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Space Disposal of Azardous Waste

Synthesis Note

Contract ESA 19310/05/F/ND

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ABSTRACT

This synthesis note presents works performed by Yuzhnoye SDO and Astrium ST on Nuclear Waste Disposal in Space. After an overview on the Nuclear Waste Disposal current situation, a space option was analyzed from technical, environmental (container design), economical and legal point of view. A flight test using Dniepr launch vehicle was defined.

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Summary

1. SCOPE

The overall objective of the study is to assess the technical and economical feasibility of removing the high-level radioactive waste away from the Earth biosphere and to dispose them in the outer space.

2. BACKGROUND

As a consequence of the steady increase in energy demand and the economical and environmental problematic associated to the greenhouse gas-emitting fuel burning, there is a worldwide increasing energy dependence on nuclear power sources, resulting in large quantity of radioactive waste to deal with. Nevertheless, the nuclear energy turns out to be one of the most efficient ways to reduce drastically the inclusion of carbon dioxide and associated components into the atmosphere whereas maintaining a high level of energy production.

Even if effective methods to improve the efficiency of the nuclear reactors and to reduce the amount of radioactive waste generated are currently investigated, the problem of disposing of the already existing waste remains. This issue is even more acute in the countries developing nuclear weapons.

Enriched uranium is the fuel in a typical nuclear power reactor. The uranium is in a ceramic oxide form, shaped into small pellets which are, in turn, contained in structures called fuel elements. "Enriched" means that the fissile isotope, U-235, comprises about 3% of the total uranium - the remainder being U-238. During operation, U-235 is consumed producing energy. At the same time, a significant amount of the U-238 is converted to plutonium which is similar to U-235 in its ability to produce energy. Radioactive "fission products" are also generated.

Note that plutonium is not "waste" -- it is a potential source of power generation. It is also the vital component in nuclear weapons although the plutonium discharged from power reactors is not really well suited for this purpose

After about three years of power production, the U-235 has been largely consumed leaving behind plutonium along with the highly radioactive fission products and structural components which constitute "nuclear waste."

The recycling process consists of disassembling the fuel element, dissolving the spent fuel pellets, and separating the remaining uranium, plutonium and fission products into separate streams through chemical processes. The uranium and plutonium can be re-used in new fuel elements and the radioactive wastes are in a concentrated form which can be treated and disposed. High-level wastes are produced when the fuel rods undergo this reprocessing to extract the unused uranium and plutonium.

Although there is no generally applicable classification of radioactive wastes, it is often convenient to refer to low-level, intermediate-level and high-level radioactive wastes, depending on their radionuclide content, heat generation rates and methods of treatment.

With recycling, the nuclear waste amount would be about the same in terms of radioactivity - the principal valid measurement standard. However, waste would be much more concentrated in volume and more readily handled.

Most of the time, these wastes appear in liquid form, and some are treated to form a dry substance called calcine. The wastes from the process of reprocessing are intensely radioactive, and must be kept isolated, away from the environment. But because there is little knowledge about how to handle these kinds of waste, they are just stored, untreated in temporary containers, until the technology comes up to safely store them away. Deep geological burial is the preferred method.

On the other hand, transuranic wastes are produced when uranium absorbs an extra particle, instead of splitting. Thus, plutonium and other transuranic elements are formed. Commercial power plants produce small amounts of transuranic wastes. It is in the reprocessing plants where majority of the wastes are produced. Though they are not intensely radioactive, these wastes take much longer to decay. It is for this that they are termed as the longest living kind of radioactive wastes.

Currently, worldwide nuclear, chemical, biological waste and residues are disposed, after storage processing, under the seas, in open-air disposal areas or inside geological repository sites forming a dreadful threat for the generations to come.

The availability of disposal sites for low-and intermediate-level waste is the most important factor in several countries which are choosing decommissioning strategies. Most of the waste from nuclear power plant decommissioning is low-level waste, although a small amount of intermediate- and high-level waste is also produced. Low- and intermediate-level decommissioning wastes can be disposed of in the same facilities that accept the waste continuously produced by the operating facilities. The decommissioning waste volume from a nuclear power plant is of the same order of magnitude as the volume of operations waste produced throughout the normal lifetime of the plant. The volume of decommissioning waste can be substantially reduced using such techniques as surface decontamination, compaction, segmentation, special packaging and incineration.

Guidelines must be observed to make sure that the disposal method is safe. If ever a nation decides to store their wastes, they must keep in mind that the location must be in an area where earthquakes and volcanic activity would not pose as a problem, as well as there would be very little possibility that the groundwater might reach the wastes and carry them towards the surface, contaminating everything in its path.

Only in the US, there is the need to dispose around 52,000 tons of wasted nuclear fuel and tens of tons of plutonium, not to mention the rest of the solid and liquid radioactive waste of all sorts, especially coming from the decommissioning of the nuclear power plants, and stored in low-level waste repositories. After 20 years of study, in July 2002, US president George Bush gave to go-ahead to make Yucca Mountain, located in a desolated ridge in the Nevada desert, the planned site to house 70,000 metric tons of the US high-level nuclear waste safely for 10 000 years. The site will start receiving trains and trucks loaded with high-level waste in 2010; over 4 B$ have been invested already only in the testing and conditioning this storage facility. It is controversial whether the site (e.g. geological instability such as likelihood of volcanic activity and earthquakes) and especially the storage method (e.g. corrosion rate of the confinement material over the long haul) will remain safe more than a few hundreds or thousands of years though many elements remain dangerous for much longer, as for instance the Pu 239 that has a half-life of 240 000 years and it is only considered harmless after ten times this period, whereas the geologic and engineering barriers will inevitably weaken over time.

The magnitude of the problem, large uncertainties existing and the staggering amounts of money involved make it mandatory to look for safer alternatives, no matter how exotic these could be. Today costs of disposal of low-level waste in repositories can run around € 20 000/m^3, depending on the availability of such repositories. High-level nulear waste disposal cost could top at 40 times the one of the low-level waste.

All of the technology described above is proven and is currently being employed in Europe (UK and France) and CIS. Whether it is economically viable depends on a number of factors. Today, nuclear recycling is not economically feasible in the USA. But, what happens when the oil eventually runs out and nuclear energy be the only alternative? There are no other resources that could produce energy on the scale required in today's global economy. This is a very serious problem.

3. INTRODUCTION

The problem to protect the Earth biosphere from effects of the high-level activity elements and "long half-life" components of radioactive waste of nuclear power plants could impact the growth of the nuclear energy production in Europe and CIS. According to the forecast of experts, the problem must be effectively solved during the next ten years otherwise the nuclear energy growth will slow down and production decrease influencing negatively the economy of many countries.

The most dangerous situation is created with the high-level radioactive wastes of the nuclear industry due to their easy penetration into the biosphere, extreme toxicity and powerful lethal radiation for living organisms. The problem of the containement is not solved to a sufficient extent. The way the wastes are disposed at great depth under unpopulated areas have drawbacks such as:

- during the long term storage (hundreds or even thousands of years), the integrity of the containers with the high-level activity and «long half-life» radioactive waste is threatened by the tectonic dislocations, by destructions during earthquakes as well as by material corrosion,

- possible attempts to damage the long term depots by terrorists,

and so on.

The cost of highly reliable burial sites and the cost to support an accurate continuous monitoring of these depositaries to protect them for hundreds of years will probably exceed the cost which is necessary to remove the radioactive waste away from the Earth biosphere using launchers. It’s why, since long ago, the disposal of processed nuclear waste in space, especially the longest-live and most toxic isotopes, was considered as a promising as a practical and economically liable option in order to maintain a clean Earth for the next generations.

As an example, it is said that the high-level activity nuclear waste produced by the European nuclear power plants represents the payload of around a hundred Ariane 5 flights with a launcher conditioned to carry this waste to a safe orbit. As soon as space transportation systems will reach a quite low cost and a safety comparable to that of ground transportation system, waste disposal in space will become reality.

NASA and DOE have intensively studied the space disposal of hazardous waste in the 70’s and 80’s. As an example, NASA designed payload container that would survive a worst-case accident for application on the Space Shuttle when the US space Transportation System was yet considered to fly 50+ times a year for tens of million dollars per launch.

Various possibilities for disposing of nuclear waste in outer space were described in the literature. The use of earth orbit as repository for the nuclear waste was considered, giving attention to the distances of the waste containers from the earth. The acceleration of the containers to a velocity that is sufficient to ensure that the waste containers will leave the solar system was also taken into account. The solution of transporting and delivering waste containers to the Sun, the planets or moons was studied as well as the use of the libration points of the Earth-Moon or Earth-Sun system. However, the issues like pollution induced and the way to get rid of this problem for the future generations was not very well tackled by the previous studies.

All these studies have never succeeded mainly due to the difficulty to demonstrate the overall safety associated with all phases of launching and operation - normal, emergency, abort and accident - of such a system and the affordability of the system, knowing that only unsound and costly space transportation system could be proposed. However, the launching techniques proposed to make such a system acceptable at the horizon 2020 need to be carefully revisited at European and CIS level taking into consideration the launchers available in Europe and CIS as well as the new building block developments and possible breakthroughs foreseen with the current future launcher programmes planned.

Besides, recent breakthroughs in electromagnetic applied technologies restarted the interest of accelerating space vehicle from ground in order to reduce drastically the need for burning hundreds of tons of propellant to reach orbit and thus reduce scale, complexity and eventually the launch cost of access to space. NASA and US Navy are currently exploring such electromagnetic space launches (MAGLEV systems). Other systems aiming at providing the initial impulse from ground without requiring additional or complex propulsion system are also considered, e.g. catapult and gun systems (HARP, for High Altitude Research Project, was a study of the upper atmosphere by instruments shot from a cannon), laser-powered system. For the time being, these launch systems were not developed as not adapted to the fragile payloads. However, from the preliminary studies, it appears that solutions can be found that should make the risks acceptable when compared to the benefits to be obtained from the terrestrial disposal of the nuclear waste.

The interest of this study proposal is to combine on one hand the utmost interest of waste disposal in deep space and on the other hand, the new opportunities offered by existing European and CIS launchers and/or robust and rustic new space transportation systems. However, eventually, an additional trade-off has to be performed taking into account the exhaust from chemical rocket engines (the only kind we can use right now) that would may be pollute the atmosphere far more than the radioactive waste they would carry!.

4. OBJECTIVES

The practice of burning and burying waste may lead to catastrophic consequences and to a worldwide ecological disaster. However, the ways of deep ground disposal for the low-level and intermediate-level activity components of radioactive waste to some extent can meet, after appropriate treatment, the modern requirements of ecology, which is not the case for high-level activity nuclear waste.

The study shall determine the feasibility of the space option for disposal of certain European and CIS processed high-level activity nuclear waste in space as a complement to mined geological repositories. This option must be cost effective and must feature, if any, a cost increase limited to a few percent per kW-h to the customer.

Therefore, “cheap” LEO launch system together with expendable and reusable orbital stages shall be investigated to securely dispose the waste material to the preferred destination. Orbit transfer systems range from upper stages, space tugs and to tether systems.

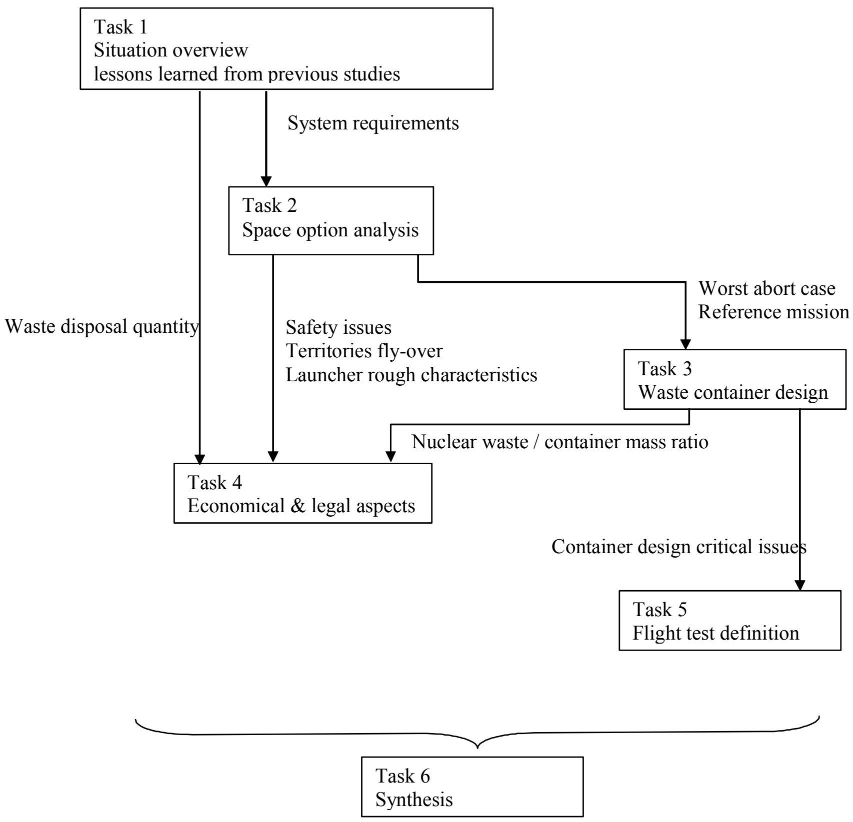
The nuclear waste disposals by lunar burial, performed either robotically or by human astronauts, or by impact, leading to a risk of spreading the waste, are expensive and represent a hazard for future lunar colonies. The ideal solution, by putting them in colliding course with asteroids, the Sun or even with Jupiter, might be too demanding in terms of ΔV, though additional gravity-assist swing-bys trajectories shall be investigated. The technical feasibility of a MEO storage system shall be addressed as well.

For instance, as a first estimation an orbit above 2000 km would be completely free of any atmospheric drag. It would also meet the requirement in terms of orbital debris avoidance as most of these are either in orbits below about 2000 km altitude -in all inclinations- or in a smaller "ring" near geosynchronous orbit. Nevertheless, ideally, the minimum time of in-orbit permanence should be over half a million years. Long-term instability of these orbits due to the perturbations must be assessed as well as, depending on the orbit, the possible influence of the Van Allen belts on the payload.

The safety problems associated with all phases of launching and operation (normal, emergency, abort and accident) of such a system shall be examined. It must be demonstrated that nuclear waste can be packaged in a container designed to provide thermal control, radiation shielding, mechanical containment, and an abort re-entry thermal protection system.

5. WORK LOGIC

The study logic is shown in the following figure:



6. WORK BREAKDOWN

The following subsections describe the various work packages aiming at fulfilling the requirements given in the statement of work. For each work package, the scope, an overview of the background, the objectives, the approach, the solutions found and their limitations are given.

6.1 WP1000 – OVERVIEW OF THE CURRENT SITUATION

An evaluation of the current situation regarding the disposal of nuclear waste will be performed, including its forecast in twenty years time and the assessment of the forecast credibility.

- Survey for disposal of highly radioactive waste. Types and current disposals and processing techniques, including drawbacks.

- Status of previous studies& concepts

The different types of waste and their specific problematic will be defined, and the current disposal and processing procedures and its limitations will be discussed. Clarification of the following points with respect to high-level activity nuclear waste: types of elements, technical approaches, processing techniques, current disposal and processing alternatives, solid or liquid waste, waste quantity involved, space disposal and threats for the future generations, etc, based on existing literature.

An analysis of previous studies and concepts envisaged to get rid of nuclear wastes through space means will be led.

Finally, the main outputs of this task will be:

- the quantification of the needs in terms of nuclear waste disposal,

- the identification of the types of nuclear wastes that should be considered in priority for space disposal,

- the lessons learned from previous studies to orient the next steps of the study.

6.2 WP2000 - SPACE OPTION ANALYSIS

The industrial team will define an appropriate mission definition of the space option.

Preliminary trade studies on at least three different missions will be performed including selection criteria. The following critical aspects are relevant to this work:

- Using the results of WP1000, the characteristics of waste forms and quantities (masses) suitable for space disposal will be identified and the waste payload system, launch site, launch system, and orbit transfer system will be featured. The suitable target orbits, trajectories and performance requirements shall be discussed.

- Safety conditions and attention to the risks to the Earth and orbiting satellites, including rescue mission requirements

- Develop and apply reliable and robust remote sensing methods to the spacecrafts or asteroids fit to bury the high-level active waste

- Over such a long period of time orbital perturbations can play a fundamental role in the stability of the orbit. These aspects will be assessed as well as other like for instance micrometeorites collision, to study the stability and identify the most adequate orbit, if any, for safe storage of the waste over the required periods of time.

- Launch system. Technical feasibility using the launch vehicles building blocks currently available or to be developed in the European relevant programmes and international cooperation (e.g. with CIS). Reliability requirements of conventional or alternative systems (e.g. kinetic launch systems) for small, compact and robust passive payloads (e.g. small casks) and with a simple, reliable apogee raising system.

- The effects of variations in space system concepts and timeframe will be studied in order to provide data for determining the system risks-benefits resulting from space disposal.

One of these systems being selected, a study will be carried out, aiming at preliminary defining the solution in terms of:

- Preliminary technical definition
- Required technological building-blocks identification, including their relevance with other technological fields
- Safety aspects (a worst mission abort case will be identified and will be used as an input for the container design)

Finally, a programmatic plan over a development and implementation period will be proposed.

6.3 WP 3000 – SAFETY AND ENVIRONMENT: WASTE CONTAINER DESIGN

This work package will focus on the design and analysis of a container for high-level activity nuclear waste.

WP3100: With the inputs from the previous work package, the team will define the minimum requirements to design such a container. The requirements will take into account the Earth-to-orbit segment as well as the in-orbit storage segment. The interest of using safety schemes (health monitoring, payload ejection system…) designed for mission aborts on man-rated launches will be addressed. As such, the requirements will specify the main functional features and operational constraints of the container system stage which will include for instance a robust module for the waste containment, a module for emergency operation with landing and recovery / positioning system, a compartment for control and communication (including positioning once on station in the orbit), a propulsion stage for emergency separation and attitude control, a thermal protection system, etc. … thermal control, reliability and safety, operational modes in the near and long term (active/dormant mode), radiation issues, sensing, monitoring and remote communication problem, decommissioning scenario(s) in the long term, etc.

WP3200: The team will design and analyse a container meeting the previous requirements of safety and environment for both segments. In particular, the team will verify the endurance and integrity of the waste container for in-orbit degradation, when exposed to the space environment, but also in case of unplanned re-entry and impact with Earth.

(It should be noted that the 238 PuO_2 pellets of US RTGs were constructed to withstand high accidental impacts, e.g. in case of launch failures. For instance, the SNAP19 power source of the Nimbus-B-1 weather satellite, which suffered a launch failure in 1968 was recovered intact in the Pacific and reused later).

Additionally, this container system type could be developed as Earth-to-orbit nuclear fuel transportation module to in-orbit inert nuclear propulsion stages needed for mankind space exploration.

6.4 WP 4000 - ECONOMICAL AND LEGAL ASPECTS

Based on the previous work package, the team will demonstrate the economical cost in the long term of sending nuclear waste in space using the mission proposed here above, and compare it to the cost induced by deep geological disposal (economical trade-off between deep geological burial and space solution). A complete economical performance evaluation and business case will be performed (taking into account the envisaged launcher configuration as a reference for this preliminary evaluation). This analysis of the cost of the entire system is indeed a preliminary one. This cost analysis should not be considered too detailed due to the existence of large uncertainties in many of the aspects affecting the economical viability of the system.

In this prospect, the team will take into account factors such as the price variation of oil/natural gas vs that of uranium in the next 50 years, the future growth in nuclear power generation and power plant technological development (new reactor system, possible breakthroughs in fusion, etc.), the risk for an accelerated global warming, assess the geopolitical trends, additional costs to the consumer and so on.

The team will also investigate the legal aspects and derived potential show stoppers. The issues of territories fly-over will have to be especially regarded (using the reference mission issued from the previous task).

6.5 WP 5000 - FLIGHT TEST DEFINITION

The team will prepare a full size test plan aiming at the verification of the integrity of the container as designed in WP 3000 after an aborted launch and impact on ground. In particular, the test plan will include the container stage design and manufacturing, analysis and testing, launcher selection for the purpose of the demonstration (ballistic flight?), launcher adaptation and integration, launch and recovery, post flight analysis. Assessment of the cost of this test shall be provided.

6.6 WP 6000 – PERSPECTIVES AND FINAL REPORT

The team will elaborate on the project to sketch a sellable future demonstration programme and a policy regarding the disposal of nuclear waste in space.

7. ASTRIUM ANALYSIS

In parallel with Yuzhnoye, Astrium has performed an analysis on the nuclear waste disposal problematic, a trade-off on the potential space-based solutions and a preliminary cost-analysis to evaluate the cost-effectiveness of this solution. Yuzhnoye works are presented in chapters 8, 9, 10, 11, 12 and 13.

7.1 ACRONYMS

A5ECB – Ariane 5 with Vinci cryogenic upper stage
AU – Astronomical unit (~150 million km)
DOE – Department of Energy (US)
ESA – European Space Agency
GW – Gigawatt
HLW – High Level Waste
Isp – Specific Impulse
kWh – Kilowatt hour
LEO – Low Earth Orbit
MWh – Megawatt hour
NASA – National Aeronautics and Space Agency (US)
NWD – Nuclear Waste Disposal
P/L – Payload

7.2 REFERENCES

[R1] Status report on Nuclear Disposal in Space - IAF 80-A-44 – D. Hayn et al, Technische Universität München, 1980

[R2] ESA ITT AO/1-1.226/80/F: Study on Description and Assessment of the potential of Nuclear Waste Disposal in Space

[R3] US Program Assessing Nuclear Disposal in Space: Status Report - IAF 80-IAA-50 – E. Rice et al, Battelle’s Columbus Laboratories, 1980

[R4] Disposal of High-Level Nuclear Waste in Space, 1999 AIAA Annual Technical Symposium, J. Coopersmith, Texas University

[R5] Nuclear Waste Disposal in Space, NASA Technical Paper 1225, R.E. Burns et al, NASA-MSFC, 1978

7.3 OVERVIEW OF THE CURRENT SITUATION

Many types of waste come out of a nuclear power plant today. Among all of them, only some kinds of hazardous waste should be considered for space disposal:

- The waste for which there is no possible treatment to make them less dangerous
- Those which will present a hazard for a very long period (with respect to human life scale)
- Those for which there is no economic terrestrial solution
- Or those for which there is no safe terrestrial solution

The best candidate solution for storage or disposal is space is known as Nuclear High Level Waste (HLW). This is the waste which represents a medium and high radioactivity and for the long term (half life higher than 30 years).

Today, spent nuclear rods coming out from power plants are first vitrified and spend 10 years cooling in swimming pools. These rods are made up for 25% of their mass by HLW. These rods are stored in power plants or dedicated sites (the barrels were dumped in oceans in the 1950's and 1960's).

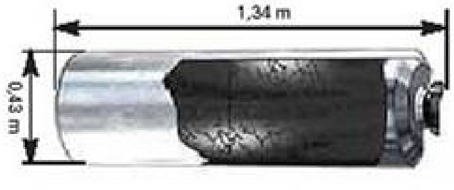


Figure 1 – Vitrified rod with C-type waste R7T7

HLW quantities

The amounts of high level waste that are stored today in various countries are rather high:

- In France, in 2004 there were 1851 m^3
- In Great Britain, in 2005 there were around 2000 m^3
- In the United States there are 52 000 tons of used nuclear fuel and thousands of tons coming from plutonium used for military applications.

Considering the countries that represent the 20 first contributors in terms of nuclear power generation, the situation was the following in 1997: there were 122 000 tons of waste and 12 000 additional tons were produced each year. It was then considered that the existing storage capacity would be full in 2006 (226 000 tons).

Moreover, with the fear of accidents (Three Miles Islands, Chernobyl), HLW are contributing to the low acceptance of nuclear energy by public opinions and are the main obstacles to its expansion. Nuclear energy represents today only 6% of the worldwide energy and 17% of the worldwide electricity consumption. Few nuclear power plants were built in the last decade and some countries have even abandoned nuclear energy: Sweden in 1980, Italy in 1987, Belgium in 1999 and Germany in 2000. The Netherlands and Spain are planning a ban.

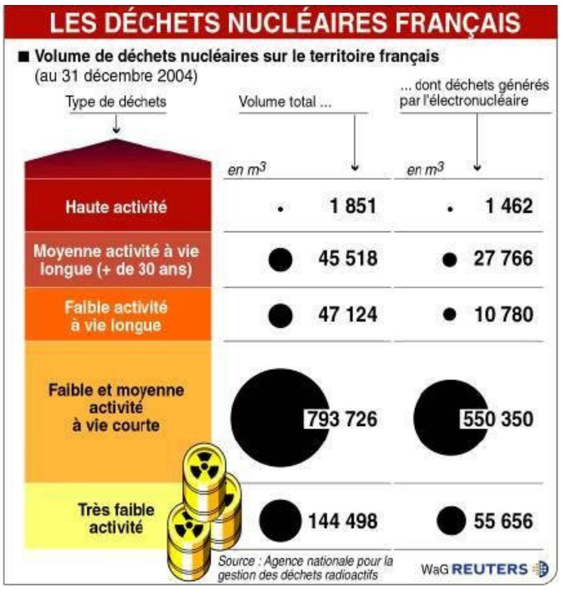


Figure 2 – Nuclear waste situation in France in 2004: Amount of waste as a function of radiation level (vertical axis)

Current solutions for HLW

Several solutions are used or investigated today for HLV.

Transmutation consists in using reactors that consume nuclear waste and transmute it to other, less-harmful nuclear waste. They produce no transuranic waste and could even consume transuranic waste. A fusion reactor where plasma could be "doped" with a small amount of the "minor" transuranic atoms could transmute them into lighter elements. Experimental reactors have not yet demonstrated an industrial feasibility: the Integral Fast Reactor was cancelled by the US, Superphoenix was closed by France, and there are mixed results and accidents in Russia and Japan.

Geological disposal is today the most used solution which can be implemented in different ways.

With **Remix & Return** HLW are blended with uranium mine and milled. When the original radioactivity of the uranium ore is reached, the mix is replaced in empty uranium mines.

Sea-based options for disposal are: burial beneath a stable abyssal plain, burial in a subduction zone that would slowly carry the waste downward into the Earth's mantle and burial beneath a remote natural or human-made island. These approaches are currently not being seriously considered because of the legal barrier of the Law of Sea and because in North America and Europe sea-based burial has become taboo from fear that such a repository could leak and cause widespread damage.

Deep ground final repositories are being studied and considered by several countries (first decisions expected some time after 2010):

- Switzerland: the Grimsel Test Site is an international research facility investigating the open questions in radioactive waste disposal.
- Sweden: Plans for direct disposal of spent fuel are quite far, since its Parliament decided that this is acceptably safe, using the KBS-3 technology.
- France: There is a research center for deep geological disposal in Bure. It is considered as the future French HLW final repository site.
- Germany: There are political discussions and protests. Gorleben is presently being used to store radioactive waste temporarily, with a decision on final disposal to be made some time in the future.
- United States: There is a final repository at Yucca Mountain in Nevada, but this project is widely opposed and is a hotly debated topic.
- Finland, China, Taiwan and South Korea are also evaluating sites.

There is also a proposal for an international HLW repository in optimum geology, with Australia or Russia as possible locations. Today there is a worldwide consensus for deep geological burial (« less bad solution »).

But there is no real acceptance of this kind of solution by public opinions because of the existing drawbacks:

- No reversibility (shallow and reversible solutions are emerging)

- Monitoring and security for thousands of years is difficult to demonstrate since our « modern world » is only centuries old and the potential danger is neither visible nor immediate. The closest possible example is sea-wall maintenance: done correctly since 1277 in the Netherlands, budget cuts and delays in New Orleans. Long term nuclear waste monitoring will have a cost without providing revenue.
- Container integrity has not been proven with respect to earthquakes, tectonic dislocation and material corrosion (risks of soil and aquifers contamination).
- New risks are appearing, such as terrorism.

7.4 SPACE DISPOSAL SOLUTION

Space disposal could therefore become today a viable alternative. Even if the new world situation today could make this possible, the idea was suggested several decades ago.

Past studies

Reference [R5] in 1978 showed one of the first ideas. Their proposal was based on the following principles:

- Shuttle launch based on the development hypothesis, namely that the Shuttle would perform more than 50 flights per year for a cost of a few tens of M$ per flight.
- Given the launcher's mass constraint only high activity long half-life non-reusable elements are concerned for economical (high kilo-in-orbit price) and ecological reasons (several tens of tons of toxic propellants used by the Shuttle for one ton in Earth orbit).
- HLW mass can be reduced by a factor of 40 after separation of unused uranium and cladding (75 tons/year in 1997).
- The waste-to-container mass ratio must be maximized, while assuring radiation shielding, thermal control, reentry and impact protection. The ratio proposed was 15% in this study (this leads to a launch mass of 500 tons per year for the yearly production plus 10 000 tons for the already stocked waste).
- The orbits retained for the disposal were: High Earth Orbit (55000 km, LEO+4000 m/s), Lunar Soft Landing (LEO+6053 m/s), Solar Orbit (0,86 UA, LEO+4450 m/s) and Solar System Escape (LEO+8750 m/s).

Another paper was presented ([R4]) in 1999 proposing an alternative to the Shuttle launcher. The main conclusions of this paper were the following:

- The huge amount of spent fuel rods (77 100 tons by 2020 for US civilian reactors) justifies the development of a reliable and low recurring cost launching system (10 000 tons launched per year).
- Ground launch systems are proposed as alternatives: laser and microwave propulsion, electromagnetic rail-guns. These system offer low payload masses but quick turn around times.
- The simplest orbit was considered, namely solar system escape and was assured by a continuous thrust by laser.

- An alternative orbit proposed was a solar orbit inside Venus which would guarantee HLW retrieval by future generations if this was considered valuable.

A paper presented in 1980 the status of the on-going studies ([R1]):

- The waste generation hypothesis commonly accepted were that a 1000-MWh nuclear power plant produces 1,2 tons of HLW per year, which meant that 420 tons were produced worldwide with the 1997 production of 353 GWh.
- There was an ESA Call For Tender on June, 13th 1980 ([R2]).
- It was also commonly accepted that no nuclear power plant expansion could occur without a HLW long term solution.
- High earth orbits were seen as an economical and promising way but all alternatives (into the Sun, outside the solar system, on the Moon or others planets) had to be investigated.

Orbit	**DV (m/s)**	**Orbit**	**Orbital boosts**	**Plus**	**Minus**	**Rank**
High Earth Orbit	4000	55000-km	2	Easily rescued & recovered, lowest DV	Orbital stability uncertain, public controversy, non-permanent disposal	5
Lunar Orbit	4250	21700-km	5	Possible rescue & recovery, low DV	Orbital stability uncertain, complex flight profile	4
Lunar Soft Landing	6050	Lunar back-side	5	Possible rescue & recovery, permanent disposal on celestial body, no orbital stability problem	Potential lunar contamination, public & scientific controversy, complex flight profile	2
Solar Orbit	**4450**	**0,85 AU**	**2**	**Permanent disposal, excellent orbital stability (> 10^6 years)**	**High subsystem lifetime, difficult rescue**	**1**
Solar System Escape	8750	-	1	Permanent disposal, high public acceptance, operationally simple	High DV, difficult rescue, non recoverable	3
Sun impact	24000	-	1	Permanent disposal, operationally simple	Very high DV, small fraction of waste returns to Earth	6

Table 1 – Possible waste disposal options in space (cf [R3])

7.5 WASTE CONTAINER AND RELIABILITY

One of the critical aspects of the feasibility of the nuclear waste disposal in space is safety in case of launcher failure.

It goes without saying that the container must withstand by means of active or passive systems:

- The heat released by the radioactive source contained during the launch.
- The heat and the mechanical shocks released in case of explosion of the launcher at any time during the launch.
- The heat and the mechanical loads encountered during a high speed reentry into the atmosphere in case of launcher failure just prior to orbital insertion.

- The mechanical loads and shocks encountered upon impact on the ground after a launcher failure and container reentry.
- The extreme conditions that could be encountered on the ground prior to retrieval following a launch failure (extreme heat in case impact in the dessert, extreme pressure in case of impact in deep ocean waters).

These various requirements on the container have led in past studies to the definition of a serious of layers or containers instead of a single one:

- A waste canister which assures the physical integrity of the waste.
- A radiation shield which guarantees the safety of the ground crews during handling and launch preparation.
- A mechanical shield which will guarantee the integrity in case of launcher failure and impact on the ground.
- A thermal protection shield which will protect the previous containers during reentry into the atmosphere.

This last layer could break upon impact on the ground which will actually facilitate cooling during the wait time before retrieval of the container. The studies have shown that in case of fall down in the ocean the mechanical container should withstand the heat coming from the nuclear source thanks to the cooling effect of water. However, the worst case would be the fall and burial in dry ground, in which case the heating coming from the waste will be the sizing effect for the mechanical shield.

