Technological Aspects and Necessary Engineering Means for Nuclear Multi-Purpose Submarine Dismantling in the North-Western Region of Russia

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1. PURPOSE

The Report deals with the unsolved problems of Nuclear Multi-Purpose Submarines dismantling at the Shipbuilding and Shiprepair Plants of the North-Western region of Russia based on the experience of the dismantlement of more than thirty Strategic Submarines (SSBNs).

2. HISTORY

Dismantling is the final stage of any weapon life cycle.

It is ordinary process. Designers of the first Nuclear Submarine (NS) did not take Navy and industry problems of NS dismantling into account.

Suffice it to say that general requirements of NS dismantling were included in the RF standard concerning NS design only in 1994.

In the late sixties the problem of NS dismantling emerged for the first time when the Soviet Union and the USA faced with necessity of accident NS disposal. At that time the economical method was used: in 1968 the USA damped the accident reactor of the Seawolf NS at the coast of Delaware state at the depth of 2800 m. In the Soviet Union accident reactors of NS were damped in the area of Novaya Zemlya.

At the end of 80-ies the decommission of NS in the USA, the United Kingdom, France and the Soviet Union showed that neither of countries have been ready to solve the problems of NS dismantling.

From 1955 four hundred and seventy eight Nuclear Submarines were built in the world. Now more than two hundred and seventy five Nuclear Subs are decommissioned. In Russia one hundred and eighty three NS (total number is two hundred and forty nine) are decommissioned being at the end of their service life in accordance with "Treaty on Further Reduction and Limitation of Strategic Offensive Arms".

In addition long-term storage of reactor compartments (RC) is a threat for environment and radiation safety of NS storage areas.

Nuclear Powered Ships construction demanded the solve of nuclear and radiation safety problem in the operation and overhaul of NS and Ships.

In Russia the underestimation of the problem led to that fact that RW management infrastructure has been constructed slowly.

The dismantlement of decommissioned NS including the Multi-Purpose ones becomes the serious problem for Russia and the international community.

NS are stored at the holding areas near Murmansk and Severodvinsk not far from Scandinavian countries for a long time Their equipment is in a bad state.

3. BASIC WORKS

"Conception of Nuclear Powered Submarines and Ships Dismantling" approved by Minatom and GOST PB 50811 Standard determines basic works of NS dismantling.

In conformity with requirements of these documents NS dismantling includes the following operations:

- NS decommissioning and interim storing afloat;
- NS towing to the Shipyard, preparation and unloading of Spent Nuclear Fuel (SNF);
- NS delivery to the slipway and RC cut-out as three-compartment unit;
- Removal of bow and aft ends of the Submarine;
- SNF shipment and treatment, Radioactive Waste (RW) collection, conditioning and disposal;
- Secondary materials processing and sale;
- Industrial toxic waste collection, treatment, shipment and disposal;
- Reactor Compartment preparation to transportation and interim storage afloat (till on-shore storage facility is available);
- RC units transportation from interim storage facility to the Shipyard, preparation and delivery to on-shore storages;
- RC long-term storage in the long-term storage facilities with future disassembling and RW with high activity disposal.

NS dismantling procedure differs from other weapons recycling because NS has nuclear power installation.

4. GENERAL TECHNOLOGICAL PLAN OF NS DISMANTLING

Now the below given procedures of NS dismantling are used at the Shipyards of the North-Western Region of Russia:

- NS preparation for interim storage afloat (without RC cutting out) – multi-compartment unit;
- Three-compartment units cutting out and interim storage afloat (RC with two adjacent compartments or floats), Sub's bow and aft ends removal;
- NPS dismantling with RC cutting out and storing in the long-term storage facility.

Now three-compartment approach of NPS dismantling is used as the most expedient. The following technological plan is applied:

- NS preparation for dismantling;
- Delivery to the slipway;
- Three-compartment units cutting out and formation;
- Three-compartment units launching;
- Three-compartment units towing to the interim storage facility;
- Three-compartment units interim storage afloat;
- Equipment removal in Sub's bow and aft ends;
- Hull's structures cutting out into large parts;
- Large parts cutting into martin pieces;
- Processing of removed equipment, pipes, cables as a secondary raw materials;
- RW and toxic industrial waste collection and delivery for treatment and disposal.

Figure 1 shows organizational flow diagram of the NS dismantling with selection of different stages.

But it is necessary to note that one-compartment way of NPS dismantling is the most safe from the ecological point of view and it can be carried out in accordance with the technological plan given below:

- Design and technological preparation of production;
- NS preparation for dismantling;
- Delivery to the slipway;
- RC cutting out
- RC disposition at the interim storage sites at the Shipyards of Rossudostroyenie Agency;
- RC towing to the regional interim storage facility;
- Equipment removal in Sub's bow and aft end;
- Hulls cutting into large parts;
- Large parts cutting into martin pieces;
- Processing of removed equipment, pipes, cables as a secondary raw materials;
- RW and toxic industrial waste collection and delivery for treatment and disposal.

