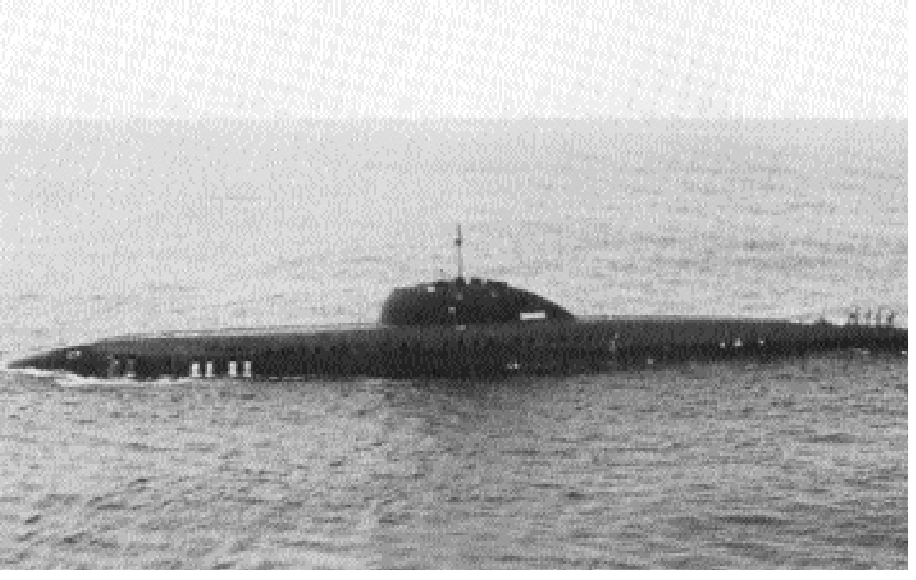
Of the 12 inactive Victor-I class submarines in the Northern Fleet, 9 are laid up at Gremikha, 1(reactor section) in Sayda Bay and 2 have unknown location.



Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
No data	1984: Critical underspace leakage of primary circuit Mar 1985: Fire 1986: Critical underspace leakage of primary circuit	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 1, 5, 6, 9, 11, 12, 13 are leaky[2].
No data	No data	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 5, 7, 10, 12, 13 are leaky.
No data	No data	No data
No data	1984: Collision with Russian surface ship, Bratstvo, in the Mediterranean Sea	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 2, 5, 6, 11, 12, 13 are leaky.
No data	No data	Laid-up in Gremikha; Reactors not defuelled; Starboard reactor primary cooling circuit has cracks; Main ballast tanks no. 5, 6, 7, 12, 13 are leaky.
No data	No data	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 1, 2 (port.); 3, 5, 8 (starb.); 6, 7, 12, 13 are leaky.
No data	No data	Laid-up in Gremikha; Reactors not defuelled; Starboard reactor primary cooling circuit has cracks; Main ballast tanks no. 2, 5, 11, 13 are leaky.
No data	1985: Reactor control rod malfunction	Laid-up in Gremikha; Reactors not defuelled.
No data	No data	Laid-up in Gremikha; Reactors not defuelled.
No data	No data	Laid-up in Gremikha; Port-side reactor primary cooling circuit has cracks; Reactors not defuelled.
No data	1984: Critical underspace leakage of primary circuit 1986: Critical underspace leakage of primary circuit	No data
No data	No data	Submarine decommissioned at Nerpa shipyard in 1995. The reactor compartment was mounted with two floating pontoons and towed to Sayda Bay for storage on 16/08 1995.



VM-4 PWR (OK-300)
Low magnetic steel
2x72 MWt (2x31,500 hp)
4,673/7,190 tons
8



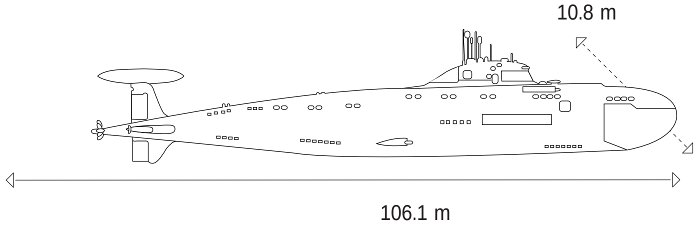
	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	4	0	4
- defuelled	3	0	3
Dismantled	0	0	0
Number	7	0	7

Of the 7 inactive Victor-II class submarines in the Northern Fleet, 3 are laid up at Gremikha, 1in Nerpa and 3 at the Shkval shipyard, Polyarny.