7.6 ECONOMIC FEASIBILITY TODAY

7.6.1 Hypothesis

The economic feasibility of nuclear waste disposal in space has been studied with the first preliminary figures and hypothesis that are available today.

In the European Union (25-countries) 129,4 GW x year were produced by nuclear power plants in 2006 (35% of world capacity).

Two scenarios were considered:

- a constant European nuclear power plant production and
- an increase of 4% per year in the next 50 years. This yearly increase corresponds to the increase of the nuclear part in the overall electricity production, to the increase of the electricity part in the overall energy consumption and to the increase in the electricity needs. A 1% per year increase was considered afterwards, corresponding to only the increase of electricity needs.

It was considered that the mass of waste to launch per GW x year of electricity produced was 71.4 kg. In this numbers plutonium and reusable uranium components were not considered as waste. It was then assumed that the waste was stored in swimming pools on the Earth for 20 to 30 years for cooling before launch (heat flux reduction).

The study was performed assuming NWD into a solar orbit at 0,85 AU which was considered as the best option in past studies: long term stable orbit between Earth and Venus, « reversible » storage, safe location with respect to terrorist acts, short transfer duration (less than six months), intermediate DeltaV need (with respect to other solutions), no celestial body contamination.

The proposed mission scenario was the following:

- Injection by a launcher into a low Earth orbit of a transfer stage, the container and the waste
- Transfer stage boost for transfer to final orbit
- Transfer stage second boost upon arrival to the storage orbit, for circularization.

Assuming an Ariane 5 ESCB type launcher from Kourou, the following graph gives the performance of the launcher with a perigee altitude of 200 km, free inclination (5,24°) and a launch azimuth of 90°.

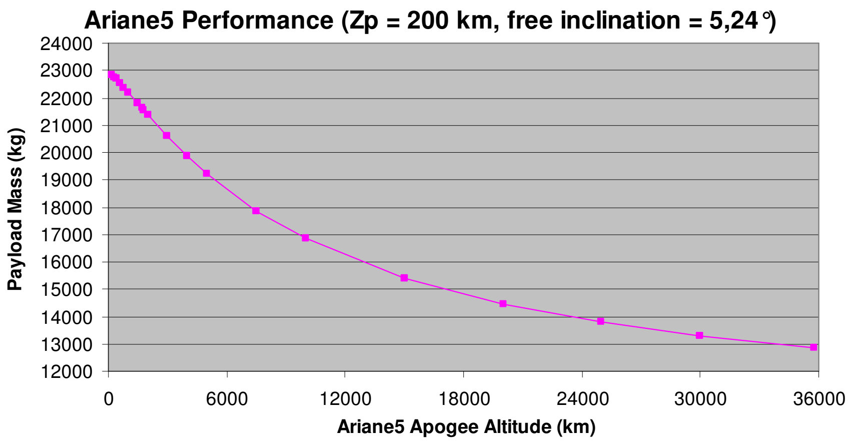


Figure 3 – Ariane 5 ESCB performances

Velocity Increase needs (based on an Hohman transfer): reach liberation velocity with a 200-km perigee (11,008 km/s), 1,231 km/s to lower the heliocentric perigee to 0,85 AU, and 1,282 km/s to circularize upon arrival at 0,85 AU

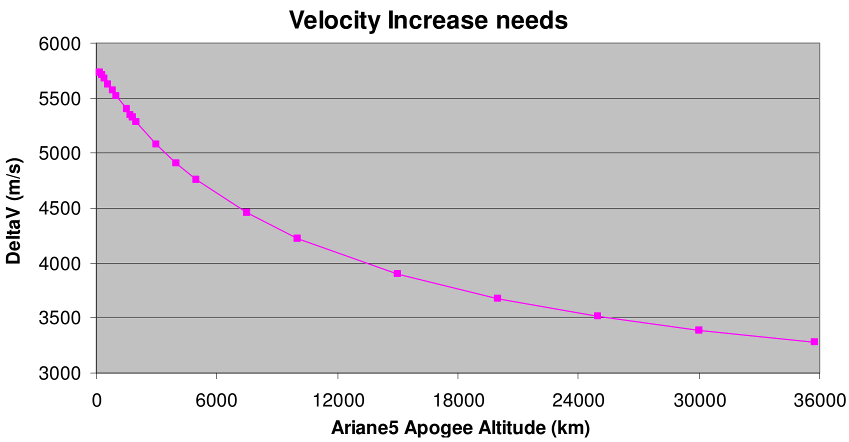


Figure 4 – Overall transfer stage DV needs

7.6.2 Mission scenario trade-off

The transfer stage hypotheses were the following:

- Single stage
- Storable propellant. This solution was taken to avoid the thermal constraints of cryogenic propellants and to avoid thrust-to-weight ratio issues that could come with electric propulsion.
- Aestus-2 type of engine (339-s Isp)
- Structural coefficient law ranging from 17,7% for a 5-ton propellant loading to 12,8% for a 10-ton propellant loading

Two scenarios were then considered:

- First scenario: the nuclear waste is sent with the container to the final depository orbit, or
- Second scenario: the nuclear waste is extracted from the container after the Ariane 5 injection (limited to Earth orbits) and before departing for the final depository orbit. In this case, containers can be reused (since in any case they are designed to resist reentry in case of launcher failure).

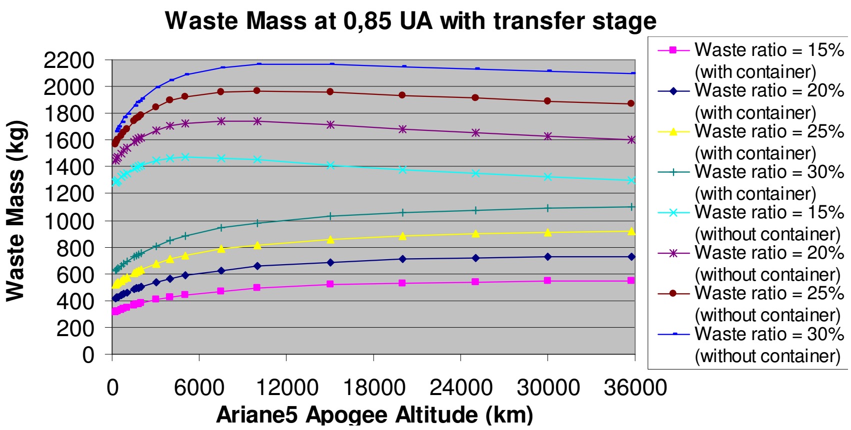


Figure 5 – Waste mass per Ariane 5 launch

Considering the graph above, a reference scenario was considered for the economical analysis:

- Launch by A5/ESCB into a 200 km X 5000 km X 5,24° orbit of a 19200 kg payload composed of :
  - 1470 kg of waste
  - 8320 kg of container (waste to container ratio of 15%)
  - 9410 kg of transfer stage (including 8,3 tons of propellant).
- It was assumed that the container was removed in Earth orbit and reused after controlled reentry (de-orbiting boost at apogee performed by a small solid motor).
- The transfer stage performs a first boost of 3476 m/s to leave the Earth (leading to an Earth departure velocity of 1231 m/s with respect to the Earth velocity around the Sun) and a circularization boost of 1282 m/s upon arrival at the heliocentric perigee of 0,85 AU.

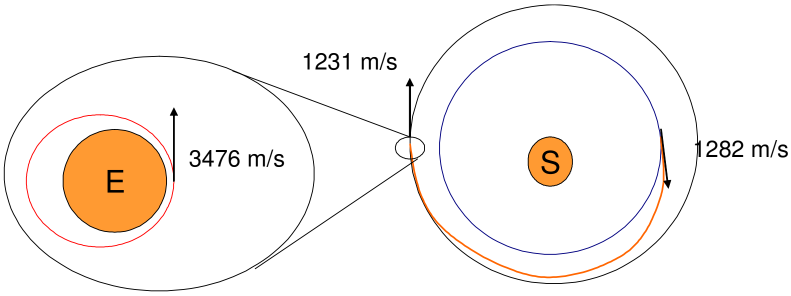


Figure 6 – Transfer stage boosts

To cancel the performance gain due to container remove in Earth orbit and reusability, the waste ratio without reusability should be around four times lower (10% without reusability and 40% with reusability for instance).

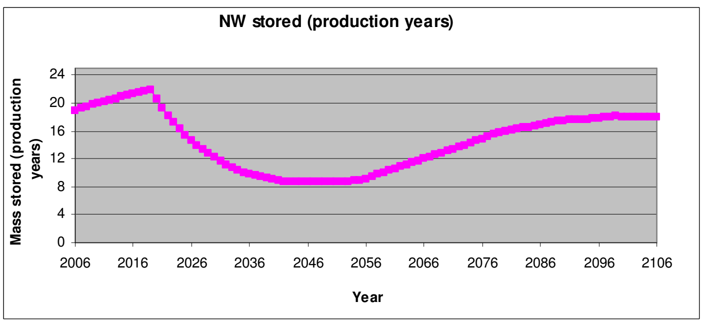
The economical analysis was then performed with a launch of 1470 kg of nuclear waste:

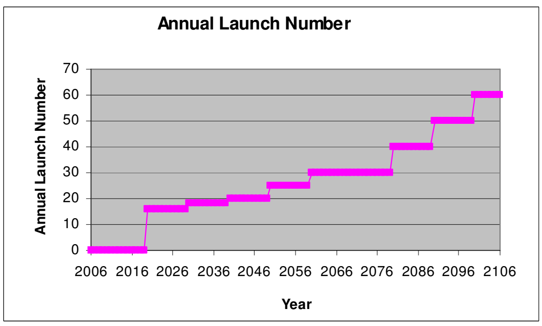
- This amount of nuclear waste is produced by the production of 20,6 GW x year of electricity, or in other words, 150 billions of kWh.
- At the current public cost of electricity of 0,1 € per kWh, this represents a cost of electricity of 15 B€.
- Assume a cost of the space mission of 150 M€ (round number used for easy comparison, which would include the launcher, the transfer stage and the recurring cost of the reusable container).

Therefore the cost of space disposal would increase the cost of electricity by 1% (or 0,001 €/kWh). For comparison purposes, the budget allocated today to NWD using ground-based solutions is 0,0015 €/kWh (including disposal of all waste, not only HLW)

Going back to the original nuclear energy production scenarios, if a constant nuclear production scenario is assumed, this would require 6 launches per year to get rid of all the HLW.

With the second scenario, assuming an increase in nuclear energy use, this could go up to the equivalent of 73 Ariane 5 launches per year in 2106 (but 60 launches by year are sufficient to maintain around 20 years of waste production stored for cooling purpose).





Of course by that time, we should have higher performance launchers and nuclear fusion should be working. It can also be expected that waste-to-container ratio should increase, and recurring launch cost should decrease with higher launch rates. The contribution of the space disposal to the electricity cost could therefore we expected to go down in the mid-term.

7.7 SYNTHESIS AND RECOMMENDATIONS

Launch of Nuclear Waste into Space is a very interesting solution for the space industry (driving force to reduce launch costs and promote new space applications) and a very good long-term solution for nuclear energy.

With the current energy demands and the forecast for the coming years, only nuclear fission energy (and coal) appear as possible solutions in the short to midterm. Even if massive investment is put into alternative energy solutions (like nuclear fusion and renewable energies), the problem of nuclear waste disposal will remain for the existing stock and for the near term production.

Diposal of this waste in space would require the development of a fail-proof container able to withstand any possible mission failure, merging the technologies currently used by the space and the nuclear industries.

Preliminary analysis shows that this could be a very attractive long term solution from a safety point of view and with an accessible cost. Further studies in cooperation between the space and nuclear sectors will be required in the coming years to analyze in detail this solution and its advantages with respect to ground storage.

8. WP1000 – OVERVIEW OF THE CURRENT SITUATION

8.1 LIST OF ABBREVIATIONS

APP	_	atomic power plant
CSCU	_	control system and communication unit
SRC	_	space rocket complex
RM	_	reboost module
MRAW	_	module with capsules with radioactive wastes
ODS	_	orbital disposal stage
UNF	_	used nuclear fuel
TB	_	transition bay
HARAW	_	highly active radioactive wastes
ILV	_	integrated launch vehicle
SRS	_	space rocket system
LV	_	launch vehicle
RAW	_	radioactive wastes
ES	_	escape system
CS	_	control system

8.2 REFERENCES

1. "Safe Danger". Interview of Y. Velikhov, N. Kluyev, N. Glazovskiy, magazine "Round the world", № 7 (2754), June 2003, Russian Federation, Moscow, pages 18-29.

2. J. Coopersmith, "Real probability for Russian-American cooperation", magazine "Energy", № 6, 1992, pages 54-56.

M.Y. Herzenstein, V.V. Klavdiyev, "Radioactive wastes into space? Why not", magazine "Ener

8.3 INTRODUCTION

A perspective new mission for space rocketry is removal of the most hazardous technogenic wastes outside the Earth biosphere. The Report proposes the options of cardinal methods to save the Earth from hazardous technogenic wastes forever:

- removal of wastes outside the solar system;
- annihilation (utter destruction) of wastes by their delivery to the Sun;
- disposal of wastes on asteroids, which orbits never pass near the Earth.

The practice of creating on the Earth the dumps, waste burial places or waste incineration that developed during the centuries, due to the global scale of present-day production, can lead to irreversible consequences and even to an ecological catastrophe.

A potential of removing hazardous wastes outside the Earth biosphere with the help of space rocket systems is shown by the example of theoretical investigations of the options of removal of highly active and "long-living" radioactive wastes from atomic industry.

The progress achieved in advanced countries of atomic industry in recent years in the field of processing low-active and medium-active parts of radioactive wastes can mitigate acuteness of the problem to same extent. However, in experts' opinion, this minimizes the amount of non-isolated wastes but does not solve the problem on the whole. No matter how the used nuclear fuel is processed, anyway, in this case, the substances of extremely high radioactivity remain (in small quantity). Just this, relative small amount of substances extremely harmful for Earth biosphere is proposed to be removed from our planet forever with the help of space rocket systems.

Creation of such systems will save the planet forever from the hazard of accumulation of extremely harmful wastes. The growth of atomic power-generating industry meeting the environmental safety standards will be ensured. Besides, a considerable contribution into the growth of commercial effectiveness of space rocket industry and nuclear waste processing industry will be ensured.

8.4 THE CURRENT STATUS OF THE ISSUE OF ATOMIC POWER-PLANTS (APP) RADIOACTIVE WASTES ISOLATION

8.4.1 Types and volumes of highly-active waste

With the development of industry, the problems of liquidation or disposal of wastes of any type of production assume higher and higher topicality and importance. The practice of creating on the Earth the dumps, waste burial places or waste incineration that developed during the centuries, due to the global scale of present-day production, can lead to irreversible consequences and even to an ecological catastrophe. The most hazardous situation is developing with the atomic industry wastes due to their extreme toxicity, easy penetration in biosphere, and inability of living matter to resist relatively strong irradiation.
The urgency of the problem of Earth biosphere isolation from the effect of radioactive wastes grows with the increase in share of atomic power-plants energy in the all-world amount of electric power generated.
In many respects, one can agree with the opinion of an American researcher J. Coopersmith(2) that wastes injection into space will ensure stable market for science-intensive products of aerospace industry, first of all, civil products.

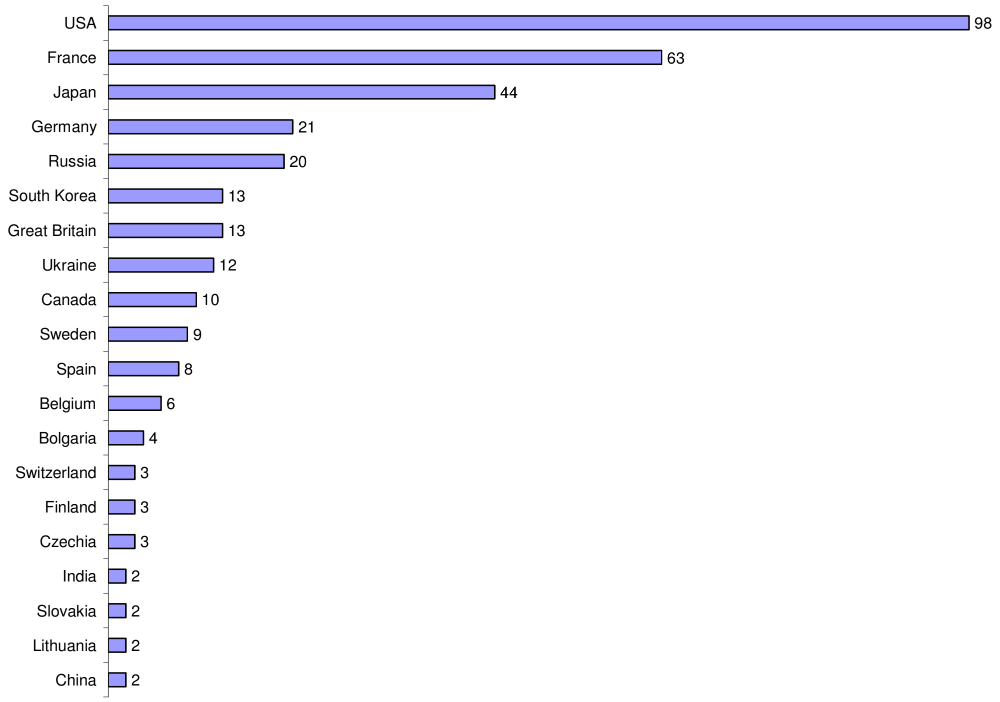


Figure 2.1 – Total Power of Atomic Power-Plants in the Countries in GW.

In the review of situation with atomic industry wastes disposal containing an interview with E.P. Velikhov, N.F. Glazovsky, N.N. Klyuyev /1/, it is stated that by 2003, about 240 thousands ton of used unclear fuel (UNF) has been accumulated in the world and only 85 thousands ton has been processed. With reference: Reuters, ITAR-TASS according to IAEA materials, that review presents the data on the total power of atomic power-plants (APP) of a number of countries (Figure 2.1) and an the atomic power percentage with reference to all electric power generated in a country (Figure 2.2).

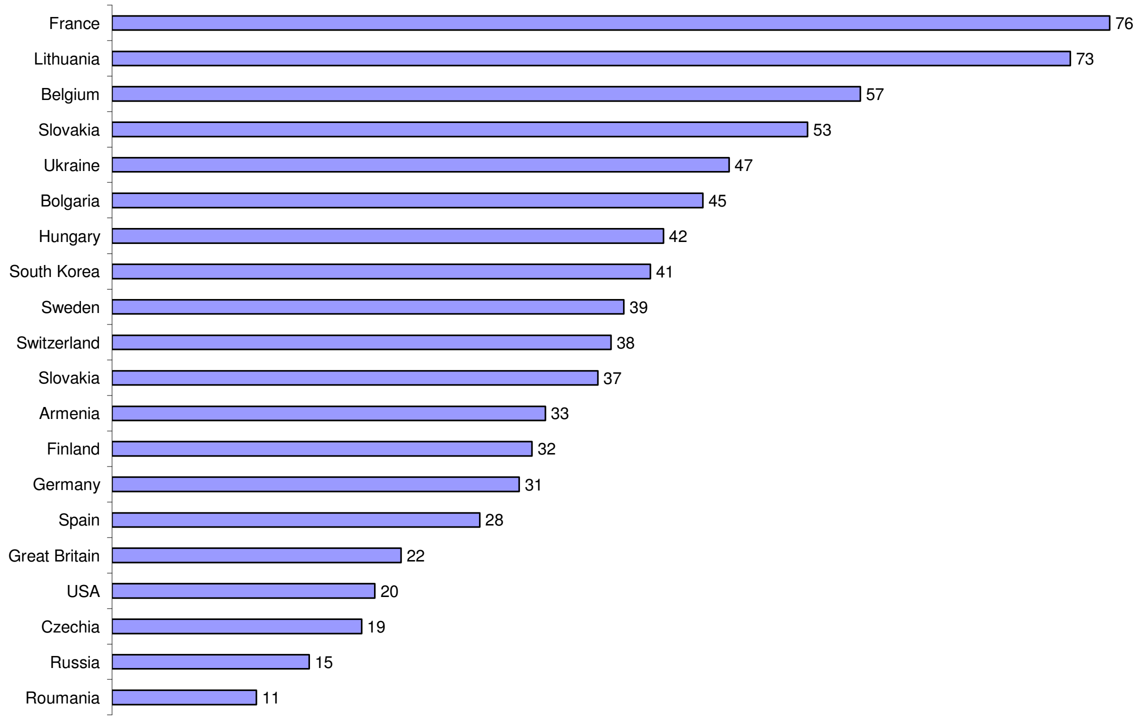


Figure 2.2 – Share of Atomic Power-Plants in All Power Generation Industry of the Countries (in %)

At the present time, low – and medium – active wastes are transferred into solid form, after which they are placed in near-surface burials. The problem of isolation of highly active wastes is much more complicated. At present, the technology is being developed of their inclusion into solid matrices-glassy or crystal form for subsequent burial in the ground at the depth of up to 1 km. However, this method can not fully exclude wastes penetration into the sphere of human vital activity. Apparently, in this case, the came situation is developing as with APP safety: in his time, a Nobel Prise – Winner Academician P.L. Kapitsa wrote about inadequacy of the probabilistic approach to particularly hazardous objects when the probability of emergency event is low but if it occurs, its consequences are of global nature. In our case, this means that the places of underground burials of highly active radioactive wastes will require a special status and will be under continuous monitoring during hundreds and thousands of years.

To select an ORS technical configuration, very essential is the weight of annual amount of highly active RAW subject to space isolation.
Determination of a share of highly active RAW with respects to their total mass was made according to the technique proposed by M.E. Herzenstein and V.V. Klavdiyev /3/.
The RAW composition depends on reactor mode, intensity of neutron exchange, and burn-out rate.
In the reactors on light water, from one ton of nuclear fuel, during three years of operation 35 kg of fission fragments with atomic weight 80-140 and 14 kg of actinides with atomic weight of more than 200 are formed. The actinides consists of 8.9 kg of different isotopes of plutonium, 4.6 kg of U-236 and less than 1 kg of other isotopes. At ideal chemical processing, from one ton of fuel 0.475 kg of neptunium-237, 0.12 kg of americium-243, and 0.04 kg of curium-244, i.e. less than 1 kg per ton of fuel go to waste.
One reactor with electric power of 1 GW uses 20 ton of uranium in a year. Thus, at ideal chemical processing, less than 20 kg/GW per year are subject to removal into space. Naturally, it is not possible to achieve ideal chemical processing, the real amount of long-living RAW subject to space isolation (according to work /3/) is 71.428 kg per 1 GW of generated electric power.
The processes of used nuclear fuel (UNF) treatment are presented in more detail in review /2/. It notes, that one of the main problems in handling the UNF is that it is a

mixture of different substances, part of which still may be useful and part is not fit for use already. At that, the UNF composition is commonly conventionally divided into two categories:
– 97.5 % of UNF are power-valuable uranium isotopes dioxides and plutonium processed in a reactor that may be used after long storage;
– 2.5 % – radioactive wastes subject to disposal (and only part of them – highly active wastes – is proposed to be removed into space).
It follows from the above, that it is rational to solve the problem of amount of highly active wastes recommended for removal into space during joint investigations of the experts in nuclear physics, power-generating industry, space-rocket industry, and ecology.
At this phase of investigations, to determine the main elements of technical configuration of a space rocket system, the ratio presented in work /3/ is adopted: it is recommended to remove into space 71.428 kg of highly active RAW per 1 GW of generated electric power.
An article by L. Preobrazhenskaya contains the forecast till 2020 of the total power of atomic power-plants in the regions of the world (Table 2.1).

Table 2.1 – The Forecast till 2020 of the Total Power of Atomic Power-Plants in the Regions of the World (GW)

Region	2010		2020	
Far East	128.0	101.0	190.0	119.0
Western Europe	129.0	122.0	145.0	91.0
North America	103.0	93.0	126.0	61.0
Eastern Europe (former USSR)	7.2	4.7	16.0	8.0
Middle East and South Asia	7.2	4.7	16.0	8.0
Latin America	4.9	3.8	10.0	3.3
Africa	1.9	1.9	5.7	1.9
Total in the world	**434.0**	**375.0**	**575.0**	**320.0**

Note: The table indicates two values of power – maximal and minimal:
– optimistic evaluation in case if the problem of wastes removal is solved;
– minimal value in case if APP development is artificially restrained.
Table 3.1 does not contain the data on some regions where the generation of electric power by APP is small and they were not taken into account in the total APP power of the world. That is why, the value "Total in the world" somewhat differs from the total APP power of the regions presented in the table.
As initial data to determine SRS parameters, the upper forecasted value of electric power generated by APP in 2010 (434 GW) and in 2020 (575 GW) may be taken.

8.4.2 Technical approaches to isolation of radioactive waste

8.4.2.1 The burial in geological formations

The burial in geological formations is the most studied approach to long-term storage of nuclear waste. The basic idea consists in removing containers with waste in the deep storehouse surrounded by engineering protective barriers, such as special filling materials.

There are three basic difficulties at burial in geological storehouses.

1. There is a probability that there will be a leakage of some radioactive waste through walls of containers and through other barriers specially constructed with the protective purposes.

2. It is difficult to predict what is going to be operational characteristics of the storehouse in the far future.

3. In essence it is impossible to guarantee that there will be no unintentional or deliberate penetration of an individual into the storehouse.

The solving of these problems demands thoroughly considered approach to choice of site, carrying out of corresponding researches and development in the field of engineering barriers and thorough examination of the reasons of penetration of an individual in the storehouse. In the beginning we shall consider the last question.

One of the most complicated questions concerning not authorized penetration into the storehouse is whether it is worth and if it is worth how to warn people about danger of radioactive waste in the far future? Systems of the prevention that access is forbidden at the best is of doubtful benefit and at the worst - promote development of feeling of unreasonable self-calmness. Moreover, means of the prevention of future generations from unintentional penetration into storehouse would pay attention to these sites and would increase danger of deliberate penetration with the purpose of extraction of plutonium or other materials from waste.

The probability of the deliberate penetration into storehouse can be minimized if to design storehouse or engineering protective barriers so that extraction of the spent fuel and its delivery to surface would become technically and economically much more difficult than construction of a new nuclear reactor for manufacture of plutonium. The probability of deliberate penetration also decreases at absence of constant warning signals that here there is a storehouse and also about its contents.

The most important security measure for prevention of inadvertent penetration is the reasonable choice of site, i.e. in such place where there is no probability that an individual will search resources. It is logical to consider that the best guarantee from unauthorized penetration into a storehouse is the choice of site where is:

- the lowest probability of that the water source which are located within the limits of site of storehouse or on adjacent sites will be demanded (for example because of bad quality of water) and thus pollution of these waters will not create potential danger to people;
- within the limits of site or in vicinity there are no known industrially significant useful resources;
- basically all elements and minerals are more accessible and available in lots in the given geographical area as a whole instead of on site where the storehouse or in its vicinities is located.

Unauthorized access is the only one problem which is necessary for considering at development of the program on long-term storehouse. Besides at storage in storehouse (or at any other ways of removal) nature protection, public health and technical criteria should be satisfied. Here some the most important of them:

- Operational parameters both storehouses and engineering protective barriers separately should satisfy strict requirements based on public health criteria so that the element of redundancy has been provided. It is very important as at estimation of operational parameters of any system for greater periods of time significant uncertainty is always inevitable;
- the degree of reliability of operational parameter characteristics of storehouse and engineering protective barriers should be such that it was possible to judge conformity to strict public health standards confidently;
- the site should not create threat of destruction or serious destruction of unique ecological resources, for example it is absolutely unacceptable if unique kinds of wildlife will be subjected to risk.

Apparently from the above-stated search of suitable site for storehouse is very difficult and demands coordination on a number of questions. It is necessary to study various kinds of sites for storehouse carrying out theoretical researches with use of computer modeling and also carrying out laboratory, geological and other field works within ten-fifteen years for revealing potential sites for storehouse without any attempts of ranging or selection of these sites.

8.4.2.2 Burial under Bottom of Ocean

The burial under bottom of ocean was studied to a lesser degree than burial in geological formations. It is important to distinguish burial under bottom of ocean and dump of radioactive waste in the sea. At dump in the sea waste gets in water where they surely dissipate. Unlike this way if the burial under sea-bottom was successful waste will not dissipate at ocean.

For today in that kind as it is was considered two approaches to burial under bottom of ocean exist:

- placement of waste in the holes drilled in the bottom of ocean on tens of meters in depth;
- placement of waste in containers in the form of an oblong shell which put into the oceanic bottom. Depth of introduction in soft clay can make several tens of meters.

It is often mentioned as a possible site the part of the sea-bottom on the depth of 100 meters in northern part of Pacific Ocean with the area of 100 million km^2 covered with soft red clay.

The main advantage of burial under the bottom of ocean to burial in geological formations is that at this way there is the smallest probability of getting of great dozes of radiation in potable water.

Usually it is considered that use of waters for drinking and irrigation is the most serious mechanism of radiation exposure possible at a burial in geological formations. However it is also possible reception of the certain dozes of radiation with food. On modern level of development of techniques the deliberate unauthorized access would be much more difficult to realize at this way than at burial in geological formations. Considering that the technology will be probable to continue improving the probability of the unauthorized access increases, however absence of signs or any other surface displays should make this opportunity the less probable than in case of burial within the limits of land. The indeliberate unauthorized access under the bottom of ocean apparently would be even less probable in the areas which are removed from coastal strip and without easily accessible mineral resources of oceanic shelf.

As concerning problems of burial under the bottom of ocean it was carried out less researches, it is known less about potential problems connected with this method of storage. For example oceanographic scientists have noted that though the concentration of a living matter in deep-water conditions is less, the living forms there are very various. The preservation of such variety of life in deep-water conditions is promoted by some factors, and one important of them is that this medium is very stable.

"Such stability minimizes probability of vanishing even of those kinds which density of population is extremely low, and thus allows to accumulate to variety of communities up to very high levels... "

"... Anybody has not yet conducted measurements of levels of tolerance of deep-water organisms but it is possible to assert with almost full confidence that they can adapt only in very narrow range of changes of the environment... Thus any kind of human activity on deep-water sites of the ocean bottom - whether it is burial of waste, extraction of minerals or something else - for certain will render much more pernicious effect than if the similar disturbance was made in not deep waters.

In the final analysis the problems of isolation from the human environment in case of burial in the oceanic bottom can be similar in the wide sense to problems with which we can confront at the burial in geological formations. Transporting, placing of waste and licensing also create serious problems. And at last international convention according to which it is prohibited dropping of RW in the sea, can forbid burial under the oceanic bottom.

Taking into account potential fragility of life in deep-water conditions and susceptibility to human activity, the burial under the oceanic bottom can not be considered as the solution of problem of waste removal. It can appear that general problems with which we confront at all kinds of burial, at this way of the burial will be no more serious, than at the burial in geological formations, however specific problems of this method can appear more difficult. Therefore, now it is necessary to allocate significant resources for study of problems of burial under the oceanic bottom. These resources should not be used for dropping of radioactive materials to ocean space or delivering of them under the oceanic bottom. International cooperating in researches in the field of burial in the oceanic bottom can be the main component at conversion of engineering of naval forces of nuclear powers of cold war times for purposes of peace.

One of disadvantage of burial under the oceanic bottom is also that the burial will be carried out at territories the responsibility for which bears all mankind. Countries which have accepted the precipitate solutions concerning development of atomic power engineering and manufacture of weapon can carry out burial of waste not taking upon themselves the proportionate responsibility on domestic obligations for this problem. What even worse is that the countries which do not work out RW will be also exposed to possible harmful consequences. The burial under the oceanic bottom or use of any other approach at which a lot of countries are involved should be considered only in the context of full and irreversible gradual discontinuance of manufacturing of atomic energy and working out of tritium and nuclear materials in the military purposes.

8.4.2.3 Burial outside the biosphere

There is a version of nuclear waste removal outside the biosphere – under earth's crust in the upper mantle (burial lower than the biosphere level).

It is difficult to define precisely the lower biosphere boundary as there is a constant interaction between various layers of the Earth. For example at eruption of volcanoes magma getting up from the Earth's interior goes to the biosphere. The working definition of "biosphere" at discussion of problems of burial of nuclear waste should in itself become a problem of significant scientific researches. There are two rather various definitions which can be considered satisfactory:

- deep layers of earth's crust where there is no water even in pores of mountain rocks;
- the stable part of the upper mantle (which lies under the earth's crust) within the limits of which there is no exchange of substances with the biosphere on time scale less than tens of millions of years.

