Science & Global Security, 1995, Volume 5, pp.245–271
Reprints available directly from the publisher
Photocopying permitted by license only

Russian Nuclear-Powered Submarine Decommissioning

Oleg Bukharin[a] and Joshua Handler[b]

Russia is facing technical, economic and organizational difficulties in dismantling its oversized and unsafe fleet of nuclear powered submarines. The inability of Russia to deal effectively with the submarine decommissioning crisis increases the risk of environmental disaster and may hamper the implementation of the START I and START II treaties. This paper discusses the nuclear fleet support infrastructure, the problems of submarine decommissioning, and recommends international cooperation in addressing these problems.

INTRODUCTION

Since the 1950s, the world's nuclear powers — the United States, Soviet Union/Russia, Britain, France and China — have constructed over 464 nuclear-powered submarines. Approximately, half of these submarines are now retired due to age, arms control agreements or lack of financing. These submarines contain a considerable amount of nuclear waste in the form of spent fuel, irradiated reactor compartments, cooling waters and solid radioactive waste. Decommissioning them generates further amounts of liquid and solid radioactive wastes.

The Soviet Union and now Russia, which built the largest such underwater nuclear fleet of 245 boats, faces the largest problem in dealing with decommissioned nuclear submarines. By earlv 1995, 126 submarines had been decommissioned, most in the past five years. Another 40-80 nuclear submarines may be decommissioned by the end of the decade. The naval nuclear support infrastructure in the former Soviet Union was already in poor condition prior to this massive write-off of submarines. It is now stressed to its limit, with decommissioned submarines with their fuel still on board stacking up at bases and shipyards in the North and Far East. Service ships and shore-side

a Visiting Researcher, Center for Energy and Environmental Studies, Princeton University, Princeton, New Jersey.
b Research Coordinator for Greenpeace International's Disarmament Campaign, Washington, DC.

naval nuclear waste storage sites are also near or at capacity and in poor shape. Finally, there is no land-based repository for decommissioned reactor compartments. As a result, spent nuclear fuel, reactor compartments, and other radioactive waste are piling up on land or afloat near the shore.

There is growing national and international concern that Russian nuclear naval facilities pose an environmental threat to surrounding regions, and that Russia is either not taking the steps or does not have the resources to deal with this crisis.[1] There are also security implications. The decommissioning crisis may compromise safe operation of Russia's active-duty submarine fleet. And Russia's inability to dismantle strategic submarines may hamper the implementation of the START I and START II treaties.

This paper provides an overview of the size and scope of the Russian submarine force, its support infrastructure, its spent nuclear fuel management procedures, and the nuclear submarine decommissioning problems. The paper also makes some recommendations for further actions to alleviate the situation, laying emphasis on opportunities for international cooperation.

THE SOVIET/RUSSIAN SUBMARINE FORCE

Nuclear Submarine Force

From the 1950s until the end of 1994, the Soviet Union and Russia constructed 245 nuclear-powered submarines, including 91 ballistic missile submarines (SSBNs), 64 cruise missile submarines (SSGNs), 86 attack submarines (SSNs), and four research submarines.[2] These submarines contain 445 nuclear reactors, as most vessels are powered by two reactors (see table 1). Deployment reached a highpoint in 1989, when approximately 196 submarines were counted in service; at the beginning of 1995 some 115 submarines were thought to be in service (see figure 1).

The Soviet nuclear submarine program had its origins in wartime discussions and planning among Soviet nuclear and naval engineers. Through the late 1940s, however, all work on this project was banned by L. Beria to avoid any dilution of the effort to build the Soviet atomic bomb, and it was not until September 1952 that the Soviet naval reactor program formally got underway.[3] In the Kurchatov Institute in Moscow, A. Alexandrov established a group to develop a water-cooled water-moderated reactor (PWR).[4] Simultaneously, in the Physics and Power Institute in Obninsk, A. Leipunsky initiated a project to develop a lead-bismuth cooled reactor (liquid metal reactor, LMR).

Table 1: Soviet/Russian Submarine and Surface Ship Reactor Numbers.

Type and NATO Code Name	Reactors per Ship	Number of Ships Built	Reactors per Class
SSBN Hotel	2	8	16
SSBN Yankee I	2	34	68
SSBN Delta I-IV	2	43	86
SSBN Typhoon	2	6	12
SSGN Papa	2	1	2
SSGN Charlie I-II	1	17	17
SSGN Echo II	2	29	58
SSGN Oscar I-II	2	12	24
SSN November	2	13	26
SSN K-27	2	1	2
SSN Echo I	2	5	10
SSN Victor I-III	2	48	96
SSN Mike	1	1	1
SSN Alfa	1	7	7
SSN Sierra I-II	1	4	4
SSN Akula	1	12	12
Research	1	4	4
Total submarines		**245**	**445**
CGN Cruisers	2	3	6
SSV Communications	2	1	2
Total cruisers		**4**	**8**
Icebreaker Lenin	2	1	2
Icebreaker Arktika	2	5	10
Icebreaker Taymyr	1	2	2
Transport Sevmorput	1	1	1
Total civil		**9**	**15**
TOTAL		**258**	**468**

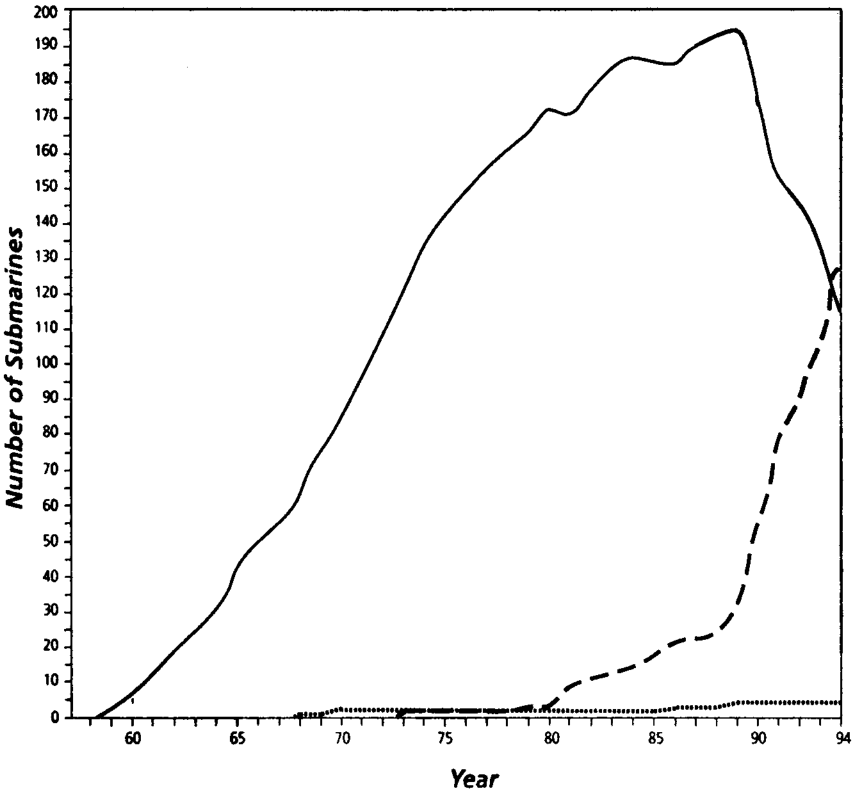

Figure 1: Soviet/Russian nuclear-powered submarine force levels. Solid line represents operational submarines, dashed line represents submarines to be scrapped, and dotted line represents lost or dumped submarines.

In 1953, the government resolved to start construction of full-scale prototypes of reactors and associated propulsion units. The installations — 27/VM (PWR) and 27/VT (LMR) — were commissioned in Obninsk in March 1956 and January 1959. They became both a research and development base and were among the first Soviet Navy reactor training centers.

These developments were paralleled by the designing and construction of four classes of nuclear-powered submarines and the selection and training of crews. In December 1952, the USSR Council of Ministers issued a decree to build nuclear-powered submarines at the Sevmashpredpriyatie (Northern Machine Building plant or SMP) shipbuilding facility in Severodvinsk.[5] The construction of the first Soviet submarine, a November class boat, the K-3, began in 1954.[6] Its reactors were loaded and went critical for the first time during 13-14 September 1957. K-3 went on its first sea trials in the White Sea in July 1958, and was accepted into service of the Northern Fleet in March 1959. It was renamed the "Leninsky Komsomol" in 1962 in honor of its exploits. Three additional projects of first-generation nuclear-powered submarines were designed and put into production in the 1950s -- Echo class cruise missile submarines, Hotel class ballistic missile submarines, and a modified November LMR-powered submarine.[7]

INFRASTRUCTURE DEVELOPMENT

Design Bureaus

The first nuclear-powered submarines were designed at Special Design Bureau No. 143 (SKB-143) in Leningrad, headed by chief designer V. N. Peregudov. Subsequent reorganizations in the 1960s and 1970s of submarine design bureaus yielded three major submarine design bureaus: (1) the Malakhit design bureau (St. Petersburg), which traces its origins to SKB-143 and which designed most of the attack submarines in the Russian navy (November, LMR modified November, Victor, Alfa, Akula, and Papa SSGN classes); (2) the Rubin Central Marine Design Bureau (St. Petersburg) which (it or its predecessor bureaus) designed most of Russia's ballistic and cruise missile submarines; and (3) the Lazurit Central Design Bureau (Nizhny Novgorod) which designed single-reactor submarines of the Charlie cruise missile and Sierra attack submarine classes.