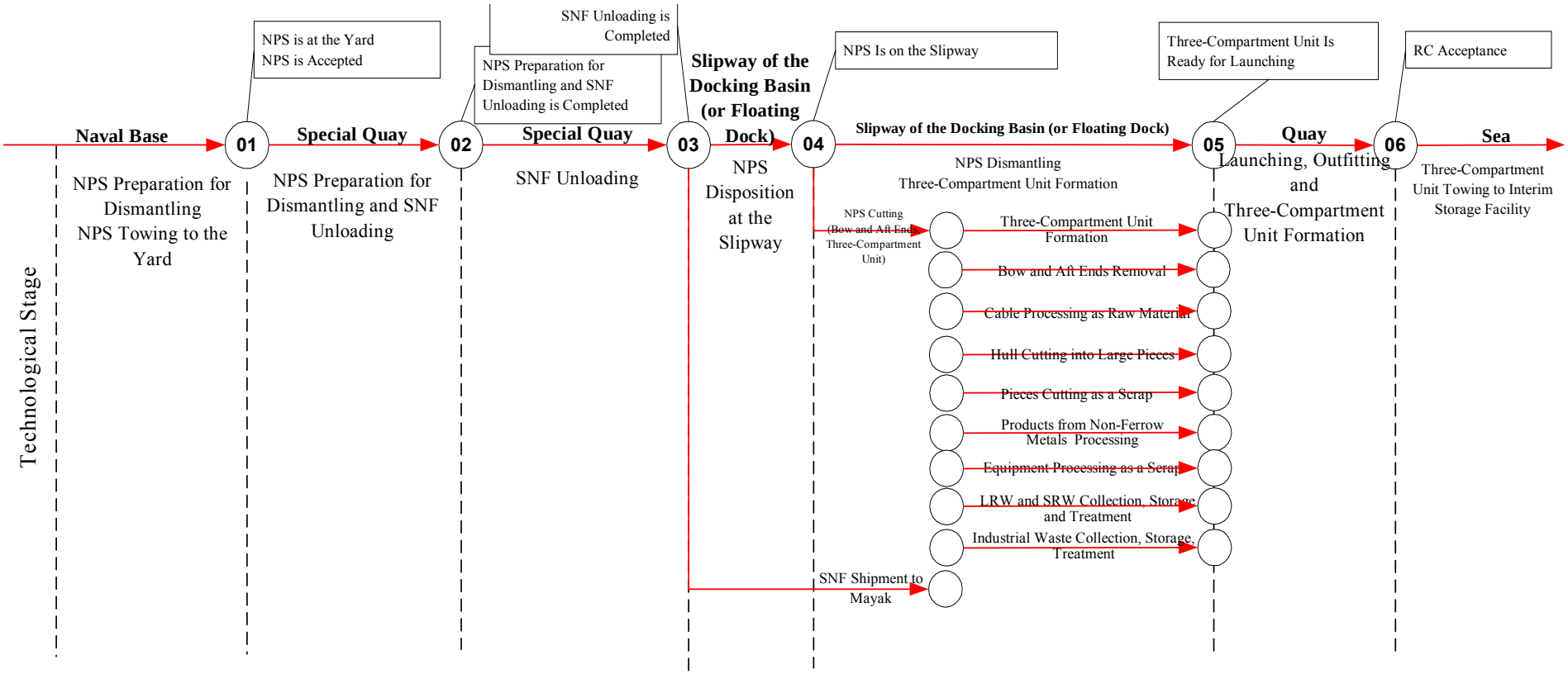


Fig. 1 Organizational flow diagram of the NS dismantling

4.1 INDUSTRIAL EQUIPMENT FOR NS DISMANTLING

The List of the main industrial equipment is given in Tables 1 and 2.

The List of equipment delivered by the US Department of Defense to "Zvezdochka" and "Nerpa" Shipyards in the frame of international cooperation is given in Table 3.

Table 1 - List of the Main Industrial Equipment For NS Dismantling

Description	Document	Note
1. Special Quay. NS Preparation for Dismantling and SNF Unloading		
1.1 The set of the special industrial equipment for NS mooring	-	The special quay is equipped with three portal cranes with the lifting capacity of 80 tons
1.2 The removable enclosure at the NS superstructure	НЯДИ.305117.002МЧ (Т291.1335.022МЧ)	
1.3 Ladders, power gangways, catwalk bridges	Т291.0133.055 ИО	
1.4 The outboard scaffold	НЯДИ.364514.001 (Т291.1521.042)	
1.5 The plan of fuel and oil tanks steaming	НЯДИ.302389.041	
1.6 The contamination control area with ladders, passageways, and platforms	Т291.1335.091	
1.7 The plant for the reactor compartment ventilation	НЯДИ.362912.056	
1.8 SRW containers	610.16-Г4-0599.00сб	
1.9 LRW tanks	Т291.6263.003	
1.10 The coaming with the cover	71.Б2-479.00	
1.11 The scaffold for SNF unloading	Т291.1521.057МЧ	
1.12 Pads		
1.13 Extension rods	Т291.4727.333	
1.14 The piping for chemical agents introduction, agitation, and air removing	Т291.4727.330, Т291.4727.307	
1.15 The transfer tank for the vacuum plant	610.16-Б5-0948.00	
1.16 The vacuum plant	71В3-613.00А	
1.17 The auxiliary platform in the reactor compartment's area	71.Б2-479.00	
1.18 The floating health monitoring facility	-	
1.19 Containers for the industrial waste: - metal scrap;	610.16-Б5-0909.00 71.Г4-284.00 82.72.2542.503	