The thickness the earth's under ocean makes approximately 5-10 km (for comparison under the continental areas its thickness is 20-70 km). The boundary separating the earth's crust from the upper mantle and called "Mokhorovitch boundary" or in abbreviated form "Mokho" is characterized by sharp increase of density with the change of depth. From the geological point of view it allows (and therefore from the point of view of use for burial) to define the upper mantle as distinctly fixed layer. In some areas the upper mantle rocks are in melted or semi-melted state but in the most of areas they are solid. The research of the Earth's layers in those places where it is still impossible to drill boreholes is carry out by indirect methods such as study of change of seismic waves speed at the boundary between layers.

Some characteristics of burial in the uppermost mantle layer and in deep boreholes in the earth's crust will be similar. In case of burial in the upper mantle tanks with waste will be placed in ultradeep boreholes which will be sinked below the earth's crust. The boreholes will be drilled in geologically stable areas i.e. at the distance from those places where there takes place convergence of tectonic plates (on the continental edges) or divergence (as for example at Middle-Atlantic or East Pacific ridges).

The stable areas in the upper mantle can isolate RW from the biosphere for million years though before choosing of the given method this hypothesis should be carefully investigated. At burial in the upper mantle it will be easier to solve such difficult problems as the intentional or unintentional unauthorized access than at two other approaches.

The problems of safety and also technological and scientific problems which are connected with this way of burial are as great as hopes connected with it and it is completely unclear whether they can be solved. For example there are no technologies of drilling on of the upper mantle, now they are just developed. It is extremely improbable that they will be developed in the near future. However drilling of ultradeep boreholes gets more real with appearance of such new technologies as splitting of rocks with the help of laser. It is also possible burial of waste in stable areas of the upper mantle under the oceanic bottom where the earth's crust is not as thick as under the continental sites.

There is a lot of problems of safety at burial in the upper mantle. For example even if it will be possible to drill boreholes deep enough whether they will be steady enough that it was possible to load waste in the upper mantle over them? How to act in case of rising of problems at immersion of the waste? How will the isolation of various layers of subterranean waters on great depths be implemented which would make possible placement of waste?

At last the scientific concept of estimation of burial efficiency in the upper mantle is not developed. For example at drilling of boreholes in the upper mantle a channel can be created which will allow magma to flow out to the surface bearing radioactivity. During licensing it will be necessary to estimate probability of such event on certain sites. Further the upper mantle defies studying by direct methods of research, therefore its properties are studied indirectly. And though these indirect methods allow to understand its general composition and structure it does not follow from this unambiguously that it is possible to receive knowledge detailed enough which would allow to use this method of burial with full confidence. In conditions of absence of new methods of research the process of actual licensing of this burial method will remain of doubt.

Considering all above mentioned factors we come to conclusion that theoretically potential possibility of burial the upper layers of mantle with the purpose of isolation of long-living radioactive waste from the biosphere is high enough and the study of this method deserves allocation of the appropriate financial resources. Though now it occurs improbable that this approach will return positive results.

8.4.2.4 Underwater avalanches

It is uneasy to understand that the existing practice of burial of the RW does not stand up to serious criticism though the cost of the similar projects amounts to tens billion dollars. But the matter is not in criticism. It is done the utmost and with the best motives. Other problem is that these efforts are unavailing and do not give desirable results.

In our opinion new approaches to the problem are necessary. The task to turn from historical way of burial to geological when storage period of RW would be estimated not in tens and hundreds of years but in millions of years commensurable with terms of flow of natural radioactivity. Thus the burial area of RW should be completely insolated from the environment and be at the lower level of the Earth's surface.

The unique place corresponding to these conditions is the bottom of the Ocean. And the unique way of RW burial within its limits is conservation of containers with RW under the thick cover of fine-dispersed bottom sediment.

There are huge spaces at the Ocean where the thick masses of bottom sediment with thickness up to 10-15 km are accumulated. These spaces are placed in the neighborhood with continents and represent rather flat underwater slopes smoothly passing from a shallow shelf to deep-water plains of the oceanic bottom. The bottom of the continental slope - continental bottom - is an attractive potential place of RW burial.

Under certain conditions - seismic movements, earthquakes, excesses of loads on the continental slope - there are landslides and other movements of sedimentary material. Its significant part take down to bottom of the slope and there is laid up for eternal time. The intensive coming of bottom sediment from the part of the continental slope to its bottom was named as avalanche sedimentation (by analogy with snow avalanches falling down from mountain slopes).

This natural phenomenon - landslide on continental slopes and bottoms - is broadly widespread in the ocean. There are a lot of facts about scopes of underwater landslides in zone of the continental slope and continental bottom. In 1985 it is fixed the displacement of mass of deposits on the area of 11 700 sq. km in total amount more than 10 thousand cubic meter on the continental slope and bottom of the South-east Africa. Thus the bottom of the continental slope has receded to the side of the ocean on 25 km. The general front of landslide movement has made 180 km.

Landslide scar from the slipping down of sedimentary masses at the coast of the North-west Africa takes the area of 18 thousand sq. km and area of the bottom covered by sediments of this landslide takes 30 thousand sq. km. The volume of the displaced material is estimated at 1100 cubic kilometers.

As a whole on the continental slope of North-west Africa the deposits were moved on the area of 45 thousand sq. km. It is the area equivalent to territories of Estonia, Moscow region or Netherlands.

One more example of dynamics of large landslide. In 1987 it is researched the landslip with the volume of 5700 cubic kilometers on the continental slope of Norway. These masses of deposits are moved on 900 kms. The thickness of shifted blocks of sedimentary rocks amount to 1.5 km at mean value of 400 m. Width the landslide head is 290 km. Landslide blocks have come off the slope on the depth of 1000 m and have slipped 200 km up to the depth of 2000-2500 m. The general area of disruption has made 34 thousand sq. km.

Especially we shall note that these grandiose volumes of bottom sediment consist of clay particles having the ability of maximum adsorption and ensuring the most dense packing and conservation of any objects which have appeared in final point of the landslide movement.

It is easy to imagine how strongly and securely the containers with RW would be buried if they appear in zone of landslip sediments.

To realize the offered concept it should be created conditions for initiation of landslide in the necessary time and in the necessary place. As the landslides are more often caused by earthquakes we should to follow the nature and to invent something similar.

Probably, it is necessary to check up how will react sedimentary mass to explosions in deep boreholes of the continental slope. The technical feasibilities allow to use methods of control of explosion energy distribution. Other ways of excitation of landslide processes are not excluded as well.

Generally speaking the conditions for developing of landslip with the purpose of RW burial can be created on the continental slopes of many areas of the Ocean. However determining criteria of selection of such areas should be sufficient thickness of sedimentary mass and relevant geometry of slopes.

Especially lots of deposits – up to 5-17 km – were accumulated on the continental slopes of the Atlantic and Indian oceans, in the Arctic Region and Antarctic Region. The slopes of the Pacific Ocean are less favorable in this respect They are placed within the limits of "fiery ring" where active tectonic processes have not allowed to form the thick sedimentary cover on the slopes.

At the same time the deep-water hollows of the Pacific Ocean are attractive structures for RW burial because the bottom of hollows is located between two opposite slopes - natural limiters of the landslide movement. In this case it is possible to execute a direct hit of the landslide to the intended point. Use of deep-water hollows of the Pacific Ocean with the purpose of RW burial will require careful researches and forecasts. However in any other cases such researches are necessary.
First of all it should be obtained geographical panorama of the selected area, specified the parameters of internal structure of sedimentary mass, carried out the drilling, detected the layers of sedimentary mass effect on that will cause maximum effective sliding of deposits. It is necessary to conduct laboratory simulation with the purpose of reproduction of expected displacement of one or another mass of ground. Such preliminary preparation will ensure success of unprecedented operation on burial of RW or any other waste.

8.4.3 Issues of radioactive waste treatment

8.4.3.1 Compacting of RW by pyro-gazificating thermo-processing

For long years the great quantities of RW were accumulated and organic radioactive polluted materials including materials of composite structure containing wood, graphite and building material. The task of ecological safe thermo-processing of this waste, decrease of volume of RW for reduction of costs on their burial has vital importance.

It was created the experimental pyro-gazificating plant thermo-processing of combustible radioactive polluted materials with productivity of 50 kg/hour. The plant contains following assemblies and systems: load assembly, pyro-gazificating reactor, boiler of pyro-gaz utilization, system of gas purification of ventilation and dust cleaning, assembly of ash take-over. In the plant reactor there is a column of continuously falling stock of 2 m altitude serving as additional catcher and sorbent of volatile nuclides that leads to decrease of their mass transfer, especially of cesium, to gas phase and gas purification typical for plants of direct burning.

The researches of features of thermo-processing were conducted with the use of various types of stock. As the stock it was investigated:

1) Deciduous and coniferous felling materials polluted with fission products (with cesium and strontium) and also with supertransuranic elements (with plutonium and americium);

2) Mixes of wood with diverse inorganic materials and also with the mineral components. The contents of main dose-forming radionuclides of cesium-137 and strontium-90 in wood was 0, 1-0, 3 kBq/kg. It was studied the influence of technological parameters on process of pyro-gazificating, coefficient of compacting of stock, conversion coefficient of cesium and strontium in ashes and mass transfer in various assemblies of the plant. It was investigated the influence of the components in stock on phase structure of ashes and forming of proof chemical compounds with the purpose of their immobilization.

It is experimentally determined that at processing of felling wood the factor of stock compacting is 90-95, conversion coefficient of cesium and strontium in ashes is up to 90-98%, contents of cesium and strontium in ashes is up to 10-30 kBq/kg. The ashes relate to underactive RW, phase structure of ashes is mix of simple oxides, contents of radionuclides and their mixes in smoke emissions after gas purification is 3-4 times below the permissible concentration in the air. It was shown the possibility of thermo-processing of emergency waste from mix of diverse materials of wood, graphite, concrete, brick, determined coefficients of compacting, transition of nuclides to ashes, structure of ashes and products of thermodestruction of the inert components. It is shown that putting of the clay components promotes increase of conversion coefficient of cesium and strontium in ashes and forming of proof chemical connections as glass-ceramic material aluminum silicates, silicates of cesium and strontium $CsAlSi_2O_6$, $Cs_2Si_4O_9$, $Ca_{0,5}Sr_{1,5}SiO_4$ in ashes.

There were developed the technical proposals on renovation of the plant for improvement of technologies of thermo-processing of small flows of the specific RW.

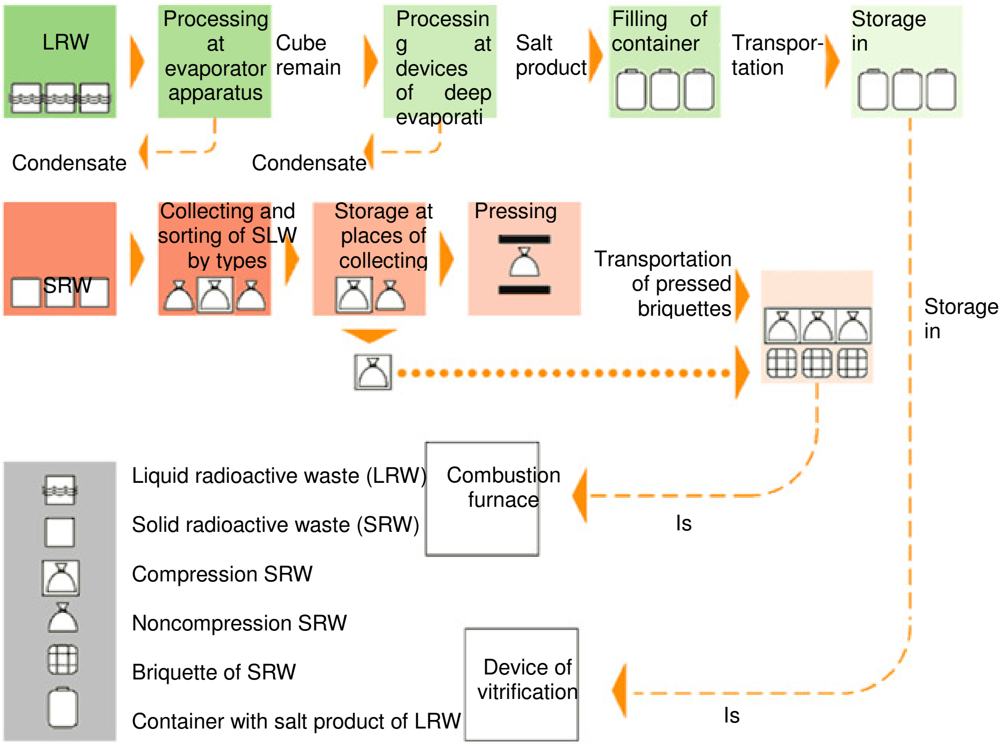
8.4.3.2 Storehouses of radioactive waste and spent nuclear fuel

The main part of total amount of solid RW (SRW) is made of low-activity and medium-active waste – about 98 % of formed in process of APP exploitation.

The storage of solid RW is made in storehouses which represent concrete facilities having an internal waterproofing.

It was developed and works the technological scheme of handling of solid radioactive waste providing it collecting, sorting, processing (pressing), transporting and safe storage.

The scheme of RW processing :



All liquid RW (LRW) formed at power generating unit are stored in containers of stainless steel. With the help of the deep evaporation plants steep UGU-500 it is made the processing of vat remainder up to salt concentrate which in hot molten state is filled up in metal barrels transforming after cooling in monolith. The barrels are stored in storehouse of solid waste. It allows to reduce volumes of liquid RW and store them in more safe solid state.

The spent nuclear fuel as heat-generating assemblies on every power generating unit is stored in pool with exposure time no less than three years.

8.4.3.3 Cementation of radioactive waste

The technological progress has resulted to wide use of sources of ionizing radiation and radio-isotope preparations in various branches. The side effect of their use was the formation of secondary waste of low and average activity level that should be reliably localized for maintenance of radiation safety of the population.

The process of RW localization is intended for transfer of waste to the steady forms which reduce potential danger of waste during their temporary storage, transporting and final removal. For localization of waste of the various materials there are used: cement, bitumen, organic polymers. The materials used as matrixes are sampled taking into consideration character of radioactive components of waste (types of radionuclides, specific activity, total level of radioactivity), chemical and physical properties of the waste forms. Besides the materials of matrixes should be rather simple in technological processing, its use should not lead to substantial growth of volume of final product in comparison with initial volumes of waste. At selection of material of matrixes there is also taken into consideration presence of its industrial manufacture and economic problems connected with this. The materials used as matrixes should provide homogeneity of the localized forms of waste, stability to leaching-out influence of water and water resistance, mechanical strength, stability to influence of the external factors (chemical, biological and others), thermal and radiation stability, stability during the storage.

Inclusion to cement is the first and most widespread way of conditioning of RW of low and average activity level. Reasons of broad distribution of cementation are: incombustibility, absence of plasticity of the conditioned product, relative simplicity of technological process.

The ability of cement to immobilize water is important for conditioning of liquid RW.

The process of cementation of RW should be improved and meet the modern requirements together with development of industry appearance of new kinds of RW, increase of their volume and simultaneous strengthening of control over the safe handling and storage of radioactive materials.

The perfecting of technology of RW cementation is carried out on several directions in state unitary enterprise Moscow scientific production association “Radon”. There are created new, more perfect equipment, new technological processes, improved the quality of cement matrix and containers where RW is localized, constantly improved the technological and normative documentation, strengthened the quality control over the process of cementation, carried out the licensing and certification of technological processes and equipment.

Thus now it is put into operation the plant of RW cementation (fig. 1) with exact proportioning of components of cement solution which allows to prepare the cement compound meeting all requirements of all-Union State Standard «Cemented radioactive waste». Meeting the requirements of this document provides safety at the handling of waste at their temporary storage and burial in surface facilities for period of radionuclide decay included to cement compound up to the safe level. A number of engineering solutions considerably increasing ecological safety of technological process is used in the plant.

The new plant of cementation is created and put into operation which intended for conditioning of ash remainder from burning of RW in steel containers and also other kinds of solid waste having interstices in bulk volume (fig. 2).

At the work of the plant it is realized the new method of cementation – impregnation of bulk volume of solid RW with special multicomponent high-penetrating cement solutions on the basis hyperfine ground cement.

The cementation by impregnation consists of supply through the probe of high-penetrating cement solution in near-bottom part of the container with solid waste previously placed in it and rolling of cement solution through the bulk volume of waste. Cement solution rises from bottom to top of container, uniformly filling the smallest interstices and pores between particles of waste. Upon termination of impregnation the volume of obtained cement compound is equal to the bulk volume of waste that is the volume of final product in comparison with the initial bulk volume of waste do not increase. After cementation the final product is sent for storage in the initial container as an additional protective barrier (fig. 3). The final product of cementation by the method of impregnation is uniform cement compound proof against chemical and physical effects which quality meets all regulated requirements of all-Union State Standard.

The prevention of biodamages of building materials on the basis of cements is a rather actual problem. The microbiological factor of corrosion is stipulated by settlement and development of bacteria and microorganisms on a surface of concrete facilities evolving during vital functions (metabolism) methane, carbonic acid, sulfuric anhydride, hydrogen, volatile chlorinated components, sulfuric acid and other chemical substances that aggressively effect on building mortars, concrete and steel/ferro-concrete reinforcement, that essentially reduces characteristics of cement stone.

The formation of various biocenoses, using organic substances as a nutrient medium happens at the contact of concrete surfaces with water, soil and air, at decomposition of albuminous and cellulose-containing materials accidentally fallen into cement compound.

It is known that first of all the destruction in concrete facilities happens at the expense of dissolution of hydrosilicates during interaction of acid with binding material. Though the alkaline hydrates will neutralize initially formed acid fermentation and metabolic activity continue as the nutrient medium, bacteria and humidity are saved, that results to loss of strength characteristics by concrete.

The situation is even more aggravated by seasonal temperature fluctuations which with time promote the increase of porosity of cement compound, formation in body of cement monolith of interstices and cavities, and then penetration of surface and subterranean waters deep into compound.

Having studied a broad range of produced domestic and foreign preparations as the most prospective for protection of cement matrix in technologies of RW cementation were chosen biocide polymers of polyhexamethyleneguanidine (PHMG) class. The main advantages of the chosen preparations - high biocide activity, good solubility in water, very low toxicity, long storage time without loss of functional properties, domestic producer. Biocide materials of PHMG class were developed in the Institute of ecological and technological problems.

Further it was determined that PHMG preparations not only do not worsen properties of cement compositions as the majority of biocide preparations but also are capable to improve them considerably:

• Strength and stability to aggressive effects of cement compounds;

• rheological and penetration properties of high-penetrating cement solutions at impregnation of RW;

• building-technical properties of cement-sand mixes at manufacturing of the concrete containers intended for long-term storage of conditioned RW.

On the basis of the obtained results the admixture of polyhexamethyleneguanidine class was determined as multifunctional, integrating in itself biocide, plasticizing, stabilizing, increasing strength of action, and was recommended for use in various technologies of RW cementation.

During activities together with the Institute of ecological and technological problems there were developed and have begun to be applied the multifunctional complex admixtures (MCA) containing PHMG preparation for modifications of properties of cement compound. The multifunctional components at RW cementation are added to usual cement in quantity of 5-20 %. MCA consist of 3-5 macro- and microcomponents. The MCA components do not react among themselves and do not change their properties in multicomponent structure. MCA simultaneously improves some properties of cement compound.

Multifunctional admixture contains components which increase strength, frost and water resistance of cement stone, its crack-resistance and biological stability, penetrating ability and viability of cement solution, modify its term of stiffening and stabilize consistence, considerably decrease speed of radionuclide leaching, exclude formation of foam at preparation of cement solution.

Varying quantity of MCA in the mix with traditional Portland cement it is possible to change various properties of cement compound to greater or lesser extent necessary in one or other method of cementation both liquid and solid RW. Thus MCA allow considerably to improve quality of cement compound and to increase its filling with radioactive waste reducing volume of final product.

It is important that the component is used at cementation in dry ready form. It is entered directly in the mixer together with the cement. The ready multicomponent component saves of necessity to complicate hardwarily process of RW cementation applying expensive and fragile proportioning equipment in plant composition. Besides uniformly, distributed macro- and microcomponents in the admixture make the process of cementation more simple increasing productivity at the expense of decrease of time for thorough mixing of cement compound.

It is actively carried out the work on development of technological processes, equipment and cement compositions which can find application at cementation of radioactive waste of atomic power stations and various radiochemical manufactures.

The technological process is developed and it is exploited the experimental technological line on cementation of radioactive uliginous sediments and grounds (fig. 4). The process includes stage of high-temperature processing. It is 3-6 times decrease of volume of the final product in comparison with the initial volume, for example sludge.
There are developed the equipment and technology of cementation of liquid RW containing boracic acid or a lot of organic compounds with the use of electromagnetic processing in velocity layer (fig. 5).

There are optimized the structures of compounds for joint cementation of high-soline liquid RW with soline-containing up to 1000 g/l and spent ion-exchanging of resins.

The RW are rather various by physicochemical state therefore it is very important to find the correct technological solution for localization of each kind of waste. The methods and equipment permitting to convert waste to forms safe for long storage are developed in state unitary enterprise Moscow scientific production association "Radon". The technologies have passed test of time and have proved the reliability.

Fig. 1. The plant of RW cementation

Fig. 2. The plant of cementation of ash remainder from burning of radioactive waste

Fig. 3.

Samples of cemented by the method of impregnation of ash remainder

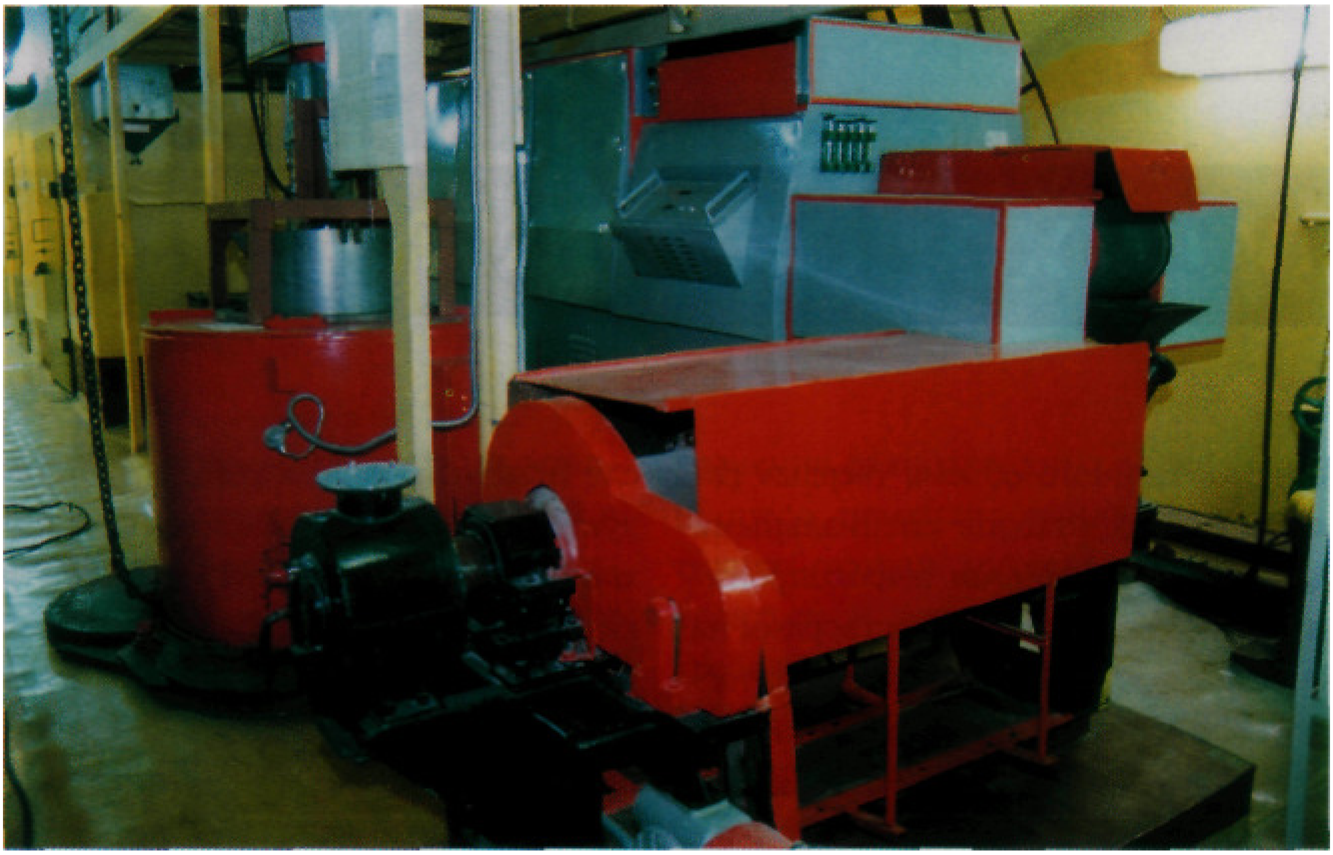


Fig. 4. Experimental technological line on cementation of radioactive uliginous sediments and grounds

Fig. 5. The plant of cementation of liquid RW with the electromagnetic mixer

8.4.3.4 Marine transporting of nuclear fuel waste

Utilization of nuclear submarines and nuclear ships is one of primal problems which now should be decided by the Russian ship-building industry. Despite of significant successes reached in the solution of this task for the last years it remains a lot of problems serious enough among them one of most difficult is the problem of safety control at handling of NFW discharge from the utilized ships.

The problem is complicated by following circumstances:

Only at the Northern fleet it is wrecked from military register and subject to utilization about 110 of nuclear submarines which have about 200 nuclear reactors.

The acceleration of process of NFW removal from these bases of the Northern fleet can be only provided by the creation of base of NFW long storage in area less dangerous than Kola peninsula, for example in the New Land island.

It is necessary to speed up the creation of the specialized vessel for transportation of containers with NFW for transportation of NFW from storehouses in Andreev bay and maritime technical base Gremikha to places of loading to special trains and to places of temporary and long storage.

First of all the necessity for construction of the new vessel is stipulated by understanding that problems of protection of population and environment now gain the special value.

Existing vessels of atomic-technological service can be basically used for transporting of NFW. However analysis of the characteristics and state shows that it is rather problematic to provide secure at implementation of massed transportations of such hazardous freights as containers with NFW.

Thus one of the knot of the matter in the solution of problem of safety at handling of NFW and radioactive waste (RW) from the utilized submarines and surface ships with API is building and putting into operation of the specialized vessel permitting to execute transporting of various containers with NFW and RW to places of loading of transport containers to special train and places of temporary and long storage of metal-concrete containers at platforms of shipyards or on the New Land and this vessel should meet to the most rigid requirements on safety.

Thus the vessel should be cheap in operation as far as possible: at minimum displacement - 2-3 times less than the project 11510 vessel, i.e. does not exceed 2.5-3 thousand tons, has rather small crew - of no more than 25-30 men. The vessel should be adapted to transportations of all types of containers with NFW, have sufficient carrying capacity of RW.

Central scientific research institute named by acad. A. Krylov was explicitly studied a problem of determination of appearance of such vessel and its basic performances.

The experience of creation of similar vessels and presence of studies of the projects of the specialized vessel allow - at presence of the appropriate financing - in the shortest terms to execute its designing by forces of central scientific research institute named by acad. A. Krylov and central design office "Baltsudoproect" with engaging of a number of organizations arranging the appropriate experience. The construction of the vessel can be most successfully carried out by plants "Asterisk", Vyborg plant, plant "Severnaya verf" etc., its exploitation can be provided by enterprises Russian shipbuilding: "Zvezdochka" and "Nerpa", and in the Far East region – federal state unitary enterprise "Zvezda".

8.4.3.5 Complex of RW processing in federal state unitary machine-building enterprise "Zvezdochka"

Project purpose: the solution of the problem of safe radioactive waste processing (RW) formed at repair and utilization of nuclear submarines of Russian Navy (decrease of activity and volume of the primary and secondary RW, transfer of RW to the safe aggregative state).

Project participants: the Ministry of atomic energy of Russia, "Lockheed Martin" (the USA), Association "Aspect", MBE "Zvezdochka", R & D Technological Bureau "Onega" (Russia), SGN|COGEMA (France), "Kwaerner" (Norway).

Structure of activities of "Onega" R & D Technological Bureau:

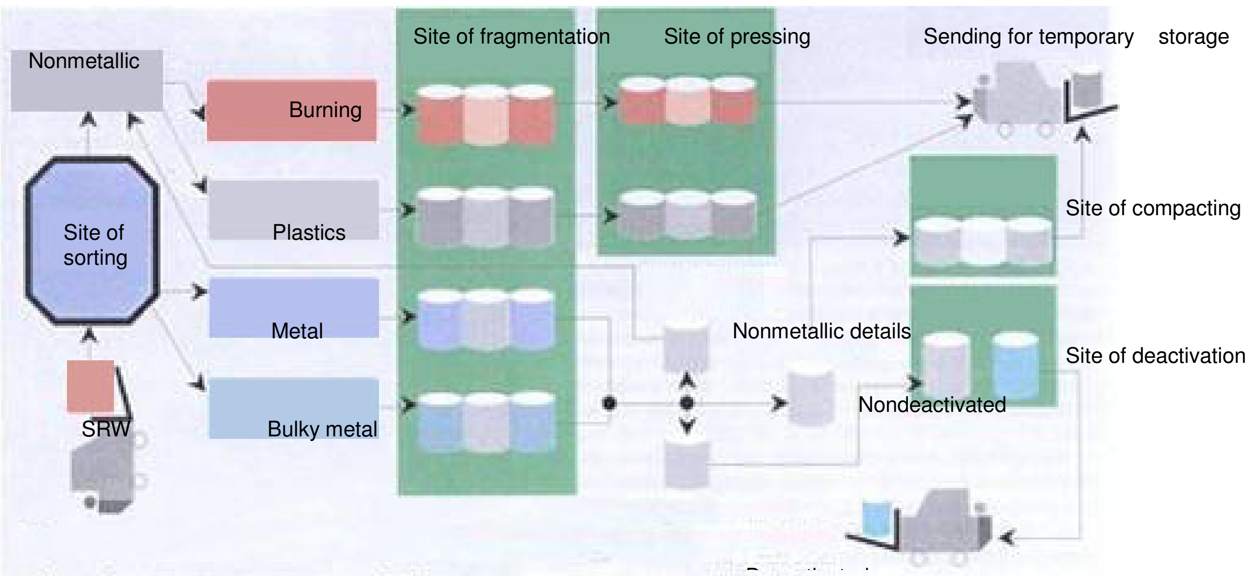
- Development of the hardware-technological schemes of cleansing of liquid RW (LRW)

- Development of the working design documentation for the optional equipment for processing of RW

- Follow-on and technical maintenance of manufacturing of the equipment and putting into operation of the complex

Basic principle of liquid RW processing (LRW):

- Extraction of radioactive substances from total mass of waste with the purpose of the subsequent maximum decrease of the volume of secondary SRW



Principal scheme of SRW processing

Technological principle of LRW processing: - Universal sorptive-membrane scheme with sanitarian ion-exchange afterpurification and finishing concentrating of brine up to dry salts at devices of deep concentrating and drying (selective removal of the main quantity of radionuclides with the kelp of inorganic sorbents)

Technical parameters of the complex:

- Productivity (maximum volume of processed LRW), cubic meters per year:

- low-salt solutions of the first contour of nuclear reactor - 200

- Solutions of tanks of biological protection of nuclear reactor - 700

- Salt deactivate and mixed solutions - 600

- Waste water and solutions of special laundry - 2500

- **Concentrating of radionuclides extracted from LRW** - 4000-times

- **Reduction of secondary SLW volume - 2-4-times**

- Final products of LRW processing:

- Spent sorbents packed in the special protective steel filter-container

- Dry salts packed into metal barrel of 55 gallons volume set in the second barrel of 85 gallons volume which has inside hermetic plastic cover and after filling it is set in the concrete contaner such as HIC-container (for salts of 1 contour solutions).

Ecological parameters and parameters of complex safety:

The limits of emission of the main radioactive isotopes with the processed liquid RW meet the requirements demanded by "Standards of radiation control" of the Russian Federation.

The clean water also meets the requirements demanded by Standards of the Russian Federation to the contents of chemical substances in output flows directed to the canalization system of object.

The complex is capable to process LRW with the concentration of radioactive isotopes exceeding square means by 100 times.

Designing, building and putting into operation were executed under the control of State atomic control of Russia and Arkhangelsk Committee of protection of environment and natural resources.

8.4.3.6 Technology of metal radioactive waste treatment

For the solution of problem of handling with metal radioactive waste (MRW) the enterprise developed a complex technology of processing and utilization that permits to return to industry a big part of polluted metal after its cleansing for re-use and to convert formed secondary radioactive waste in the ecological safe form convenient and safe for transporting and burial if its quantity does not exceed 2-8 % of initial volume of waste. The technology is based on use of way of remelting at final stage of handling with metal waste.