Project 671RT (Semga) - Victor-II Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-387 (N801)	Krasnoe Sormovo shipyard 02/04 1971 02/09 1972	30/12 1972 ~1995	No data	No data	1967: Main condenser breakage (2 persons injured to death)	Laid-up in Gremikha;Reactors not defuelled.
K-371 (N802)	Krasnoe Sormovo shipyard 12/05 1973 30/07 1974	29/12 1974 ~1995	No data	No data	1986: Critical underspace leakage of primary circuit	Reactors defuelled by Imandra service ship autumn 2000. Submarine laid up at Shkval shipyard in Polyarny.
K-495 (N01621)	Admiralty Shipyard 28/09 1974 26/08 1975	30/12 1975 ~1995	No data	No data	No data	Possibly laid-up in Polyarny
K-513 (N01625)	Admiralty Shipyard 22/07 1975 21/08 1976	27/12 1976 1993	No data	No data	No data	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 7, 12, 13 are leaky.
K-467 (N803)	Krasnoe Sormovo shipyard 06/09 1975 12/08 1976	29/12 1976 ~1992	No data	No data	No data	Reactors defuelled by Imandra service ship autumn 1999. Submarine laid up at Nerpa shipyard.
K-488 (N804)	Krasnoe Sormovo shipyard 15/12 1976 08/10 1977	29/10 1978 ~1995	No data	No data	No data	Reactors defuelled by Imandra service ship autumn 2000. Submarine laid up at Shkval shipyard in Polyarny.
K-517 (N01627)	Admiralty Shipyard 23/03 1977 24/08 1978	31/12 1978 ~1993	No data	No data	May 1984: Fire	Laid-up in Gremikha; Reactors not defuelled; Main ballast tanks no. 7, 11, 13 are leaky.

1 K-numbers and fabric-numbers from Typhoon magazine, 4/1997.



VM-4 PWR(OK-300)

Low magnetic steel

2x72 MWt (2x31.000 hp)

6.990/7.250 m3/tonnes????

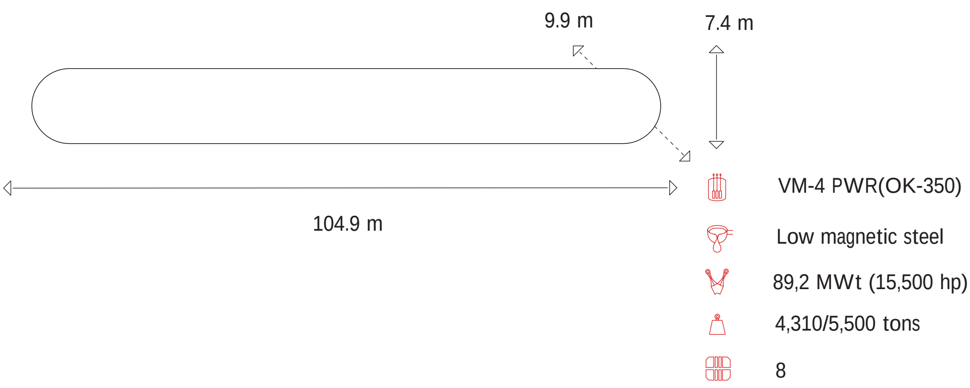
8

	Northern Fleet	Pacific Fleet	Total
In service	8	2	10
Inactive			
- with fuel	8	8	16
- defuelled	0	0	0
Dismantled	0	0	0
Number	16	10	26

The 16 Victor-III class submarines in the Northern Fleet, are at Zapadnaya Litsa (Bolshay Lopatka)-8 laid up -8 in service.