Description	Document	Note
- thermal insulation, special lining, etc. a) Special Quay. NS Preparation for Dismantling and SNF Unloading 1.1 Special industrial equipment set for NS mooring	-	The special quay is equipped with three portal cranes with the lifting capacity of 80 tons
2. Special Quay. SNF Unloading		
2.1 The set of the special industrial equipment for NPS mooring	-	The special quay is equipped with three portal cranes with the lifting capacity of 80 tons.
2.2 The hanging scaffold	НЯДИ.364514.001сб (Т291.1521.042сб)	
2.3 The removable enclosure at the NS superstructure	НЯДИ.305117.002МЧ (Т291.1335.022МЧ)	
2.4 Power gangways, catwalk bridges	Т291.0133.055 ИО	
2.5 SRW containers	610.16-Г4-0599.00сб	
2.6 LRW tanks	Т291.6263.003	
2.7 Containers for the industrial waste: - metal scrap; - thermal insulation, - special lining, etc.	610.16-Б5-0909.00 610.16-Б5-0921.00 82.72.2542.503 71.Г4-284.00 МО5-232-00	
2.8 The set of SNF transloading equipment	ОК-300ПБ	It is included in the Tender's standard equipment
2.9 The removable enclosure over the technological cut-out of the reactor compartment ("Rubka" enclosure)	326М-283-390	It is included in the Tender's standard equipment
2.10 The vacuum plant	-	
2.11 The tank for primary circuit drainage	Т291.6263.003	
2.12 The contamination control area with ladders, passageways, and platforms	Т291.1335.091	
2.13 The plant for reactor compartment ventilation	-	

Description	Document	Note
2.17 The auxiliary platform in the reactor compartment's area	71.Б2-479.00	
2.18 The floating health monitoring facility	-	
2.19 Tender (Project # 2020)		
3. Docking Basin. NS Dismantling. The Formation of Three-Compartment Unit		
3.1 Cribbing	-	The docking basin is equipped with three portal cranes with the lifting capacity of 30 tons.
3.2 Hauling carriages system for bow and aft ends transportation	-	
3.3 Keel-track cribbing	-	
3.4 The guard rail at the NS superstructure	НЯДИ.305117.002МЧ (Т291.1335.022МЧ)	
3.5 Ladders, power gangways, catwalk bridges	Т291.0133.055 ИО	
3.6 The permanent scaffold	-	
3.7 Platforms for equipment, cables, and structures unloading	-	
3.8 The temporary tubular scaffold	-	
3.9 Sections of the enclosure and sites of Contamination Control Area	71.Б3-303.50.08 71.Б3-303.50.09	
3.9 Sections of the enclosure and platform of the contamination control area	71.Б3-303.50.08 71.Б3-303.50.09	
3.10 The auxiliary platform in the reactor compartment's area	71.Б2-479.001	
3.11 Companion locks	Т.291.5721.1211	
3.12 SRW and LRW containers	-	
3.13 Containers for non-radioactive waste collection	610.16-Б5-0909.00 82.72.2542.503 71.Г4-284.00	
4. Sites for Hull Structures Cutting as a Scrap.		
4.1 Sites for hull sections cutting as a scrap	-	Sites are equipped with: - gantry crane (12 tons); - crane (32 tons) - traveling crane (18 tons).
4.2 Temporary scaffold	-	
4.3 Ladders, gangways, and guard rails	-	
4.4 The technological schemes and route cards for sections cutting and	-	

Description	Document	Note
scrapping, plans of weight slinging and transportation 4.5 Containers for production waste collection: - metal scrap; - thermal insulation, special lining, etc.; 4.6 Multi jaw grab 47 La Bounty shears 4.8 Temporary scaffold 4.9 Ladders, gangways, and guard rails	 610.16-Б5-0909.00 610.16-Б5-0921.00 82.72.2542.503 71.Г4-284.00 МО5-232-00 Model 3392 (with the lifting capacity of 2000 kg) - - -	 At the site near Building 26 and at the site of mechanical cutting
5. Scrap Shipment		
5.1 Platform for slinger 5.2 Ladders for railway wagons 5.3 Technological plans of scrap loading into railway wagons	- - -	Site is equipped with wagon balances, cranes with lifting capacity of 12 tons, 32 tons
6. Hull's structures cutting by Harris guillotine **7. Cable Processing** **8. LRW and SRW Treatment**		

Table 2 – List of Equipment for Hull's Structures Removal

Equipment	Operations
1 "Plamya 62" Cutter for hand cutting 2 РВДУ-500-1 Air Arc Cutter 3 УПР-201 У3 Plasma Cutting Installation	Pressure and outer hulls cutting into large pieces, hull's structures cutting into martin pieces
4 "Volna" Pneumatic Stripping Tool 5 ТПЦ-1 Pneumatic Turbine 6 ТУ5.978-13235-79 Pneumatic Brush	Paint coating removal in the area of hull's structures cutting, epoxy putty removal.
7 ИП-4109, ИП- МР-6 (УВ4)4110 Pneumatic Hammers	Rubber Removal
8 Balances 9 Electric Loader	Work with metal

Table 3 List of Imported Equipment

Equipment	Operation
"L-Tech Deuce Pac 150" Plasma Cutters	Hull's structures cutting (thickness is 80 mm).
1. "Harris 62-3EL" Cutter	Hull's structures cutting.
"La Bounty MPS-150" Shears	Hull's structures cutting
"Caterpillar".	
2. "Triple S Dynamics, Inc" Installation.	Cable shredding.
3. "KEI –5015-3" Portable Filter Ventilation Installation	Ventilation.
4. "Neoretic TF3" protection helmet for cutters and welders	Eyes protection
5. BSH-30-2205A Automatic Shears	Hull's structures cutting
6. Span Deck Crane, Model 3612	
7. Electrical fork loader	
8. Rotary Air Compressor and system of air distribution	
9. Platform Balance	
10. Wagon Balance	
11. On-shore SNF Unloading Facility	
12. Treatment installation of RW with low activity in:	
– LRW treatment line;	
– LRW treatment facility;	
– Special laundry	

4.2. LABOR INTENSITY OF NUCLEAR MULTI-PURPOSE SUBS DISMANTLING

The labor intensity of NS dismantling depends on the constructive features of the Project, scope and nomenclature of works, organization of production.