Naval Reactor Developments

Significant effort was also invested in the designing of ship nuclear propulsion systems. The Soviet Union has developed three generations of naval pressurized water reactors, each generation featuring improved reliability, compactness, and quietness. Reactors of the first generation (VM-A type) were deployed between 1957 and 1968, and virtually all have been retired. Reactors of the second generation (VM-4 type) were deployed between 1968 and 1987 and, as of the beginning of 1995, many of them were still in use. The third generation reactors (OK-650 type) began entering service in 1987. In addition, several one-of-a-kind designs of PWRs were developed for research submarines and other vessels.

The Soviet Union has also developed and deployed liquid-metal reactors (LMRs) with compact, high power density reactor cores. However, despite these attractions, maintenance problems, accidents, and advances in designs of PWRs have precluded the further development and wide use of LMRs.

The first models of naval reactors were developed at the research center at Obninsk and at the Kurchatov Institute, assisted by other design institutes, such as the Institute of Power Technologies (NIKIET, Moscow). Subsequently, reactor design and development work was consolidated at the Design Bureau of Machine-Building (OKBM) in Nizhny Novgorod.[8] Reactor construction was undertaken at the Izhorsky Zavod, at Kolpino, near St.Petersburg, and at the Nizhny Novgorod Machine-Building Plant.[9]

Naval reactors cores are described as having 248-252 fuel assemblies depending on the type of reactor. There may be up to few tens of fuel rods per assembly.[10] Fuel rods differ in design from traditional round to more advanced cross shapes.

Most PWR fuel is uranium-aluminum dispersed fuel (also called cermet) in steel or zirconium cladding.[11] Enrichment of the PWR cores varies from about 21 percent U-235 for the first and second generation cores to 43-45 percent for the third generation cores. (Some naval reactors, however, were designed to use uranium of higher enrichments.[12]) Third generation cores have three zones of different enrichments, with the lowest inner ring having about 21 percent enrichment and the highest outer ring being enriched to 43-45 percent. A typical first generation core had approximately 50 kg U-235 per reactor.[13] Fissile content was likely increased for reactors of the subsequent generations.[14]

Shipyards

Five shipyards were used for the construction of nuclear- powered submarines in Russia (see figure 2).[15] The Sevmashpredpriyatie (SMP), located in Severodvinsk was the first shipyard to build nuclear-powered vessels. The second was the Lenin Komsomol shipyard in Komsomolsk-na-Amure on the Amur river in the Russian Far East. Its first Echo I SSGN submarine was started in 1957 and completed in 1960. Submarines built at the yard were transferred to Bolshoi Kamen near Vladivostok for final fitting out. Three other shipyards became involved in nuclear submarine construction in the 1960s: the Krasnoye Sormovo shipyard located in Nizhny Novgorod, which launched its first Charlie SSGN in 1966; the Admiralty shipyard in St. Petersburg, which started building Victor I SSNs in the mid-1960s; and the adjacent Sudomekh yard, which began building Alfa class titanium hulled submarines in the 1960s. Submarines from the last three yards were transferred to Severodvinsk via the inland water-way system for final fitting out.

On 19 November 1992, President Yeltsin announced during a visit to South Korea that nuclear submarine production would stop at Komsomolsk-na-Amure, and that nuclear submarine construction would be centered at Severodvinsk.[16] Nuclear submarine construction has stopped at Nizhny Novgorod (reportedly some Sierra class submarines under construction have

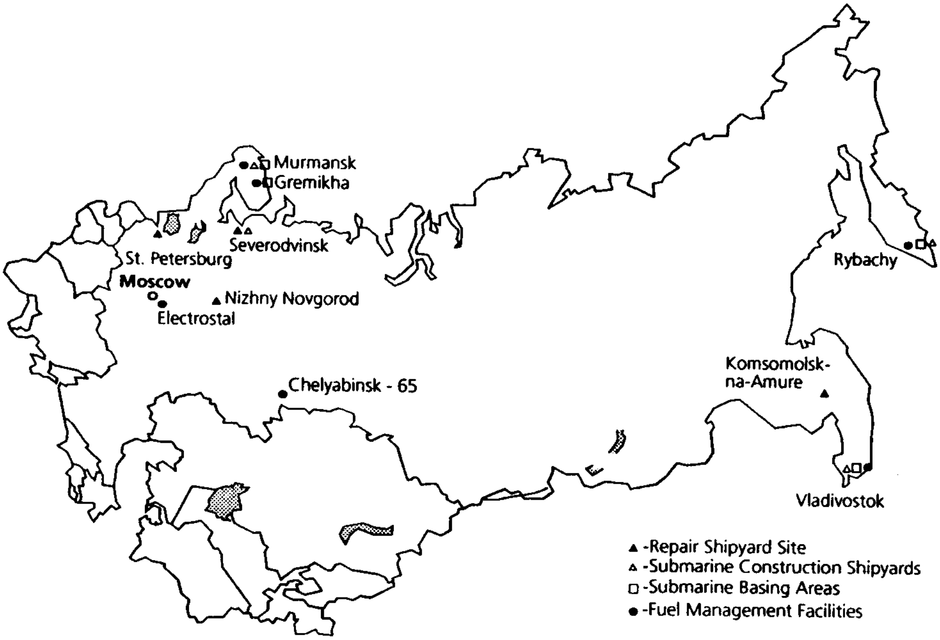

Figure 2: Nuclear submarine support infrastructure.

been scrapped) and in St. Petersburg. Despite economic hardships, SMP in Severodvinsk continues to complete Akula SSN and Oscar SSGN class submarines started in previous years. Also, in December 1993, the keel of a new class attack submarine was laid.

Severodvinsk has been the most important submarine construction center. By 1995, it had launched 125 boats, or some 52 percent of the total. Fifty-six submarines had been constructed at Komsomolsk-na-Amure, 39 at the St. Petersburg yards, and 25 at Nizhny Novgorod.[17]

In addition to submarine construction shipyards, there are Navy and shipbuilding industry shipyards devoted to the repair and maintenance of nuclear-powered submarines. It is at these shipyards that the majority of re/defuelings of nuclear submarines and decommissioning work is carried out. In the Northern Fleet area, repair shipyards are located at Malaya Lopatka Guba in Zapadnaya Litsa, in Olenya Guba (the Nerpa facility), at Pala Guba (No. 10, abutting the town of Polyarny), and at the Rosta shipyard in Murmansk (No. 35). Also, in Severodvinsk on the north side of the river Dvina across from the SMP plant on Yagary Island is the Zvezdochka or Little Star plant which is a major facility for repair, overhaul and decommissioning of nuclear-powered submarines. In the Far East, the Gornyak repair yard (No. 30) is located near the Rybachy nuclear submarine base on Kamchatka. To the southeast of Vladivostok there is the Zvezda or Star plant in Bolshoi Kamen and the Chazhma Bay plant is next to the town of Dunay. Shipyards have varying capacity to temporarily or for extended periods store solid and/or liquid radioactive waste.

Naval Bases

The Soviet Union developed a series of bases and shipyards for its nuclear-powered submarines in the North and the Far East. To maintain secrecy and to insure access to ice-free waters, many of these facilities were located in remote areas which have always been logistically difficult to support. Conversely, their remote location encouraged the widespread use of service vessels to support the nuclear-powered submarine fleet.[18]

The first base for the operation of nuclear-powered submarines was constructed on the Kola peninsula at Zapadnaya Litsa in the late 1950s.[19] Construction of more bases in the North and Far East soon followed. In the Northern Fleet, large nuclear-powered submarine bases are located in the Zapadnaya Litsa fjord (in Nerpichya Guba and Bolshaya Lopatka Guba), Ara Guba, Yagelnaya Guba inside of Sayda Guba, and Olenya Guba, (all located northwest of Murmansk on the Kola peninsula), and at Gremikha (to the east of Murmansk on the Kola peninsula). In the Far East, large bases are located at Rybachy near Petropavlovsk-Kamchatsky and Pavlovsk, located between Vladivostok and Nakhodka on the Sea of Japan. Smaller submarine bases were located at Rakushka (near Olga) and Zavety Ilyicha (near Sovetskaya Gavan) (both facilities reportedly only hold decommissioned vessels now).[20]

Fuel Management Infrastructure

During its early years, the naval reactor program remained experimental and most fuel and reactor support operations, such as refuelings, were conducted ad hoc, at the existing facilities. In the 1960s and 1970s, the nuclear industry, shipbuilding industry and the Navy developed a dedicated infrastructure and equipment to produce and deliver fresh fuel, refuel submarines, provide interim storage of spent fuel at naval bases, and ship away and reprocess spent fuel. To a significant extent this infrastructure remains in place and serves as a basis for fuel management in the today's Navy.