Technicians of "Ecomet-C" succeded not only to develop technology of MRW processing and principles of normalization of residual pollution of metals ensuring return of refined metal to industry, but also to carry these developments to inclusion to the normative-legal documents of federal level. The necessity of realization on radiation objects of mandatory preliminary remelting of passed desactivation metal raw material before dispatch to the processing enterprises is confirmed by inclusion of this rule to operational now «The main sanitary rules of maintenance of radiation safety» (MSRMRS-99) and «Sanitary rules of handling with radioactive waste» (MSRMRS -2002).

The main stages of MRW processing

- **The input radiation control** implements at receipt of containers or packings with MRW to the enterprise for determination of degree and character of radionuclide pollution of particular MRW batch. The pollution control is made by portable radiometric devices and with the help of the stationary laboratory spectrometric equipment.

- **The sorting of waste** by radionuclide pollution degree weight-dimensional and qualitative characteristics of material is made for forming of batches of metal directed further over the technological scheme. Under the radiation characteristics the waste is divided to waste requiring preliminary desactivation before remelting and waste suitable to remelting without desactivation. The necessity of fragmentation is determined by the weight-dimensional characteristics of waste.

- **Fragmentation of waste** is carried out up to the sizes permitting to make a load of fragments in melting furnace. There are applied manual, mechanical, gas, plasma cutting, stationary hydraulic and crocodile shearing machine.

- **Desactivation** is carried out if necessary depending on structure and level of radioactive contamination with the use of mechanical (shot-jetting) and thermal plant of desactivation.

- **Remelting** is carried out in induction melting furnace under the layer of refining fluxes. It is made the removal of the formed slag after full melting and small overheating of metal. Melt metal is teemed in moulds, after cooling the ingots are taken out of moulds and directed for the radiation control. Slag and used refractory-lined materials with radionuclides passed to them from metal are directed to burial.

- **The radiation technological control** is carried out at all stages of processing. At stages of fragmentation, desactivation and remelting of MRW it is exercised the control over power of doze of gamma radiation of waste, control surface pollution of fragments of waste and equipment, gamma-spectrometric analysis of samples of waste and melt, control of pollution of air emitted in the atmosphere. The output control of pollution of metal ingots intended for re-use is exercised in protective housing on power of exposition doze of gamma radiation of each ingot. Depending on specific activity remelt metal can be directed for reuse to industry without limitations, use for the limited purposes (for example in atomic engineering etc. after the appropriate coordination) or directed for cooling to site of temporary storage in controlled conditions up to decrease of metal pollution with the rest radionuclides, basically cobalt-60.

Main advantages of MRW processing with application of "Ecomet-C" technology:

- decrease of volume of solid radioactive waste (SRW) directed to burial (long-term storage) in 20-100 times (quantity of secondary radioactive waste is 5-10 % of initial quantity of processed metal waste polluted with radioactive waste);
- reducing of costs for conditioning and long-term storage of SRW;
- rational use of areas of storehouses (at conditioning of SRW by the method of cementation used at special industrial complexes "Radon", the volume of SRW decreases in 1.2-1.3 times);
- return of metal to industry for repeated unlimited use;
- presence of normative-legal base (Sanitary rules and normative, all-Union State Standard, methods);
- presence of production facilities;
- presence of certificated packing for transportation of metal waste polluted with radioactive waste.

As a whole application of "Ecomet-C" technology provides the significant reduction of SRW volumes (in 20-80 times) directed to burial, also allows to reduce essentially total costs for processing and burial of MRW.

8.4.3.7 Complex on processing and utilization of MRW

The industrial complex on processing and utilization of MRW is put into operation in 2002. The complex is located at industrial site of Leningrad APP.

The complex is intended for cleansing of radioactive contamination of metal waste of non-corrosive chromium-nickel and carbon steel, copper and its alloys, and also aluminium alloys with the purpose of reduction of volume of buried solid radioactive waste, reduction of costs for building and maintaining of storehouses for SRW and receiving of metal suitable for re-use in industry.

The structure of MRW that subject to processing is completed their resource and demounted equipment, which level of radiological contamination corresponds to a category of low-active solid radioactive waste by MSRMRS-99 and MSRMRS-2002.

The design documentation of the complex is developed by Federal state unitary enterprise Sosnovoborsk state design and survey institute "VNIPIET". The complex is made in accordance with the rules and standards of radiation safety, meets the sanitary-epidemiological, ecological, fire-prevention, building standards and rules, state standards. The control of state of the environment and process of processing of metal waste polluted with radioactive substances is exercised by special laboratories accredited by State Standard of Russia.

The brief characteristic of the complex:

- Estimated capacity - 5000 tons per year.
- Radionuclide composition of processed SRW - radionuclides of natural and man-caused origin.
- Initial levels of waste pollution – up to 0.3 mZv/hour.
- Residual levels of metal pollution after processing directed to industry for unlimited use:

  - Quantity of secondary radioactive waste – 5- 10 % of initial quantity of processed MRW.

  - Power level of doze of gamma radiation - 0, 2 mcZv/hour
- Emissions in the environment of radioactive and harmful chemical substances - no more than 3 % of planned values.
- Production space - 3000 square m.

The complex on processing and utilization of MRW includes the following three main sections: section of accepting and fragmentation, section of deactivation, section of remelting; and also: assemblies of metal radiation control; systems of gas purification; radiochemical laboratory; physico-chemical laboratory; assembly of preparation and distribution of deactivating solutions; assembly of receiving and giving out of trap waters; storage of pure and non-standard ingots; systems of air-supplying; section of deactivation of containers.

Section of receiving and fragmentation

The section of receiving and fragmentation is intended for cutting of MRW to sizes permitting to carry out their deactivation and remelting and also for sorting of waste by the sorts of metal and levels of radioactive pollution.

MRW cutting is made into fragments with the maximum size of 500 mm, and long-sized subjects (pipe, rolled metal) - no more than 800 mm.

The section is equipped with the following equipment:

- the plant of mechanized air-plasma cutting and semiautomatic plasma cutting which are located in box under discharging and intended for localization in a closed volume of harmful effects on the environment and the maintenance staff, such as sparks, dust-gas emissions, powerful infrared and ultra-violet radiation, noise. Maximum thickness of cut metal - 100 and 50 mm accordingly;
- the hydraulic lever scissors intended for cutting of metal in cold state. The scissors from input have the hydraulic automatic clamping device for fixing of an ongoing breakage during cutting. Maximum section of cut metal: circle - 115 mm, sheet - 38 mm (thickness) x 457 mm (width);
- crocodile shearing machine intended for cutting of shaped rolled metal, maximum thickness of cut metal – 25mm.

Section of deactivation

The section of deactivation includes section of thermal deactivation, section of abrasive deactivation, section of container deactivation.

The section of thermal deactivation is intended for cleansing of copper and its alloys and also for removal of lacquer coating and organic contaminations from MRW surface. The section consists of annealling electro-thermal furnace (maximum temperature - 1150 C^0), table for cooling and vibroimpact plant. The annealling furnace is equipped with the system of local suction of air. The vibroimpact plant and table for cooling of the container are equipped with rotary umbrella. The consumption of the sucked air is 5000 m^3/hour.

The section of abrasive deactivation is intended for deep deactivation of MRW from non-corrosive and carbon steel and also for afterpurification of MRW from non-ferrous metals and alloys up to levels after remelting ensuring return of metal to economic turnover for re-use. The section is equipped with shot-jetting plant with productivity up to 3 t/hour (weight of single load of MRW is 1 t, time of processing is 10-30 minutes).

The plant of shot-jetting deactivation is completed payloader and system of gas purification with productivity of 10000 m^3/hour including cartridge filter-dust collector and filter of fine cleaning. General efficiency of air cleansing is no less than 99.9%.

It is deleted radioactive sediments and corrosion film and also layer of metal of thickness up to 100 microns from MRW surface in the process of shot-jetting. Shot is regenerated and used repeatedly. Metal dust and radioactive oxides are separated from shot and assemble in the special collectors. Deactivated metal (picture) is unloaded to technological containers and directed to box for the setting of the technological control. All activities on site of abrasive deactivation are completely mechanized. It is provided the capability of automatic operation of shot-jetting plant under the specified program.

Unit of the radiation technological control

The unit of the radiation technological control of MRW is intended for measurement of radionuclide composition and levels of radiological contamination of MRW coming from section of fragmentation to section of deactivation and from section of deactivation to section of remelting. The unit is equipped with two boxes with the special highly sensitive gamma-spectrometric plants, the computer processing and fixing of the data is provided. By results of measurements it is made the decision on ways of the further MRW processing.

The section of remelting

The section of remelting is intended for afterpurification of metal from radioactive contamination in process of remelting or for reduction of volume of compacting

The section consists of site of melting, site of reverse water-cooling, site of metal teeming in moulds, cooling and extraction of ingots, storage and preparation of ingots for transporting, preparation of fluxes, anti-burning composition and lining materials, storage of secondary waste, repair of inductor and its preparation to work.

The section of melting. The section of melting is intended for melting of metal with the use of the induction furnace IST-2, 5/1, 6-M4. The section is equipped with working site, panel of control over systems of the furnace, lift-rotary umbrella for suction from crucible of the furnace of air-gas mix (productivity - 5000 m^3/hour), reverse slag-forming plant for receiving of slag, emergency tank for metal running-off.

The section of reverse water-cooling is intended for cooling of electric equipment and elements of the furnace. It is made under the double-circuit scheme with the closed first contour filled up with special afterpurificated condensate.

The section of metal teeming to moulds is intended for teeming of metal to moulds placed at self-propelled teeming car of semigantry type. Five moulds and slag-forming plant is installed on the car, the control over the car is exercised from the console of the electric furnace placed on working site.

The maturing of ingots in moulds on a dolly is made within one hour. After that moulds are removed from the car by cathead, set in site of cooling of ingots. It is set beforehand prepared moulds on the teeming car after conditioning of platform and the car is transfer in initial position.

The section of cooling and extraction of ingots is intended for cooling and extraction of ingots. The extraction of the partially cooled ingots is implemented by tipping of moulds at 180 C^0 with the help of the pull device hung on a hook of the bridge crane. The further cooling of ingots and moulds happens separately. The cooling of ingots happens at the expense of natural circulation of air.

The control system of radiation safety

The operative control over radiation situation, control of pollution of surfaces of the equipment and building constructions is conducted with the help of radiometers - dosimeters of a MKS-01, portable dosimeters DRG-01T, DBG-06T.

It is set stationary signalling devices of beta - contamination RZB-04, velocity meters of the count UIM2-2 with beta-sensors UDB-01P for the control of pollution of coverlet and clothes of the personnel at entrance and exit from sanitary inspection room.

The calculation of personal dozes of irradiation of the personnel is conducted with the help of system of the personal control Fluorad DRG-711-RFL.

The automatic monitoring of power of gamma background in premises and control of air emitted in the atmosphere by systems of gas purification is implemented by means of two ten-channel stations of data acquisition of system of automatic control over radiation safety by development of close corporation «SNIIP - AKRO ».

The station of data acquisition includes:

- Units of detecting of doze power of gamma radiation BDMG-08R;
- Units of detecting of radioactive aerosols BDAK-03P;
- Ten-channel device of processing UNO-84R.

The information on radiation parameters comes to UNO-84P to the shield chamber of control of radiation safety (CRS) and to the central computer of the head of RS service. It is conducted the control over stations, setting and control over state of measuring channels from shield chamber of CRS.

The control over the contents of radioactive substances in the air of premises, air on inputs and outputs of gas purification filters and in the air emitted in atmosphere is conducted by the method of sampling for standard analytical filters with the subsequent laboratory analysis. The same samples are used for determination of the composition of heavy metals in the air on roentgen fluorescent spectrometric complex "SPECTROSCAN-LF".

The analysis of radionuclide structure of contamination of waste, ingots of metal, contents of radionuclides in liquid waste is carried out in the plants:

- Gamma - spectrometric complex on the basis of the semiconducting detector of especially pure germanium;
- scintillation gamma-spectrometric plant SEG-08T with detectors on the basis of chips NaI;
- Beta-gamma-spectrometer USK "Gamma Plus Beta".

The determination of elemental structure of MRW, ingots and contents of metals in liquid waste is made on roentgen fluorescent spectrometric complex "SPECTROSCAN-LF".

It is set the protective measuring chambers equipped with the gamma - spectrometric complex (unit of the technological radiation control) for the technological control of MRW loaded to containers between sections of fragmentation - deactivation and deactivation - remelting.

The output control of ingots of metal

It is provided the special chamber for the output control of ingots of metal. The chamber is equipped with protective walls, cantilever crane for moving of ingots and devices for the control over power of exposition doze and levels of surface contamination of ingots in accordance to the developed techniques. The control of pollution of batch of ingots is provided by selection and measurement by gamma-spectrometer of melt sample before teeming of metal to moulds.

Residual pollution of ingots of metal is regulated by all-Union State Standard R 51713-2001 «Ingots of black and non-ferrous metals. Permissible level of gamma-emitting radionuclides. Method of the radiation control».

The handling of radioactive waste

The solid radioactive waste from all three sections are packaged to regular metal containers of Leningrad APP and they are sent by motor transport to station for processing through the site of receiving of MRW.

The liquid radioactive waste (LRW) - trap water from deactivation of premises and equipment collects in receiving tanks on negative marker of section of deactivation, and then they are put in tanks of LRW of Leningrad APP over pipes of special canalization.

Gaseous radioactive waste - the emissions pass cleansing up to the standards by systems separately:

General ventilation;

- Local suctions of section of fragmentation;
- Local suctions of section of deactivation;
- Local suctions of section of remelting.

The drop of radioactive emissions in the atmosphere is carried out through pipes of 20-24 m height.

Conditions of receiving of MPO for processing

Now close corporation "ECOMET-S" can render and it renders services of broad range to the interested enterprises and organizations in the field of handling of MRW including reception of waste with the low level of activity for processing at the production facilities with condition of return of the secondary RW formed during processing of MRW. Quantity of the secondary RW averages 5-7 % mass (maximum value - up to 10 % mass.) of initial quantity of waste coming for processing. Over the radiation characteristics the main part of the secondary RW corresponds (meets) to a category of low-active SRW. The secondary RW returns MRW to the supplier in 200-liter barrels or in another container coordinated with the supplier.

It is necessary fragmentation of MRW to the sizes ensuring load and transportation in the appropriate containers before their dispatch. It can be carried out the delivery of MRW to the complex close corporation "ECOMET-S":

- In metal transport containers KTBN-3000 (carrying capacity - 3 t, volume - 1, 8 cubic m), developed by the close corporation "ECOMET-S" and certificated in accordance with established procedure as packing of type"A" for transportation of low-active MRW by automobile and railway transport;
- In universal large-capacity transport container of ICC-20 type structurally modified and having the certificate - permission for use of data of containers as industrial packing for transportation of law-active MRW;

In containers for transporting and storage of solid radioactive waste УКТ IA ГОСТ 16327-88 (carrying capacity at transporting – 2.3 t, volume – 2.58 m^3) made by federal state unitary «Machine-building enterprise «Zvezdochka».

8.4.4 Disadvantages of geological way of burial

It can’t be said that the problem is not tried to be solved but these solutions is hardly to be cardinal. There is prevailing the traditional approach – burial in stable geological formations. Huge costs are spent for this. Thus, for research works ob building of national storage in Nevada State there were spent 9 billion dollars. Cost of storage in one isle of the Pacific Ocean is estimated to bigger sum.

This approach is very vulnerable. At first, waste has to be stored very long time. Decay of radioactive elements takes hundreds of thousands of years. None of technical constructions will stand even hundredth part of these terms. Metal and glass grow old, concrete is destroyed. Danger is aggravated by the fact that the Earth core is astir. For example in lime-pits of Moscow region were found out splits splitting rock massifs to rectangular blocks up to several meters. In other words in crystalline rocks there is an absolutely free exchange of water and gas flows.

In 1997 Committee of radioactive waste of the Great Britain paid attention to danger of RW burial in geological formations. It demanded an independent examination on evaluation of rock permeability in the area of supposed storage of RW of Sellafield atomic power plant in the north-west of England. There is storage at 1.5 km depth in Sweden. But also in that place there is found out a stream of salt water and possibly there is a water exchange with the Earth surface.

Huge quantities of RW are bottomed at the Ocean. Nevertheless metallic containers stand in aggressive marine environment no more than 15 years and concrete – about 25 years. In fiords of the Barents Sea similar containers are in tumble-down state and leak. Some nuclear reactors are entirely buried at the bottom of the Barents Sea. Previously they were covered with lead and plastic. Calculations show in that state reactors will safely remain no less than 500 years. No specialists realized in 25 years that radionuclides began to get in water. And 500 years are not so long time for human history but for the nature it is a moment.

Ways of RW burial at the big depth in unsettled areas even with arrangement of costly steady control are not deprived of essential disadvantages:

- during long-term storage (hundreds of years) of capsules with highly active and long-life radioactive waste their hermeticity are threatened with tectonic slides and destructions during earthquakes and also corrosion;

- there is no ponderable guarantee of excluding of attempts of damages of long-term storages by terrorists.

Costs for provision of steady control of burial places and their effective protection during hundreds of years will probably exceed costs needed for RW removal outside the Earth's biosphere with the help of space-rocket systems.

That's why it is created alternative projects in addition to developed technologies of RW burial.

8.5 HIGHLY-ACTIVE WASTE DISPOSAL IN SPACE AS AN ALTERNATIVE WAY OF PROBLEM DECISION

The cardinal solution of the problem is removal of long-living radioactive wastes from the Earth with the help of space rocket systems.
To implement such a project, solution of a complex of the following scientific and technical problems is required.
1. Selection of a composition of removed masses.
The main problems:
– development of the technology of extraction of long-living radioactive wastes from the overall mass of wastes:
– development of the technology of preparation of removed compound and filling of capsules to be placed on orbital disposal stage.
2. Investigation of a family of SRS elements trajectories at injection outside the limits of near – Earth space and their subsequent motion.
The following options of radioactive wastes removal into space are possible:
– transportation of radioactive wastes to the Sun;
– removal into geliocentric orbit to big distances, not less than several million kilometers from the Earth orbit;
– disposal on celestial bodies where there is no life and which orbits do not approach the Earth orbit, for example, on asteroids.
3. Development of ODS technological configuration.
In the framework of this task solution, it is expedient to develop new highly active engines operating in orbital segments of approach to the Sun and using solar radiation energy.
4. The Problem of Creating SRS Reliable Elements
This problem needs special attention, as it is required to ensure safety of a capsule with wastes in all standard and off-nominal cases, including the case of launch vehicle failure since launch till the end of orbital injection.
5. Determination of SRS Technical Configuration
The SRS potentially fit for injecting the radioactive wastes into space may be conventionally divided into the following groups:
– existing medium-class systems of Zenit type;
– heavy-class systems;
– newly developed SRS, in which the specific character of operation with radioactive payload may be taken into account from the first steps of designing.
When selecting a SRS type, the economic aspects are of greet importance.
Taking into account global nature of the problem, it is not improbable that intensive research and SRS realization will go in several directions simultaneously and in different space developed countries.

8.6 ECOLOGICAL AND LEGAL ASPECTS OF HARAW REMOVAL INTO SPACE

There are three approaches for solution of a problem of the used nuclear fuel (UNF) treatment in the world: fuel processing for extraction of useful components and reduction of the activity of the buried radioactive wastes (RAW); direct burial without any processing; long storage when the selection of UNF treatment method is postponed for later terms.

Each method has its advantages and disadvantages. For example, the extracted plutonium and uranium (as a result of processing) are used for production of fresh nuclear fuel. A significant factor is that UNF radiochemical processing leads to reduction of the amount of highly active wastes to be buried.

Various states have large-scale nuclear programs. They use various approaches for treatment of UNF from their nuclear stations. The USA, Canada and Finland plan to use direct burial of the nuclear fuel used. Great Britain, France, Russia and Japan perform its processing with subsequent final burial of highly active wastes vitrified. Other states provide temporary long-term UNF storage in special storehouses; they postpone the solution of this problem for later terms.

The report of Special Committee at the Nuclear Power Agency of Japan was published in November, 2004. In that report there was the comparison of the cost of two technologies for the first time. According to the data of the report, the direct UNF burial without its processing will cost 1.5-1.8 times cheaper. It proves the perspectiveness of the methods which have been determined in the USA, Finland and Sweden as the national strategies. It should be noted that up to the present no state has buried the used nuclear fuel in industrial scales.

Besides, our practice shows that the political situation, the national practice of making the decisions, the degree of mastering the modern technologies in this sphere should be taken into account when the cost values are reviewed.

8.7 CONCLUSIONS

1. The analysis of the ecological situation connected with the increasing amount of NPS wastes shows that the issue of isolation of radioactive wastes will be very urgent for the mankind in the nearest future.
2. At present there is a technical capability of creation of the space rocket complex on the basis of Zenit-2SLB ILV (Zenit-3SLB ILV) that can-be used for radioactive wastes removal into the deep space with a sufficient safety level for the environment.
3. Continuity of the power production process at APP leads to a necessity of constant removal of high-active and toxic radioactive wastes in the industrial technology; it will provide the increasing demand and profitability of the space rocket complex proposed.

9. WP2000 – SPACE OPTION ANALYSIS

9.1 LIST OF ABBREVIATIONS

APP	_	atomic power plant
CSCU	_	control system and communication unit
SRC	_	space rocket complex
RM	_	reboost module
MRAW	_	module with capsules with radioactive wastes
ODS	_	orbital disposal stage
UNF	_	used nuclear fuel
TB	_	transition bay
HARAW	_	highly active radioactive wastes
ILV	_	integrated launch vehicle
SRS	_	space rocket system
LV	_	launch vehicle
RAW	_	radioactive wastes
ES	_	escape system
CS	_	control system

9.2 REFERENCES

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4. M.Y. Herzenstein, V.V. Klavdiyev, "Radioactive wastes into space? Why not", magazine "Energy", № 6, 1991, p. 32.
5. A. Koval, V. Korob, "Radioactive wastes into space", magazine "Science in USSR", № 6, 1991, p. 92.
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9.3 INTRODUCTION

The new perspective mission for rocket-space technique is removal dangerous man-caused waste outside the Earth's biosphere. The variants of cardinal methods to free the Earth from man-caused waste forever are proposed in the report:

- the waste removal outside the Solar System;
- the waste destruction (total destruction) due to its delivery to the Sun;
- waste disposal on the asteroids, orbits of which never pass near the Earth.

The centuries' practice of the dump creation on the Earth, waste burial and incineration in view of global scale of production could lead to the irreversible consequences and even to an ecocatastrophe.

The potential possibility of waste removal outside the Solar System using rocket-space systems is shown by the example of theoretical research of high-level and removal of long-life waste of nuclear industry.

The progress reached in the leading countries of nuclear industry during the last years in the field of processing of low-active and middle-active parts of RW allows to reduce, to some extent, the acuteness of the problem. However, in opinion of experts this minimizes volume of non-storable waste but does not solve the problem as a whole. Whatsoever the

way the used nuclear fuel is processed, small volume of extremely long half life high radio-activity elements remains. Just this rather small part of substances extremely dangerous for the Earth's biosphere is supposed to dispose forever in space with the help of rocket-space systems.
The creation of these systems will free our planet from dangerous accumulation of extremely high-level waste. It will support the growth of atomic industry if the standards of environmental ecological security are observed.
At the same time it will be observed essential contribution to the growth of commercial effectiveness of rocket-space field and field of processing of atomic industry waste.

9.4 SUBSTANTIATION OF CHOICE OF RW DISPOSAL

At the present time, low – and medium – active wastes are transferred into solid form, after which they are placed in near-surface burials. The problem of isolation of highly active wastes is much more complicated. At present, the technology is being developed of their inclusion into solid matrices-glassy or crystal form for subsequent burial in the ground at the depth of up to 1 km. However, this method can not fully exclude wastes penetration into the sphere of human vital activity. Apparently, in this case, the came situation is developing as with APP safety: in his time, a Nobel Prise – Winner Academician P.L. Kapitsa wrote about inadequacy of the probabilistic approach to particularly hazardous objects when the probability of emergency event is low but if it occurs, its consequences are of global nature. In our case, this means that the places of underground burials of highly active radioactive wastes will require a special status and will be under continuous monitoring during hundreds and thousands of years.
Mass of annual amount of highly-active RAW that is subject to space disposal is very essential for selection of ORS technical configuration.
Determination of a share of highly active RAW with respects to their total mass was made according to the method proposed by M. Herzenstein and V. Klavdiyev /2/.
The RAW composition depends on reactor mode, intensity of neutron exchange, and burn-out rate.
35 kg of fission fragments with atomic weight of 80-140 and 14 kg of actinides with atomic weight of more than 200 are formed in the reactors on light water from one ton of nuclear fuel during three years of operation. The actinides consists of 8.9 kg of different isotopes of plutonium, 4.6 kg of U-236 and less than 1 kg of other isotopes. At ideal chemical processing 0.475 kg of neptunium-237, 0.12 kg of americium-243 and 0.04 kg of curium-244 go to waste from one ton of fuel, i.e. less than 1 kg per ton of fuel.
One reactor with electric power of 1 GW uses 20 ton of uranium per year. Thus, at ideal chemical processing, less than 20 kg/GW per year are subject to removal into space. Naturally, it is not possible to achieve ideal chemical processing, the real amount of long-living RAW is subject to space isolation (according to work /2/) that is 71.428 kg per 1 GW of generated electric power.
The processes of used nuclear fuel (UNF) treatment are presented in more detail in review /1/. It underlines that one of the main problems in handling the UNF is that it is a mixture of different substances, part of which still may be useful and part is already not utilizable. At that the UNF composition is commonly conventionally divided into two categories:
– 97.5 % of UNF are power-valuable dioxides of uranium isotopes and plutonium processed in a reactor that may be used after long storage;
– 2.5 % – radioactive waste that is subject to disposal (and only part of them – highly active waste – is proposed to be removed into space).
It follows from the above-mentioned that it is rational to solve the problem of amount of highly-active waste recommended for removal into space during joint investigations of the experts in nuclear physics, power-generating industry, space-rocket industry and ecology.
At this phase of researches is adopted the ratio presented in work /3/ in order to determine the main elements of technical configuration of a space rocket system: it is

recommended 71.428 kg of highly-active RAW per 1 GW of generated electric power to remove into space.

9.5 THE SPACE REMOVAL HIGH-ACTIVE RADIOACTIVE WASTE AS THE ALTERNATIVE AWARD OF THE ISSUE

The cardinal solution of the problem is the long-lived radioactive waste removal from the Earth using the rocket-space systems.

It is necessary to solve the next scientific and technical by complex for to realize this project:

1. The choice of disposed mass composition

The main issues:

- the development of technology of detachment long–lived radioactive waste from the whole mass waste:
- the development of technology of removing composition preparation and filling capsule which are subject to locate in removal orbiter.

2. The elements trajectory researches of rocket-space systems of removal them outside the Earth and their further movement.

It is possibly the next variants of radioactive space removal in space:

- transportation of radioactive waste to the Sun;
- removal to heliocentric orbit at a great distance that is no less than several millions of kilometers from the Earth orbit;
- disposal on the heavenly bodies that don't have the life ant which orbits never near to the Earth orbits, for example on the asteroids.

3. The development of technological aspects of orbital removal system.

For solving of this problem it is advisable to develop new high-active engines working on the orbital phase near to the Sun and using energy of the solar radiation.

4. The issue of safe space-rocket systems elements creation.

This problem requires the special attention because it is necessary to ensure the safety of capsule with waste in optimum and emergency cases including cases of launch vehicle crash in every moment from launch to the end of orbital injection.

5. The determination of rocket-space technological aspects.

The potential rocket-pace systems for radioactive waste removal in space are conventionally divided into the following groups:

- exploited of medium level systems as "Zenit";
- heavy level systems;
- newly-developed rocket-space systems where the specific work with net load could be taken into consideration from the first stage of designing.

The economic aspects are essential for choosing the rocket-space system type.

This issue has the global character, so it is not inconceivable that intensive research and realization of rocket-space systems would go by some ways and in different space developed countries.

9.6 THE CAPABILITIES OF SPACE ROCKETRY IN SOLVING THE PROBLEM OF HARAW REMOVAL OUTSIDE THE LIMITS OF EARTH BIOSPHERE

The task of radioactive wastes removal into space with the help of space rocket systems is solved in the following sequence:

1. An LV injects a special orbital disposal stage (with RAW) into reference circular Earth orbit.

2. The orbital disposal stage with the help of its own propulsion system ensures motion in departure trajectory.

The orbital disposal stage of new development is considered as LV upper stage.

To solve the task of radioactive wastes removal into orbit, the LV of various types modified as required may be used. In particular, in published works /4; 5/ the variants of Energia LV modification and Trezubets LV project implying the creation of a specialized LV for technogenic wastes removal into space are presented.

Table 4.1 presents a preliminary forecast of the amount of radioactive wastes that can be removed into space by these launch vehicles.

Table 5.1 – Preliminary Forecast of the Amount of Radioactive Wastes Subject to Removal

	Zenit-2 SLB	Zenit-3 SLB
ILV lift-off weight, t	462	468
Weight of orbital disposal stage in reference orbit H≈200 km, t	14	
Weight of orbital disposal stage in departure trajectory, t		~4
Weight of removed compound containing radioactive wastes, t	0.9	1.2

Taking into account the specific character of the task of radioactive wastes removal into space, when selecting a type of basic launch vehicle, the following shall be taken into consideration:

– LV reliability with sufficiently high power capabilities;

– level of LV pre-launch operations automation;

– availability of ground infrastructure;

– technical and economic indices.

At the present time, the Zenit family LV conforms to these criteria most fully. In this connection, taking into account the experience of its operation at Baikonur cosmodrome, it is proposed to use the Zenit launch vehicle in two-stage or three-stage variants to remove RAW from our planet.

It is proposed to develop a space rocket system to remove highly active radioactive active wastes from the Earth in two practically parallel phases:

Phase 1. Development of an orbital radioactive wastes disposal stage and demonstration of its reliability and safety using the launch vehicles based at Baikonur cosmodrome.

Phase 2. Creation and pilot operation of a space rocket system for HARAW removal based on Zenit-M SRS at Baikonur cosmodrome.

9.7 ZENIT-3 SLB AND ZENIT-2 SLB ILV. GENERAL DESCRIPTION

The Zenit LV was developed by Yuzhnoye SDO in late 1970-s-early 1980 according to the task of the USSR Defence Ministry for the injection means for quick and effective replenishment of military satellite group. The first Zenit launch was conducted on April 13, 1985. The rocket was conceived as a universal launch vehicle to replace a great number of rockets of previous generation and that is why it absorbed the greatest number of advanced design and technological solutions of space rocketry at that time.
The Zenit LV was made according to the most rational and technologically simple monoblock scheme with minimal number of stages (two) and engines (one on the 1-st stage and two on the 2-nd stage). Due to their high specific characteristics and dense layout of the stages, high LV power capabilities were achieved. The rationality and high reliability of LV scheme and the design of its systems, internal redundancy and many other measures of increasing the reliability were introduced during designing, as it was planned to use the rocket for manned flights and the respective level of safety and off-nominal situations counteracting was ensured.

The launching and technical complexes developed by KBTM were built at high technical level and with high degree of automation, which allowed to realize on Zenit complex the scheme "Unattended Launch" – fully automated pre-launch operations and launch and to minimize the quantity of expendable elements of launching device and the period of pre-launch preparation. Zenit uses the ecologically safe propellant pair "liquid oxygen-kerosene" and minimal number of separable parts during orbital injection, which minimizes the ecological effect from the launches on environment.
Later, the Zenit LV was updated for use as a part of the Sea Launch system together with the upper stage DM-SL developed by Energia RSC, which allowed the Zenit-3 SL (a three-stage modification of Zenit) to occupy a deserved place on the launch services market and to further improve the LV characteristics and reliability.
The work performed for the Sea Launch allowed also to update the ground complex at the Baikonur cosmodrome and to develop the Zenit-2 SLB and Zenit-3 SLB space rockets for it, based on the best solutions used in Zenit and Zenit-3 SL.
Altogether, the Zenit family rockets made 55 launches from the Baikonur cosmodrome and the sea launch platform Odyssey of the Sea Launch system. Besides, the Zenit first stage was used as a booster for Energia launch vehicle, and during two LV launches, 8 units of the Zenit first stage operated successfully.

The two-stage Zenit-2 SLB ILV includes:
– Zenit-2 SB launch vehicle;
– payload unit consisting of;
– payload fairing of 13.652 m length and 3.9 m diameter;
– transition bay to ensure payload fairing and payload mating to LV;
– payload SC with the means to ensure installation and separation (adapters and dispensers).