The labor intensity and duration of each NS dismantling depend on following factors:

– NS technical condition, including reactor core state (level of NS radiation contamination);

– Technical equipment of the Shipyard;

– Chosen way of NS dismantling (one or three-compartment units formation, procedure of Sub's ends cutting).

The considerable reduce in labor intensity (up to 60 %) is in the progress of following works execution:

- RC formation and preparation for long-term storage;
- Equipment and special lining removal from the bow and aft ends of the Submarine (up to 40 %).

Standard indices of labor intensity of Yankee SSBN dismantling at "Zvezdochka" were reduced by 40-55 % in comparison with 1992. Fig.2**.**

The labor intensity of main stages of work for three-compartment and one-compartment approaches of NS dismantling is given in Fig.3.

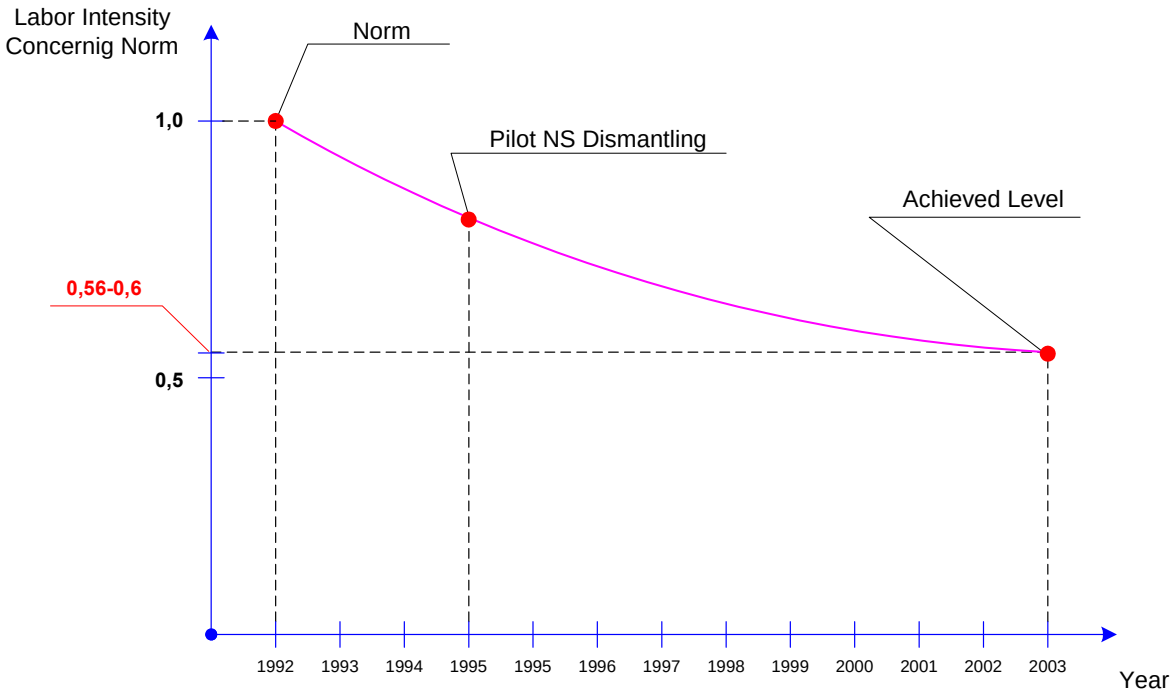
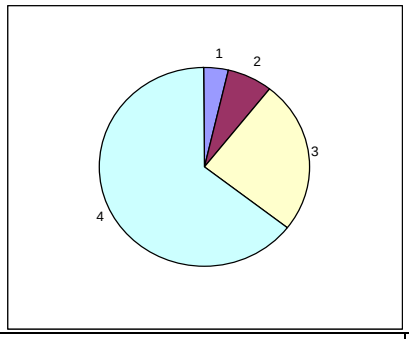
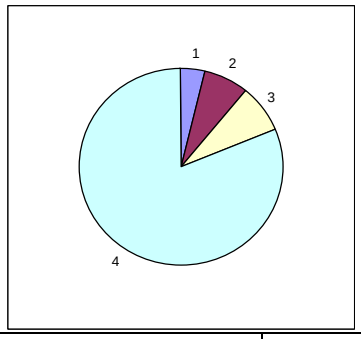


Fig.2 - Schedule of Decrease in Labor Intensity of NS Dismantling Works





Description	Three-Compartment Unit	One-Compartment Unit
NS Acceptance for Dismantling	3,6-3,9	3,7-4,0
SNF unloading	6,5-7,5	6,6-7,7
RC Unit Formation	24,7-25,1	7,9-8,1
Ends Cutting as a Secondary Raw Material and Production for Sale	63,8-64,9	80,5-81,8
including:		
– Works at the slipway	45,6	59,0
– Works at the Cutting Site	19,4	22,5