A special naval fuel fabrication line was established at the Machine-Building Plant at Electrostal near Moscow. HEU-beryllium alloy fuels for LMRs also were produced at the Ulbinsky Metallurgical Plant in Ust'-Kamenogorsk in Kazakhstan. (The operation at the Ulbinsky Plant was terminated in the 1970s and the production of naval reactor fuel was consolidated in Electrostal.) From Electrostal, fuel was delivered to the Navy which conducted most refuelings. Fresh fuel was also delivered to shipyards of the shipbuilding industry for loading into newly built submarines and refueling submarines during major overhauls.[21]

From the start of the nuclear submarine program, the Navy developed the technology of refueling of submarines afloat, i.e. with a service ship next to the submarine tied up at dockside, and, at present, all defuelings and refuelings are conducted in this manner.[22] (Until the early 1990s, a small number of refuelings were conducted in dry docks of shipyards of the shipbuilding industry.) In this approach, all principal operations -- removal of spent fuel, insertion of fresh fuel, and initial storage of spent fuel -- are conducted by the submarine service ship.[23] In the 1960s, the Navy procured a fleet of specialized PM-124 class ships (converted Finnish-built cargo barges) equipped with cranes and storage compartments for these operations.[24] They have holds for fresh and spent fuel (approximately one submarine's worth) and radioactive waste.

From the service ship, spent fuel is transferred to a land- based storage facility. Four land-based storage facilities were constructed in the 1960s to early 1970s: at the Gremikha base and at Andreeva Guba in Zapadnaya Litsa in the North and at the Kamchatka and Shkotovo waste sites in the Pacific. (Because of the poor quality of construction, the Kamchatka facility has never been used for storing spent fuel.) The facilities were designed for wet storage in which spent fuel was suspended in pools with cooling water.

The problem of disposal of naval spent fuel also was addressed. The Soviet nuclear industry developed the capability to ship spent fuel from naval bases to the RT-1 reprocessing plant at the Mayak site (also known as Chelyabinsk-65) in the Urals. This included construction of special shipping casks (TUK-11 and TUK-12s) and rail-cars, and development of a railway infrastructure at the naval bases at Murmansk, Severodvinsk, and Shkotovo. More than 200 shipments were made between 1973 and 1993.[25] In 1976, after more than a decade of technology development, the HEU-aluminum naval fuel reprocessing line, first line of the RT-1 plant, was brought into operation at the Mayak site.

In the 1980s, the Navy began upgrading and modernizing its fuel management infrastructure. Three modern submarine-service ships of the PM-2020 (Malina) class entered service in 1984-91. The ships are capable of servicing all types of nuclear submarines and have holds for six reactor cores of spent fuel. Construction of the fourth ship was started (but never completed) at the

Nikolayev shipyard in Ukraine. New spent fuel storage facilities (Buildings 29 and 30) were constructed at the Shkotovo waste site in 1981 and 1986. (In the early 1980s, equipment corrosion and contamination accidents at the existing storage facilities forced the Navy to move spent fuel to dry storage.[26]) The government also resolved to improve the fuel shipment infrastructure and, starting in 1983, to use new shipping casks TUK-18 which meet IAEA safety requirements.[27]

Many of these plans, however, have been delayed or never implemented. Because of poor resources management, the Navy failed to implement the governmental decision to upgrade the existing transportation infrastructure for the use of the new shipping casks. (Because the new casks are significantly heavier and larger, their use requires new cask-handling equipment and upgrades of the local road and railway transportation systems.) The break-up of the USSR and the economic crisis of the 1990s further worsened the situation.

Personnel Training Facilities

The massive construction of nuclear-propelled submarines of the 1960s and 1970s was supported by development of personnel training facilities. The first training center was established in Obninsk in 1956-59.[28] Subsequently, the Navy established reactor training facilities at Sevastopol in Ukraine (training on SSBN missile launchers and reactors) and Paldisky in Estonia (crew-integration and reactor training for SSBN crews). The centers were equipped with reactor experimental and training facilities including land-based prototypes of naval reactors and critical assemblies. The center at Paldisky contained full scale mock-ups of submarine hulls with two reactors. The first reactor was started in 1968 and the second in 1982. Both reactors were shut down in 1989.[29]

The break-up of the Soviet Union has made facilities at Sevastopol and Paldisky inaccessible to the Russian navy and undermined the naval-reactor training base.[30] As of 1995, the Navy planned to expand training facilities in Obninsk and at the Institute of Technology in Sosnovy Bor near St.Petersburg. Future training is expected to rely on reactor simulators. Implementation of these plans, however, is hampered by the lack of funding.

SUBMARINE DECOMMISSIONING AND RADIOACTIVE WASTE PROBLEMS

Once a nuclear submarine is removed from service, the general sequence of events of full decommissioning of the vessel involves removing the spent nuclear fuel, dismantling the missile launchers (for the SSBNs to be eliminated under the START I treaty), removing and recovering usable equipment and metals, separating the reactor compartment from the rest of the hull and sealing it for long- term storage, and finally cutting up the remaining parts of the hull for scrap.

In Russia, each one of the steps is facing serious problems. As of March 1995, 126 nuclear-powered submarines had been removed from service, approximately 70 of which were retired in the last five years.[31] Some 50 decommissioned submarines are in the Pacific Fleet and the rest in the Northern Fleet. Of these 126 submarines, the spent nuclear fuel has been removed from only a third. Some 80 submarine remain to be defueled (including three in the Pacific Fleet which had nuclear accidents, making the removal of the fuel perhaps technically impossible).

Approximately, 20-22 submarines have been scrapped in various degrees, and prepared for long-term storage afloat (10-11 each in the Far East and North). Since there currently is no land-based storage site for reactor compartments, reactor compartments which are removed from submarines are sealed up with the adjoining compartments and stored afloat pending the development of a land-based storage site.[32] In the Far East, these reactor compartments are stored in Razboinik Bay near the Chazhma Bay shipyard. In the North, some are kept in Severodvinsk, but they generally are delivered back to the Navy from the shipyard, which in turn tows them for storage afloat on the Kola peninsula (some have been located in Sayda Guba near Murmansk)[33]

Due to these delays there is widespread concern in the Navy and among city and regional officials in areas where nuclear shipyards and naval bases are located that these submarines may sink causing an ecological catastrophe. Civilian authorities are also concerned about accidents during defueling or scrapping operations, as well as about dangers posed by overfilled or decrepit storage sites or nuclear service ships which are used for holding solid and liquid radioactive waste.[34]

Problems with Decommissioning

A key problem with the decommissioning of submarines has been the lack of financing and the non-fulfillment of various programs that have been developed to deal with this problem since the mid-1980s. As a result, shipyard capacity is low, there is a lack of service ships for defueling operations, the infrastructure to ship spent fuel away from naval bases has not been upgraded, radioactive waste storage sites in the Fleet or at shipyards have not been built or upgraded, and a land-based storage site for reactor compartments has not been created.[35]

Shipyard Capacity

Seven shipyards have been involved in scrapping nuclear submarines: the SMP and the Little Star plant in Severodvinsk, and the Nerpa plant, Pala Guba shipyard, and Rosta shipyard on the Kola peninsula, and the Zvezda and Gornyak shipyards in the Far East (the Zvezda, Little Star, and Nerpa plants have been declared SSBN dismantlement facilities under the START I treaty). Collectively, these shipyards have managed to process some 20-22 submarines in the past five years, although perhaps only half of these have been fully scrapped.

In the Northern Fleet, in Severodvinsk, the SMP has been scrapping Alfa-class titanium-hulled submarines.[36] Three had been scrapped as of mid-1994. The Little Star plant has managed to process at least six submarines, four of which were scrapped down to a three-compartment configuration (i.e. the reactor compartment and the adjacent two compartments), and two were slightly stripped down to an eight-compartment configuration (i.e. most of the submarine hull is kept together, while some parts of the sail and superstructure are removed) by mid-1994. As for the Nerpa plant, in 1992 two submarines -- a Charlie SSGN and Victor SSN -- were assigned to the plant for scrapping, but work there seems to be proceeding slowly.[37] As for the Pala Guba and Rosta shipyards, apparently no full-scale scrapping operations have occurred here. Rather some removal of interior equipment and stripping down and sealing up of the hull has occurred to better prepare the submarines for storage afloat. In any event, currently some 65-70 nuclear submarines are awaiting scrapping in the Northern Fleet area, and several dozen more will be taken out of service by the end of the decade. If scrapping rates are not increased, it will take several decades to deal with the backlog of retired submarines in the Northern Fleet.

In the Far East, the Zvezda plant could have a capacity to fully scrap 5-6 submarines a year, although it is currently operating at a rate of only 1-2 submarines a year. In 1994, these operations almost ground to a halt due to lack of financing and lack of storage space for offloaded spent nuclear fuel and liquid-radioactive waste. The Gornyak yard has been preparing submarines for storage afloat in the same manner as the Pala Guba and Rosta yards. At least 60 submarines will be decommissioned in the Pacific Fleet by the end of the decade -- i.e. another 50 hulls will need to be scrapped -- and it will take another 30 years at current rates to deal with this back log.