Figure 5.1 – Zenit-2 SLB Two-Stage Integrated Launch Vehicle

The three-stage Zenit-3 SLB ILV includes:
- Zenit-2 SB launch vehicle;
- payload unit consisting of;
- upper stage DM-SLB;
- payload fairing of 10.4 m length and 4.2 m diameter;
- payload – SC with the means to ensure installation and separation (adapters).

Figure 5.2 – Zenit-3 SLB Three-Stage Integrated Launch Vehicle

9.8 ZENIT-2 SLB AND ZENIT-3 SLB ILV MAIN CHARACTERISTICS AND POWER CAPABILITIES

The Zenit-2 SB ILV main characteristics are given in Table 6.1.

Table 6.1 – Zenit-2 SB ILV Main Characteristics

Characteristics	Value	
	I stage	II stage
1. ILV lift-off mass (without SC), kg	447964	110328
2. Mass of payload fairing, kg	–	2530
3. End mass of separable part, kg	32944	9500
4. Mass of propellant used to create thrust, kg	320452	81206
5. Nominal vacuum thrust of engines in main mode, tf – main engines – control engine	 806.4 –	 93 8.1
6. Nominal specific vacuum thrust in main mode – main engines – control engine	 337.2 –	 350.5 342.8

The Zenit-2 SLB power capabilities in standard configuration with payload fairing and transfer compartment allow to inject into low near-Earth orbit with altitude of 200 km and inclination of i=51,4º a payload with the mass of no less than 13920 kg.

The Zenit-3 SB ILV main characteristics are given in Table 6.2.

Table 6.1 - Zenit-3 SB ILV Main Characteristics

Characteristics	Value		
	I stage	II stage	US
1. ILV lift-off mass (without SC), kg	463727	110328	17483
2. Mass of payload fairing, kg	-	1800	-
3. End mass of separable part (at exhaustion of working propellant), kg	32944	9500	2090
4. Mass of propellant used to create thrust, kg	320261	81518	14582
5. Nominal vacuum thrust of engines in main mode in vacuum – main engines near the Earth, in vacuum; – control engine in vacuum	 740 806.4 –	 - 93 8.1	 - 8.105 -
6. Nominal specific vacuum thrust in main mode in vacuum – main engines, – control engine	 337.2 –	- 350.5 342.8	- 356 -

The Zenit-3 SLB power capabilities in standard configuration allow to inject into escape trajectory (the Earth escape velocity) a payload with the mass of no less than 3780 kg.

9.9 CONCLUSIONS

The analysis of the ecological situation connected with the increasing amount of NPS wastes shows that the issue of isolation of radioactive wastes will be very urgent for the mankind in the nearest future.

At present there is a technical capability of creation of the space rocket complex on the basis of Zenit-2SLB ILV (Zenit-3SLB ILV) that can-be used for radioactive wastes removal into the deep space with a sufficient safety level for the environment.

Continuity of the power production process at APP leads to a necessity of constant removal of high-active and toxic radioactive wastes in the industrial technology; it will provide the increasing demand and profitability of the space rocket complex proposed.

10. WP3000 - SAFETY AND ENVIRONMENT: WASTE CONTAINER DESIGN

10.1 LIST OF ABBREVIATIONS

APP	_	atomic power plant
CSCU	_	control system and communication unit
SRC	_	space rocket complex
RM	_	reboost module
MRAW	_	module with capsules with radioactive wastes
ODS	_	orbital disposal stage
UNF	_	used nuclear fuel
TB	_	transition bay
HARAW	_	highly active radioactive wastes
ILV	_	integrated launch vehicle
SRS	_	space rocket system
LV	_	launch vehicle
RAW	_	radioactive wastes
ES	_	escape system
CS	_	control system

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10.3 INPUT DATA

The problem of creation of reliable SCR devices demands a special attention as these elements should ensure the safety of the capsule containing the waste products in any nominal and emergency events, including emergency situations of the carrier at any moment of the launch until the end of injection into the orbit.

Together with OSR the new highly-active engines operating at orbital segments approaching to the Sun and using energy of sunlight are the subjects to development.
Development of the OSR technological shape is needed, including an assisted take-off launcher and compartments of a payload.

The economic aspects may have an essential value at the time of SCR selection. It is conditionally possible to divide different SCRs designed for an injection of RW into space according to the following groups:

– existing complexes, built upon the maintained launchers, including ZENIT launcher;
– rocket complexes with a large lift-off weight, such as Russian ENERGIYA;
– newly developed SCRs, in which the specific activity of works with radioactive payload may be taken into account from the first steps of design.

Taking into account the global assertion of this problem, it is quite possible that intensive researches and creation of SCR will take at once the several paths and be held in different space-advanced countries.
In many respects, it is possible to agree with the opinion of American researcher J. Kupersmit (1), that removal of the waste products into space would ensure a stable market for the high-tech production of space industry, and first of all – the civilian production.

Removal of RW into space can be executed in different ways:
– transportation of RW to the Sun;
– removal into the heliocentric orbit at large distances, not less than several millions of kilometers away from an orbit of the Earth;
– entombment at celestial bodies with no life, whose orbits do not approach an orbit of the Earth, e.g. asteroids.

10.4 ESTIMATION OF MIXTURE VOLUME, BEING A SUBJECT TO ISOLATION WITH RW

The annual volume of HRW, being a subject to space isolation is rather essential for selecting the technical shape of the RW utilization module (UM). Determination of HRW among the general mass of radwaste is rationally carried out on a basis of the technique offered by M. Gertsenshtein and V. Klavdiev (2).

Compound of RW depends on a mode of operation of the reactor, intensity of a neutron flux and burn-out. In light-water reactors during three years of its operation on one ton of nuclear fuel 35 kg of fission debris with an atomic weight of 80-140 and 14 kg of actinides with an atomic weight of more than 200 is formed. Actinides consist from 8.9 kg of various isotopes of plutonium, 4.6 kg of U-236 and less than 1 kg of other isotopes. At ideal chemical processing one ton of fuel gives 0.475 kg of Neptunium-237, 0.12 kg of Americium-243 and 0.04 kg of Curium-244 as waste products, which is less than 1 kg per ton of fuel. One reactor with electric power of 1GW consumes about 20 tons of Uranium per year. Thus, at ideal chemical processing less than 20 kg/GW per one year is a subject to removal into space. Naturally, it is impossible to achieve an ideal chemical processing and the actual quantity of long-lived RW, which is a subject to space isolation, makes up to 71.428 kg per 1 GW of the produced electric power (according to publication (2)).

The processing of the used nuclear fuel (UNF) is introduced in the survey in more detail (see1). It is mentioned there, that "one of the most important problems in UNF management is a fact, that it represents a mixture of various substances, one part from which might be still useful, and the other part is not so suitable for consumption". At the same time, the compound of UNF is conditionally divided into two categories:
– 97.5% of UNF are energy-valuable dioxides of isotopes of Uranium, and Plutonium formed in the reactor, which may be used after the long-lived storage;
– 2.5% forms the RW, which is being a subject to entombment (and there is only one part of them, which is HW, is offered to be removed into space).

According to the all mentioned above, the volume of HRW recommended to be removed in space should be rationally determined at a joint research of experts in the nuclear physics, energy, space industry, and ecology.

At initial phase of the research in order to define the basic elements of technical shape of SCR, the authors have assumed the adjusted ratio (see[3]): 714.28 N of highly-active RW (HRW) per 1GW of the produced electric power is recommended for removal into space.

The forecast on the overall APPs in different regions of the world until 2020 is adduced in the article of L. Preobrazhenskaya (Table 1).

Table 1

Region	2010 (GW)	2020 (GW)
North America	103.0 93.0	126.0 61.0
Latin America	4.9 3.8	10.0 3.3
Europe, West	129.0 122.0	145.0 91.0
Europe, East (former USSR)	7.2 4.7	16.0 8.0
Africa	1.9 1.9	5.7 1.9
Middle East, South Asia	7.2 4.7	16.0 8.0
Far East	128.0 101.0	190.0 119.0
Total in the world	434.0 375.0	575.0 320.0

In this connection, there are two versions of power values are specified:
– optimum, in case the development of the APP will be prolonged;
– minimum, in case the development of the APP will be artificially restrained, basically, because of the unsolved problems with RW.

In Table 1 some data is not adduced on the modes of operation, in which the development of electric power by APP is insignificant, but in a total power index in the world it is taken into account. Therefore, the global value "Total in the world" is different from the total of powers of APPs in the regions introduced in the Table 1.

10.5 SCR AND OSR BASIC FEATURES

Taking into account the global assertion of this problem, it is quite possible that intensive research and creation of SCR will take at once the several paths and be held in different

space-advanced countries. The research works of A.Koval (3), V.Korob, and N.Ivanov (4) are published in the Russian Federation regarding this problem.
The international project on creation of SCR would be rather attractive from the ecological point of view, maintaining all customer-countries from a launching site in the removed region, e.g. one of the numerous atolls in the Pacific Ocean.

It is expedient to move on gradually while finding the solution of this global problem. The creation of SCR for removal of RW from the planet is offered to be implemented into three stages:
– I Stage. Development of the RW removal module (RM), its integration with existing SCR and demo-launch;
– II Stage. Improvement and operation of modified SCR on the basis of existing launching facilities;
– III Stage. Creation of the specialized SCR with launching site removed from human settlements (sea launch) for removal of RW on a global scale.
–

Let's consider the utilization of ZENIT-3SL launcher in SCR for RW removal. The specifications of ZENIT-3SL basic version is shown on Fig.1.
The modification consists of the new Launch Escape System (LES) installed on the launcher, and the Orbital Removal Stage (ORS), which is used instead of the last stage of the launcher.
The modification layout is introduced on Fig 2.
The first stages of the launcher inject the Orbital Removal Stage into planned circular orbit of the Earth. The key parameters of the ORS at a moment of separation from the first stages of the launcher are introduced in Table 2.

Fig. 1.

Table 2

Weight of ORS (N)	143000
Weight of removed RW composition (N)	9000
Weight of capsule with RW (N)	12000
Weight of propulsion system (N)	4000
Weight of fuel (N)	100000

The engine is started on the planned orbit (thrust is 81000 N) and the SCR is accelerated to V_1=11.616 km/s. The vector of relative velocity V_1 forms the angle of 12.95 degrees with the local horizon at altitude H_{1E}=603.5 km.

On reaching the velocity V_1 the engine is cut off and the 6120 N of fuel reserve is preserved in tanks in order to start the engine up to 6 times at apoheli thereby increasing the distance of the planned orbit from the Earth at every other turn around the Sun.

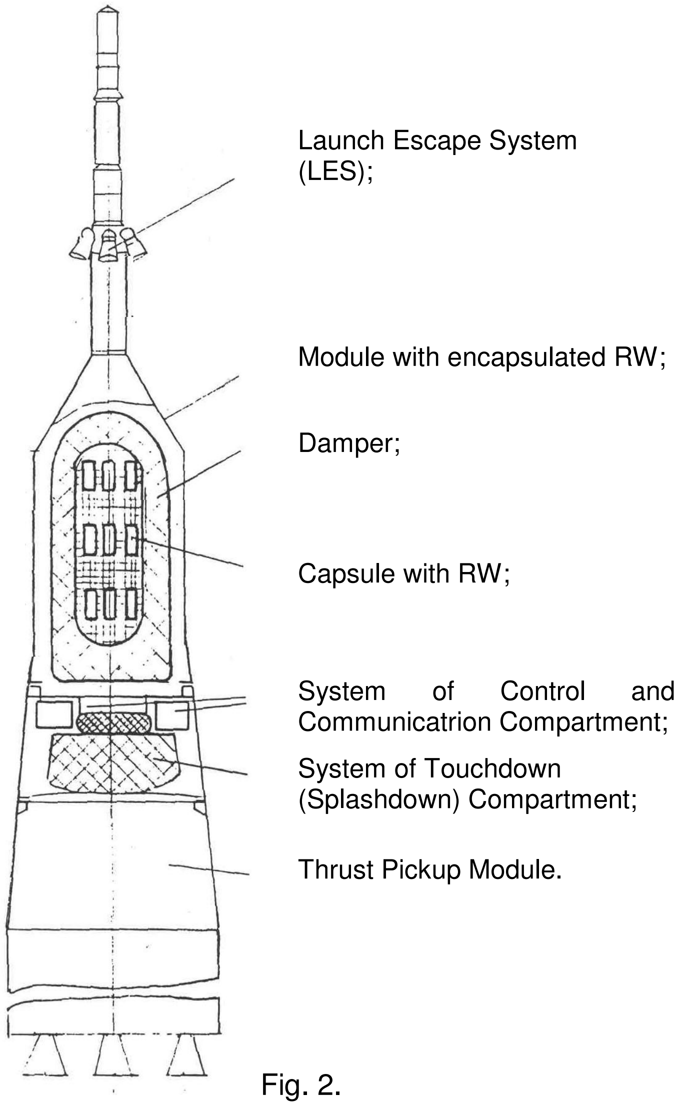


Fig. 2.

The Orbital Stage of Removal consists of (see Fig.2):
- Module with the encapsulated RW (CM);
- Thrust Pickup Module, including the propulsion system and fuel tanks (TPM).

The Module with the encapsulated RW consists of:
- control system and communication unit (CSCU);
- touchdown (splashdown) system compartment;
- capsule with the RW.

The designs of the capsule may be various depending on features of the RW, which is being removed. We shall note only the basic elements of the capsule, which are conventional at the present stage of design.

The primary structure of the capsule represents a honeycomb cell with high-strength walls. Graphite ampoules with inner ceramics made of the RW oxides are placed in cubicles of the cell. Ceramic mass including the RW with the density of ~8g/cm^3 and temperature of melting above 2000℃ is placed inside the ceramic shell. Honeycomb skeleton is covered by the case made of the multilayer heat-resistant material on the basis of Titanium or steel alloys.

Modified launchers ARIANE-5 and DELTA-4 may be used for an injection of the ORS into the planned orbit. It is possible to assume, that their modification will be initiated in the event of successful injection performed by lighter class launcher, e.g. ZENIT. Besides, the modification of ENERGIYA launcher, as well as TREZUBETS launcher project are introduced in the published articles. TREZUBETS project impacts on creation of the specialized launcher, designed plainly for removal of technogenic wastes into space.

10.6 PROPOSALS ON THE FIRST STAGE OF ACTIVITIES

It is expedient to use the reliable launcher of an easy class at the first stage of research on creation of SCR for experimental safety acknowledgement of capsules with the RW in emergency events, e.g. DNEPR launcher.

During the launch of DNEPR it is possible to simulate the heaviest emergency event when the capsule with the RW enters in atmosphere and drops on a ground. For this purpose it is required to start a module with the RW capsule on a ballistic trajectory from BAYKONUR Space Port with a point of fall in area of Russian ground KURA. Parameters of the entrance to the atmosphere (angle of entrance – θ, velocity V_e) are being selected in such values, so that at flight in atmosphere and the subsequent fall on a ground effects on the capsule with the RW were realized much heavier, than in an emergency event of nominal flight. It is rational to invite the potential customers at the demo-launch in a zone of fall of the capsule with the RW so that they could be personally convinced in safety of the capsule.

Such demonstrating of reliability may essentially affect their determination to invest the activities on creation of SCR for removal of RW into space. Besides, the experimental data for optimization of the RW compound and weight of the Orbital Stage of Removal will be received.

$$\mathbf{K_{ef} = C_{RW} / C_{OSR}}$$

At teamwork of scientists and designers in the field of nuclear physics, heating engineering, mechanics, and space-rocket engineering at the second stage of SCR creation the improvements of K_{ef} are expected.
Today, the research on the RW capsule with non-traditional space shape has been held at Yuzhnoye SDO. During these activities the capability was shown to increase the K_{ef} up to 10% and even more due to improvement of aerodynamic characteristics of the capsule. The important fact is that at designing the capsule with the RW of the new aerodynamic shape, all the changes of aerodynamic characteristics decrease rather essentially at ablation of a heat-shielding at atmospheric entry.

10.7 EVALUATION OF RADIATION CHARACTERISTICS OF LLW CONTAINER

At present, the information concerning detailed characteristics of LLW (long-live waste) to disposed using LV (Launch Vehicles) is inaccessible. Therefore, for the purposes of this paper, we will make several assumptions on the element and isotopic composition, spectral characteristics of radiation of disposed products and the layout of the container intended for mounting on LV.

The basic assumption consists in the fact that SNF (spent nuclear fuel) was held within not less than 3-5 years before processing, and in the course of radio-chemical processing practically all uranium, thorium, plutonium are extracted from it as valuable raw material for subsequent power-generating or military use. Besides, we assume that a major part of gamma- and beta-active isotopes widely used in industry and medicine such as, for example, cobalt-60, strontium-90, cesium-137, radium-226 is also extracted. At the same time, it is clear that absolutely complete extraction of all these isotopes from SNF is not technically feasible. Therefore, two variants of isotopic composition will be considered hereafter; "an optimistic", which takes into account only the isotopes with decay period of more than 100 years with complete absence of uranium, thorium and plutonium and "a pessimistic", in which together with the isotopes of optimistic variant, totally 10% of all the abovementioned elements are also present.

The next assumption concerns the relative content of separate elements in the mixture and respectively, its average atomic number and density. These values will be needed to evaluate the radiation characteristics of container as a source with self-absorption. At this stage, we assume that equal amount (mass) of all isotopes is contained in the mixture.

The next assumption refers to which long-lived isotopes shall be taken into account in radiation evaluations. It is clear that all isotopes – pure alpha-radiators may not be taken into consideration due to low penetrability of alpha particles with energy 2.5-8.8 MeV and because of minute contribution of alpha particles with such energy into secondary slowing-down gamma-radiation. Among the long-lived nuclei-gamma-radiators, those may not be taken into account whose basic conversion mechanism is K-capture and respectively, the radiated quanta lie in X-ray range and are practically completely absorbed by the source itself and the container structural materials. For the same reason we may not take into account the isotopes – pure beta-radiators with the maximal energy of electrons (positrons) in the spectrum less that 150 KeV.

Tables 3 and 4 present the isotopic composition of LLW mixtures of both variants taking into consideration the above assumptions (2, 10).

Table 3. Isotopic Composition and Some Characteristics of LLW Mixture Nuclides of "Optimistic" Variant

Number	Isotope	T ½, years	Activity, Ci/g	E_g, MeV	Yield, qu./decay	E_β, MeV	Yield, part./decay	Content in Mixture, Fraction	Atomic Number	Gamma-Constant, $R \cdot cm^2/h \cdot mCi$
1	Be-10	2.70E+06	1.32E-02			0.212	1	0.05	4	
2	Al-26	7.38E+05	1.86E-02	0.511	1.64	0.447	0.85	0.05	13	4.836
	Al-26			1.81	1					8.423
3	Cl-36	3.01E+05	3.20E-02			0.251	0.981	0.05	17	
4	K-40	1.28E+09	7.02E-06	1.46	0.107			0.05	19	0.774
5	Se-79	6.50E+04	6.96E-02			0.057	1	0.05	34	
6	Rb-87	4.70E+10	1.82E-07			0.104	1	0.05	37	
7	Nb-94	2.03E+04	0.187	0.703	1	0.179	1	0.05	41	3.956
	Nb-94			0.873	1					4.787
8	Tc-99	2.13E+05	1.69E-02			0.111	1	0.05	43	
9	I-129	1.60E+07	1.73E-04			0.057	1	0.05	53	
10	Cs-135	2.10E+06	1.26E-03			0.079	1	0.05	55	
11	La-138	1.35E+11	2.38E-08	0.788	0.32	0.078	0.3	0.05	57	1.408
	La-138			1.435	0.68					4.847
12	Tb-158	1.50E+02	9.34E+00	0.182	0.09			0.05	65	0.0849
	Tb-158			0.78	0.09					0.41
	Tb-158			0.96	0.24					1.27
13	Lu-176	3.60E+10	4.07E-08	0.202	0.8	0.1	1	0.05	71	0.831
	Lu-176			0.307	0.93					1.589
14	Hf-182	9.00E+06	2.54E-04	0.271	0.84			0.05	72	1.244
15	Bi-208	3.68E+05	4.67E-03	2.615	1			0.05	83	10.88
16	Bi-210	3.50E+06	6.55E-04	0.266	0.51	0.64	1	0.05	83	0.738
	Bi-210			0.305	0.28					0.475
17	Am-243	7.38E+03	0.185	0.25	0.41	0.16	1	0.05	95	0.23
18	Cm-245	8.50E+03	0.157	0.153	0.28			0.05	96	0.206
19	Bk-247	1.38E+03	1.05	0.265	0.3			0.05	97	0.433
20	Cf-249	351	3.99	0.36	0.82			0.05	98	1.744

Table 4. Isotopic Composition and Some Characteristics of LLW Mixture Nuclides of "Pessimistic" Variant

Number	Isotope	T ½, years	Activity, Ci/g	E_g, MeV	Yield, qu./decay	E_β, MeV	Yield, part./decay	Content in Mixture, Fraction	Atomic Number	Gamma-Constant, R·cm^2/h·mCi
1	Be-10	2.70E+06	1.32E-02			0.212	1	0.045	4	
2	Al-26	7.38E+05	1.86E-02	0.511	1.64	0.447	0.85	0.045	13	4.836
	Al-26			1.81	1					8.423
3	Cl-36	3.01E+05	3.20E-02			0.251	0.981	0.045	17	
4	K-40	1.28E+09	7.02E-06	1.46	0.107			0.045	19	0.774
5	Se-79	6.50E+04	6.96E-02			0.057	1	0.045	34	
6	Rb-87	4.70E+10	1.82E-07			0.104	1	0.045	37	
7	Nb-94	2.03E+04	0.187	0.703	1	0.179	1	0.045	41	3.956
	Nb-94			0.873	1					4.787
8	Tc-99	2.13E+05	1.69E-02			0.111	1	0.045	43	
9	I-129	1.60E+07	1.73E-04			0.057	1	0.045	53	
10	Cs-135	2.10E+06	1.26E-03			0.079	1	0.045	55	
11	La-138	1.35E+11	2.38E-08	0.788	0.32	0.078	0.3	0.045	57	1.408
	La-138			1.435	0.68					4.847
12	Tb-158	1.50E+02	9.34E+00	0.182	0.09			0.045	65	0.0849
	Tb-158			0.78	0.09					0.41
	Tb-158			0.96	0.24					1.27
13	Lu-176	3.60E+10	4.07E-08	0.202	0.8	0.1	1	0.045	71	0.831
	Lu-176			0.307	0.93					1.589
14	Hf-182	9.00E+06	2.54E-04	0.271	0.84			0.045	72	1.244
15	Bi-208	3.68E+05	4.67E-03	2.615	1			0.045	83	10.88
16	Bi-210	3.50E+06	6.55E-04	0.266	0.51	0.64	1	0.045	83	0.738
	Bi-210			0.305	0.28					0.475
17	Am-243	7.38E+03	0.185	0.25	0.41	0.16	1	0.045	95	0.23
18	Cm-245	8.50E+03	0.157	0.153	0.28			0.045	96	0.206
19	Bk-247	1.38E+03	1.05	0.265	0.3			0.045	97	0.433
20	Cf-249	351	3.99	0.36	0.82			0.045	98	1.744

Table 4. Continued

21	Co-60	5.272	1130	1.173	0.999	0.097	1	0.01667	27	6.107
	Co-60			1.333	1					6.746
22	Cs-137	30	87.6	0.662	0.846	0.188	1	0.01667	55	3.192
23	Ra-226	1620	1	0.079	0.223	0.45	2	0.01667	88	0.0793
	Ra-226			0.295	0.201					0.329
	Ra-226			0.352	0.393					0.779
	Ra-226			0.609	0.484					1.681
	Ra-236			1.12	0.16					0.943
	Ra-226			1.765	0.166					1.378
	Ra-226			2.118	0.012					0.116
	Ra-226			2.205	0.054					0.514
	Ra-226			2.448	0.0177					0.172
24	Th-229	7.34E+03	0.213	0.124	0.2	0.281	3	0.01667	90	0.114
	Th-229			0.154	0.2					0.148
	Th-229			0.193	0.14					0.137
26	U-235	7.13E+08	2.14E-06	0.143	0.105	0.094	1	0.01667	92	0.0716
	U-235			0.163	0.048					0.0382
	U-235			0.186	0.54					0.506
	U-235			0.205	0.047					0.0497

Table 5 presents some radiation characteristics of the mixtures of both variants required for further estimations. These figures were obtained based on the data from Tables 3 and 4.

Table 5. Basic Radiation Characteristics of Different Variants of LLW Mixtures

Variant	Optimistic	Pessimistic
Activity of mixture, Ci/g	0.753	21
Weighted-mean (by activity and isotope content) energy of gamma-quanta, MeV	0.571	1.230
Maximal energy of gamma-quanta, MeV	2.615	2.615
Weighted-mean (by activity and isotope content) energy of beta-particles, MeV	0.167	0.104
Maximal energy of beta-particles, MeV	0.64	0.64
Gamma-constant, $R \cdot cm^2/h \cdot mCi$	2.460	2.598
Weighted-mean atomic number	56.7	56.85

The assumed density, weighted-mean atomic number and mass coefficients of gamma-radiation attenuation for both LLW mixture variants are taken to be equal and presented in Table 6. Density prediction was made taking into consideration that the above elements, most probably, will be presented in mixture with oxides or non-organic salts (8).

Table 6. Some Mechanical and Radiation-Physical Properties of LLW Material

Density, g/cm^3		7
Weighted-mean atomic number		57
Mass coefficient of gamma-radiation attenuation, cm^2/g for energy	0.104 MeV	2.293
	0.167 MeV	0.693
	0.571 MeV	0.087
	1.230 MeV	0.052
	2.615 MeV	0.039

In this section, the container layout is considered mainly from the viewpoint of evaluating the radiation characteristics of this object. It is supposed that after radio-chemical processing the conditioned LLW will be placed into small bimetal capsules in portions of about 100-150 g. The capsules in their turn will be accommodated in a lightweight volumetric cellular structure that ensures their spatial fixation inside the container and damping of mechanical loads. Finally, all this is placed in a strong container casing which fulfils a number of functions: ensures mechanical strength of the whole structure, its tightness, possibility of installation on LV and of course, radiation protection.

The shape of capsules is taken to be cylindrical (Fig. 3). In this case, for their manufacturing and filling the existing technology of manufacturing and filling the fuel elements for NPP (nuclear power plants) may be used after respective modification. As container shapes, cylinder and sphere are considered. For this moment, it is the most natural solution, grounded by layout considerations of "building-in" the container into the structure of the last stage and by strength criteria.

As the materials of capsule's bimetal jacket, a tantalum-wolfram alloy (internal layer, thickness 0.5 mm) and rhenium-molybdenum alloy (external layer, thickness 0.5 mm) are used. As a damper, a material based on carbon will be used. To manufacture a strong container casing, it is planned to use steel. The basic characteristics of the above materials required for estimations are given in Table 7 (5, 8).

Table 7. Some Mechanical and Radiation-Physical Properties of Materials of Capsule and Container

Material		Ta-W	Re-Mo	Steel	Carbon
Density, g/cm^3		16	14	7.8	1
Weighted-mean atomic number		74	58	26	6
Mass coefficient of gamma-radiation attenuation, cm^2/g for energy	0.104 MeV	4.23	2.433	0.331	0.148
	0.167 MeV	1.1	0.644	0.151	0.129
	0.571 MeV	0.108	0.090	0.076	0.082
	1.230 MeV	0.055	0.051	0.053	0.057
	2.615 MeV	0.041	0.038	0.038	0.038

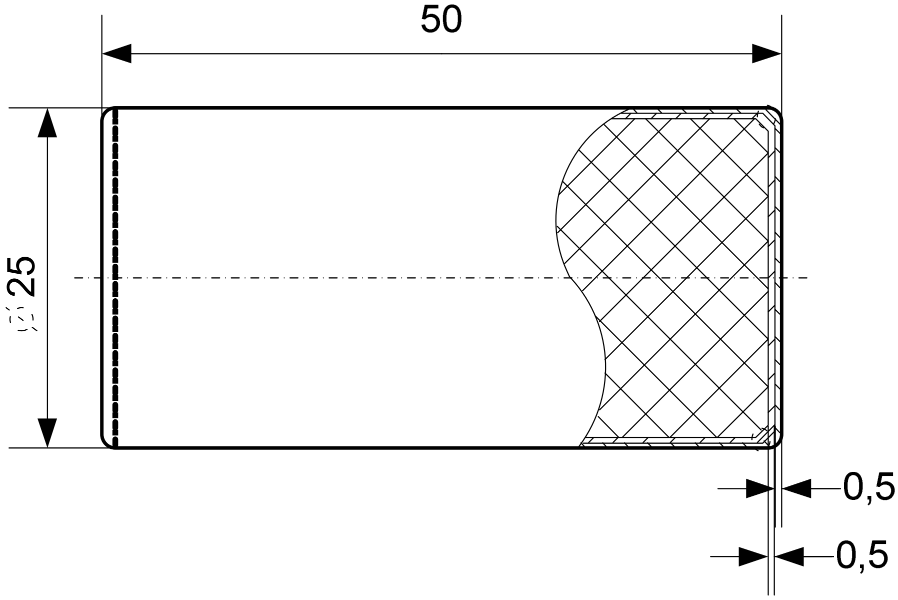


Fig. 3. A Sketch of LLW Capsule

Table 8. Filled Capsule Mass Breakdown

Capsule Element	Weight, g
Jacket	70.1
LLW	139.6
TOTAL	209.7

The capsule volume (by external dimensions) is 24.5 cm^3. The internal volume is 19.9 cm^3. The average density of capsule is 8.559 g/cm^3. The average density of capsule in the volume of respective parallelepiped is 6.71 g/cm^3. When filling the volume of parallelepiped outside the capsule by carbon damper (plus 0.1 cm for one side), the average specific weight is (209.7 g + 13.4 g)/ 2.7·2.7·5.2 cm^3=5.886 g/cm^3.

The evaluation of the dose power of gamma-radiation on capsule surface taking into account self-absorption in the radioactive material and some radiation attenuation by the bimetal capsule jacket gives the values of about 1.4…1.6 R/s for the optimistic and about 57…61 R/s for the pessimistic variant (7). In the assumption that the mounting operations of container to LV mating will not be fully automated and will take about 6 hours, the dose power on its surface must not exceed $5 \cdot 10^{-5}$ R/s (180 mR/h) (6, 11). These figures determine the required attenuation coefficient, which shall be ensured by the strong container casing; about 32000 (steel thickness about

27 cm) for the optimistic variant and 1220000 (steel thickness about 42 cm) for the pessimistic variant (6).

The mass of cylindrical container with zero internal volume will be respectively about 965 kg for the optimistic and about 3630 kg for the pessimistic variant. The mass of spherical container with zero internal volume will be respectively about 643 kg for the optimistic and about 2421 kg for the pessimistic variant.

When using an additional protection of personnel, which reduces by an order the power of radiation dose between the container and a person, the respective figures will be 336 kg, 2287 kg, 224 kg and 1524 kg correspondingly (see Table 9).

Table 9. Container with "Zero" Internal Volume

Characteristic	Container Variant			
	Optimistic	Pessimistic	Optimistic, Additional Protection of Personnel	Pessimistic, Additional Protection of Personnel
Required attenuation coefficient	$3.2 \cdot 10^4$	$1.22 \cdot 10^6$	$3.2 \cdot 10^3$	$1.22 \cdot 10^5$
Wall thickness, cm	27	42	19	36
Mass at zero internal volume (cylinder), kg	965	3630	336	2287
Mass at zero internal volume (sphere), kg	643	2421	224	1524

Evidently, there is point to making further evaluations for the container of spherical shape. Proceeding from the fact that the weight in escape trajectory is 3750 kg, the weight of the elements of container attachment to LV is (supposedly) 100 kg, and numerically solving the equations that connect the dimension of internal cavity in the spherical container, full weight of filled container and the weight of capsules with damper we may evaluate the number of capsules and respective LLW weight for four variants from the last line of Table 9. The respective numbers are given in Table 10.

Table 10. Basic Mass-Dimensional Characteristics of Spherical Container

Characteristic	Container Variant			
	Optimistic	Pessimistic	Optimistic, Additional Protection of Personnel	Pessimistic, Additional Protection of Personnel
	1	2	3	4
Internal diameter of cavity, cm	43	12.2	60.2	24.4
External diameter of container, cm	97	96.2	98.2	96.4
Cavity volume, cm^3	41630	951	114232	7606
Number of capsules, pcs	1098	25	3013	200
Total LLW weight, kg	**153.2**	**3.49**	**420.6**	**27.92**
Total damper weight, kg	14.73	0.338	40.414	2.706
Total weight of filled capsules and damper, kg	244.98	5.58	672.24	44.65
Weight of attachment elements, kg	100	100	100	100

Weight of strong container casing, kg	3402.71	3628.54	2976.47	3599.35
Total weight of filled container, kg	**3747.69**	**3734.12**	**3748.71**	**3744.00**

For each of four variants presented in Table 7, in accordance with the technique set out in (9), the dose power on the surface of spherical container and for the distance of 0.1 m, 1 m, 5 m, and 10 m from the container was evaluated in the assumption that activity contained in it is evenly distributed in the whole volume of internal cavity. The results of evaluations are presented in Table 11.