Fig.3 The labor intensity of main stages of work for three-compartment and one-compartment approaches of NS dismantling

5. INFRASTRUCTURE OF NUCLEAR POWERED MULTI-PURPOSE SUBS DISMANTLING

The infrastructure for NS dismantling is to include:

- Decommissioned NS holding areas;
- SNF unloading facilities (floating Nuclear Service Ships and on-shore unloading complexes);
- Shipyards (Plants of Rossudostroyenie);
- Three-compartment units interim storage points;
- RC long-term storage points (on-shore sites);
- SRW treatment and interim storage sites, technical means for SRW and LRW shipment;
- Liquid Radioactive Waste (LRW) interim storage and treatment sites;
- Toxic waste handling, treatment and disposal sites;
- SNF interim storage facilities (as a part of on-shore SNF unloading complex);
- Sites for SNF loading onto special railcars;
- SNF unloading equipment (Nuclear Service Ships, SNF loading equipment, special industrial equipment);
- Technical means for SNF interim storage and shipment.

Now there are following facilities and equipment for NPS preparation for dismantling at the Shipyards of the North-Western Region:

- Nuclear Service Ships for SNF refueling;
- Special Ships for LRW collection and transportation;
- Pads for SRW containers interim storage;
- On-shore tanks for LRW interim storage;
- Facilities of gas purification and vacuum pumping systems;
- Contamination Controlled Areas;
- NS temporary service systems.

Plants of Rossudostroyenie Agency have necessary industrial infrastructure and skilled staff for carrying out NS dismantling process.

At present time available capacities of three plants in the North-Western Region of Russia can dismantle 11-12 NS per year**.**

5.1 TECHNICAL CAPABILITIES OF NUCLEAR MULTI-PURPOSE SUBS DISMANTLING AT "ZVEZDOCHKA" SHIPYARD

Zvezdochka Shipyard can dismantle four NS per year. The Shipyard has necessary facilities and structures including covered berths, docking basin, and special quay with length of pier wall of 475 meters.

There is necessary infrastructure to RW management, storage and treatment at the Shipyard (Special Tanker, LRW on-shore storage facility, SRW storages and interim storage sites included).

The shipyard has the infrastructure for SNF unloading (SNF unloading facility, interim storage pad for SNF containers and their loading onto special railcar).

Highly effective equipment for hull's structures cutting and cable shredding was delivered to the Shipyard in accordance with Cooperative Threat Reduction Program. The facility for RW with low activity treatment was built at the Shipyard.

The duration of slipway period of the NS dismantling is 3 - 3,5 months.

5.2 TECHNICAL CAPABILITIES OF NUCLEAR MULTI-PURPOSE SUBS DISMANTLING AT SEVMASH SHIPYARD

SEVMASH Shipyard can dismantle two NS per year without additional investments.

SRW and LRW generated by NPS dismantling are transferred to Zvezdochka Shipyard for treatment. SNF is unloaded from reactors by industrial equipment of Zvezdochka.

SEVMASH carries out accompanying works of SNF unloading, RC cutting out and preparation for long-term storage afloat.

5.3 TECHNICAL CAPABILITIES OF NUCLEAR MULTI-PURPOSE SUBS DISMANTLING AT NERPA SHIPYARD

Nerpa Shipyard is the leading Plant engaged in NS dismantling procedure at Kolsky Peninsula.

The industrial capacities make it possible to dismantle four NS per year. The Shipyard has necessary structures and facilities including covered berth, transferring dock and special quay.

6. PROBLEMS AND MEASURES OF INFRASTRUCTURE UPGRATING

There are some problems in the procedure of NS dismantling. In case of solution these problems we would be able to expand possibilities and speed up dismantling of Nuclear Multi-Purpose Submarines**.**

6.1 Zvezdochka Shipyard

The following measures are to be carried out at Zvezdochka to increase the radiation and environment safety:

- To rehabilitate SRW incineration site;
- To rehabilitate metal SRW melting site;
- To rehabilitate SRW interim storage facility;
- To rehabilitate the equipment decontamination site;
- To acquire mobile cranes with the lifting capacity of 50-90 tons and trailer with capacity of 50 – 120 tons;
- To mechanize the site for non-ferrous metals and alloys sorting;
- To widen the existent open site for containers storage near Harris guillotine;
- To rehabilitate docking basin, special quay and shallow-water quay; to acquire gantry crane with lifting capacity of 160 tons;
- To acquire radiation control and monitoring devices;

- To acquire devices and equipment for updating systems of fire warning and fire extinguishing;
- To update the existent system of physical protection in conformity with modern requirements for defense from terrorism and nuclear materials theft.

6.2 SEVMASH Shipyard

It is necessary to carry out the following works at SEVMASH Shipyard:

– To develop designs for dismantling of Oscar-1 and Papa class Submarines being at the area of the Shipyard;
- To complete quay for SNF unloading;
- To complete quay for hull's structures and equipment cutting;
- To acquire auto crane with lifting capacity of 500 tons to cut hull's structures in the docking basin;
- To rehabilitate SRW interim collector;
- To equip the site for industrial waste collection, storage and disposal;
- To construct the site for fluorescent lamps demercurization;
- To construct the site for the neutralization of industrial waste of II – III class of danger;
- To rehabilitate SRW storage site;
- To update radiation monitoring system.