Another factor slowing the overall scrapping process at shipyards may be the necessity of eliminating ballistic missile launching facilities on SSBNs declared to be taken out of service by the START I treaty. Once a SSBN has been declared to have started the elimination process for SLBM launchers, which involves either cutting out the missile section of the submarine or dismantlement of the launching tubes and support structures, a strict timetable for completing the process goes into effect, 270 days and 180 days, respectively.

Of the 62 SSBNs declared under the START I treaty data exchange of September 1990, by December 1994, 14 had officially been removed from operational service (13 had completed their SLBM launcher elimination) - a dismantlement rate of about 3.5 SSBNs per year.[38] To achieve this rate Russia expanded the list of the START-designated SLBM dismantlement facilities to include the Nerpa shipyard.[39] Unless scrapping capacity is significantly increased, the START treaty compliance will continue to adversely affect the general decommissioning program.[40] Or conversely, if dealing with decommissioned general-purpose submarines becomes an acute issue, then dismantling of SSBN SLBM launch compartments under the START treaties may suffer.

Problems of Spent Fuel Management

Difficulties of managing spent fuel are also a principal bottleneck in the submarine-decommissioning program. Indeed, by 1995 the Navy and the icebreaker fleet already had approximately 120 reactor cores of spent fuel stored at coastal facilities and at service ships. This backlog stressed the fuel management infrastructure to the limit and may hamper the operational activities of the nuclear fleets. Defueling of the currently retired submarines would roughly double the amount of spent fuel and, in any event, despite the reduction in fueling requirements to support active-duty nuclear submarines, is not feasible in the near-term. This, in turn, in some cases creates further fuel management and environmental problems because reactor cores and equipment are close to or beyond the end of their design life and the fuel inside the reactor may fail creating complications for its future handling and disposition.[41] Specific problems of fuel management include a) difficulties with submarine defueling, b) shortage of spent fuel storage capacity, c) low rate of spent fuel shipments to Mayak, and d) low capacity of the RT-1 reprocessing plant.

Service ships are essential for submarine decommissioning. The PM-124 and Malina class vessels defuel and provide interim storage of spent fuel. Technical tankers of TNT classes collect and treat radioactive waste. The service ship capacity of the Navy is not sufficient to support high rates of submarine decommissioning. Indeed, the service ship force was designed to support approximately 10 refuelings per year. Even at full capacity, it would take several years to defuel all the currently retired submarines. Recently, however, the capacity of the service ship fleet has significantly decreased.

The bulk of the fleet -- nine PM-124 class ships -- was built in the 1960s. The ships have outlived their designed life- time, cannot be used safely, and three in the Pacific Fleet are already non-operational due to age and accidents (two have damaged fuel on board which cannot be removed).[48] Provision of new equipment is complicated. For example, the construction of the fourth Malina class ship, destined for the Pacific Fleet, at the Nikolayev shipyard in Ukraine has not been completed. And the plans to start construction of Malina class ships at Severodvinsk has been stalled by the lack of funding.

There are other factors limiting the capacity of service ships. The ships, including those of the Malina class, need an overhaul. This is not being done in a timely manner because of the lack of funding and because ships cannot be substituted in performing their duties. Finally, there are competing tasks of decommissioning and supporting active duty submarines. There are not enough service ships to meet both requirements.

The shortage of storage capacity at naval facilities has been caused by both high rates of submarine decommissioning and by the slow rate of spent fuel shipments to the RT-1 reprocessing plant. The situation became critical in October 1993, when the Russian nuclear regulatory agency Gosatomnadzor banned the use of the old TUK-11 and TUK-12 shipping casks on safety grounds, although the full upgrading and licensing of facilities for the handling the TUK-18 containers had not been finished. The Northern Fleet and the Murmansk Shipping Company have carried out some upgrades which have permitted two trial shipments of spent naval fuel in 1994–1995 from Severodvinsk (May 1994) and Murmansk (February 1995).[42] The shipments were to certify that the loading areas and railroads can handle the TUK-18s and their associated rail cars. However, military units in the Northern Fleet which handle spent nuclear fuel had not submitted their applications for certification to Gosatomnadzor as of March 1995 and may be prohibited from new shipments.[43]

The situation at the Pacific Fleet, which has not shipped spent fuel since October 1993, remains grave. As of 1995, the spent nuclear fuel storage facility at the Shkotovo waste site, the only land-based storage facility in the Far East, was 93 percent full.[44] New fuel handling equipment was installed at the storage facility but not at the loading area at the Shkotovo waste site. There is also the need to upgrade the rail link to the central rail system and the 5 km road between the storage facility and the loading area. Since it appears unlikely that the Navy will finish upgrading the facilities in Shkotovo or find an alternative shipment route in the near future, it has begun to agitate for permission to ship spent fuel in the old TUK-11/12 containers, which so far Gosatomnadzor has denied.[45]

Even if the Navy were successful in upgrading its bases to send spent fuel away for reprocessing, the rate of shipments would be limited by the availability of special railcars (TK-VG-18). Presently, there is only one four-car train, capable of carrying approximately 1.5-2 cores worth of spent fuel.[46] Also, the RT-1 plant would not be able to process large amounts of fuel in short time. The capacity of the plant is limited by the criticality-safe size of the fuel dissolver tank to four to five reactor cores per year.[47] At this processing rate, even clearing the existing backlog of spent fuel will take tens of years. (Mayak has pools to store spent fuel prior to reprocessing. It, however, refuses to make this capacity available for extended storage of naval fuel.)

Disposition of Liquid and Solid Radioactive Waste

The disposal of low and medium level solid and liquid radioactive waste (SRW and LRW) is another problem besetting the submarine decommissioning program.[49] Since the late 1950s until 1993, the regular procedure for the Soviet/ Russian Navy was to dump these materials at sea in designated sites in the Arctic and Pacific Oceans. Due to international outcry when one dumping operation in the Sea of Japan was discovered in October 1993, the Russian government forbade any more dumping at sea by the Russian Navy. Storage sites on land and on the technical tankers and other service ships for liquid and solid radioactive waste were already nearly full or in poor shape. Banning further dumping heightened the Russian Navy's radioactive waste disposal crisis. With little or no place to store liquid or solid radioactive waste, decommissioning operations were further slowed, particularly in the Pacific Fleet. The Pacific Fleet threatened several times during 1994 to dump at sea again, and in mid-1994 the Severodvinsk plants also expressed a need to do at least one more dump.

However, since October 1993, further dumping at sea has been avoided. In the Northern Fleet, the Navy has begun to process its LRW at a facility on the Atomflot base of the Murmansk Shipping Company where the civilian icebreakers are based. Also, the United States and Norway have been working in 1994-1995 to provide assistance to further upgrade and increase the capacity of the facility.[50] In the Pacific, in late 1993, the Japanese government promised to provide assistance to construct a LRW processing facility if the Russian Navy did not dump at sea again. However, the assistance has been slow in coming.[51] As a result the Navy has had to start devoting some additional funds to this problem. In 1994, two new small-scale processing units -- known as SHARYA-04 -- began to process the LRW stored on the technical tankers located near Vladivostok and Kamchatka. This has somewhat alleviated the crisis for the moment.[52]

As for solid radioactive waste, there is some expansion of storage capacity at the Little Star plant in Severodvinsk. In addition, the Little Star plant has begun to load SRW into some of the separated reactor compartments.[53] Still the capacity remains inadequate, and a search for a larger burial site is being conducted. In the case of the North, there is some interest in developing a storage site on the island of Novaya Zemlya.[54]

Disposition of Reactor Compartments

Storage of the separated reactor compartments has also been a major problem. In the early 1990s, the large numbers of decommissioned submarines were beginning to take up a large amount of space at piers in naval bases and shipyards. Moreover, the submarines required manning and expensive servicing to insure they did not sink. Even so, their decrepit condition meant the possibility of one sinking was real (already a number of retired submarines are continuously having air forced into their ballast tanks to keep them afloat).[55] However, due to lack of financing and the absence of planning the Navy had not developed land-based storage sites (in the United States these reactor compartments are stored on land at the Hanford reservation). Thus, the Navy began to separate out the reactor compartments and to seal them up with adjoining compartments for storage afloat as a compromise measure.[56]

Storage of these reactor compartments has in turn become another major problem. Currently, they are tied up in sheltered bays in the North and Far East (a few are also at shipyards). However, the possibility remains they could sink or break lose. Also, once again pier space to put them is limited. Currently, the Navy is exploring the option of putting some reactor compartments into tunnels near submarine bases in the North and Far East. However, the prospects for the implementation of this program and its potential environmental impact are not known.