Project 671RTM (Schuka) - Victor-III Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-524 (N01636)	Admiralty Shipyard 07/05 1976 31/07 1977	28/12 1977 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).
K-255 (-)	Komsomolsk-na-Amur 07/11 1979 20/08 1980	26/12 1980 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).
K-324 (-)	Komsomolsk-na-Amur 29/02 1980 07/10 1980	30/12 1980 ~1995	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-502 (N01641)	Admiralty Shipyard 23/07 1979 17/08 1980	31/12 1980 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).
K-254 (N01638)	Admiralty Shipyard 24/09 1977 06/09 1979	18/09 1981 ~1995	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-527 (N01643)	Admiralty Shipyard 28/09 1978 24/07 1981	30/12 1981 ~1995	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-298 (N01645)	Admiralty Shipyard 25/02 1981 14/07 1982	27/12 1982 ~1995	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-218 (-)	Komsomolsk-na-Amur 03/06 1981 24/07 1982	28/12 1982 ~1995	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-358 (N01647)	Admiralty Shipyard 23/07 1982 15/07 1983	29/12 1983 in service	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-299 (N01649)	Admiralty Shipyard 01/07 1983 29/06 1984	22/12 1984 ~1995	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-244 (N01652)	Admiralty Shipyard 25/12 1984 09/07 1985	25/12 1985 ~1995	No data	No data	No data	Laid up in Zapadnaya Litsa (Bolshaya Lopatka).
K-292 (N01655)	Admiralty Shipyard 15/04 1986 29/04 1987	27/11 1987 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).
K-388 (N01657)	Admiralty Shipyard 08/05 1987 03/06 1988	30/11 1988 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).
K-414 (N01695)	Admiralty Shipyard 01/12 1988 31/08 1990	30/12 1990 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).
K-138 (N01659)	Admiralty Shipyard 07/12 1988 05/08 1989	10/05 1990 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).
K-448 (N01696)	Admiralty Shipyard 31/01 1991 17/10 1991	24/09 1992 in service	No data	No data	No data	Based in Zapadnaya Litsa (Bolshaya Lopatka).



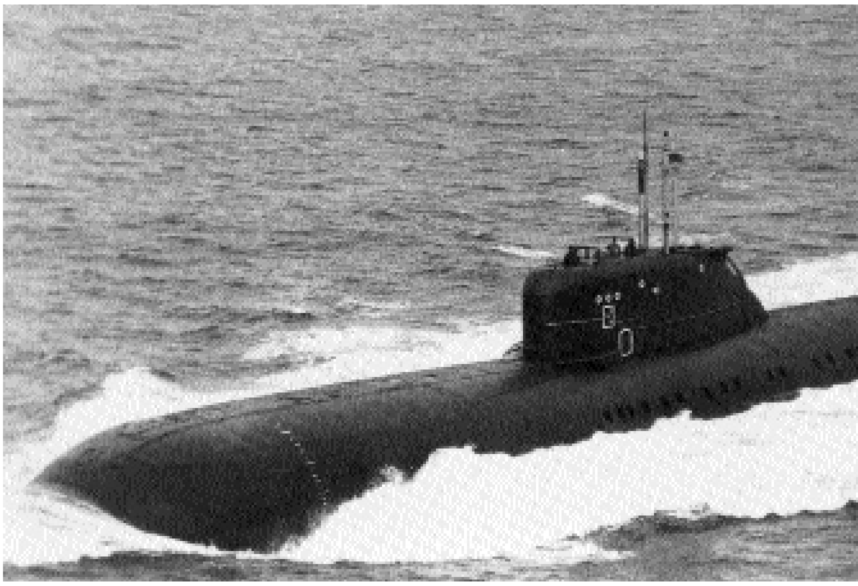
Project 670 (Chaika) Charlie-II class

K-no. (factory no.)	Ship yard -Laid down -Launched	Ship yard -Laid down -Launched	Repairs
K-452 (N901)	Krasnoe Sormovo 30/12 1972 25/07 1973	30/12 1973 1998	1986-92: Overhaul repairs and upgrade 1990: Refuelling
K-458 (N902)	Krasnoe Sormovo 12/02 1974 30/06 1975	29/12 1975 1991	1986-88: Repairs, upgrade and refuelling
K-479 (N903)	Krasnoe Sormovo 01/10 1975 06/05 1977	30/09 1977 1992	1991: Overhaul repairs until taken out of service
K-503 (N904)	Krasnoe Sormovo 07/02 1977 22/09 1978	31/12 1978 1993	1979: Repairs after accident 1984-86: Overhaul repairs and refuelling
K-508 (N905)	Krasnoe Sormovo 10/12 1977 03/10 1979	30/12 1979 1995	1984: Repairs and refuelling 1990-91: Overhaul repairs
K-209 (N911)	Krasnoe Sormovo 20/12 1979 16/09 1980	30/12 1980 1995	1993: Repairs until taken out of service

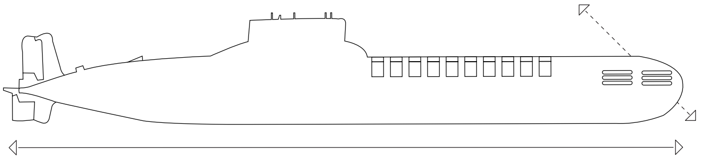
1 Submarines ID-numbers, years of commissioning and data on repairs from Typhoon Magazine, 6/2000.
2 Murmansk GAN inspection, 2001.