6.3 Nerpa Shipyard

It is necessary to carry out the following works at Nerpa Shipyard:
- To update and enlarge the site for SRW storage;
- To rehabilitate site for Ship's equipment decontamination;
- To manufacture new tank for LRW interim storage;
- To repair two tanks for LRW interim storage;
- To cut one tank for LRW interim storage;
- To repair available LRW collection and storage tanks;
- To acquire special foreign equipment for hull's structures cutting (the same as delivered in the frame of Cooperative Threat Reduction Program);
- To acquire equipment for nuclear, radiation and environment monitoring system at the Shipyard and in Saida Bay;
- To construct system of physical protection of LRW, SRW, SNF and RC handling facilities at the Shipyard and in Saida Bay;
- To construct RC long-term storage facility in Saida Bay;
- To construct RC interim storage site;
- To construct additional floating landing stages to store RC afloat in Saida Bay;
- To develop project and construct special Ship for SNF and RW containers shipment.

7. DISLOCATION OF NUCLEAR MULTI-PURPOSE SUBS AT THE SHIPYARDS OF ROSSUDOSTROYENIE AGENCY

All Nuclear Multi-Purpose Subs are distributed among the Shipyards of Rossudostroyenie Agency in accordance with the schedule of decommissioned Subs transfer to the Shipyards.

The detailed information is given in Fig. 4. The plan of Nuclear Multi-Purpose Subs dismantling (2003-2006) is given in Table 4.

Table 4 – Nuclear Multi-Purpose dismantling in North-Western region of Russia (2003-2006)

NS Generation	Year			
	2003	2004	2005	2006
The first generation	**3**	**6**	**1**	**–**
The second generation	**6**	**6**	**8**	**5**
The third generation	**1**	**1**	**1**	**–**
Total	**10**	**13**	**10**	**5**
*** Victor class**	**3**	**5**	**8**	**5**

Note: * The information about Victor SSN is given in separate column because this class of Subs is chosen for the development of the pilot design of Nuclear Multi-Purpose Subs dismantling.