Institutional and Financial Problems

Institutional and financial problems have also hindered the development of a coherent submarine decommissioning problem. Although several decrees and programs have been developed that would specifically deal with or incorporate the decommissioning problem since the mid-1980s, these programs and decrees either have not been adopted or have not been fully implemented.[57] This occurred despite the fact that there has been almost continual commentary for several years from national and regional government officials, from military officers, and in the press about the seriousness of the decommissioning and naval nuclear waste problem and the need to do something urgently about it.[58]

The central government agencies which play key roles in the submarine decommissioning process include: the Navy, the Ministry of Defense, Ministry of Atomic Energy (Minatom), the Shipbuilding Directorate of the State Committee for Defense Industries, the Ministry of Nature Protection, and Gosatomnadzor (the nuclear federal regulatory agency). Other central government bodies which have been involved include the Academy of Sciences, the Ministry of Transport (icebreaker and LRW activities), the Ministry of Railways (spent fuel shipments), the Ministry of Finance, the Ministry of Economics, and the Ministry of Health. At the regional and local levels, the administrations of the Murmansk region, Arkhangelsk region, and Primorsky Kray, and the city administrations of Murmansk and Severodvinsk have also been involved in the planning process for decommissioning submarines and dealing with their associated wastes.

In regards to the roles of the key agencies, the Navy is responsible for the management of all spent fuel (until it is passed to Minatom) and radioactive waste at naval bases, and submarine deactivation and decommissioning. It is specifically responsible for decommissioning work done at naval shipyards (e.g. Pala Guba and Rosta). The Shipbuilding Directorate of the State Committee for Defense Industries is directly involved in submarine scrapping at its shipyards (e.g. Nerpa, Little Star, SMP, and Zvezda), but this is in theory supposed to be financed by the Navy. Minatom develops waste management and submarine decommissioning technologies, and provides equipment and services to ship away and dispose of spent fuel. Gosatomnadzor provides regulatory oversight to insure nuclear safety of operations. The Ministry of Nature Protection plays some role in environmental monitoring and insuring environmental safety.

Although there is coordination among these agencies, there is also considerable confusion and competition, particularly for scares funds to finance various parts of the decommissioning work. Also, there has been conflicts between regional and local governments and the central agencies. This has at times hindered the implementation of decommissioning plans.

Finally, insufficient funding has a major impact on every stage of submarine decommissioning, including infrastructure upgrades, shipment and the disposal of spent fuel, personnel management, etc. Although the costs of decommissioning are hard to estimate as well as the level of government funding for the various programs, the funds allocated so far have been insufficient, or, if allocated in the budget, have not been released or delivered by the government. For example, in 1994, less than a quarter of the funds earmarked for decommissioning nuclear submarines in the state defense order were actually disbursed.[59] In the Pacific Fleet from 1992 to 1994, only 15 percent of the budgeted funds for decommissioning were received.[60] In the North, less than seven percent of the Nerpa shipyard's 1994 defense orders were paid for as of October 1994.[61] Shipyard workers and officials in the North and Far East also complain that the Navy owes them billions of rubles for the decommissioning work already done.[62]

CONCLUSIONS

Decommissioning of nuclear submarines will remain a problem for Russia for years to come. The problem cannot be solved without increased funding, better organization, clearer division of institutional responsibilities in the Russian government, strong regulatory oversight, and greater public involvement.

Important near-term priorities include: constructing stores for spent nuclear fuel in the Northern and Pacific Fleets; offloading spent nuclear fuel from submarines and service ships (new service ships may need to be purchased or direct submarine-to-shore transfer of spent fuel organized); upgrading and/or enlarging the LRW processing capability and SRW storage areas in the fleets; increasing the training and radiation monitoring capabilities of naval personnel and environmental (governmental and non-governmental) organizations in the North and Far East; conducting open and complete radiation surveys of the nuclear submarine bases, shipyards, and waste sites; and improving the social infrastructure in the cities, towns, and settlements near or around these facilities. In the near term, there is need to increase the scrapping capability at shipyards and to develop a land-based storage site for reactor compartments and associated transport infrastructure.

The close proximity of Russian nuclear submarine naval bases, shipyards, and waste sites to neighboring countries means the Russian decommissioning problem also has international implications. This has led to offers of assistance by Norway, Japan and the United States to deal with the radioactive waste crisis facing the Navy, in particular to expand the capacity of the LRW treatment facility at the Murmansk Atomflot icebreaker base (Norway and the United States) and to provide a LRW treatment facility to the Zvezda plant at Bolshoi Kamen (Japan). Also, the United States, under the Cooperative Threat Reduction program delivered equipment starting in late 1994 to assist with the dismantlement of SSBN missile launchers (the equipment may also help to increase the overall rate of submarine scrapping).[63]

This incipient cooperation could be expanded to address the larger issues of submarine scrapping, reactor compartment storage, and issues of spent fuel management, including interim and long-term storage of spent submarine fuel. Russian naval officers, government officials, scientists, and shipyard managers have all expressed an interest in increased cooperation. The U.S. Navy, however, has mostly opposed such efforts, curtailing efforts to broaden assistance programs for decommissioning submarines and to bring Russian specialists to the U.S. naval shipyards which do decommissioning work. Some are concerned that the United States might be held liable for Russian environmental problems. Others argue that the Russians are still building nuclear submarines so they should devote resources instead to the decommissioning problem.

Issues of liability are complicated, but given Russian interest in outside assistance and cooperation, undoubtedly they can be resolved.[64] In regards to the Russian nuclear submarine program, from the point of view of environmental and international security it would be much better if more funds were devoted to the decommissioning program even if it was at the expense of submarine construction and operation. However, Russia is unlikely to give up its nuclear submarine program as long as the U.S. maintains its own. U.S.-Russian cooperation around decommissioning nuclear-powered submarines could become an important post-Cold War confidence and security building measure -- along with the increased number of port-visit exchanges, joint wargaming exercises, exercises at sea, and exchanges of senior naval officers (which have already occurred). Such confidence building could lead to further reductions in naval forces and to fostering cooperative relationships between the U.S. and Russian navies. In any event, the substantial back-end costs of nuclear-powered submarines may yet provide an impetus in both the U.S. and Russia to down-size their nuclear fleets even more drastically than has already occurred.

NOTES AND REFERENCES

1. Norwegian and Japanese officials have expressed the most concern about the situation. However, concerns have also been raised in the United States by the Alaskan congressional delegation, and the Arctic, environmental and oceanographic scientific, policy, and non-governmental communities.

2. Valery Marinin, "Nuclear Submarine Construction in Russia," *Military Parade*, (Moscow), pp. 114-119; authors' estimates (March/April 1995).

3. For the discussion of the early period of the Soviet nuclear submarine program see K.Smirnov, "How the Bomb Was Made — Interview With Academician A.Alexandrov," *Izvestia*, (23 July 1988); Captain Lt. Yu. Stvolinskiy, "In the Annals of the Fatherland: Designer of the Nuclear Submarine," *Krasnaya Zvezda* (15 October 1988), (translated in JPRS-UMA-88-027, 18 November 1988, p. 19); Captain 1st Rank S.Bystrov, "Annals of the Fatherland: A Reactor for Submarines," *Krasnaya Zvezda* (21 October 1989), (translated in JPRS-UMA-89-029, 20 December 1989, p. 43); Admiral of the Fleet, V.Chernavin, "Test-Commander," *Morskci Sbornik*, No. 9 (September 1991), (translated in JPRS-UMA-91-031, 12 December 1991, p. 36); Vitaly Novozhilov, "The K-27: The Atomic Ship of Heros and Laureates," *Krasnaya Zvezda* (3 June 1993); V.Stepanov, "Numbered Building," *Gorod* (Obninsk), No. 3-4 (1994), pp. 76-79; Rear Admiral S.Yefremov (Ret.), "Engineer Officer Boris Akulov: The First Engineer Officer Aboard the First Nuclear-Powered Submarine," *Krasnaya Zvezda* (30 August 1991), (translated in JPRS-UMA-91-025, 16 October 1991, p. 35); L.Giltsov, N.Mormoul, L.Ossipenko, *La Dramatique Histoire des Sous-Marins Nucleaires Sovietiques* (Robert Laffont: Paris, 1992).

Academician Alexandrov noted that as early as 1948 he organized a group to look into the feasibility of building a nuclear-powered submarine. The approximate dimension of the nuclear power plant were determined and the results were shown to Kurchatov. They were not allowed to proceed, however, with the project by Beria. Nonetheless, they continued to think about nuclear submarines. Finally, the decree to start the program was signed by Stalin on 9 September 1952.

4. N.A.Dolezhal was chief designer of the submarine reactor.

5. "State Russian Center for Atomic Shipbuilding: Main Problems and Measures for Insuring Nuclear and Radiation Safety While During Construction, Repairs (Modernization) and Decommissioning of Nuclear Powered Submarines," Severodvinsk, Russia (1993).

6. Around 1954, U.S. Naval Intelligence assessed submarine construction program had been established at Severodvinsk and submarine crews had been recruited and assigned to training. U.S. Navy, Office of Naval Intelligence, "Soviets Believed To Have Operational Nuclear Submarines," (secret) *ONI Review*, **16**, No. 2, p. 52 (February 1961), (declassified by ONI, 19 July 1993).

The first Soviet submarine — the November attack submarine — was designed by Engineer Captain 1st Rank Vladimir N. Peregudov, who was selected to head the design efforts in 1952.

7. Academician Professor Igor D. Spassky, General Designer of Submarines, "The Role and Missions of Soviet Navy Submarines in the Cold War," paper for delivery to "Naval History Symposium," U.S. Naval Academy, Annapolis, Maryland, p. 5 (23 October 1993).