	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	5	0	5
- defuelled	0	0	0
Dismantled	1	0	1
Number	6	0	6

Of the 6 inactive Charlie-II class submarines in the Northern Fleet, 5 are laid up at Vidayaevo, and 1 in Sayda Bay.



Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
No data	No data	Laid-up in Ara Bay, Vidyaevo; Last refuelling in 1990.
No data	No data	Laid-up in Ara Bay, Vidyaevo; Last refuelling in 1988.
No data	No data	Dismantled at Nerpa shipyard in 1995-1996; Reactor compartment towed to Sayda Bay on 26/06 1996[3].
No data	March 1979: Fire Jan 1984: Reactor compartment flooded	Laid-up in Ara Bay, Vidyaevo; Last refuelling in 1985-86.
No data	4/08 1995: Collision with surface vessel Apr. 1984: Fire 1984: Leaky steam generator	Laid-up in Ara Bay, Vidyaevo; Last refuelling in 1990-91.
No data	No data	Laid-up in Ura Bay, Vidyaevo; Last refuelling in 1990-91.



OK-650 PWR

28,500/49,800 tons

2x190 MWt (2x100,000 hp)

Low magnetic steel/Titanium

19

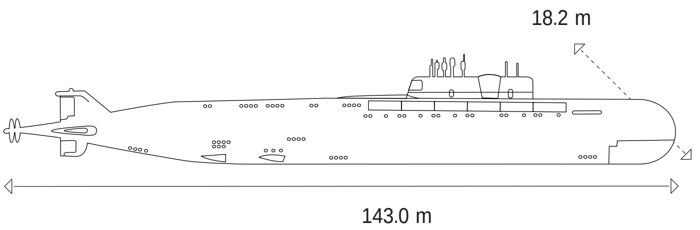
	Northern Fleet	Pacific Fleet	Total
In service	3	0	3
Inactive			
- with fuel	3	0	3
- defuelled	0	0	0
Dismantled	0	0	0
Number	6	0	6

Of the 6 Typhoon class submarines in the Northern Fleet, 3 are at Nerpichia Bay and 2 are laid up in Severodvinsk.

Project 941 (Akula) – Typhoon Class

K-no. (factory no.)	**Ship yard -Laid down -Launched**	**Active service -Start date -End date**	**Repairs**	**Operation intensity -Covered miles -Hours (years)**	**Accidents**	**Present condition**
						The submarine has been under upgrade and repairs at Sevmash shipyard since 1990, was to enter active service in 2001.
TK-208	Sevmash 30/06 1976 23/09 1979	12/12 1981 in service	No data	No data	No data	Under decommissioning with CTR funds at Sevmash shipyard in Severodvinsk since July 1999[3].
TK-202	Sevmash 01/10 1980 26/04 1982	28/12 1983 1996[2]	No data	No data	No data	Laid-up in Nerpichya Bay, Zapadnaya Litsa.
TK-12	Sevmash 27/04 1982 17/12 1983	27/12 1984 1996	No data	No data	No data	Laid-up in Nerpichya Bay, Zapadnaya Litsa.
TK-13	Sevmash 05/01 1984 30/04 1985	30/12 1985 1997	No data	No data	No data	Based in Nerpichya Bay, Zapadnaya Litsa.
TK-17	Sevmash 24/02 1985 Aug 1986	06/11 1987 in service	No data	No data	No data	Based in Nerpichya Bay, Zapadnaya Litsa.
TK-20	Sevmash 06/01 1986 Jul 1988	Sep 1989 In service	No data	No data	No data	

1Tekhnika i Vooruzhenie, May/June 2000.
2 Russian media have published controversial reports regarding the Typhoon class submarine decommissioning. The Russian Navy has never confirmed officially that the decommissioning work is in progress. The reports from Severodvinsk say that the decommissioning work proceeds as planned.