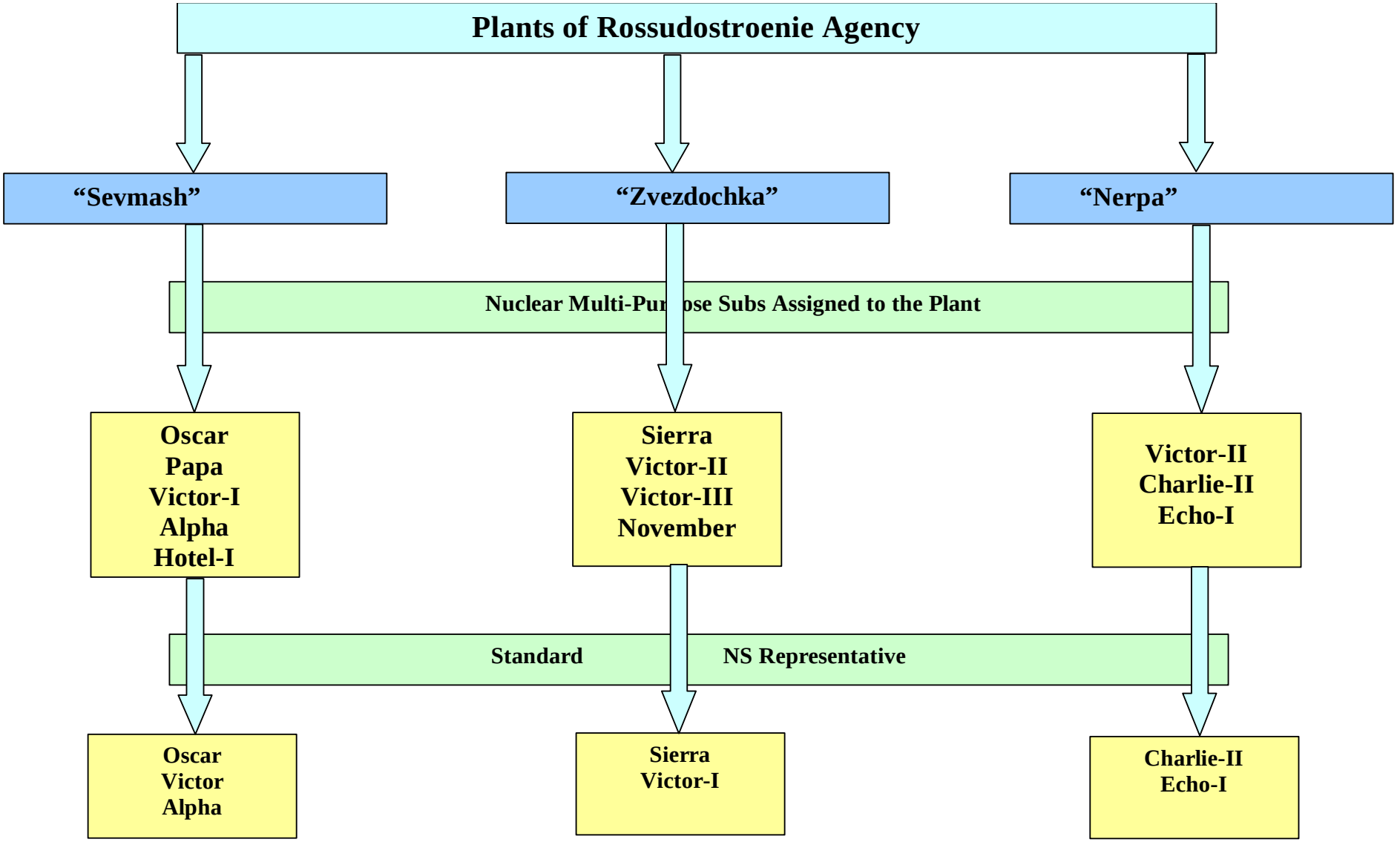


Fig. 4 NS Assigned to the shipyards

8. PILOT DESIGN FOR NUCLEAR MULTI-PURPOSE SUBS DISMANTLING

The information about development of "Pilot Design of Nuclear Multi-Purpose Submarines Dismantling at Zvezdochka Shipyard" is given in Fig.5.

The proposed task presents some difficulties. So there is a necessity to involve several subcontractors including Subs and power plants designers in the development of the Pilot Project. The List of these institutions is given in Fig. 6.

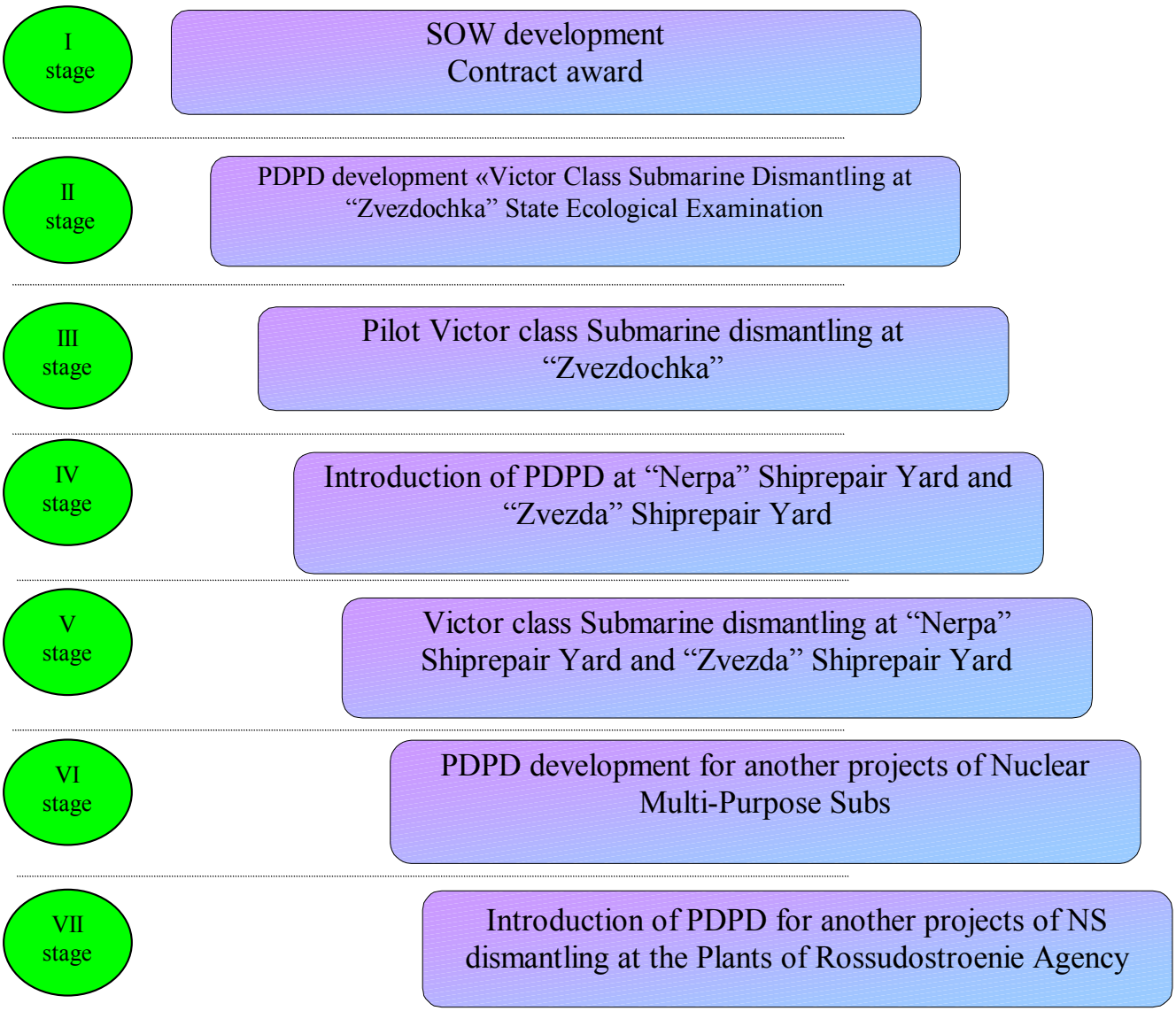


Fig. 5 Development of the pilot design for Victor-class submarine dismantling at Zvezdochka Shipyard