8. Related work also takes place in other Minatom's institutes and Kurchatov Institute.

9. The Izhora plant produces nuclear reactors for submarines and titanium for submarine hulls. The plant is also a major producer of reactor components, fuel casks, and other nuclear equipment for nuclear power plants.

The Nizhny Novgorod Plant produces components for reactor assemblies and reactors for submarines. The plant closely works with the design bureau OKBM with which it has formed the Nizhny Novgorod Machine-Building Plant Production Association. U.S. Department of Commerce, U.S.-Russia Business Development Committee, Defense Conversion Subcommittee, *Russian Defense Business Directory* (September 1993 edition).

10. Fuel assemblies of the first reactors of the icebreaker Lenin were composed of 36 fuel rods. This is, reportedly, also the case for cross-shaped rods utilized on modern icebreaker reactors. V. A. Kuznetsov, *Marine Nuclear Power Plant: A Textbook*, (Sudostroenie: Leningrad, 1989), Fig. 1.16; Y. Sivintsev, "Study of Nuclides Composition and Characteristics of Fuel in Dumped Submarine Reactors and Atomic Icebreaker 'Lenin': Part I — Atomic Icebreaker," Kurchatov Institute (Moscow), p. 5 (December 1993).

11. B.N. Papkovsky, Minatom, "Status and Problems of Marine Reactors Decommissioning in Russia," paper presented at Office of Technology Assessment Workshop, Washington, D.C. (17-18 January 1995).

12. For example, KN-3 type reactors, installed on the communication ship Kapusta, are fueled with 55–90 percent enriched uranium. Bulletin of Public Information, Atom-Inform, No. 4, p. 14 (1994). Also, LMR fuel is enriched to 90 percent U-235. Indeed, the HEU airlifted to the US from the Ulba metallurgical plant in Kazakhstan and described as submarine fuel for the Alfa program was characterized as uranium-beryllium alloy and beryllium oxide-uranium oxide ceramic fuel rods (90 percent enriched uranium). "Sapphire Sampling Plan," DE-AC05-84)R21400, Oak Ridge Y-12 (December

1994). Uranium-zirconium alloy fuel for some of icebreaker reactor cores is also 90 percent enriched. V.Zakharkin "Chemical Basis for Reprocessing Spent Fuel of Transport Reactors at the RT-1 Plant," paper presented at Office of Technology Assessment Workshop, Washington, D.C. (17–18 January 1995).

13. The amount of U-235 in each reactor dumped with fuel in the Kara Sea by the Soviet Navy was about 50 kgs. Y. Sivintsev, "Study of Nuclides Composition and Characteristics of Fuel in Dumped Submarine Reactors and Atomic Icebreaker 'Lenin': Part 2 — Nuclear Submarines," Kurchatov Institute, Moscow, pp. 3, 8–13 (August 1994).

An Echo II SSGN which exploded at Chazhma Bay on 10 August 1985 reportedly had 47 kg of uranium-235 in each reactor. Joshua Handler, "Preliminary Report on: Greenpeace Visit to Vladivostok and Areas Around the Chazhma Bay and Bolshoi Kamen Submarine Repair and Refueling Facilities, 9–19 October 1991," p. 8 (Washington, D.C.: Greenpeace, 6 November 1991).

14. Igor Spassky, head of the Rubin Submarine Design Bureau, said that 116 kg of uranium (U-235) remained in the sunken Komsomolets submarine's reactor. Yuri Teplyakov, "Black April," *Moscow News*, No. 48 (29 November 1992). One fuel assembly for a second generation reactor VM-4AM contains 1.4 kg of 20 percent enriched uranium. *Yaderny Kontrol*, Moscow, p. 14 (February 1995). Assuming 250 fuel assemblies per reactor, the total amount of uranium in the core is 350 kg and the U-235 content is 70 kg.

15. The Little Star shipyard may have participated in nuclear submarine construction in the early years as well.

16. V.I. Anufriyev, ITAR-TASS, "Subs Still to Be Built at Severodvinsk," (20 November 1992), (transcribed in FBIS-SOV-92-226, 23 November 1992, p. 2); "Severo-Zapad: The Center of Atomic Shipbuilding in the North," *Nezavisimaya Gazeta* (18 November 1992).

Despite President Yeltsin's declaration the actual situation at Komsomolsk remains unclear. In mid 1994, the shipyards' director, Pavel Bely reportedly told ITAR-TASS that the plant will not resume production of nuclear submarines because the government has only paid 50 percent of its debt to the shipyard. "No More Nuclear Subs to be Built in Komsomolsk," *Military-Industrial Complex Newsletter*, p. 4 (September 1994).

However, another recent article suggests that some of the partially completed submarines at Komsomolsk-na-Amure may yet be finished. Valery Marinin, "Nuclear Submarine Construction in Russia," *Military Parade* (Moscow), p. 119 (March/April 1995).

Also, U.S. Naval Intelligence reported in 1994 that Russian television showed two more Akula SSNs under construction at Komsomolsk-na-Amure. Director of Naval Intelligence, *DNI Posture Statement*, p. 39 (1994).

In any event, Komsomolsk only produced Akula SSNs as of the 1980s, and Akula production is coming to an end.

17. Valery Marinin, "Nuclear Submarine Construction in Russia," *Military Parade* (Moscow), p. 115, authors' estimates (March/April 1995).

18. The use of service vessels was also promoted by the post World War II shift of emphasis from the Baltic and Black Sea Fleets to a build-up of the Northern and Pacific Fleets in the 1950s. Difficulties in constructing adequate shore-based logistical to some degree contributed to the use of service vessels as substitutes.

19. Lev Giltsov, Nicolai Mormoul, Leonid Ossipenko, *La Dramatique Histoire des Sous-Marins Nucleaires Sovietiques*, Robert Laffont: Paris, pp. 126–127, **154** (1992).

20. See Joshua Handler, "The Northern Fleet's Nuclear Submarine Bases," *Jane's Intelligence Review*, pp. 551–556 (December 1993); Joshua Handler, "Russia's Pacific

Fleet — Submarine Bases and Facilities," *Jane's Intelligence Review*, pp. 166–171 (April 1994).

21. This most probably only occurred at Severodvinsk, and perhaps at Rosta. In the Far East, fresh fuel was delivered to the Shkotovo waste site before being transferred to the Navy PMs for the refueling operations. Refueling operations at the Kola shipyards other than Rosta (to which fresh fuel was delivered directly by rail) would also have involved Navy PMs.

22. This capability also may have extended to being able to refuel submarines at sea. In the case of the civilian ice-breaker fleet, the Lotta refueling ship reportedly had such a capability.

23. Refueling operations include (a) removing a portion of the submarine hull and lifting the reactor lid, disconnecting the primary cooling circuit, removing spent fuel, inserting fresh fuel, and sealing the reactor and the submarine. Fuel is removed assembly by assembly by the cranes of the service ship with the help of a special metal sleeve to shield spent fuel. Spent fuel is accommodated inside cylindrical cases which are placed in the storage tanks of the service ship.

24. Arthur D. Baker III, "Their Ship Types: Part III," *U.S. Naval Institute Proceedings*, p. 172 (October 1982).

25. Statement by Admiral N.Yurasov of the Nuclear Safety Inspectorate of the Ministry of Defense. (BBC Summary of World Broadcasts, March 14, 1995.)

26. At the Shkotovo waste site, spent fuel is stored in an array of cylindrical cells made in the concrete floor of the storage building. Each cell contains a case with seven fuel assemblies.

27. Unlike casks of the old TUK-11/12 designs, new TUK-18 casks are capable to withstand a head-on collision without losing their integrity and can operate in a broad range of temperatures.

28. Submarine training was also conducted at other facilities, including the leading Soviet submarine school and shipbuilding plant (presumably at Severodvinsk). According to the US Naval Intelligence, two or three crews were trained for each submarine, so that the crews could alternate. Reportedly this was done both to train crews for other submarines, but also to avoid overexposure to radiation. U.S. Navy, Office of Naval Intelligence, "Soviets Believed To Have Operational Nuclear Submarines," (secret) *ONI Review*, **16**, No. 2, p. 52 (February 1961), (declassified by ONI, 19 July 1993).

Subsequently, the Obninsk facility has become a center for reactor training of crews of SSN and SSGN submarines.

29. Alexander Emelianenkov, "Russia Is Leaving the Baltic Region... and Takes Away Its Radioactive Waste," *Rossiyskaya Gazeta* (17 June 1993).

30. In regards to Sevastopol see: Senior Lieutenant V. Fatigarov, "Do Not Be Discouraged, Naval Cadets?" *Krasnaya Zvezda* (27 February 1992), (translated in JPRS-UMA-92-011, p. 27, 1 April 1992); I. Chernyak "Komsomolskaya Pravda Investigation: The Russian Fleet has Opened Its Kingston Valves," *Komsomolskaya Pravda* (25 December 1992), (translated in JPRS-UMA-93-011, p. 46, 31 March 1993); Valeriy Anuchin interviews Vice Admiral Oleg Yarofeyev, new commanding officer of the Northern Fleet, Moscow Mayak Radio Network (21 April 92), (transcribed/translated in FBIS-SOV-92-077, 21 April 1992, p. 11); I. Chernyak, "The Russian Navy is Surrendering Without a Fight," *Rabochaya Tribuna* (18 December 1992), (translated in JPRS-UMA-93-011, 31

March 1993, p. 45); Interview with Admiral Felix Gromov, "Reforming the Russian Navy," *Naval Forces*, No. IV, p. 10 (1993).