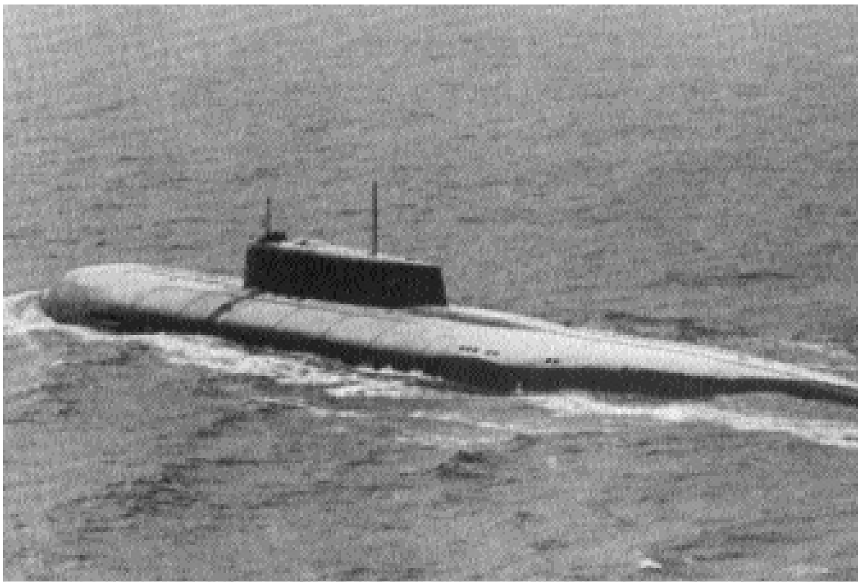
OK-650 PWR

Low magnetic steel

2x190 MWt (98,000 hp)

13,400/17,000 tons

10



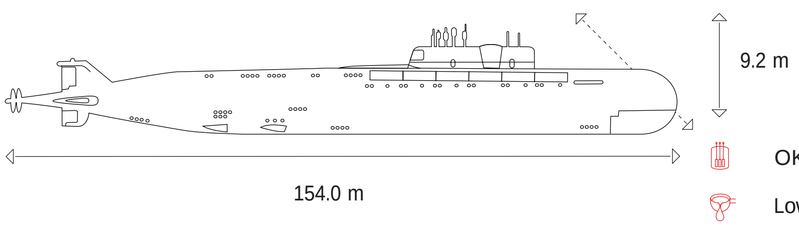
	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	2	0	0
- defuelled	0	0	0
Dismantled	0	0	0
Number	2	0	2

The 2 inactive Oscar-I class submarines in the Northern Fleet, are laid up at Severodvinsk.

Project 949 (Granit) – Oscar-I Class

K-no. (factory no.)	**Ship yard -Laid down -Launched**	**Active service -Start date -End date**	**Repairs**	**Operation intensity -Covered miles -Hours (years)**	**Accidents**	**Present condition**
K-525 (605/Arkhangelsk)	Sevmash 1978 -	30/12 1980 2000	No data	No data	No data	In Severodvinsk, awaits dismantlement at Sevmash shipyard[2].
K-206 (606/Murmansk)	Sevmash - -	1981 2000	No data	No data	No data	In Severodvinsk, awaits dismantlement at Sevmash shipyard[3].

1 Severny Rabochy, 27/04 2000.
2 Ibid.



OK-650B PWR

Low magnetic steel

2x190 MWt (98,000 hp)