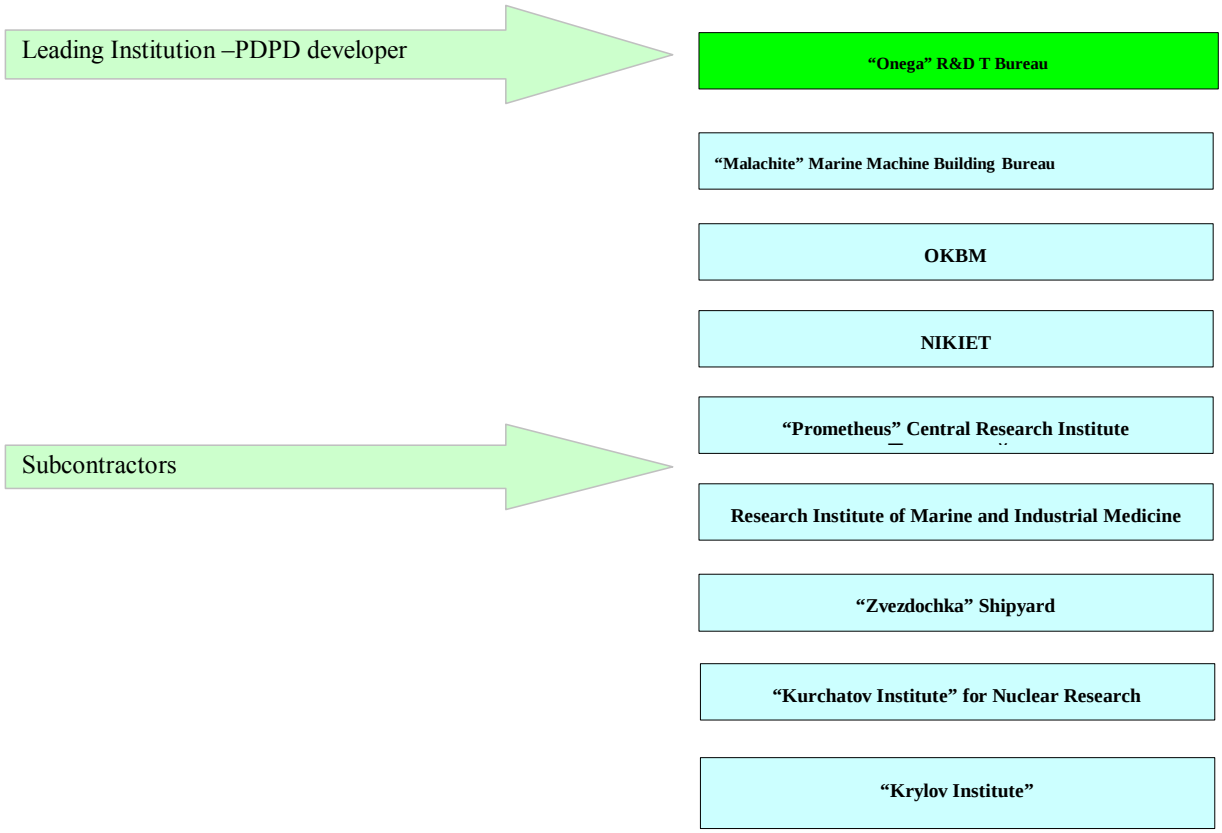


Fig. 6 Subcontractors Engaged in NS Dismantling Project Development

9. LEGAL SECURITY OF NUCLEAR MULTI-PURPOSE SUBMARINES DISMANTLING

Scientific approach to NS dismantling can be achieved if regulatory documents regulating NS dismantling process in the North-Western Region are available. NIKIET (Moscow) and Onega (Severodvinsk) are assigned as Leading Institutions for the development of regulatory and procedural documents provided legal basis for decommissioned NS transfer to the Shipyards for dismantling. The development and introduction of new regulatory and procedural documents covering NS decommissioning specific characters will favor the execution of works at the plants of Rossudostroyenie Agency.

Now new costs norms are developed in accordance with:

- Disposal of three-compartment and multi-compartment units being at the interim storage facilities;
- NS dismantling in accordance with one-compartment approach;
- RC cutting out for storage at sites.

It is necessary to note that all stages of NS life cycle have regulatory support but NS dismantling stage has not.

In the frame of Federal Task-Oriented Program for NS dismantling the task of regulatory documents package development is set in the following directions:

- The development and improvement of NS dismantling support standards;

- The development and introduction of NS dismantling procedures and typical technological processes of the equipment removal.

10. INTERNATIONAL COOPERATION

The international cooperation and free aid in solving problems of NS dismantling is carried out in the frame of relevant agreements**.** Help provided to the Shipyards of the North-Western Region of Russia in the frame of Treaty on Further Reduction and Limitation of Strategic Offensive Arms allowed:

- to dismantle Strategic Submarines;
- to get modern high-class equipment for NS dismantling;
- to construct the on-shore SNF unloading facility at "Zvezdochka" Shipyard;
- to construct LRW treatment facility at "Zvezdochka" Shipyard.

The international help and investments in SNF unloading and safe handling made it possible:

- to speed up the rate of SNF unloading from reactors;
- -to reduce the duration of NS dismantling;
- to ensure NS dismantling safety.

We hope that this workshop will help to specify priorities for the international cooperation in the area of Nuclear Multi-Purpose Submarines dismantling in the North-Western Region of Russia.

11. ABBREVIATIONS

LRW - Liquid Radioactive Waste
NS - Nuclear Submarines
PDPD - Package of Design and Procedural Documents
RC - Reactor Compartment
RW - Radioactive Waste
SNF - Spent Nuclear Fuel
SOW - Statement of Works
SRW - Solid Radioactive Waste