31. Vladimir Kucherenko, "Smoking Even in Mines," *Rossiyskaya Gazeta* (16 March 1995).

32. However, some submarines are in an "eight-compartment configuration," which means that only some stripping down of the superstructure and sealing of the hull has occurred.

The Navy would like to move to a one-compartment configuration, but lack of financing is precluding the financing of this plan; Captain 1st Rank P. Bogdanov, "Nuclear-Powered Submarine Decommissioning: The Problem Sharpens," *Morskoi Sbornik*, No. 5 (1994).

33. Collegium for Issues of Environmental Protection with the Administration of the Arkhangelsk Oblast, "Memorandum On the Course of Implementation of the Programs for Handling Radioactive Waste and Spent Nuclear Fuel on the Territory of the City of Severodvinsk," (June 1994); Joshua Handler, "The Northern Fleet's Nuclear Submarine Bases," *Jane's Intelligence Review*, pp. 551-556 (December 1993); Joshua Handler, "Russia's Pacific Fleet — Submarine Bases and Facilities," *Jane's Intelligence Review*, pp. 166–171 (April 1994).

34. Spurred by fears of a radiation accident, opposition by local residents has had at times a significant impact on the Navy's decommissioning plans. In the summer of 1990, residents of the area around Sovetskaya Gavan, Vanino, and Zavety Ilyicha successfully stopped the Pacific Fleet's plans to offload the fuel from four retired first generations submarines at the Zavety Ilyicha base. The Murmansk administration has also forbid the offloading of cores at the Rosta shipyard which is in the city. The City Council of Severodvinsk prohibited the preparation of reactor compartments for storage afloat which still contained their spent nuclear fuel and also constrained the Navy from sending any more decommissioned submarines with spent nuclear fuel aboard to Severodvinsk.

35. Although Russia has a number of large submarine construction facilities, they are not so easily "reversed" into a submarine scrapping capability.

As early as 1990, U.S. Naval Intelligence knew the Soviet Navy was having trouble scrapping nuclear submarines due to a lack of capacity. Rear Admiral Thomas A. Brooks, Director of Naval Intelligence wrote, "The scrapping of old nuclear submarines [in 1990] was slowed not by requirement to keep the boats in the order-of-battle, but by the unavailability of enough scrapping facilities to accommodate them and the absence of a program to dispose of the reactors and nuclear material." He added, "Environmental concerns, late to surface in the Soviet Union, precluded following the traditional Soviet disposal method of merely dumping the material at sea." Rear Admiral Thomas A. Brooks, "The Soviet Navy in 1990: A U.S. View — Still Cautious," U.S. Naval Institute, *Proceedings*, Naval Review 1991, p. 184 (May 1991).

In 1991, U.S. naval intelligence concluded that in general, "Although each Soviet fleet has a limited capability to scrap units, existing breaker yards can handle only a few units at a time. The Soviets announced construction of four larger, more modern breaker yards (one per fleet) to be used to scrap the over 200 naval combatants currently assessed as immediately available for scrapping, plus an untold number of merchant and fishing ships. They initially announced that these new yards would be operational in 1990, but none has been completed." Naval Intelligence Command, Naval Operational Intelligence Center, "Soviet Naval Scrapping — An Economic Necessity," NIC-2660S-017-91, p. ix, partially declassified and released under the Freedom of Information Act (September 1991).

36. The Alfa class submarines were originally built in a specially prepared building hall No. 42 of the SMP. This same hall now seemingly is used for their disassembly.

37. See Collegium for Issues of Environmental Protection with the Administration of the Arkhangelsk Oblast, "Memorandum On the Course of Implementation of the Programs for Handling Radioactive Waste and Spent Nuclear Fuel on the Territory of the City of Severodvinsk," (June 1994); The Resolution of the Government of the Russian Federation, "On Measures for the Commencement of Experimental Decommissioning of Submarines and Surface Ships Retired from the Navy, No. 514, Moscow (24 July 1992).

The shipyard's deputy-director recently claimed not enough funds were allocated to construct the scrapping facility; Nikolai Zlaman, deputy director of the Nerpa shipyard, "Seventy Nuclear 'Bombs' Near Murmansk: Submarine Decommissioning Cannot Be Postponed," *Krasnaya Zvezda* (17 December 1994).

38. See: START I "Memorandum of Understanding on the Establishment of the Data Base," (data as of 1 September 1990) and the "START Treaty Memorandum of Understanding Data Notification," released by the U.S. Arms Control and Disarmament Agency on 7 April 1995 (data was effective as of 5 December 1994, barring corrections resulting from the subsequent verification inspections).

39. Initially, only the Little Star and the Zvezda plants were the START-designated SLBM dismantlement facilities.

40. The rate of 3.5 submarine per year is required in order to dismantle at least another 28 SSBNs that will be retired by the end of 2002, if the START II treaty is ratified.

41. Some submarines at Severodvinsk have been tied-up with their spent fuel on board for over 15 years.

42. The Murmansk shipment also included some Navy fuel which has been on the premises of the Murmansk Shipping Company.

43. They have until 1 June 1995 to do so, but if they do not or are tardy in their applications, spent fuel shipments may continue from the Murmansk Shipping Company's icebreakers' fleet, but the Navy itself will face delays in shipping its spent nuclear fuel or will not be able to ship it at all.

44. 1,057 of 1,132 cells for storing spent nuclear fuel at the Shkotovo waste facility are full. The radioactive inventory of the spent fuel in the Pacific Fleet is four million curies. Capt. 1st Rank, Viktor M. Zakharov, Chief of Radioactive, Chemical, and Biological Protection Service of the Russian Navy, "The Status of and Solutions to the Problem of Handling Radioactive Waste at the Pacific Fleet;" Capts. 1st Rank V. A. Danilyan and V. A. Vysotksy, "Nuclear Waste Disposal Practices in Russia's Pacific Ocean Region," presentation made at "Japan-Russia-United States Group on Dumped Nuclear Waste in the Sea of Japan, Sea of Okhotsk, and the North Pacific Ocean," organized by Mississippi State University, Vanderbilt University, and U.S. Geological Service, Biloxi, MS (12–13 January 1995).

45. The Navy is considering sending spent fuel by sea to the Zvezda shipyard which would serve as a rail terminal for shipments to Mayak. However, poor technical conditions of Zvezda piers and the inability of the Navy to pay the shipyard for fuel transfer operations make implementation of this plan unlikely as of early 1995.

46. Each special train car for transport of the TUK-18 casks cost some $200,000 in 1994 prices. Minatom currently does not plan to spend $800,000 for the four cars needed to form a new train.

47. The capacity can be somewhat increased by using neutron absorbers.

48. These two ships are also reportedly in poor shape and in danger of sinking.

49. Land-based processing facilities had been constructed in the Northern and Pacific Fleet waste storage facilities and at shipyards but were never put into operation as dumping of LRW at sea proved to be easier and cheaper.

The Malina and PM-124 class ships have a temporary LRW storage capacity after which the LRW was transferred to TNTs for dumping at sea. There are also two Amur class special tankers which are used to hold LRW (one each in the Northern and Pacific Fleet). Also, some shipyards or naval bases have temporary holding tanks (either on land or floating), small barges, or other tankers for the temporary storage of LRW prior to dumping.

SRW is also temporarily stored on the service ships before transfer to the land-based naval storage sites or dumping at sea. Some shipyards also have a SRW storage facility. There is also a SRW storage facility at Mironova Mountain near Severodvinsk. See: Collegium for Issues of Environmental Protection with the Administration of the Arkhangelsk Oblast, "Memorandum On the Course of Implementation of the Programs for Handling Radioactive Waste and Spent Nuclear Fuel on the Territory of the City of Severodvinsk," (June 1994).

In the Pacific, as of 1995, the Pacific Fleet had accumulated some 10,000–16,000 m^3 of SRW with up to 300,000 Ci of activity and 5,000–6,500 m^3 of LRW with an activity of up to 65 Ci. Some 5,000 m^3 of SRW and 2,000 m^3 of LRW were anticipated to be accumulated a year for the next 10-15 years under the current fleet decommissioning schedule. Capt. 1st Rank, Viktor M. Zakharov, Chief of Radioactive, Chemical, and Biological Protection Service of the Russian Navy, "The Status of and Solutions to the Problem of Handling Radioactive Waste at the Pacific Fleet;" Capts. 1st Rank V. A. Danilyan and V. A. Vysotksy, "Nuclear Waste Disposal Practices in Russia's Pacific Ocean Region." Presentations made at "Japan-Russia-United States Group on Dumped Nuclear Waste in the Sea of Japan, Sea of Okhotsk, and the North Pacific Ocean," organized by Mississippi State University, Vanderbilt University, and U.S. Geological Service, Biloxi, MS (12-13 January 1995).