14,700/23,860 tons

11

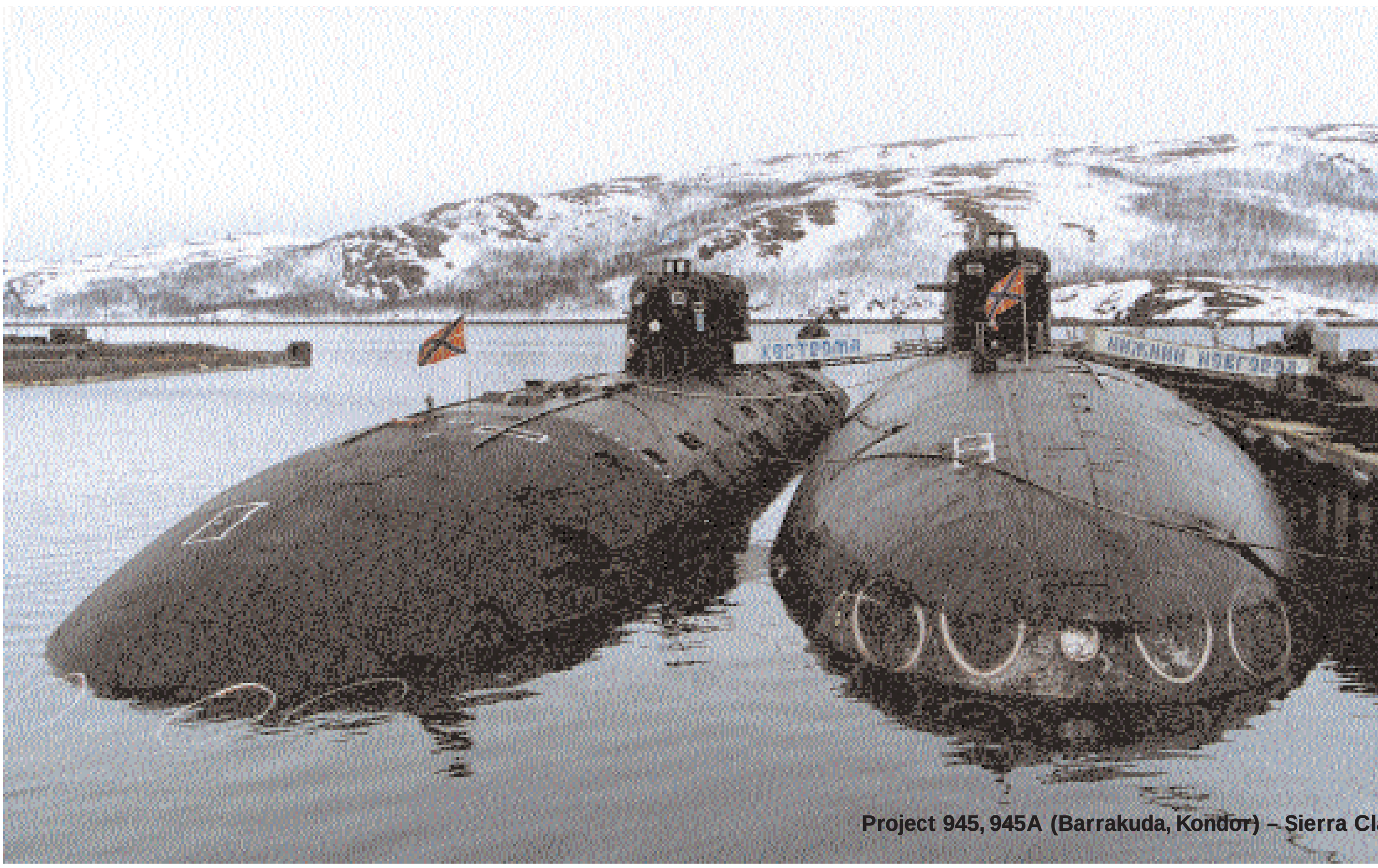
	Northern Fleet	Pacific Fleet	Total
In service	5	5	10
Inactive			
- with fuel	0	0	0
- defuelled	0	0	0
Dismantled	0	0	0
Sunk	1	0	1
Number	6	5	11

The 5 Oscar-II class submarines in the Northern Fleet are based at Vidyaevo and Bolshaya Lopatka (Zapadnaya Litsa)

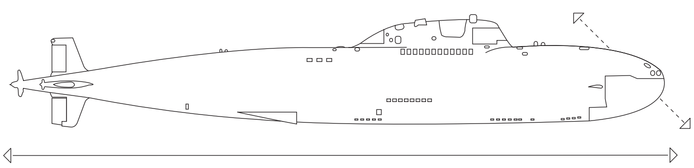
Project 949A (Antey) – Oscar-II Class

K-no. (factory no.)	**Ship yard -Laid down -Launched**	**Active service -Start date -End date**	**Repairs**	**Operation intensity -Covered miles -Hours (years)**	**Accidents**	**Present condition**
K-148 (Krasnodar)	Sevmash - -	1986 in service	No data	No data	No data	Based in Vidyaevo or Bolshaya Lopatka.
K-119 (Voronezh)	Sevmash - -	1988 in service	No data	No data	No data	Based in Vidyaevo or Bolshaya Lopatka.
K-410 (Smolensk)	Sevmash - -	1990 in service	No data	No data	No data	Based in Vidyaevo or Bolshaya Lopatka.
K-266 (Orel)	Sevmash - 22/05 1992	1992 in service	No data	No data	No data	Based in Vidyaevo or Bolshaya Lopatka.
K-141 (Kursk)	Sevmash 1992 1994	20/01 1995 sank	No data	No data	No data	Sank in the Barents Sea on August 12th 2000.
K-150 (Tomsk)	Sevmash - 18/07 1996	1997 in service	No data	No data	No data	Based in Vidyaevo or Bolshaya Lopatka.