Table 11. Dose Power at Different Distances from Container

Distance from Spherical Container Surface, m	Dose Power, mR/h for Variant			
	1	2	3	4
0	0.39	0.82	19.4	37.5
0.1	0.36	0.72	19.3	28.7
1.0	0.22	0.21	7.4	4.71
5.0	0.04	0.15	1.00	1.43
10.0	0.015	0.10	0.34	1.02

An exclusively evaluative nature of the figures that characterize the capsule and container radiation properties should be noted. This is connected with the considerable number of assumptions concerning LLW isotopic composition and with the great number of simplifying assumptions used in calculations of LLW radiation properties. A correct calculation of radiation characteristics of real container presents a difficult task and requires the use of Monte-Carlo method.

An issue of radio active material heat emission should be set aside. It is clear from the general considerations that for long-lived isotopes this issue is hardly to be very acute. Nevertheless, the respective calculations are needed, as their results may have an impact on the basic structural-arrangement solutions.

10.8 ANALYSIS OF SAFETY CRITERIA OF THE EARTH BIOSPHERE

The mankind enters the third millennium. The past century was a century of rough development of technical activity in world community with indeed fantastic change of its life-style. However together with a civilization development there was a new and difficult problem of ecological safety of the Earth and environment preservation in all its variety. And this problem becomes more complicated year by year because of extremely high level of man-caused effect on the Earth biosphere accompanying by environment pollution and ecological imbalance.

The most serious threat is radiation pollution of a hydrosphere, atmosphere, population territories and biosphere as a whole. The special danger for the future mankind brings highly toxic, long-living radioactive waste of atomic power engineering (with a half-life period from hundred thousand to 10 million years). First of all it is nuclides of neptunium -237, plutonium -239, americium -242, curium -244, technetium -99, iodine -129, zirconium - 93 and others, contained in used nuclear fuel in quantity up to 1 %. By now in the world the temporal storages have already accumulated about 200 thousand used nuclear fuel and its quantity is increased by 10 thousand annually, which corresponds to 2000 tons of especially dangerous and radioactive long-living nuclides and their annual increase by 100 tons. The figures corresponding to the existing waste from weapon plutonium manufacture here were not taken into account.

It is well known, that the atomic power engineering is the factor of steady development of the world leading industrial countries and in the near future there is still no any alternative because of the limited resources of organic fuel.

The atomic power plants (APP) of the Russian Federation now generate more than 20 GW, which corresponds to 10 % from all electric energy, made in the country. It is much lower than similar index of the other advanced countries. In the USA the general power is equal 104 GW which makes 19 % from the country's general energy potential, in France - 55 GW (74 %), in Germany - 24 GW (34 %), in Japan - 32 GW (28 %). The summarized APP power on the planet has already exceeded 330 GW, and according to forecasts it will be increased by 100 GW in the nearest future. It means, that quantity of radioactive waste of atomic power engineering will steadily grow, increasing the danger of radiation pollution of the Earth biosphere. If the problem of radiation safety of atomic power plants is virtually solved, the problems concerned with the radioactive waste treatment and its localization are in the initial stage and claim the most serious attention and the fastest solution. In view of this the most dangerous and long-living nuclides present the special difficulty, so that it is necessary to ensure their absolute insulation from the Earth biosphere during approximately 100 million years. It is a whole geological epoch and it is extremely difficult and unsafe to make a prediction for such long period concerning the absence of any natural or artificial cataclysms which can cause the hit of nuclides on biosphere.

The hit of significant quantity of long-living nuclides on the Earth biosphere during such long period of their toxic properties conservation inevitably will cause their diffusion throughout the planet. And the result will be degeneration of the mankind and death of the gene pool. Despite it is extremely far prospect the civilized society is obliged to think about the future by now.

Today we became aware of pernicious influence of radioactive waste of atomic power engineering in the separate areas of former USSR countries (Chernobyl, Chelyabinsk and Kola Peninsula). The one more danger is that we often make a rash, unskilled or hasty decisions which will become a real trouble for us in centuries and thousand years, when the tragic consequences can't be corrected.

The problem of radioactive waste safety treatment and its localization is a concern for not only separate countries using atomic power engineering, but international problem. It is because the negligent and rash decisions on radioactive waste localization in anyone single country will cause the catastrophic consequences in others, and any state borders can't prevent this. It is a question of time. That's way it is necessary to reach the consensus in this problem in all international community, to develop the common methods of radioactive waste treatment, its localization under the international control of the established standards and rules compliance.

The scientists of the countries with atomic power engineering understand well the danger of accumulation of the great quantity of used nuclear fuel and the necessity of substantial problem solutions concerning the treatment of radioactive waste and its safe localization. However it is only the beginning of this problem solution. Today two methods of localization of the especially dangerous for human health long-living radioactive waste are seriously studied. The first one is the method of radioactive waste deep disposal in steady geological formation. And the second one is the method of transmutation, i.e. the converting of the long-living nuclides into short-living ones which are steady in special reactors and power accelerators.

The method of radioactive waste deep disposal is obvious and it is a quite reliable solution for short-living nuclides. But for long-living nuclides demanding for safe insulation from the Earth biosphere during ten-hundred million years, this method of deep disposal requires of serious study and convincing substantiation of its safety. It is necessary to solve the problems of disposal controllability and possibility of effective interference in a threatening situation in the case of danger. These difficult solutions we should leave to our far offspring in order to not place their lives in jeopardy of biological survival. The method of transmutation also requires a detailed researches and experimental acknowledgement of long-living nuclides processing efficiency, i.e. the depth of their "converting" and the elimination of possibility of new long-living and not less dangerous nuclides appearance during the processing.

The biosphere radiation

The radiation pollutions have essential difference from others. The radioactive nuclides are the nucleuses of unstable chemical elements beaming charged particles and short-wave electromagnetic radiations. These particles and radiations, striking the human body destroy the cells and as a result there can be a various sickness, including radiation one.

Everywhere in a biosphere there are natural sources of radioactivity and the man, as well as all living organism was always subjected to natural irradiation. The external irradiation is a result of space radiation and radioactive nuclides of environment. The internal irradiation arises by radioactive elements getting inside the human body with the air, water and food.

For making a quantitative assessment of radiation effect on the man the following units are used: roentgen-equivalent-man (Rem) or sievert (Sv): 1 Sv = 100 Rem. Since the radioactive radiation can cause the serious changes in the human body each man should know its tolerance.

As a result of internal and external irradiation the man during one year on average gets a 0.1 Rem doze and hence about 7 Rem during the whole his/her life. These dozes can't harm to the man. However in the world there are single areas where the annual radiation doze is higher than the average one. For example, the people living in high-mountainous areas because of the space radiation can get a radiation doze a several times greater. The great radiation dozes we can observe in the areas with a great deal of natural radioactive sources. For instance, in Brazil (200 km from San Paulu) there is a height where the annual radiation doze equals 25 Rem. This area is uninhabited.

The radioactive pollution of the Earth biosphere as a result of human activity represents the greatest danger. Now the radioactive elements are widely used in the various spheres. The negligent treatment of the storage and transportation of these elements can cause the serious radioactive pollutions. The radioactive pollution of biosphere is concerned, for example, with the nuclear weapon tests.

The atomic power plants, ice-breakers, submarines with the nuclear plants were begun to put into operation in the second half of the 19-th century. The environment pollution by radioactive nuclides under the normal operation of the objects of atomic power engineering and industry is insignificant in comparison with the natural radioactive background. But it's absolutely different situation when the accident happens at the atomic power plant. So, when the explosion of Chernobyl's APP happened the environment was polluted by just about 5 % nuclear fuel. But it caused the irradiation of many people, the large territories were so much polluted, that they became dangerous for the health. Thus the resettlement of thousand inhabitants from the contaminated areas was required.

10.9 THE RADIOACTIVE WASTE AND ECOLOGICAL PROBLEMS

During the rush Nuclear Arms Race in the middle and in the second half of 20-th century there was no time for the development of up-to-date schemes for radioactive waste treatment, and this problem seemed to be less important than the task of uranium and its derivatives production. Thus the huge territories have been polluted for a long time by the man-caused radionuclides because of the great radioactive substances fallout formed during the nuclear weapon tests implemented by the USA, the USSR and the Great Britain in 1945-1962 and later by China and France. Here the maximum level of radionuclides fallout was attained at the beginning of 1970-s before the terrestrial and air nuclear tests were prohibited and during several years later.

The nuclear weapon tests and the huge radiation accidents have caused not only the significant local contamination of environment but irradiation of the population. In view of this it became indeed necessary to ensure the man protection under the conditions of fast nuclear power engineering development. It has stimulated the researches on migration of the artificial radionuclides in the different areas of biosphere and food circuits as well as the researches on the ionizing radiation effect on the human body and animals.

The Republic of Kirghizia has significant radioecological problems. When the country has attained the political independence in 1991 it has inherited from the former Soviet Union 49 uranium tailing dumps. Owing to the ineffective mining and the unreasonable reprocessing of minerals more than 600 million m^3 potentially dangerous chemical elements and their compounds in dumps and waste of used mineral raw were stored throughout the whole territory of republic. Since uranium was the important strategic raw material for the country its mining and reprocessing were under the central control of Moscow city. That's why the central authority's interests were in conflict with the interests of republic especially concerning the problems of protection and reasonable use of the natural environment. For example, during the operation of uranium deposit (1946 - 1968) it was mined more than 10 thousand tones of uranium. According to the geologists and geochemists assessment the radioactive waste here is equivalent to the mass of the mined uranium. The reprocessing waste of uranium raw material was also delivered here from Germany, Czech Republic, Bulgaria, China and Tajikistan. This waste is stored in 23 tailing dumps and 13 dump pits. The total amount of radioactive tails is 1.97 million m^3, mass – 2.3 million tons. The huge masses of residual uranium and its long-living isotopes (Th-230, Ra-226 etc.) are accumulated in the tailing dumps. Hence the radioactivity of the tailing dumps will be conserved for a long time.

Today the condition of these dump pits and storages is real bad so that the radioactive waste, heavy metals and toxic substances pollute the environment, surface and underground waters, atmosphere and soil. And the most dangerous tailing dumps are the tailing dumps № 3, 9, 10, and 18 which are located on the coast of the river Maylooousoou opposite to Kyrgizizolit plant and situated in the landslide zones or zones of possible water logging.

The necessity of environment protection from the dangerous industry man-caused effects on ecosystems

The ecological condition of many areas of our planet disturbs the community. In the numerous publications we can find the steady tendency of multiple excess of the sanitary-hygienic standards in many regions of our planet concerning the contents of carbon and nitrogen oxides, dust, toxic metal compounds, amines and other hazardous substances in the urban atmospheres. Also we can observe the serious problems with land improvement, unregulated application of the mineral fertilizers in agriculture, excessive use of pesticides and herbicides. The large and small rivers, lakes and coastal marine waters are polluted by the run-off water of the industrial and municipal enterprises. The constant pollution of the air, surface and underground waters, soils, vegetation causes the ecosystems degradation, productive degradation of the biosphere.

It is known that the industry consumes a huge quantity of sweet water. Approximately 40 % of this water returns in the cycle but with the liquid waste containing corrosion products, used oil, organic fertilizers, particles of ash, resins, process waste including the hazardous components such as heavy metals and radioactive substances. These liquids spread in water systems, moreover the hazardous substances deposit in phytocenosises, bottom sediment, fishes, spread in the food circuits and finally in the human food. The consumption of sweet water on agricultural needs (for irrigation) in separate areas became so great that it has caused the large irreversible shifts in ecological balance of the whole regions. Among the other ecological problems concerning the anthropogenous effect on the biosphere we would like to mention the risk of ozone layer disturbance, the World Ocean contamination, soil degradation, crops regions desertification, natural environment oxidizing and change of electrical properties of the atmosphere.

Distinctive anthropogenous radiation effects on the environment:

- Atmosphere and territories pollution by the nuclear explosions products because of the nuclear weapon tests;
- Dust poisoning of the air, territories contamination by slag containing radioactive substances during the burning process of minerals in the boilers of power stations;
- Contamination of the territories in case of the accidents at the atomic power plants and plants.

More local but not less unpleasant consequences are the lakes and rivers pollution because of the crude radioactive waste disposal of the industrial enterprises.

The accidents at the chemical and nuclear industry plants as well as the accidents occurred while in shipment of dangerous and hazardous substances presents the significant danger for living entities and for populations of organisms in ecosystems. The accidents at the chemical plant of Bhopal (India), at the APP of Chernobyl (Ukraine) etc. tell us that we need to radically review our attitudes to the nature, to strength the effect of normative levers on economic practice. It is completely inadmissible that maximum permissible concentrations of hazardous substances in the air and water established by the standards were really exceeded in a hundred times. It is necessary to make the neglect of environmental protection disadvantageous or even ruinous. The human rights of pure air, rivers and lakes have to be not only declared but also be provided using all means available for the state.

The main directions of the limitations of hazardous man-caused effects on the biosphere are the following: resource saving and pollution-free or wasteless technologies development. The purity of waters can be improved by the methods of biotechnology. The radical way of environment improvement is the reduction of hazardous emissions and disposals, increase the level of fail-safety and safety of the dangerous manufactures, transfer to the wasteless technology, concentration and safe disposal of hazardous waste, reasonable cooperation and international mutual aid during the ecological catastrophes.

The environmental services play the important role for the environment improvement and limitation of the hazardous substances effects on the biosphere. These services equipped by the up-to-date measuring devices and inspection tools should operatively notify the population about the whole cases of the environmental parameters approach to the dangerous level. The global system of environment monitoring covering the World Ocean and all continents based on the national systems but which is under the aegis of UNO should play an important role in environment protection from the contamination. The replacement of the traditional power engineering by the nuclear power engineering will play more and more essential role in reduction of carbon dioxide emissions and solutions of many ecological problems. Today it is universally recognized that the atomic power plants can be developed with the high levels of reliability and safety ensuring the compliance of the strictest requirements of the oversight bodies including the biosphere protection from the pollution by radioactive and other hazardous substances. However it is necessary to undertake the additional efforts to decline the accident risk at APP. In particular the solution of this task seems to be on the way of development of the new generation reactors with internally intrinsic safety, i.e. the reactors with the powerful internal feedbacks of self-defense and self-compensation.

The atomic power plants effect on environment

The man-caused effects on environment during the construction and operation of APP are diverse. It is usually said that there are physical, chemical, radiation and other factors of the APP man-caused effect on the environment.

The main factors are the following:

· Local mechanical effect on relief – during the construction;

· An injury of the individuals in the technological systems – during the operation;

· An outflow of the surface and subsoil waters containing chemical and radioactive components;

· Change of the character of land tenure and exchange processes near the APP;

· Change of the microclimatic characteristics of the adjacent areas.

The initiation of powerful heat sources as cooling towers, water reservoir-coolers during the APP operation usually noticeable changes the microclimatic characteristics of the adjacent areas. The motion of water in the external heat sink system, the disposals of technological waters containing the different chemical components can cause the injuring effect on populations, flora and fauna of the ecosystems.

The safety problems of the atomic power plants which are going for replacement of the thermoelectric power stations using organic fossil fuel have a great public significance among the difficult problems of environment protection. It is well-known that APPs while in normal operation are ecologically cleaner than the thermoelectric power stations using the coal. However in case of accident the APP can cause an essential radiation effect on the people and ecosystems. Therefore the ecosphere safety control and environment protection from the hazardous effects of the APP are an important scientific and technological task of the nuclear power engineering ensuring its future.

Let's mark an importance of not only the radiation factors of possible hazardous effects of the APP on the ecosystems but also thermal and chemical pollution of the environment, mechanical effect on the inhabitants of water reservoir-coolers, changes of the hydrological characteristics of the adjacent to the APP areas, i.e. the whole man-caused effects complex influencing on the ecological balance of the environment.

Emissions and dumping of hazardous substances at APP operation

The radioactivity transfer in environment

The radioactive emissions are divided on gas and aerosol ejected to the atmosphere through a pipes, and liquid discharges containing the detrimental impurities as a solutions or fine-dispersed mixtures striking the water reservoirs. It is possible to observe also the intermediate situations, for example, when in case of some accidents the hot water is ejected to the atmosphere and is divided on the steam and water.

The emissions can be constant being under the personnel control as well as emergency, volley emission. Penetrating the different atmosphere motions, surface and underground water flows, the radioactive and toxic substances spread in environment, strike the plants, animal and human bodies. In the figure it is shown the air, surface and underground ways of hazardous substances migration in environment. The secondary ways (less significant for us) such as wind transfer of dust and evaporations, as well as the final users of hazardous substances are not shown in the figure.

The radioactive emissions effect on human body

Let's consider the tool of effect of the radiation on human body: the ways of effect of the various radioactive substances on human body, its diffusion in body, depositing, effect on the different organs and organism systems and the consequences of this effect. In view of this it is used a term «the entry of radiation» which means in what way human body can be reached by the radioactive substances and isotope radiations.

The various radioactive substances can penetrate the human organism in different ways. It depends on the chemical properties of radioactive element.

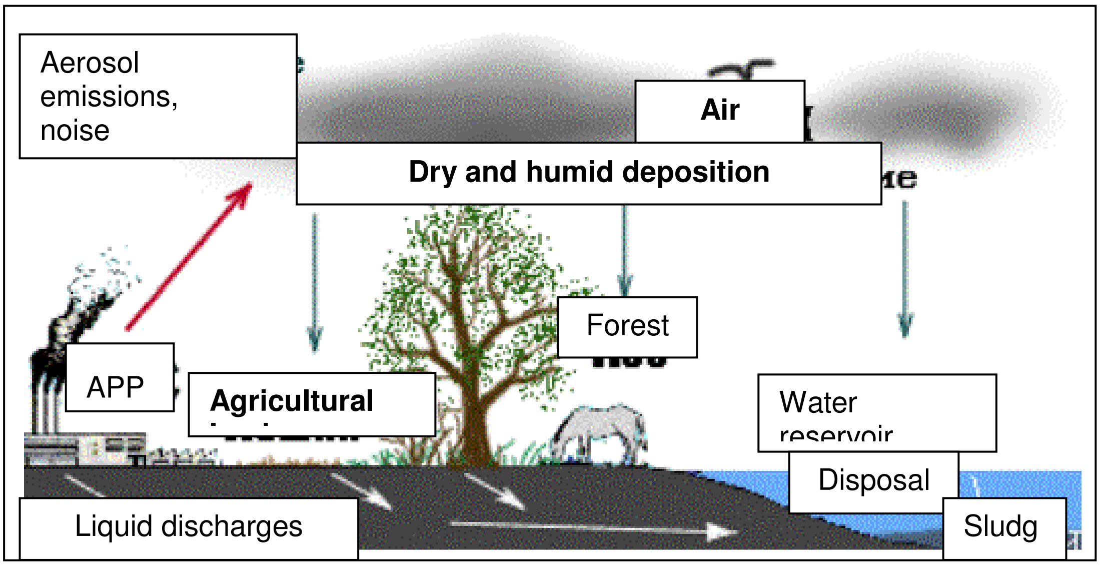


Figure 4.

Radioactive radiation kinds		
The alpha-particles are the atoms of helium without the electrons, i.e. two protons and two neutrons. These particles are comparatively large and heavy and consequently it is easier for them to brake. Their track in the air makes about several centimeters. At the stopping moment they eject a great amount of energy per unit area, so that they can bring the large destructions. Because of the limited particles track for getting a doze it is necessary to place the source inside the organism. The isotopes emitting the alpha-particles are, for example, uranium (235U and 238U) and plutonium (239Pu).	**The beta-particles** is a negatively or positively charged electrons (positively charged electrons are called positrons). Their track in the air makes about several meters. The thin clothes is capable to stop the radiation flow. In order to get an irradiation doze it is necessary to place the source of radiation inside the organism. The isotopes emitting the beta-particles are tritium (3H) and strontium (90Sr).	**The gamma - radiation** is a variety of electromagnetic radiation, accurate similar to a visible light. However the energy of gamma - particles is a much greater than the energy of photons. These particles have a huge penetrating power and gamma - radiation is one of three types of radiation which is capable to irradiate the organism outside. Two isotopes radiating gamma - radiation are the following: cesium (137Cs) and cobalt (60Co).

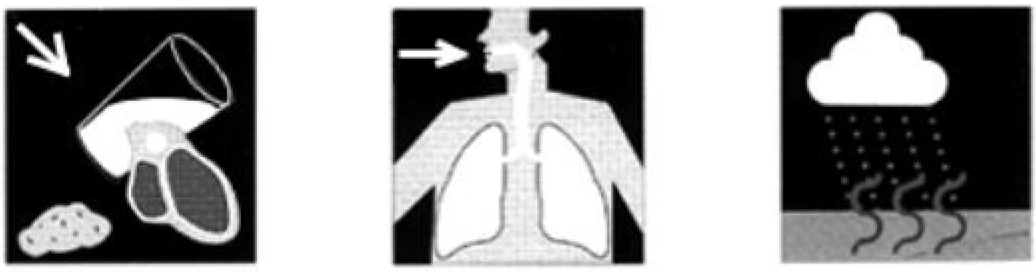


Figure 5. In what way human body can be penetrated by the radiation

The organs exposed by the irradiation

Figure 6.

The limitation of APP hazardous effects on ecosystems

APP and other industrial enterprises in a different way effect on the combination of natural ecosystems which form the ecosphere region of the APP. Under the impact of these constantly operational atomic power plants or their emergency effects we can observe the ecosystems evolution, the changes of dynamic balance conditions are accumulated and fixed. People are completely not indifferent concerning the directions of these ecosystem changes, as far as they are reversible, what are the reserves of stability until the significant disturbances. The normalization of anthropogenous stresses on the ecosystems also is intended to prevent all adverse changes in them, and in the best case to guide these changes to the favorable direction. In order to reasonably regulate the relation of APP with environment it is necessary to know the biocenose reactions on disturbing effects of the APP. The approach to a normalization of anthropogenous effects can be based on the ecological- toxicogenic concept, i.e. it can be based on the need of prevention the ecosystem poisoning by hazardous substances and its degradation because of the excessive stresses. In other words it is impossible to poison the ecosystems, as well as to disable them in free development, stressing them by a noise, dust, waste and limiting their natural habitats and food resources.

In order to avoid the ecosystem damages, it is necessary to determine and normatively fix some of hazardous substances limits for individual organisms and other limits of effects which could cause the unacceptable consequences at a level of populations. In other words we should know the ecological volumes of ecosystems which values should not be exceeded during the man-caused effects. The ecological volumes of ecosystems for the different hazardous substances should be determined from the intensity of these substances inflow, during which at least in one biocenose component there will be a critical situation, i.e. when the substances accumulation approaches to a dangerous limit, the critical concentration will be reached. In the maximum concentration values of toxicogenes, including radionuclides we should certainly take into account also the cross effects. However it is obviously not enough. In order to protect the environment effectively it is necessary to institute legislatively a principle of hazardous man-caused effects limitation, in particular concerning the emissions and dumping of dangerous substances. By analogy with the above mentioned principles of human protection from radiation we can notice that the principles of environment protection are the following:

- Unreasonable man-caused effects should be excluded;

- The accumulation of hazardous substances in biocenoses, man-caused stresses on ecosystems elements shouldn't exceed their dangerous limits,

- The inflow of hazardous substances in ecosystems elements, man-caused stresses should be so low as far as it is possible in view of economic and social factors.

The effects of APP on environment are the following: thermal, radiation, chemical and mechanical. To insure the biosphere protection the necessary and sufficient security facilities are required. The necessary environment protection means the system of measures directed on the compensation of possible exceeding the accepted values of environment temperatures, mechanical loads and radiation doses, concentrations of toxicogenic substances in ecosphere. The sufficiency of protection is reached in that case when the environment temperatures, its mechanical loads and radiation doses, hazardous substances concentration do not exceed the limiting, critical values.

So, the sanitary code of maximum permissible concentration (MPC), permissible temperatures, radiation dozes and mechanical loads should be the criterion of necessity of environment protection. The system of detailed standards of external irradiation limits, limits of radioisotopes and toxic substances content in ecosystem components and mechanical loads could normatively fix the border of limiting, critical effects on ecosystem elements for their degradation protection. In other words the ecological volumes should be known for the whole ecosystems in considered region concerning all types of effects.

Different man-caused effects on environment are characterized by their repetition frequency and intensity. For example, the emissions of hazardous substances have some constant component corresponding to a normal operation, and a random component dependent from an accident risk, i.e. from a safety level of the considered object. It is clear that the more dangerous accident is the lower its risk is. Today we know by the bitter experience of Chernobyl that a pine woods have radiosensitivity similar to a human one and the mixed woods and bushes have 5 times less. The measures of the dangerous effects prevention, their prevention during operation, promotion of their compensation and hazardous effects control should be provided at the design stage of the objects. In view of this it is necessary to develop and create the **systems of ecological monitoring of the regions**, to develop the methods of ecological damage design forecasting, to develop the recognized methods of ecosystem ecological volumes assessment and the comparison methods for different damages. These measures should create a base for the active environment control.

Destruction of dangerous waste

It is necessary to focus attention on such measures as accumulation, storage, transportation and disposal of toxic and radioactive waste.

Radioactive waste is not just a product of APP operation but also a waste of radionuclides application in medicine, industry, agriculture and science. A gathering, storage, removal and disposal of waste containing the radioactive substances are regulated by the following documents:

- *The sanitary regulations of radioactive waste handling. Moscow, The Ministry of Health of the USSR, 1986;*
- *The regulations and standards on radiation safety in atomic power engineering*;
- *The Main sanitary regulations (MSR 72/87).*

For neutralization and disposal of radioactive waste the "RADON" system consisting of sixteen radioactive waste disposal polygons was developed. Today, at the post-USSR time, the Ministry of nuclear industry of Russian Federation in cooperation with several interested ministries and organizations has developed the draft of the state program concerning the radioactive waste handling with the purpose of development the regional automated accounting systems of radioactive waste, modernization of the active waste storages and design of the new radioactive waste disposal polygons.

The selection of the land for waste storage, its disposal or destruction is made by the city form of government as agreed with the territorial bodies of the Ministry of nature and The State Sanitary Surveillance Service.

The type of container for waste storage depends on its class of danger: from the hermetical steel containers for especially dangerous waste storage up to the paper bags for less dangerous waste storage. The requirements on protection against contamination of soil, underground and surface waters as well as the requirements on concentration decrease of hazardous substances in air and dangerous substances content in the storages in the limits or lower than MPC are determined for each type of industrial waste storages (i.e. tailing dumps and slag storages, industrial waste water storages, core pools, storage pond and evaporator ponds).

The construction of the new storages for industrial waste will be allowed in the case when the arguments show that it is impossible to use low-wasted and wasteless technologies or to use waste for any other purposes.

The radioactive waste disposal takes place on special polygons. Such polygons should be remote from the center of population and large reservoirs. The container for dangerous waste storage is a very important factor of radiation protection. Its depressurization or augmented permeability can promote the negative effect of dangerous waste on ecosystems.

The radiation contamination in the case of accident

The designers consider that in the case of APP accident the expected irradiation dozes of the limited part of population (so-called «critical group») on the bound of a buffer area and outside shouldn't exceed 5 MSv (0,5 Rem) for the whole body and 50 MSv (5 Rem) for the separate organs during the first year after accident.

In the case of design accident at APP the irradiation dozes of "critical group" on the bound of protective measures zone and outside shouldn't exceed 5 MSv (0,5 Rem) for the separate organs during the first year after accident.

According to design documents the radiation safety of a floating APP should be provided by the standard for APP complex of technique and measures at its territory, water area and adjacent areas (i.e. the identification of a buffer area and control area, the application of reactor protection, closed-circuit ventilation, protection system against radioactive substances permeation from the heat transport main circuit etc. Despite the long list of these means and measures we can't be absolutely sure that they will function just so as designers plan. Basically there can't be a trouble -free operations of floating APP. The question is only one. How serious can be both an accident and its consequences? The designers claim that the presence of effective safety barriers and localizing systems of floating APP completely excludes the radioactive emission outside the APP even during the heaviest design accidents.

Let's draw our attention to the expression "design accidents". In designer's opinion the maximum design accident is the break of full section of the primary system pipe. The concept called "design accident" is invented by atomic scientists in order to calm a public. Actually in all cases of large nuclear catastrophes (Windscale, the UK, Tree Mail Island, the USA, APP accident in Leningrad in 1975, accident in Chernobyl, former USSR, accident at Tokaymura Japanese plant in 1999) not design but overdesign accidents happened.

Therefore we shall analyze the consequences of possible maximum overdesign accident which causes the active zone fusion and radioactive substances release outside the reactor. The results of such accident are shown at the figure executed using the radiation pollution calculations made for nuclear submarine reactor.

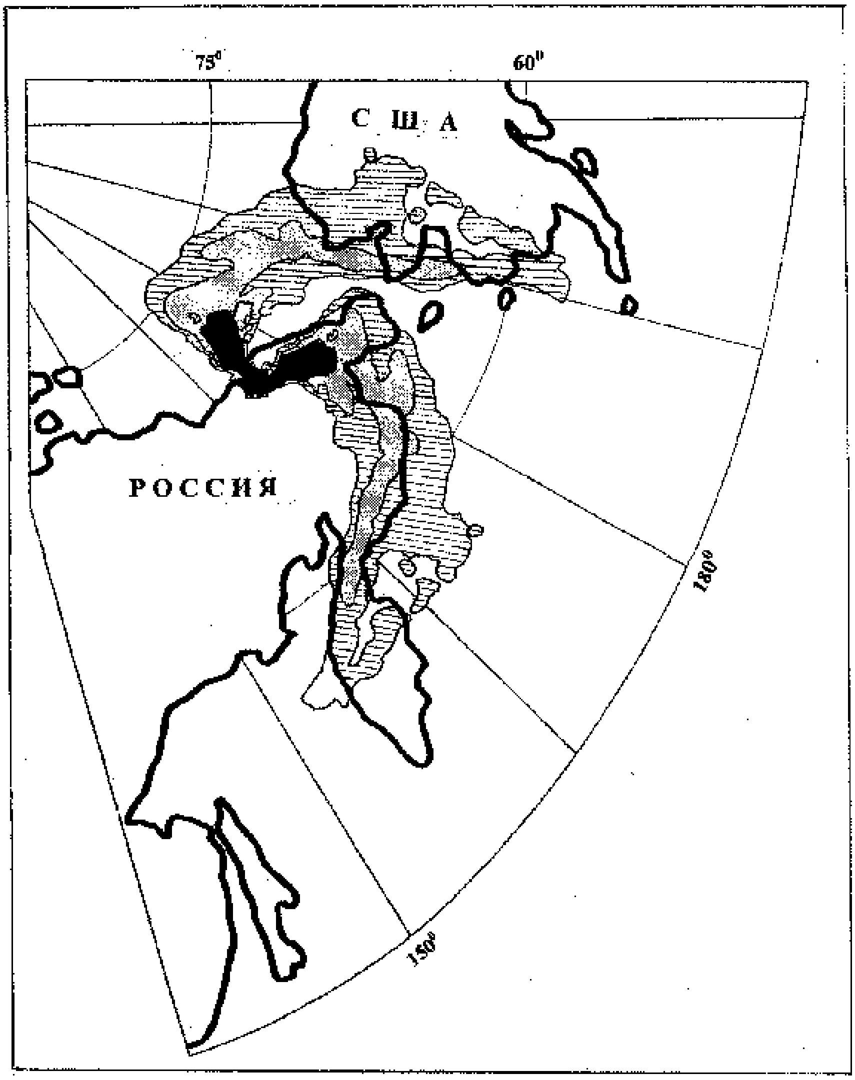


Figure 7. Two instances (1 and 2) of hypothetical accident of reactor with a power similar to the power of "КЛТ-40С" reactor facility in the area of Pevek city. Figure 3 is the result of superposition of radioactive pollution density Cs^{137} on the 5-th day after possible accident at the reactor of nuclear submarine in Are - Gooba, Kola Peninsula on the map of northeast part of Eurasia and northwest part of Northern America.

It is obvious that depending on the concrete weather conditions (wind force on the different altitude and precipitations) the radioactive cloud from river Chaunskaja Guba can cover the whole Chuckchee Peninsula, significant part of Alaska and even Kamchatka Peninsula. In case of similar accident the address to any competent rescue forces and the application of necessary means will be extremely complicated because of the remoteness and usually severe weather conditions.