In the North, the facilities in Severodvinsk generate around 500 m^3 of SRW and 2,000–3,000 m^3 of LRW a year; Collegium for Issues of Environmental Protection with the Administration of the Arkhangelsk Oblast, "Memorandum On the Course of Implementation of the Programs for Handling Radioactive Waste and Spent Nuclear Fuel on the Territory of the City of Severodvinsk," (June 1994).

Overall, the Northern Fleet generated about 3,000–4,000 m^3 of SRW a year during 1981-1993. The annual volume increased 2–2.5 times during this period and was expected to grow further due to the decommissioning program. As for LRW, from 1981–1993, the Northern Fleet generated about 8,000–12,000 m^3 a year. Col. Oleg Petrov, Chief of the Navy's Medical Service, "Radioactive Waste Generated by Boat Nuclear Power Plants," presentation at International Meeting on Assessment of Actual and Potential Consequences of Dumping of Radioactive Waste into Arctic Seas, conference sponsored by the IAEA, Norwegian Radiation Protection Authority, Scientific Production Association Typhoon, Oslo (1–5 February 1993).

50. The capacity of the existing waste treatment facility is 1200 m^3 of LRW per year. This is enough to meet requirements of the icebreaker fleet. The goal of the US-Norway-Russia project is to upgrade the facility to process 5000 m^3 of LRW per year. This would take care of liquid waste generated by both the submarine and icebreaker fleets in the North.

51. As of mid-March 1995, a contract for the construction of the facility still was not signed.

52. Yuriy Grachev, "The Pacific Fleet has Begun to Dispose of Radioactive Waste," ITAR-TASS (20 March 1995), Capts. 1st Rank V. A. Danilyan and V. A. Vysotksy, "Nuclear Waste Disposal Practices in Russia's Pacific Ocean Region"; Joshua Handler, "The Radioactive Waste Crisis in the Pacific Area," presentation made at "Japan-Russia-United States Group on Dumped Nuclear Waste in the Sea of Japan, Sea of Okhotsk, and the North Pacific Ocean," organized by Mississippi State University, Vanderbilt University, and U.S. Geological Service, Biloxi, MS (12-13 January 1995); Vladimir Maryukha, "The Retired Nuclear Ships Have Not Left Us Any Choice: Either We Bury Them, or They Bury Us," *Krasnaya Zvezda* (14 September 1994).

53. Vladimir Gundarov, "'Bottles' For Atomic Genie," *Krasnaya Zvezda* (29 November 1994).

54. Doug Mellgren, "Russia-Atomic Legacy," Associated Press (7 December 1994); The Council of Ministers — The Government of the Russian Federation, "Decree On Urgent Works in the Field of Handling Radioactive Waste and Spent Nuclear Materials," No. 805 (6 July 1994).

55. Russian Federal Nuclear Inspectorate [Gosatomnadzor], "Report on Activity of Russia's Federal Inspectorate for Nuclear and Radiation Safety in 1993, Parts I, II," Approved by Order of the Gosatomnadzor, No. 61, Moscow (13 May 1994); Nikolai Zlaman, deputy director of the Nerpa shipyard, "Seventy Nuclear 'Bombs' Near Murmansk: Submarine Decommissioning Cannot Be Postponed," *Krasnaya Zvezda* (17 December 1994); Capitan 1st Rank B. Tyurin, "The SSN — In Retirement. For How Long," Morskoy Sbornik, No. 4 (April 1992), (translated in JPRS—UMA—92–024, p. 9, 1 July 1992.)

56. Joshua Handler, "No Sleep in the Deep for Russian Subs," *Bulletin of the Atomic Scientists*, pp. 7 ff (April 1993).

57. For discussions of the non-implementation of various programs see for example Nikolai Zlaman, deputy director of the Nerpa shipyard, "Seventy Nuclear 'Bombs' Near Murmansk: Submarine Decommissioning Cannot Be Postponed," Krasnaya Zvezda (17 December 1994). Captain 1st Rank P. Bogdanov, "Nuclear-Powered Submarine Decommissioning: The Problem Sharpens," Morskoi Sbornik, No. 5, 1994. Administration of the President of the Russian Federation, Facts and Problems Related to the Dumping of Radioactive Waste in the Seas Surrounding the Territory of the Russian Federation. Materials from a government report on the dumping of radioactive waste, commissioned by the President of the Russian Federation, Decree No. 613, (24 October 1992), Moscow (1993), (translated in JPRS-TEN-93-005-L, 17 June 1993); Captain 1st Rank B. Tyurin, "The SSN — In Retirement. For How Long," *Morskoy Sbornik*, No. 4 (April 1992), (translated in JPRS- UMA-92-024, 1 July 1992, pp. 8-10); Joshua Handler, "Greenpeace Trip Report. Subject: Radioactive Waste Situation in the Russian Pacific Fleet, Nuclear Waste Disposal Problems, Submarine Decommissioning, Submarine Safety, and Security of Naval Fuel," Moscow/Washington, D.C.: Greenpeace (27 October 1994).

For recent state programs see: "State Program of Russia For Handling Radioactive Waste and Spent Nuclear Materials, for Their Disposal and Burial in 1992–1995, and in Prospect till 2005;" The Council of Ministers — The Government of the Russian Federation, "Decree On Urgent Works in the Field of Handling Radioactive Waste and Spent Nuclear Materials," No. 824 (14 August 1993); The Council of Ministers — The Government of the Russian Federation, "Decree On Urgent Works in the Field of Handling Radioactive Waste and Spent Nuclear Materials," No. 805 (6 July 1994).

Also, the dissolution of the Soviet Union in the mid 1991 to 1992 period complicated the legal implementation of decrees and programs as agreements signed between agencies under the Soviet Union had to be renegotiated and signed, sometimes with newly appointed officials.

58. Most recently, Commander-in-Chief of the Russian Navy Admiral Feliks Gromov told a Duma committee hearing in late October 1994 that from 1988, the Navy has been "agonizing" to solve one problem: "what to do with retired ships." Vladimir Yermolin, "Will the State Duma Help the Russian Navy?" *Krasnaya Zvezda* (25 October 1994).

Next in early November 1994, first deputy Commander-in-Chief of the Navy Admiral Igor Kasatonov told a meeting of the Collegium of the Defense Ministry about the size of the decommissioning problem, and that there was no unified comprehensive plan for dealing with radioactive waste. Thus, the problem was not being solved efficiently. Information and Press Directorate of the Defense Ministry of Russia, "Meeting of the Collegium of the Defense Ministry of the Russian Federation," *Krasnaya Zvezda* (2 November 1994).

In mid-November 1994, President Yeltsin even mentioned the need to deal with the submarine decommissioning problem in a major speech about the military. *Krasnaya Zvezda* (15 November 1994).

Finally, on 14 March 1995, First Deputy Prime Minister Oleg Soskovets presided over a meeting of the Russian government commission for operational matters, which discussed the nuclear submarine decommissioning problem. This governmental meeting was preceded by a trip by Deputy Minister of Defense Andrei Kokoshin and a large delegation of government and military officials to the Northern Fleet. One purpose of the visit was to examine the nuclear submarine decommissioning problem. ITAR-TASS, "Russia has Scrapped 126 Nuclear-powered Submarines (14 March 1995), (reprinted in BBC Summary of World Broadcasts March 16, 1995) and Andrey Garavskiy and Vladimir Gundarov, "Northern Fleet — the Naval Component of Russia's Nuclear Might," *Krasnaya Zvezda* (14 March 1995), (translated in FBIS-SOV-95-049, pp. 30–31, 14 March 1995).

59. Admiral F. Gromov, "The Navy Last Year," *Morskoy Sbornik*, No. 12 (December 1994), (translated in JPRS—UMA—95–007, 21 February 1995, p. 47).

60. Captain 1st Rank P. Bogdanov, "Nuclear-Powered Submarine Decommissioning: The Problem Sharpens," *Morskoi Sbornik*, No. 5 (1994).

61. As of October 1994, only 2.7 billion ruble were transferred to Nerpa. The 1994 defense orders totaled at 40 billion ruble. Nikolai Zlaman, deputy director of the Nerpa shipyard, "Seventy Nuclear 'Bombs' Near Murmansk: Submarine Decommissioning Cannot Be Postponed," *Krasnaya Zvezda* (17 December 1994).

62. Workers at the Zvezda plant at Bolshoi Kamen complained in early 1994 that government owed the plant an equivalent of $22 million for work on nuclear submarines. Ralph Boulton, "Workers at Nuclear Submarine Plant Lose Patience With Moscow," Reuters (7 March 1994).

63. The project, a part of the strategic delivery vehicle dismantlement agreement, provides $25 million worth of equipment and services. This includes shears, cable cutters, and other shipbreaking equipment.

64. For example, the liability problem was largely resolved for the purpose of safety upgrades at Russian nuclear power plants. The Russian Federation and the European Commission signed a Memorandum of Understanding (February 27, 1995) that provides indemnity from nuclear liability for western companies working under the EC's Tacis program. (*Nucleonics Week*, 2 March 1995.)