1 Surface/submerged.



Project 945, 945A (Barrakuda, Kondor) – Sierra Cl



BM-40A liquid-metal cooled reactor(lead-bismuth)

Titanium Alloy

150 MWt (38.500 hp)

2.300/3.100[2] tonnes

6

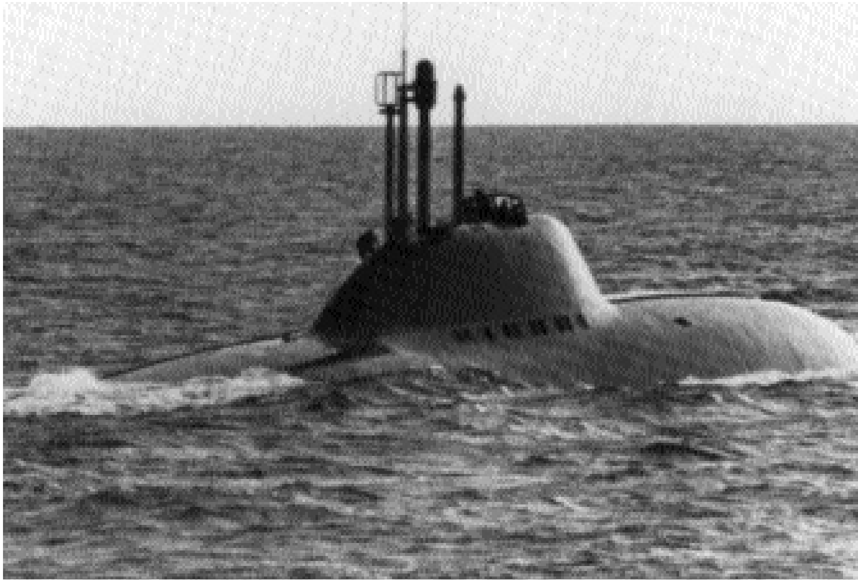
Project 705, 705K (Lira) – Alfa Class

K-no. **(factory no.)**	**Ship yard** **-Laid down** **-Launched**	**Active service** **-Start date** **-End date**	**Repairs**
K-64 (N900)	Admiralty shipyard 02/06 1968 22/04 1969	31/12 1971 ~1974	No data
K-123 (N105)	Sevmash 22/12 1967 04/04 1976	Nov 1977 ~1996	1982-1991: Overhaul repairs. Reactor section replaced and towed to Sayda Bay for storage.
K-316 (N905)	Admiralty shipyard 26/04 1969 25/07 1974	Sep 1978 ~1994	No data
K-432 (N106)	Sevmash 12/11 1967 03/11 1977	Jan 1979 ~1994	No data
K-373 (N910)	Admiralty shipyard 26/06 1972 19/04 1978	Dec 1979 ~1994	No data
K-493 (N107)	Sevmash 21/01 1972 21/09 1980	Sep 1981 ~1994	No data
K-463 (N915)	Admiralty shipyard 26/06 1975 30/04 1981	Dec 1981 ~1993	No data

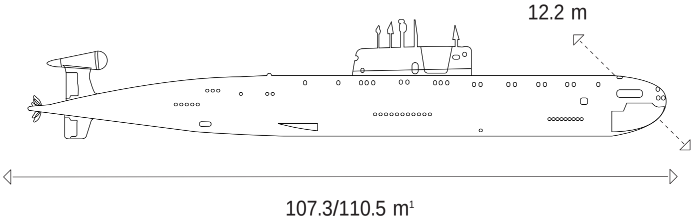
1 Including one reactor section.
2 Surface/submerged.

	Northern Fleet	Pacific Fleet	Total
In service	0	0	0
Inactive			
- with fuel	3[1]	0	3
- defuelled	0	0	0
Dismantled	4	0	4
Number	7	0	7

Of the 7 inactive Alfa class submarines in the Northern Fleet, 4 (reactor sections) are laid up in Sayda Bay, 1 (reactor section with fuel) and 2 in Bolshaya Lopatka (Zapadnaya Litsa).