One more additional aspect concerning the problem of accidents: the floating APP will be situated near the center of population. It means that the consequences of any accident with the radioactivity carry-over outside the submarine will affect these settlements adjacent to the APP with a high probability. The principle of distance protection decreasing the effect of terrestrial APP (30 km zone etc.) in the case of floating APP can't be applied. Proximity of the floating APP to the settlements in case of accident virtually doesn't give any time for protective measures implementation in adjacent settlements. In these conditions it is impossible even to warn in time and the well-timed population evacuation is simply unrealizable. Thus the citizens of Pevek, Dudinki and Severodvinsk cities certainly become hostages of nuclear plants.

Hence, it is absolutely clear that floating APP constitute a serious threat to the nature and population of the Arctic Region. Let's add that if the threat to the arctic nature can be somehow compensated by preservation of biota in other places of the Arctic Region such approach to a safety problem of the local population is simply immoral. During the overdesing accident of the floating APP a damage for the small populations gene pool of small nations can be catastrophic.
Basing on the study made for overdesign radiation accident on the atomic vessel with a similar size of reactor to that of floating APP we can divide an accident into three types:

- Under an uncontrolled chain reaction in the nuclear reactor core after the nuclear power plant testing;
- Similar accident at the recent core;
- Maximum design accident after its testing.

The accident with a burst of self-sustaining nuclear chain reaction after testing brings more difficult radiation consequences. If such accident happen in 30 days after testing the evacuation of population in the radius up to 10 km from the accident site can be required (Figure 8).

Figure 8. The scales of possible radiological pollution at more than 10^6 Bq/m^2 level in St.-Petersburg city during the overdesign accident at atomic vessel under different atmospheric conditions. The light radius shows the pollution under unstable atmospheric conditions, the dark one shows the pollution under stable atmospheric conditions.

Reservoirs with highly active waste in Hanford

The object in Hanford constructed in the beginning of 1940-s toward the south from the central part of Washington State was one of two plutonium production centers for the purposes of nuclear weapon program of the USA. Another center was in Savanna River Site in Southern Carolina. Nine reactors for plutonium production and five radiochemical enterprises for chemical plutonium separation from uranium and fission products were constructed in Hanford during 1943-1963. All reactors and reprocessing activities were halted at the end of 1980-s. Despite this fact we can observe occasionally the disputes concerning the recommencement of some technological operations at this object, for example tritium production.

As a result of five radiochemical enterprises operation in Hanford a huge quantity of highly active liquid waste was produced. This waste contained the fission products (technetium -99, cesium - 137, strontium -90) as well as residual plutonium, uranium and other heavy radioactive elements. The composition of waste was so compound and its scales seemed to be such large that the environment recovery at this site was the hardest task among all measures for environment recovery in the USA. In Hanford there are 177 reservoirs in which approximately 54 million gallons (206 000 m^3) of highly active waste are stored. The radioactivity content in them makes approximately 200 million curies (149 reservoirs with a single envelope and 28 newer reservoirs with a double envelope).

That corresponds to 60 % of all highly active waste in the USA (the most significant quantity of radioactivity, approximately two thirds of the total, is contained in reservoirs in Savanna River Site). About 67 reservoirs with a single envelope leak or it is suspected that they leak. Now the volumes and radioactive content of these leakages are not precisely determined yet. Occasionally in publications we can find the official data but, as new data appears the assessments concerning the volumes and radioactivity, as a rule, increase.

Handling of reservoirs contained radioactive waste in long-term period

Except the nearest future tasks, for instance, leakage prevention during the long-term period it will be necessary to extract a waste from reservoirs and to place them in facilities of lower risk for environment in the future. The Department of Energy plans the following measures: to extract about 99 % (or even more) of waste from reservoirs; to divide the extracted waste in highly active and low active parts; to implement the glazing of both parts of waste, at the same time to bury a highly active waste in geological storage and to bury a low active waste "at the sites". In the above proposed plan, there is a number of disadvantages including that these measures tend to considerable increase of highly active waste buried at sites. Besides there is one more problem: the glazing program was started and implements without sufficient technical study and without necessary emergency plan for the case if the currently chosen approach will be unsound.

The Department of Energy has concluded 6.9 billion dollars contract with "privatization" with British Nuclear Fuels, Limited (BNFL), the British state corporation, on glazing of 10% of waste from Hanford reservoirs. The contract has a number of disadvantages. The first disadvantage is: the technology proposed by BNFL wasn’t properly tested on those unique types of waste as in Hanford.

The second one is: the construction of the glazing enterprise is planned to start when the design work on this object will be completed on less than 50 %. If the technology is validated all expenses of BNFL corporation will be undertaken by the tax payers of the USA.

Moreover the contract with BNFL brings up the safety problems. The documents on accident prevention attached by BNFL to the Hanford contract were characterized by the Department of Energy as "unduly prepared". At last the image of BNFL in Great Britain where this corporation acts under protection of the British law on a state secret could be better. The Department of Energy didn't use such possibility as contracts with American affiliated companies of BNFL to raise a question on publication of the BNFL report concerning its activity in Great Britain.

Since this plan includes the recycling of glazed low active waste in Hanford the Department of Energy anticipates that quantity of waste to be buried in geological storage will decrease. The Department of Energy didn't take into consideration the cost of a local burial place for increasing volume of waste at the appropriate market prices. Moreover so-called "low active waste" planed to be recycled at the sites in other countries, such as Great Britain or France, will be classified as "mean active waste" and will be buried in deep geological storages.

And, at last, it seems that the Department of Energy doesn't plan a mothballing of waste resevoirs. These plans rather provide the cementation of reservoirs after the liquid waste in them will be pumped out even if up to 1% from initial volume of highly active waste remains there. In the long-term period the radioactivity of waste in many reservoirs can be a serious danger for environment. In the case of waste leakage from reservoirs their cementation will present the new serious problems which can strongly complicate any attempts to recover a zone of suspended water the in the future.

Among all types of waste left by the Cold War in the USA the waste in Hanford is the most inhomogeneous, and the problems caused by it or related to it are the most difficult to eliminate. According to the recent assessments the removal and reprocessing of waste from reservoirs in Hanford will cost about 15 billion dollars. Even this significant sum doesn't include certain costs such as reservoirs mothballing costs, costs on handling of the soil around the reservoirs polluted as a result of direct discharge or leakage as well as the costs on purification of the contaminated subsoil waters. This sum doesn't include also the costs provided for that case if the glazing technology will not be validated as it was considered above.

10.10 CONCLUSIONS

The analysis of the ecological situation connected with the increasing amount of NPS wastes shows that the issue of isolation of radioactive wastes will be very urgent for the mankind in the nearest future.

At present there is a technical capability of creation of the space rocket complex on the basis of Zenit-2SLB ILV (Zenit-3SLB ILV) that can-be used for radioactive wastes removal into the deep space with a sufficient safety level for the environment.

Continuity of the power production process at APP leads to a necessity of constant removal of high-active and toxic radioactive wastes in the industrial technology; it will provide the increasing demand and profitability of the space rocket complex proposed.

11. WP4000 - ECONOMICAL AND LEGAL ASPECTS

11.1 ANALYSIS OF LEGAL ASPECTS OF THE PROJECT WITH REFERENCE TO LEGISLATION OF UKRAINE AND CIS

Regulation on licensing of activity concerning use of radio-active materials upon performance of works on use of atomic energy

1. This Regulation, developed in compliance with Federal Law "On licensing of some kinds of activity" determines the order of licensing of activity of legal entities on use of radio-active materials (nuclear materials and radio-active matters) upon performance of works on use of atomic energy in defense purposes, including development, manufacture, testing, transportation, operation, storage, liquidation and utilization of nuclear weapons and nuclear power plants of military purposes.

2. Licensing of activity on use of radio-active materials upon performance of works on use of atomic energy in defense purposes according to the list contained in appendix is executed by Ministry on Atomic Energy of Russian Federation (hereinafter – the licensing body).

3. This Regulation is not cover the activity on use of radio-active materials upon operation of nuclear weapons and nuclear power plants of military purposes by military units of Ministry of Defense of Russian Federation.

4. State supervision of nuclear and radiation safety upon development, manufacture, testing, operation, storage and utilization of nuclear weapons and nuclear power plants of military purposes is executed by Ministry of Defense of Russian Federation.

5. License is granted for the period of 3 years. Upon request of the candidate for license it may be granted for a lesser period.

Effective term of license may be continued by request of licensee. It may be refused in prolongation of effective term of license if the breaches of license's terms and conditions are registered during its effective term.

Prolongation of the effective term of license is executed in the order, stipulated for the licensing.

6. Conducting of activity on use of radio-active materials upon performance of works on use of atomic energy in defense purposes without license is prohibited.

7. The candidate for license provides the licensing body with the documents listed below:

a) request on granting a license with declaration of:

name and legal-organizing form of legal entity, its residence, name of bank and number of an account;

licensed kind of activity and term, during which it will be conducted.

Request shall be adjusted with federal body of executive power, which have a jurisdiction over legal entity;

b) copies of statutory documents with all changes and amendments hereto and copy of certificate of state registration of candidate for a license as a legal entity;

c) reference on registration of candidate for a license in tax administration;

d) document, which confirms payment for consideration of a request;

e) documents, which confirm ability of candidate for a license to ensure the fulfillment of requirements and conditions, set by this Regulation (hereinafter – licensing requirements and conditions);

f) documents, which substantiate assurance of nuclear and radiation safety upon conducting of licensing activity, and are adjusted with Ministry of Defense of Russian Federation;

g) documents, which confirm presence of normative-methodic documents on assurance of safety upon handling of radio-active materials in the possession of candidate for license, documents, which set an order of preparation, attestation and admission personal for work with radio-active materials, and also presence of powers and means, ready for action in emergency situations and for liquidation of consequences of emergencies;

h) copy of license, granting of which is stipulated by Article 27 of the Law of Russian Federation "On state secret" (for organizations, activity of which is connected with the use of data, which comprise state secret);

i) report of state ecological examination (for developed and reconstruction objects);

j) documents on financial provision of civil liability for losses and damages, which may be caused by radiation influence.

If copies of documents are not certified by notary, besides the copies the originals are provided.

It is prohibited to require from candidate for a license the provision of other documents.

All documents, given to the licensing body for obtaining a license, are accepted according to the inventory, copy of which with the notation of accept of the documents is sent to or hand over to candidate of license.

8. Candidate for license is liable for giving inadequate or distorted information according to legislation of Russian Federation.

9. The licensing body makes a decision on granting or refusal in granting of license during 30 days since the day of the receipt of request with all necessary documents.

The licensing body shall inform candidate of license of agreed decision during 3 days from the day of its adoption.

Notice of granting of license with indication of bank account requisites and term of payment of license fee is sent to or hand over to candidate for license.

Notice of refusal in granting of license is sent to or hand over to candidate for license with indication of reasons of refusal.

10. Issuing a document, which confirms presence of license, is executed during 3 days after provision a document by candidate for license, which confirms payment of license fee.

In case when licensee has not paid license fee during 3 months, the licensing body has the right to cancel a license.

11. Ground for refusal in granting a license is:

a) presence of inadequate or distorted information in documents, provided by candidate for license;

b) non-conformity of candidate for license in license requirements and conditions.

12. Candidate for license has the right to appeal the refusal of the licensing body in granting of a license or its inaction in order, determined by legislation of Russian Federation.

13. Candidate for license upon appeal in administrative order the refusal of the licensing body in granting of a license has the right to require conducting of an

independent examination. Independent examination is executed at the account of candidate for license.

The candidate for license sends request of execution of an independent examination in the licensing body, which forms respective commission.

The employees of the licensing body have no right to be members of the licensing body.

List of commission members is sent to applicant. In case of disagreement with any candidature the applicant may offer motivated objection against participation of this person in examination.

The candidate for license has the right to be present at meeting of the commission.

14. Commission during 30 days since the day of registration of request considers documents, provideed by applicant, executes verification of correspondence to license requirements and conditions and prepares expert report on validity of decision of the licensing body.

The licensing body shall inform candidate for license of decision of commission during 3 days after its adoption.

Upon making a decision by commission on correspondence of candidate to license requirements and conditions the licensing body shall consider the matter of granting of a license to candidate during the period of 3 days. In case of recurring refusal in granting of a license the candidate shall have the right for reference to the court. In this connection the costs for execution of independent examination are paid at the expense of the licensing body.

15. Document, that confirms the presence of a license, contains the following information:

a) name of the licensing body;

b) name and residence of licensee;

c) kind of activity with indication of corresponding works, determined in appendix to this Regulation, term, during which it will be carried out.

d) conditions of carrying out of indicated kind of activity;

e) identification number of taxpayer;

f) registration number of license and date of adoption of a decision on its granting;

g) date of issuing a document, which confirms presence of a license.

Document is signed by head of the licensing body (in case of his/her absence – by deputy person) and is certified by the stamp.

16. Document sheets, which confirm presence of a license, are accounting documents and have series and number.

17. Upon carrying out of license activity licensee shall comply with:

a) legislation of Russian Federation;

b) performance requirements on nuclear, radiation and industrial safety;

c) performance requirements on physical protection of radio-active materials and on keeping state secrets;

d) performance requirements of registration and control of radioactive materials;

e) ecological, sanitary-and-epidemiologic, hygiene, fire prevention performance requirements;

f) this Regulation.

18. Supervision over licensee's compliance with license requirements and conditions is carried out by state supervision and control bodies and the licensing organ within limits of their competence.

19. The licensing body within the limits of its competence has the right:

a) to carry out inspections of correspondence of license activity to license requirements and conditions;

b) to request licensee about necessary explanations and references on issues, which arise upon carrying out of examinations;

c) to draw up acts (records) with indication of infringements on the ground of results of examinations;

d) to make decisions, which obligate the licensee to remove revealed infringements, and determine terms of their removal;

e) to pass a notice to licensee;

f) to execute other powers, which stipulated by legislation of Russian Federation.

20. State supervision and control bodies, and also other bodies of state power upon detection of infringements of license requirements and conditions within the limits of their competence shall inform of them the licensing body.

21. According to legislation of Russian Federation and this Regulation the licensee shall ensure conditions for carrying out examinations of the licensing body, including obligation to give necessary information and documents.

22. In case of reorganization of the licensee – legal entity, change of its name or residence the licensee or his assignee shall immediately file an application to the licensing body on re-execution of document, which confirms presence of a license, with attachment of documents, which confirm indicated information.

23. Upon re-execution of document, which confirms presence of license, the licensing body makes corresponding changes to the register of licenses. Re-execution of document, which confirms presence of license, is carried out during 5 days since the day of filing an appropriate application with necessary documents by the licensee.

24. In case of loss of document, which confirms presence of a license, the licensee shall immediately file an application on its re-execution.

25. The licensing body may suspend the force of license or annul it.

26. The ground for suspension of license' force are:

a) detection of licensee's infringements of license's requirements and conditions, which may cause appearance of emergencies, prejudice to the rights, lawful interests, morality and health of citizens, and also defense and security of the state, by the licensing body, state supervision and control bodies, other bodies of state power within the limits of their competence;

b) licensee's failure to execute decisions of the licensing body, which obligates to remove detected infringements.

27. The license loses legal force and is considered void if licensee during 3 months has not paid licensee fee of legal entity is liquidated or its activity is terminated as a result of reorganization.

28. The license may be annulled by decision of the court on the ground of application of the licensing body or body of state power according to its competence. Simultaneously with filing an application to the court the licensing body has the right to suspend force of a license for the period of time before coming into force the court's decision.

The ground for annulling license is:

а) detection of inadequate or distorted information in documents, filed for granting a license;

б) reiterated or gross violation of license requirements and conditions by licensee;

в) illegality of decision on granting a license.

29. Decision on suspension of license's force or on referring to the court an application of annulling license shall be informed by the licensing body to licensee in written form with respective justification during 3 days since the day of adoption of a decision.

30. Decision on suspension of license's force may be appealed in the order, determined by legislation of Russian Federation.

31. The licensing body shall set the term of removal of circumstances, which caused suspension of license's force. Indicated term shall not exceed 6 months. In case if in the determined term licensee has not removed indicated circumstances, the licensing body shall appeal to the court with application of annulling license.

After removal by licensee circumstances, which caused suspension of license's force, the licensing body in 30-day period since the day of obtaining of such confirmation shall adopt a decision on renewal of its force and during 3 days inform licensee of its decision.

32. Suspension of a license's force or its annulment don't remove an obligation of legal entity to ensure nuclear and radiation safety of objects of use of radio-active materials upon use of atomic energy in defense purposes according to performance requirements in force.

33. The licensing body forms and operates register of licenses.

34. Register of licenses shall indicate the following:

a) information on licensee;

b) information on the licensing body;

c) kind of activity with indication of respective works, determined in appendix to this Regulation, for carrying out of which a license is granted;

d) date of granting and number of a license;

e) effective term of license;

f) information on license's registration in the register, ground and date of suspension and renewal of license's force;

g) ground and date of annulment of license;

h) other necessary information.

35. Information, contained in the register of licenses, is open for legal entities. Indicated legal entities has the right to receive extracts from register of licenses subject to payment.

Indicated information is provided to bodies of state power and bodies of local government free of charge.

Term of giving the extracts from register of licenses shall not exceed 3 days since the date of filing of respective application.

36. For consideration of an application on granting a license for carrying out an activity on use of radio-active materials upon performance of work on use of atomic energy in defense purposes a fee is collected in the amount of minimum remuneration of labor, determined by federal law, for re-execution of license – in the amount of one tenth of minimum remuneration of labor, determined by federal

law, for giving an extract from the register of licenses – in ten-fold minimum remuneration of labor, determined by federal law.

For granting a license a license fee is collected in the amount of minimum remuneration of labor, determined by federal law.

Indicated payments are entered in an account of federal budget.

11.2 SAFETY CONDITIONS AND REQUIREMENTS (LICENSE CONDITIONS) OF CARRYING OUT AN ACTIVITY ON PROCESSING, STORAGE AND DISPOSAL OF RADIO-ACTIVE WASTES

11.2.1 General provisions

This statutory act determines conditions and requirements of carrying out an activity on processing, storage and disposal of radio-active wastes (hereinafter – RAW) and applies to subjects of activity in the sphere of use of nuclear energy (hereinafter – subjects of activity).

Activity on processing of RAW means any activity, which concerns physical manipulation of RAW, in consequence of which characteristics of RAW are changed, especially an activity, connected with preliminary processing (deactivation, collecting, sorting) and conditioning of RAW, including operation, withdrawal from operation of objects, designed for processing of RAW.

Activity on storage of RAW means activity, connected with construction, operation, withdrawal from operation storehouse for storage of RAW and all objects, which are allocated on the ground of storehouse and connected with it technologically.

Activity on disposal of RAW means:

- activity of operational organization in all stages of life-cycle of storehouse for disposal of RAW, including different types of works in objects of technological complex within the boundaries of ground of storehouse;

- services, rendered by subjects of activity – contractors to operational organization in stages of operation and closing of storehouse for disposal of RAW, including services on different types of works in objects of technological complex within the boundaries of ground of storehouse, which are covered by force of a license, granted to operational organization.

11.2.2 Safety conditions of carrying out an activity

Licensee is carrying out an activity on operation, storage and disposal of RAW according to:

- laws of Ukraine, effective norms, rules and standards of nuclear and radiation safety;

- conditions and requirements of license, which are set for subject of activity in accordance with the Article 29 of the Law of Ukraine “On use of nuclear energy and radiation safety” by State Committee of nuclear regulation of Ukraine (hereinafter – regulative body);

- program of ensuring of quality on safety of operation with RAW.

Licensee is carrying out an activity on operation, storage and disposal of RAW subject to:

- realization of organizational and technical measures on prevention of radiation emergencies, restriction and liquidation of their consequences;

- execution of requirements of normative documents on physical protection with the aim of prevention of unauthorized penetration to storehouses, access to RAW;

- carrying out of radiation control in enterprise, which may be carried out by own forces or on the ground of contract with enterprise-contractor. In this connection measuring laboratories, according to the Article 10 of the Law of Ukraine "On metrology and metrological activity", shall be accredited to the right of execution of measuring-ins;

- presence of financial ability for compensation of damages from radiation emergencies, which may happen during carrying out of license activity, at his own expense or at the expense of insurance companies.

Licensee is carrying out an activity on operation, storage and disposal of RAW with the use of equipment, facilities and premises and operational regulations, information on which is contained in applicant's materials on justification of safety, on the basis of which a license has been granted.

Licensee is carrying out an activity only in place and territory, which are determined in the license.

11.2.3 Requirements of safety of carrying out an activity

Upon carrying out of licensed activity sizes of individual dozes, number of persons, which are irradiated, and probability of irradiation shall be lowest of those that may be achieved practically, and not exceed determined doze limits.

In case of adoption of new norms, rules and standards on nuclear and radiation safety and physical protection or changes and amendments to them licensee carries out document analysis of correspondence of conditions and limits of safety of licensed activity to new norms, rules and standards on nuclear and radiation safety and in case of lack of correspondence to new safety requirements, according to the Article 30 of the Law of Ukraine "On use of nuclear energy and radiation safety", develops and adjusts with regulative body organization and technical measures, aimed at removal of detected discrepancies.

Licensee by means of enterprise order:

- enters into force the list of norms, rules and standards on nuclear and radiation safety in the sphere of use of nuclear energy, which applies to license activity;

- sets control levels of irradiation;

- provides access to work of personal, which has no medical contraindications and passed respective training and examination on issues of labor protection according to Model Regulation on order of carrying out of training and examination on issues of labor protection, approved by the order of State Committee of Ukraine on supervision over labor protection;

- assigns persons, responsible for:

- compliance to norms, rules and standards on nuclear and radiation safety;

- creation, implementation and functioning of system of quality in the enterprise;

- organization and conducting of radiation control;

- physical protection, register and storage of RAW.

Licensee carries out training and examination of knowledge of norms, rules and standards on issues of labor protection according to Model Regulation.

Access to special works is executed according to the Order of carrying out of special examination for giving an access to natural persons for works in nuclear powerplants and with nuclear fuel, approved by regulation of Cabinet of Ministers of Ukraine.

Licensee provides for organization and technical measures on register and control of RAW.

All changes in project and operation documentation, any reconstruction, modernization, capital repair which may affect on safety of licensed activity, according to the Article 40 of the Law of Ukraine "On use of nuclear energy and radiation safety", are subject to obligatory state examination of nuclear and radiation safety.

Licensee carries out permanent work on increase of qualification of employees, which execute licensed activity.

Licensee carries out re-evaluation of safety in the event of changes of technology upon carrying out of licensed activity, which may affect on level of safety, and also when experience of carrying out of licensed activity testifies to lacks of preliminary examination, and provides reports by its results to regulative body.

Licensee carries out independent examinations of program of ensuring of quality according to Section 10 of Requirements to program of ensuring of quality in all stages of life-cycle of nuclear powerplants, approved by the order.

In case when licensee intends to cease licensed activity, he informs of this regulative body not later than month before.

According to the Article 32 of the Law of Ukraine "On use of nuclear energy and radiation safety" deprivation of licensee of respective authorization do not exempt him of liability for safety of nuclear powerplant or source of ionizing radiation before the moment of their transfer to other persons or obtaining new authorization.

Licensee provides to the body of state regulation of nuclear and radiation safety an annual report on analysis of safety of carrying out an activity on operation, storage and disposal of radio-active wastes according to requirements, set by regulative body.

If changes occurred in documents, on the ground of which license is granted, licensee provides to regulative body information concerning those changes.

In case of arising of any situation or circumstances, which led to breaches of norms and rules of radiation safety, or in case of radiation emergency the licensee:

- during an hour informs regulative body, territorial body of Ministry of Health of Ukraine and other institutions;

- initiates respective actions on removal of breaches or, in case of emergency, actions, determined by plans of emergency's measures;

- carries out an internal investigation of reasons and circumstances, which led to breaches or emergency, and after its termination provides to regulative body a written report on results of investigation.

11.2.4 General provisions of radiation safety upon transportation of radio-active materials

For transportation of radio-active materials a program of radiation protection should be developed. Character and scale of measures, contained in the program, depends upon size and probability of irradiation. Program shall take into consideration requirements of this Regulation. Program documents shall be provided upon request for examination, which is executed by respective competent authority.

Upon carrying out of transportation protection and safety shall be optimized in such way, that size of individual dozes, number of persons, which are exposed to irradiation, and probability of irradiation would be kept at reasonably achievable level subject to economical and social factors, and dozes of individual irradiation would not exceed corresponding limits of dozes, approved by Norms of radiation safety of Ukraine. Structural and system approach should be applied, which includes interconnection of transportation and other kinds of activity.

Professional employees (personnel) shall have corresponding training on prevention of radiation danger, connected with work, carried out by them, and on warning measures, which are necessary to take to ensure decrease of irradiation, to which they are exposed, and irradiation of other persons, that could suffer the results of their actions.

Corresponding competent authority carries out sampling test of doze of irradiation, received in connection with transportation of radio-active materials, for the purpose of assuring of correspondence of system of protection and safety to Norms of radiation safety of Ukraine and “General sanitary rules” or normative documents, which will be implemented instead of them.

In case of professional irradiation upon carrying out of works, connected with transportation, when, according to the estimate, receiving of effective doze at the rate:

a) over 1 mZ per year is too improbable, – special schedules of works, detailed dosimetric control, programs of estimate of dozes or conducting an individual register are not obligatory;

b) 1 - 6 mZ per year is completely probable, - it is necessary to carry out programs of estimate of dozes by means of dosimetric control of working places or individual dosimetric control;

c) over 6 mZ per year is completely probable, – it is necessary to carry out individual dosimetric control.

Individual dosimetric control or dosimetric control of working places is due to documental execution according to requirements of “General sanitary rules” or rules, which will be implemented instead of them.

Radio-active material shall be placed at sufficient distance from employees (personnel) and persons from population. For the aim of calculation of separating distance or radiation levels the following values of dozes should be used:

a) for employees (personnel) in working areas of permanent stay - 5 mZ per year;

b) for persons from population in places of general free access - 1 mZ per year for critical group of population.

Radio-active material shall be placed at sufficient distance from non-processed films. Separating distance at this aim shall be determined, depending on the fact, that radio-active irradiation of non-processed films in connection with transportation of radio-active material shall be limited by rate of 0,1 mZ per consignment of such films.

EMERGENCY MEASURES

In case of emergencies or incidents during transportation of radio-active materials one shall comply with regulations of corresponding national and/or international organizations, approved for the case of emergencies, for the purpose of ensuring of protection of people, property and environment. Instructions on such regulations are contained in corresponding normative documents.

Emergency procedures shall take into account possibility of formation of other dangerous matters as a result of interaction of contents of cargo with environment in case of emergency.

ENSURING OF QUALITY

Programs of ensuring of quality, which have acceptable for competent authority international, national and other norms as the basis, shall be developed and carried out concerning engineering, manufacture, testing, documentation development, use, maintenance support and inspections on all radio-active materials of special type, radio-active materials with low dispersal ability and packs, and also on transport operations and transit storage for the purpose of ensuring of execution of corresponding provisions of this Rules. Competent authority shall have ability to obtain confirmation of full compliance with technical requirements of construction. Manufacturer, consignor or user shall be ready to afford to competent authority an opportunity to carry out examinations during manufacture or use and demonstrate to any plenipotentiary competent authority the facts that:

a) methods, which apply to manufacture, and materials correspond to technical requirements of approved construction; and

b) all packing sets are periodically examined, upon need are repaired and kept in due order, for the purpose of further compliance with all corresponding requirements and technical conditions even after multiple use.

If approval of competent authority is required, such approval shall take into account presence of program of ensuring and its adequacy.

ENSURING OF COMPLIANCE WITH RULES

Competent authority is liable for ensuring of compliance with these Rules. Means of realization of this liability include development and carrying out of program of control over designing, manufacture, tests, inspection and maintenance support of packing sets, radio-active materials of low ability of dispersion, and also over preparation, execution of documentation, processing and placing of packages by consignors and carriers for the purpose of demonstration of practical execution of provisions of these Rules.

SPECIAL CONDITIONS

Cargos, in relation of which correspondence to other provisions of these Rules is practically impossible, should be transported only in special conditions. If competent authority decides, that correspondence to other provisions of these Rules is practically impossible and obligatory norms of safety, set by these Rules, are observed at the account of applying of means, alternative to other provisions of these Rules, then competent authority may approve operations on transportation in special conditions of single consignment or planned series of several consignments. General level of safety upon transportation shall be at least equivalent to the level, which would be kept upon execution of all applied requirements.

11.2.5 Requirements and control upon carrying out of transportations

Before first transportation of any package it is necessary to fulfill following requirements:

a) If designed pressure of system of protection covering exceeds 35 kPa (manometric), system of protective covering of each package shall be corresponding to approved design requirements, which are relevant to ability of this system to maintain integrity at this pressure.

b) For each package, which contains fissionable material, effectiveness of its radiation protection and protective covering and, upon need, characteristics of heat-transfer and effectiveness of localization system shall be kept in limits, which applied or indicated for approved construction.

c) For packages, which contain fissionable material, which are specially equipped by absorbers of neutrons in the form of package elements for the purpose of compliance with requirements, it is necessary to carry out examinations for the purpose of justification of presence and distribution of these absorbers of neutrons.

Package shall not contain any other objects, except objects and documentation, necessary for use of radio-active material. This requirement shall not interfere transportation of materials of low specific activity or objects with surface radio-active pollution together with other objects. Transportation of such objects and documentation in package or materials of low specific activity, or objects with surface radio-active pollution together with other objects may be permitted subject to absence of their interaction with packing set or its radio-active content, which would lower safety of package.

Reservoirs and containers of medium carrying capacity for mass cargoes, which are used for transportation of radio-active material, shall not be used for storage or transportation of other cargoes, if they are not cleaned from beta- and gamma-irradiators and alfa-irradiators of low toxicity less than level of 0,4 Bq/sm^2, and also from any other alfa-irradiators less than level of 0,04 Bq/sм^2.

Transportation of other objects together with cargoes, which transported in order of exclusive use, shall be permitted if organization of such transportation is controlled only by consignor and not prohibited by other rules.

Cargoes during transportation shall be separated from other dangerous cargoes with compliance of corresponding rules of transportation of dangerous cargoes of each country, through territory of or in the territory of which materials shall be transported, and, when applicable, with compliance of all competent transport organizations, and also these Rules.

Information for carriers

Consignor shall include in transportation documents indication on actions, if they are necessary, which carrier is obliged to carry out. Such indication shall be done in languages, which consignor or corresponding authorities consider as necessary, and shall include at least the following elements:

a) additional requirements concerning loading, placing, transportation, processing and unloading of package, transport pack or load container, including any special prescriptions concerning embedding for ensuring of safety heat removal, or notice on the fact that such requirements are not prescribed;

b) limitations concerning kind of transport or transport facilities and necessary route instructions;

c) measures in case of emergency for this load.

Effective certificates, which are issued by competent authority, are not obligatory transported together with cargo. At their disposal consignor shall give carrier(-s) before loading and unloading.

Notification of competent authorities

Before first transportation of any package, which requires approval of competent authority, consignor shall ensure provision of copies of each effective certificate, which is issued by competent authority for construction of package, to competent authority of each country, through territory of or on territory of which cargo is transported. Consignor is not obliged to wait for justification of receiving a certificate from competent authority, and competent authority is not obliged to give such justifications.

On each transportation of those, which are indicated below in subparagraphs a, b, c or d, consignor informs competent body of each country, through territory of or in territory of which cargo is transported. Such notification shall be received by each competent authority before the beginning of transportation, desirable not less than 7 days before its beginning:

a) packages of type C, which contain radio-active material with activity, which exceeds 3000 A1 or 3000 A2, depending on case, or 1000 TBq – depending on the fact which value is less;

b) packages of type B (U), which contain radio-active material with activity, exceeding 3000 A1 or 3000 A2, depending on case, or 1000 TBq – depending on the fact which value is less;

c) packages of type B (M);

d) transportation in special conditions.

Notification on cargo shall include:

a) information, sufficient for identification of this package or packages, including all corresponding numbers of certificates and markings;

b) information on date of transportation, expected date of arrival and specified route;

c) names of radio-active materials or nuclides;

d) description of physical and chemical form of radio-active material or record of the fact that it is radio-active material of special kind or radio-active material with low dispersion ability; and

e) information on maximum activity of radio-active content during transportation, expressed in becquerels (Bq) with corresponding prefix SI (annex 1). Instead of activity for fissionable material a mass of fissionable material may be indicated, expressed in grams (g) or multiple units.

Consignor is not obliged to send individual notice, if necessary information has been included in request for approval of transportation.

11.2.6 General requirements to all packing sets and packages for radio-active wastes

Package shall be designed subject to its mass, volume and form in a way, which ensures simplicity and safety of its transportation. Moreover, construction of package shall be the one, which allows fixing it in a proper way on transport facility or inside it during transportation.