Operation intensity -Covered miles -Hours (years)	**Accidents**	**Present condition**
No data	1972: Primary circuit malfunction, hull cracks, liquid metal coolant frozen	Taken out of operation on August 19th 1974. Reactor section with fuel cut out and placed on Yagry Island in Severodvinsk.
No data	08/08 1982: Release of liquid metal coolant from reactor.	Laid-up in Bolshaya Lopatka Bay, Zapadnaya Litsa Fjord.
No data	1987: Reactor malfunction	Decommissioned at Sevmash shipyard in Severodvinsk in 1995. Reactor section towed to Sayda Bay for storage.
No data	No data	Decommissioned at Sevmash shipyard in Severodvinsk in 1996-98. Reactor section towed to Sayda Bay for storage.
No data	No data	Laid-up in Bolshaya Lopatka Bay, Zapadnaya Litsa Fjord.
No data	No data	Decommissioned at Sevmash shipyard in Severodvinsk in 1997. Reactor section towed to Sayda Bay for storage.
No data	No data	Decommissioned at Sevmash shipyard in Severodvinsk in 1994. Reactor section towed to Sayda Bay for storage.



OK-650/OK-650B PWR

Titanium Alloy

180/190 MWt (43.000 hp)

6.300/9.100[2] , 6.470/10.400 tonnes

6/7

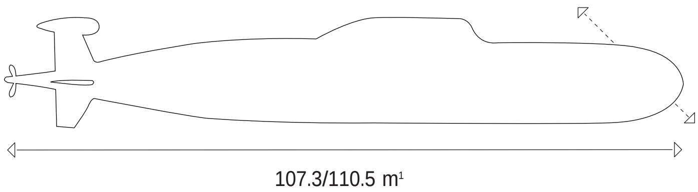
	Northern Fleet	Pacific Fleet	Total
In service	3	0	3
Inactive			
- with fuel	1	0	1
- defuelled	0	0	0
Dismantled	0	0	0
Number	4	0	4

The 4 inactive Sierra class submarines in the Northern Fleet, are laid up at Ara Bay.

Project 945, 945A (Barrakuda, Kondor) – Sierra Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-239 (Karp)	Sormovo/Sevmash 08/05 1982 29/07 1983	21/09 1989 1998	No data	No data	No data	Laid-up in Ara Bay.
K-276 [3] (Krab)	Sormovo/Sevmash Aug 1983 Apr 1984	1987 in service	No data	No data	No data	Based in Ara Bay.
K-534[4] (Zubatka)	Sormovo/Sevmash Jun 1986 Jul 1988	28/12 1990 in service	No data	No data	No data	Based in Ara Bay.
K-336[5] (Okun)	Sormovo/Sevmash May 1990 Jun 1992	1993 in service	No data	No data	No data	Based in Ara Bay.

1 For project 945A.
2 Surface/submerged.
3 Kostroma since 1996.
4 Nizhny Novgorod since 1995.
5 Pskov since 1995.



OK-650/OK-650B PWR

Titanium Alloy

180/190 MWt (43.000 hp)

6.300/9.100[2] , 6.470/10.400 tonnes

6/7

	Northern Fleet	Pacific Fleet	Total
In service	6	7	13
Inactive			
- with fuel	0	0	0
- defuelled	0	0	0
Dismantled	0	0	0
Number	6	7	13

The 6 inactive Akula class submarines in the Northern Fleet, are laid up at Gadzhievo. 1 is under construction in Sevmash.

Project 971 (Schuka B) – Akula Class

K-no. (factory no.)	Ship yard -Laid down -Launched	Active service -Start date -End date	Repairs	Operation intensity -Covered miles -Hours (years)	Accidents	Present condition
K-480 (N821/Bars)	Sevmash 1986 16/04 1988	31/12 1988 in service	No data	No data	No data	Based in Gadzhievo.
K-317 (N822/Pantera)	Sevmash 06/11 1986 May 1990	30/12 1990 in service	No data	No data	No data	Based in Gadzhievo.
K-461 (N831/Volk)	Sevmash 1986 11/06 1991	27/12 1992 in service	No data	No data	No data	Based in Gadzhievo.
K-328 (N832/Leopard)	Sevmash 29/10 1988 28/06 1992	15/12 1992 in service	No data	No data	No data	Based in Gadzhievo.
K-154 (N833/Tigr)	Sevmash 1989 26/06 1993	05/12 1993 in service	No data	No data	No data	Based in Gadzhievo.
K-157 (N834/Vepr)	Sevmash 16/06 1990 10/12 1994	25/11 1995 in service	No data	No data	No data	Based in Gadzhievo.
K-335 (N835/Gepard)	Sevmash 1991 18/09 1999	To enter service in 2001	No data	No data	No data	Currently in Severodvinsk.
K-337 (Kuguar)	Sevmash 1993	To enter service in 2002	No data	No data	No data	Currently in Severodvinsk.

1 4 meters longer starting with K-157 (Vepr).

2 Surface/submerged.

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