Construction of package shall be the one that any facility, placed on package for its lifting, do not failed upon proper handling with it, and in case of failure ability of package to comply to other requirements of this Rules do not degrade. Construction shall take into account corresponding safety factors in case of lifting the package by jerking.

Facilities and any other equipment on external surface of package, which may be used for its lifting, shall be designed in a way, that it could stand its mass according to requirements or could be replaced or becomes improper for use in other way during transportation.

Packing set shall be designed and processed in such a way, that external surfaces have no prominent parts and may be easily deactivated as far as practically achievable.

As far as practically achievable, external covering of package shall be executed in such way that it would not accumulate and retain water.

Any facilities, which are added to package during transportation, which are not component of package, shall not make it less safe.

Package shall have ability to counteract the influence of any acceleration, vibration or resonance upon vibration, which may arise in common conditions of transportation, without any decrease of effectiveness of locking arrangements of different volumes or integrity of package as a whole. In particular, female screws, bolts and other clamps shall be designed in a way that do not allow possibility of their weakening without permission or separation even after multiple use.

Materials of packing set and any elements or constructions shall be physically and chemically compatible one to another and to radio-active content. One should take into account their behavior under irradiation.

All valves, through which radio-active content may come out, shall be protected against unauthorized actions.

Construction of package shall be designed subject to temperatures and pressure of environment, which may arise in common conditions of transportation.

Construction of package, estimated on radio-active materials, which have other dangerous properties, shall consider these properties.

ADDITIONAL REQUIREMENTS TO PACKAGES, WHICH ARE TRANSPORTED BY AIR SERVICE

Temperature of accessible surfaces of packages, designed for transportation by air service, shall not exceed 50° C at temperature of environment of 38° C without taking into account a solar irradiation.

Packages, designed for transportation by air service, shall be designed in a way that at the range of external temperatures between -40° C to +55° C the integrity of protective covering do not be broken.

Packages, which are transported by air service, which contain radio-active materials, shall have system of protective covering, able to stand without flowing-out decrease of external pressure to 5 кPa.

11.2.7 Confirmation of correspondence to requirements

Confirmation of correspondence of performance characteristics to requirements, set out in chapter 6, shall be carried out by any of methods, which are listed below, or their combination.

a) Conducting of tests in samples, which are material LSA-III or radio-active material of special type, or radio-active material with low dispersion ability, or in prototypes or models of packing sets, when content of sample or packing set shall imitate as far precisely as possible estimated range of characteristics of radio-active content, and tested sample or packing set shall be prepared in that appearance, in which they are provided for transportation.

b) Reference to preliminary satisfactory confirmation of similar nature.

c) Conducting of tests in models of corresponding scale, which equipped with elements, important for tested sample, if technical experience says that results of such tests are acceptable for design purposes. Upon applying of scale models one shall take into account necessity of correction of certain parameters of tests, such as diameter of punch and compression load.

d) Calculation or justified argumentation in the events when reliability or conservatism of calculation methods and parameters are generally recognized.

After testing of sample, prototype or model corresponding estimation methods shall be applied for confirmation of execution of requirements, set out in this chapter according to acceptable norms and performance characteristics.

TESTING OF MATERIAL LSA-III

Sample of material in solid condition, which constitutes full content of package, shall sink into the water on 7 days at a temperature of environment. Volume of water for tests shall be sufficient in a way, that at the end of 7-day testing free remained volume of water, that not absorbed and reacted, comprised at least 10 % of volume of strictly solid tested sample. Initial value of water pH shall comprise 6 - 8, and maximum conductivity - 1 mSm/m at 20° C. After sinking on 7 days of tested sample, full activity of free volume of water is measured.

11.2.8 Testing of radio-active material of special kind

General provisions

Samples that constitute or imitate radio-active material of special kind, shall be tested for collision, for impact, for flexion and for thermal behavior. For each of these tests individual sample may be used. After each test evaluation of sample shall be conducted by leaching and by determination of flowing-out volume with applying of method, not less sensitive, than methods, which are specified for solid material, which is not dispersed, and for material in capsule.

Methods of tests

Test for collision. Sample is thrown down to target from height of 9 м. Target shall correspond to prescriptions.

Test for impact. Sample shall be placed to lead plate, which lies on smooth solid surface, and impact is executed by it by flat surface of mild steel pig, of the force which equals to load impact of mass of 1,4 kg upon free fall from the height of 1 m. The lower part of pig shall have diameter of 25 mm with edges, which have rounding-off radius (3,0 ± 0,3) mm. Plate of lead of solidity 3,5 - 4,5 by Vikkers scale and thickness not more than 25 mm shall have a little bigger surface than bearing area of sample. For each test for impact a new surface of lead shall be used. Impact of pig by sample shall be executed in a way, that cause maximum damage.

Test for flexion. This test shall apply only to elongated and thin sources, which have length not less 10 cm and correlation of length to minimal width equal not less than 10. Sample shall be rigidly fixed in horizontal position, so that half of it length would run out of boundaries of place of clamp. Position of sample shall be so convenient, that it would receive maximum damage upon impact by flat surface of steel pig on free edge of sample. Force of impact of pig by sample shall equal to force of impact of load of mass of 1,4 kg, which falls free from height of 1 m. Flat surface of pig shall have diameter of 25 mm with edges, which have rounding-off radius (3,0 ± 0,3) mm.

Thermal test. Sample shall heat up to temperature of 800° C, remain at this temperature during 10 minutes, and free cool after that.

Samples that constitute or imitate radio-active material, contained in sealed capsule, may be freed from tests:

a) when mass of radio-active material of special kind is less than 200 g, and they are tested instead of that for action of impact for 4th class of solidity, which is prescribed in document "Radionuclid closed sources of ionizing radiation. Norms of degrees of fixity upon climatic and mechanical influences. Classes of solidity and methods of tests".

b) when they instead of it are tested for action of temperature for 6th class of solidity, which is mentioned in document "Radionuclid closed sources of ionizing radiation. Norms of degrees of fixity upon climatic and mechanical influences. Classes of solidity and methods of tests".

Methods of evaluation of leaching and evaluation of volume flow-out

Samples that constitute or imitate solid material, which is not dispersed, evaluation of leaching shall be conducted in the following order:

a) sample shall sink into the water on 7 days at a temperature of environment. Volume of water for tests shall be sufficient in a way, that at the end of 7-day testing free remained volume of water, that not absorbed and reacted, comprised at least 10 % of volume of strictly solid tested sample. Initial value of water pH shall comprise 6 - 10, and maximum conductivity - 1 mSm/m at 20° C.

b) water with sample shall be heated up to temperature (50 ± 5)° C, and sample shall remain at this temperature during 4 hours;

c) after that activity of water shall be measured;

d) sample shall remain not less than 7 days without blowing off in the air at a temperature not less than 30° C with relative humidity not less than 90 %;

e) sample shall be further sunk into the water with parameters, specified in subparagraph "a" above; water with sample is heated up to temperature of (50 ± 5)° C, and sample remains at this temperature during 4 hours;

f) after that activity of water shall be measured.

Samples, which constitute or imitate radio-active material, which contains in sealed capsule, shall be subject of leaching evaluation or flowing-out evaluation in the following order:

a) Evaluation of leaching shall be carried out in the following stages:

i) sample shall sink into the water at a temperature of environment. Initial value of water pH shall comprise 6 - 8, and maximum conductivity - 1 mSm/m at 20° C;

ii) water with sample shall be heated up to temperature (50 ± 5)° C, and sample shall remain at this temperature during 4 hours;

iii) after that activity of water shall be measured;

iv) sample shall remain not less than 7 days without blowing off in the air at a temperature not less than 30° C with relative humidity not less than 90 %;

v) process, specified in subparagraphs i, ii and iii, shall be repeated.

b) Evaluation of volume flowing-off, which is carried out instead of this, shall include any test acceptable for competent body according to requirements “Radionuclid closed sources of ionizing radiation. General technical requirements".

As reference material it is recommended to use a document of International Standards Organization "Radiation protection – closed radio-active sources – methods of tests for flowing-out", in which description of methods of tests for flowing-out is set out.

11.2.9 Tests of radio-active material of low ability for dispersion

Samples, which constitute or imitate radio-active material of low ability for dispersion, are subject to forced thermal test and test for collision. For each of these tests an individual sample may be used. After each test sample shall be tested for leaching. After each test it is necessary to ascertain the fulfillment of corresponding requirements.

11.3 ORDER OF PLACING, DESIGNING, CONSTRUCTION AND SETTING INTO OPERATION THE OBJECTS, DESIGNED FOR HANDLING OF RADIO-ACTIVE WASTES.

11.3.1 Order of adoption a decision on carrying out of design and searching works for placing the object, designed for handling of radio-active wastes

Decision on construction an object, designed for handling of radio-active wastes, is adopted by Verkhovna Rada or Cabinet of Ministers of Ukraine according to the competence.

On adoption of a decision on construction of storehouse of radio-active wastes or object, designed for handling of radio-active wastes and on beginning of design and searching works in the planned area an enterprise, specialized in handling of radio-active wastes informs local bodies of state executive power and local government bodies, in a territory of which construction is planned.

Proposals regarding area, which are submitted by an enterprise, specialized in handling of radio-active wastes, are considered upon presence of:

necessary information on constructed object and on measures, aimed at limitation of negative influence of this object on health of population and condition of environment;

reports of state ecological examination;

reports of state examination on nuclear and radiation safety.

Reports of these examinations shall be available for citizens and their associations.

If area is considered unsuitable for construction of storehouse of radio-active wastes or object, designed for handling of radio-active wastes, licensee shall conduct works on revegetation of territory and removal of all ecologically harmful consequences, which are caused by conducting of design and searching works.

11.3.2 Design, construction and setting into operation of storehouses of radio-active wastes or objects, designed for handling of radio-active wastes

Designing of storehouses of radio-active wastes of objects, designed for handling of radio-active wastes, is carried out according to effective norms, rules and standards with use of technologies verified by experience, tests or analysis.

Design of storehouse of radio-active wastes shall include two compulsory evaluations of safety:

during operation of storehouse;

after closing of storehouse.

Evaluation of safety includes analysis of scripts of progress of possible emergencies, their consequences and comparison of results with safety criteria. In case of positive report of state examinations of design a license for construction is granted in the order, established by law.

Setting into operation of storehouse of radio-active wastes or object, designed for handling of radio-active wastes, is carried out upon presence a license on operation, granted in the order, established by law.

11.3.3 Granting of ground areas for storehouses of radio-active wastes and objects, designed for handling of radio-active wastes

Ground areas, allocated for storehouses of radio-active wastes or objects, designed for handling of radio-active wastes, are granted for whole period of operation and conservation, determined by design, according to land laws.

11.3.4 Kinds of activity, prohibited in the territories, allocated for storehouses of radio-active wastes and objects, designed for handling of radio-active wastes

Ground areas, allocated for storehouses of radio-active wastes, are excluded from economic circulation and separated from adjacent territories by sanitary and protective areas.

It is prohibited within the boundaries of sanitary and protective areas:

- for population to live;

- to carry out all kinds of water use, forest exploitation and exploitation of subsoil, excluding established by approved projects.

- to carry out scientific researches without special licenses;

- to carry out without special license agricultural, forestry and other production activity, aimed at making of marketable products, and also construction of objects for social and public purposes;

- any other activity, which do not ensure radiation safety conditions.

11.4 RESPONSIBILITY FOR INFRINGEMENTS OF LAW IN THE SPHERE OF HANDLING OF RADIO-ACTIVE WASTES

11.4.1 Responsibility for infringements of law in the sphere of handling of radio-active wastes

Persons, guilty for infringement of law on handling of radio-active wastes, are responsible for:

- handling of radio-active wastes without corresponding license;

- infringements of requirements of norms, rules and standards on safe conducting of works during handling of radio-active wastes;

- non-execution of license conditions during handling of radio-active wastes;

- non-execution of prescriptions of bodies, which carry out regulation in the sphere of handling of radio-active wastes;

- infringements of requirements of legislation on compulsory state examinations and not taking into account of its resume;

- concealment from population or falsification of information on ecological conditions in the territory, allocated for storehouse of radio-active wastes or object, designed for handling of radio-active wastes;

- non-execution of duties regarding prevention of emergences and liquidation of their consequences in storehouses of radio-active wastes and objects, designed for handling of radio-active wastes, and also concealment of information on such emergencies;

- use of radio-active wastes for the purpose of trespass to public health or individual;

- setting into operation storages of radio-active wastes or objects, designed for handling of radio-active wastes, without fulfillment of measures on ensuring of protection of personnel, population and environment;

- delivery, assembling and setting into operation of defective equipment;

- setting into operation of storehouses of radio-active wastes and objects, designed for handling of radio-active wastes, without construction and entering into operation of all complex of these objects, specified by design;

- access to work with radio-active wastes of persons without corresponding training, persons younger than 18 years, and also those, who have medical contraindications;

- infringements of requirements on ensuring of physical protection upon handling of radio-active wastes;

- unauthorized import or export of radio-active wastes abroad Ukraine.

Legislation may set responsibility for other infringements in the sphere of handling of radio-active wastes.

11.4.2 International cooperation in the sphere of handling of radio-active wastes

International cooperation in the sphere of handling of radio-active wastes is carried out according to norms of international law on the basis of broad exchange of experience and mutual assistance with other states, international organizations and scientific institutions, specialized in the sphere of handling of radio-active wastes.

Norms of international treaties, participant of which is Ukraine, are the legal basis of international cooperation in the sphere of handling of radio-active wastes.

President of Ukraine signed the law on nuclear objects

President of Ukraine Viktor Yushchenko has signed the Law of Ukraine “On the order of adoption of decisions on placing, designing, construction of nuclear powerplants and objects, designed for handling of nuclear wastes, which have national importance”. Text of corresponding document dated September 8, 2005 No. 2861-IV is placed on official site of President.

According to the document, nuclear powerplants and objects, designed for handling of radio-active wastes, which have national importance, are atomic power plants; atomic heat supply stations; research nuclear reactors; objects on reprocessing of radio-active wastes (excluding plants, included in processing cycle of nuclear power plants, or storehouses for disposal of radio-active wastes); storehouses, designed for storage of spent nuclear fuel or high-level radio-active wastes of designed period of storage more than 30 years (excluding plants, included in processing cycle of nuclear power plants); storehouses, designed for disposal of spent nuclear fuel or radio-active wastes, by information of UNIAN.

As specified in the law, decision on placing, designing, construction of nuclear power plants and objects, designed for handling of radio-active wastes, which have national importance, is adopted by Verkhovna Rada by means of adoption of corresponding law. In this connection decision on placing, designing or construction of such objects Verkhovna Rada adopts only in the event of adjustment of its placing in the territory by local bodies of executive power and local government bodies. Moreover, the document sets that decision on adjustment of placing in the territory of nuclear objects local bodies of executive power and local government bodies adopt after conducting of local advisory questioning of citizens of Ukraine (consultative referendum) on this issue.

Draft law on placing, designing, construction of nuclear power plant or object, designed for handling of radio-active wastes, which have national importance, is submitted to Verkhovna Rada by Cabinet of Ministers of Ukraine.

As specified in the document, decision regarding prolongation of operational period of existing nuclear power plants and objects, designed for handling of radio-active wastes, which have national importance and need in amendments to legislation, is adopted in the same order, that a decision on construction of nuclear power plants and objects, designed for handling of radio-active wastes, which have national importance. The same provisions apply to adoption of decisions regarding extension of existing nuclear plants.

11.5 JOINT CONVENTION

11.5.1 Joint convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management

The Contracting Parties,

i) recognizing that the operation of nuclear reactors generates spent fuel and radioactive waste and that other applications of nuclear technologies also generate radioactive waste;

ii) recognizing that the same safety objectives apply both to spent fuel and radioactive waste management;

iii) reaffirming the importance to the international community of ensuring that sound practices are planned and implemented for the safety of spent fuel and radioactive waste management;

iv) recognizing the importance of informing the public on issues regarding the safety of spent fuel and radioactive waste management;

v) desiring to promote an effective nuclear safety culture worldwide;

vi) reaffirming that the ultimate responsibility for ensuring the safety of spent fuel and radioactive waste management rests with the State;

vii) recognizing that the definition of a fuel cycle policy rests with the State, some States considering spent fuel as a valuable resource that may be reprocessed, others electing to dispose of it;

viii) recognizing that spent fuel and radioactive waste excluded from the present Convention because they are within military or defence programmes should be managed in accordance with the objectives stated in this Convention;

ix) affirming the importance of international co-operation in enhancing the safety of spent fuel and radioactive waste management through bilateral and multilateral mechanisms, and through this incentive Convention;

x) mindful of the needs of developing countries, and in particular the least developed countries, and of States with economies in transition and of the need to facilitate existing mechanisms to assist in the fulfillment of their rights and obligations set out in this incentive Convention;

xi) convinced that radioactive waste should, as far as is compatible with the safety of the management of such material, be disposed of in the State in which it was generated, whilst recognizing that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through agreements among Contracting Parties to use facilities in one of them for the benefit of the other Parties, particularly where waste originates from joint projects;

xii) recognizing that any State has the right to ban import into its territory of foreign spent fuel and radioactive waste;

xiii) keeping in mind the Convention on Nuclear Safety (1994), the Convention on Early Notification of a Nuclear Accident (1986), the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (1986), the Convention on the Physical Protection of Nuclear Material (1980), the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter as amended (1994) and other relevant international instruments;

xiv) keeping in mind the principles contained in the interagency "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources" (1996), in the IAEA Safety Fundamentals entitled "The Principles of Radioactive Waste Management" (1995), and in the existing international standards relating to the safety of the transport of radioactive materials;

xv) recalling Chapter 22 of Agenda 21 by the United Nations Conference on Environment and Development in Rio de Janeiro adopted in 1992, which reaffirms the paramount importance of the safe and environmentally sound management of radioactive waste;

xvi) recognizing the desirability of strengthening the international control system applying specifically to radioactive materials as referred to in Article 1(3) of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989);

11.5.2 Objectives, definition and scope of application

11.5.2.1 Objectives

The objectives of this Convention are:

i) to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management, through the enhancement of national measures and international co-operation, including where appropriate, safety-related technical co-operation;

ii) to ensure that during all stages of spent fuel and radioactive waste management there are effective defenses against potential hazards so that individuals, society and the environment are protected from harmful effects of ionizing radiation, now and in the future, in such a way that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations;

iii) to prevent accidents with radiological consequences and to mitigate their consequences should they occur during any stage of spent fuel or radioactive waste management.

11.5.2.2 Definitions

For the purposes of this Convention:

a) "closure" means the completion of all operations at some time after the emplacement of spent fuel or radioactive waste in a disposal facility. This includes the final engineering or other work required to bring the facility to a condition that will be safe in the long term;

b) "decommissioning" means all steps leading to the release of a nuclear facility, other than a disposal facility, from regulatory control. These steps include the processes of decontamination and dismantling;

c) "discharges" means planned and controlled releases into the environment, as a legitimate practice, within limits authorized by the regulatory body, of liquid or gaseous radioactive materials that originate from regulated nuclear facilities during normal operation;

d) "disposal" means the emplacement of spent fuel or radioactive waste in an appropriate facility without the intention of retrieval;

e) "licence" means any authorization, permission or certification granted by a regulatory body to carry out any activity related to management of spent fuel or of radioactive waste;

f) "nuclear facility" means a civilian facility and its associated land, buildings and equipment in which radioactive materials are produced, processed, used, handled, stored or disposed of on such a scale that consideration of safety is required;

g) "operating lifetime" means the period during which a spent fuel or a radioactive waste management facility is used for its intended purpose. In the case of a disposal facility, the period begins when spent fuel or radioactive waste is first emplaced in the facility and ends upon closure of the facility.

h) "radioactive waste" means radioactive material in gaseous, liquid or solid form for which no further use is foreseen by the Contracting Party or by a natural or legal person whose decision is accepted by the Contracting Party, and which is controlled as radioactive waste by a regulatory body under the legislative and regulatory framework of the Contracting Party;

i) "radioactive waste management" means all activities, including decommissioning activities, that relate to the handling, pretreatment, treatment, conditioning, storage, or disposal of radioactive waste, excluding off-site transportation. It may also involve discharges;

j) "radioactive waste management facility" means any facility or installation the primary purpose of which is radioactive waste management, including a nuclear facility in the process of being decommissioned only if it is designated by the Contracting Party as a radioactive waste management facility;

k) "regulatory body" means any body or bodies given the legal authority by the Contracting Party to regulate any aspect of the safety of spent fuel or radioactive waste management including the granting of licenses;

l) "reprocessing" means a process or operation, the purpose of which is to extract radioactive isotopes from spent fuel for further use;

m) "sealed source" means radioactive material that is permanently sealed in a capsule or closely bonded and in a solid form, excluding reactor fuel elements;

n) "spent fuel" means nuclear fuel that has been irradiated in and permanently removed from a reactor core;

o) "spent fuel management" means all activities that relate to the handling or storage of spent fuel, excluding off-site transportation. It may also involve discharges;

p) "spent fuel management facility" means any facility or installation the primary purpose of which is spent fuel management;

q) "State of destination" means a State to which a transboundary movement is planned or takes place;

r) "State of origin" means a State from which a transboundary movement is planned to be initiated or is initiated;

s) "State of transit" means any State, other than a State of origin or a State of destination, through whose territory a transboundary movement is planned or takes place;

t) "storage" means the holding of spent fuel or of radioactive waste in a facility that provides for its containment, with the intention of retrieval;

u) "transboundary movement" means any shipment of spent fuel or of radioactive waste from a State of origin to a State of destination.

11.5.2.3 Scope of application

1. This Convention shall apply to the safety of spent fuel management when the spent fuel results from the operation of civilian nuclear reactors. Spent fuel held at reprocessing facilities as part of a reprocessing activity is not covered in the scope of this Convention unless the Contracting Party declares reprocessing to be part of spent fuel management.

2. This Convention shall also apply to the safety of radioactive waste management when the radioactive waste results from civilian applications. However, this Convention shall not apply to waste that contains only naturally occurring radioactive materials and that does not originate from the nuclear fuel cycle, unless it constitutes a disused sealed source or it is declared as radioactive waste for the purposes of this Convention by the Contracting Party.

3. This Convention shall not apply to the safety of management of spent fuel or radioactive waste within military or defence programmes, unless declared as spent fuel or radioactive waste for the purposes of this Convention by the Contracting Party. However, this Convention shall apply to the safety of management of spent fuel and radioactive waste from military or defence programmes if and when such materials are transferred permanently to and managed within exclusively civilian programmes.

11.6 SAFETY OF SPENT FUEL MANAGEMENT

11.6.1 General safety requirements

Each Contracting Party shall take the appropriate steps to ensure that at all stages of spent fuel management, individuals, society and the environment are adequately protected against radiological hazards.

In so doing, each Contracting Party shall take the appropriate steps to:

i) ensure that criticality and removal of residual heat generated during spent fuel management are adequately addressed;

ii) ensure that the generation of radioactive waste associated with spent fuel management is kept to the minimum practicable, consistent with the type of fuel cycle policy adopted;

iii) take into account interdependencies among the different steps in spent fuel management;

iv) provide for effective protection of individuals, society and the environment, by applying at the national level suitable protective methods as approved by the regulatory body, in the framework of its national legislation which has due regard to internationally endorsed criteria and standards;

v) take into account the biological, chemical and other hazards that may be associated with spent fuel management;

vi) strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation;

vii) aim to avoid imposing undue burdens on future generations.

11.6.2 Existing facilities

Each Contracting Party shall take the appropriate steps to review the safety of any spent fuel management facility existing at the time the Convention enters into force for that Contracting Party and to ensure that, if necessary, all reasonably practicable improvements are made to upgrade the safety of such a facility.

11.6.3 Siting of proposed facilities

1. Each Contracting Party shall take the appropriate steps to ensure that procedures are established and implemented for a proposed spent fuel management facility:

i) to evaluate all relevant site-related factors likely to affect the safety of such a facility during its operating lifetime;

ii) to evaluate the likely safety impact of such a facility on individuals, society and the environment;

iii) to make information on the safety of such a facility available to members of the public;

iv) to consult Contracting Parties in the vicinity of such a facility, insofar as they are likely to be affected by that facility, and provide them, upon their request, with general data relating to the facility to enable them to evaluate the likely safety impact of the facility upon their territory.

2. In so doing, each Contracting Party shall take the appropriate steps to ensure that such facilities shall not have unacceptable effects on other Contracting Parties by being sited in accordance with the general safety requirements.

11.6.4 Design and construction of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

i) the design and construction of a spent fuel management facility provide for suitable measures to limit possible radiological impacts on individuals, society and the environment, including those from discharges or uncontrolled releases;

ii) at the design stage, conceptual plans and, as necessary, technical provisions for the decommissioning of a spent fuel management facility are taken into account;
iii) the technologies incorporated in the design and construction of a spent fuel management facility are supported by experience, testing or analysis.

11.6.5 Assessment of safety of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

i) before construction of a spent fuel management facility, a systematic safety assessment and an environmental assessment appropriate to the hazard presented by the facility and covering its operating lifetime shall be carried out;

ii) before the operation of a spent fuel management facility, updated and detailed versions of the safety assessment and of the environmental assessment shall be prepared when deemed necessary to complement the assessments referred to in paragraph (i).

11.6.6 Operations of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

i) the licence to operate a spent fuel management facility is based upon appropriate assessments and is conditional on the completion of a commissioning programme demonstrating that the facility, as constructed, is consistent with design and safety requirements;

ii) operational limits and conditions derived from tests, operational experience and the assessments, as specified in Article 8, are defined and revised as necessary;

iii) operation, maintenance, monitoring, inspection and testing of a spent fuel management facility are conducted in accordance with established procedures;

iv) engineering and technical support in all safety-related fields are available throughout the operating lifetime of a spent fuel management facility;

v) incidents significant to safety are reported in a timely manner by the holder of the licence to the regulatory body;

vi) programmes to collect and analyse relevant operating experience are established and that the results are acted upon, where appropriate;

vii) decommissioning plans for a spent fuel management facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility, and are reviewed by the regulatory body.

11.7 DISPOSAL OF SPENT FUEL

If, pursuant to its own legislative and regulatory framework, a Contracting Party has designated spent fuel for disposal, the disposal of such spent fuel shall be in accordance with the obligations, specified in following chapter, relating to the disposal of radioactive waste.

11.8 SAFETY OF RADIOACTIVE WASTE MANAGEMENT

11.8.1 General safety requirements

Each Contracting Party shall take the appropriate steps to ensure that at all stages of radioactive waste management individuals, society and the environment are adequately protected against radiological and other hazards.

In so doing, each Contracting Party shall take the appropriate steps to:

i) ensure that criticality and removal of residual heat generated during radioactive waste management are adequately addressed;

ii) ensure that the generation of radioactive waste is kept to the minimum practicable;

iii) take into account interdependencies among the different steps in radioactive waste management;

iv) provide for effective protection of individuals, society and the environment, by applying at the national level suitable protective methods as approved by the regulatory body, in the framework of its national legislation which has due regard to internationally endorsed criteria and standards;

v) take into account the biological, chemical and other hazards that may be associated with radioactive waste management;

vi) strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation;

vii) aim to avoid imposing undue burdens on future generations.

11.8.2 Existing facilities and past practices

Each Contracting Party shall in due course take the appropriate steps to review:

i) the safety of any radioactive waste management facility existing at the time the Convention enters into force for that Contracting Party and to ensure that, if necessary, all reasonably practicable improvements are made to upgrade the safety of such a facility;

ii) the results of past practices in order to determine whether any intervention is needed for reasons of radiation protection bearing in mind that the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including the social costs, of the intervention.

11.8.3 Siting of proposed activities

1. Each Contracting Party shall take the appropriate steps to ensure that procedures are established and implemented for a proposed radioactive waste management facility:

i) to evaluate all relevant site-related factors likely to affect the safety of such a facility during its operating lifetime as well as that of a disposal facility after closure;

ii) to evaluate the likely safety impact of such a facility on individuals, society and the environment, taking into account possible evolution of the site conditions of disposal facilities after closure;

iii) to make information on the safety of such a facility available to members of the public;

iv) to consult Contracting Parties in the vicinity of such a facility, insofar as they are likely to be affected by that facility, and provide them, upon their request, with general data relating to the facility to enable them to evaluate the likely safety impact of the facility upon their territory.

2. In so doing, each Contracting Party shall take the appropriate steps to ensure that such facilities shall not have unacceptable effects on other Contracting Parties by being sited in accordance with the general safety requirements.

11.8.4 Design and construction of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

i) the design and construction of a radioactive waste management facility provide for suitable measures to limit possible radiological impacts on individuals, society and the environment, including those from discharges or uncontrolled releases;

ii) at the design stage, conceptual plans and, as necessary, technical provisions for the decommissioning of a radioactive waste management facility other than a disposal facility are taken into account;

iii) at the design stage, technical provisions for the closure of a disposal facility are prepared;

iv) the technologies incorporated in the design and construction of a radioactive waste management facility are supported by experience, testing or analysis.

11.8.5 Assessment of safety of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

i) before construction of a radioactive waste management facility, a systematic safety assessment and an environmental assessment appropriate to the hazard presented by the facility and covering its operating lifetime shall be carried out;

ii) in addition, before construction of a disposal facility, a systematic safety assessment and an environmental assessment for the period following closure shall be carried out and the results evaluated against the criteria established by the regulatory body;

iii) before the operation of a radioactive waste management facility, updated and detailed versions of the safety assessment and of the environmental assessment shall be prepared when deemed necessary to complement the assessments referred to in paragraph (i).

11.8.6 Operations of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

i) the licence to operate a radioactive waste management facility is based upon appropriate assessments and is conditional on the completion of a commissioning programme demonstrating that the facility, as constructed, is consistent with design and safety requirements;

ii) operational limits and conditions, derived from tests, operational experience and the assessments are defined and revised as necessary;

iii) operation, maintenance, monitoring, inspection and testing of a radioactive waste management facility are conducted in accordance with established procedures. For a disposal facility the results thus obtained shall be used to verify and to review the validity of assumptions made and to update the assessments for the period after closure;

iv) engineering and technical support in all safety-related fields are available throughout the operating lifetime of a radioactive waste management facility;

v) procedures for characterization and segregation of radioactive waste are applied;

vi) incidents significant to safety are reported in a timely manner by the holder of the licence to the regulatory body;

vii) programmes to collect and analyse relevant operating experience are established and that the results are acted upon, where appropriate;
viii) decommissioning plans for a radioactive waste management facility other than a disposal facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility, and are reviewed by the regulatory body;

ix) plans for the closure of a disposal facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility and are reviewed by the regulatory body.

11.8.7 Institutional measures after closure

Each Contracting Party shall take the appropriate steps to ensure that after closure of a disposal facility:

i) records of the location, design and inventory of that facility required by the regulatory body are preserved;

ii) active or passive institutional controls such as monitoring or access restrictions are carried out, if required; and

iii) if, during any period of active institutional control, an unplanned release of radioactive materials into the environment is detected, intervention measures are implemented, if necessary.

11.8.8 Implementing measures

Each Contracting Party shall take, within the framework of its national law, the legislative, regulatory and administrative measures and other steps necessary for implementing its obligations under this Convention.

11.8.9 Legislative and regulatory framework

1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of spent fuel and radioactive waste management.

2. This legislative and regulatory framework shall provide for:

i) the establishment of applicable national safety requirements and regulations for radiation safety;

ii) a system of licensing of spent fuel and radioactive waste management activities;

iii) a system of prohibition of the operation of a spent fuel or radioactive waste management facility without a license;

iv) a system of appropriate institutional control, regulatory inspection and documentation and reporting;

v) the enforcement of applicable regulations and of the terms of the licenses;

vi) a clear allocation of responsibilities of the bodies involved in the different steps of spent fuel and of radioactive waste management.

3. When considering whether to regulate radioactive materials as radioactive waste, Contracting Parties shall take due account of the objectives of this Convention.

11.8.10 Regulatory body

1. Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework, and provided with adequate authority, competence and financial and human resources to fulfill its assigned responsibilities.

2. Each Contracting Party, in accordance with its legislative and regulatory framework, shall take the appropriate steps to ensure the effective independence of the regulatory functions from other functions where organizations are involved in both spent fuel or radioactive waste management and in their regulation.

11.8.11 Responsability of the licence holder

1. Each Contracting Party shall ensure that prime responsibility for the safety of spent fuel or radioactive waste management rests with the holder of the relevant license and shall take the appropriate steps to ensure that each such license holder meets its responsibility.

2. If there is no such license holder or other responsible party, the responsibility rests with the Contracting Party which has jurisdiction over the spent fuel or over the radioactive waste.

11.9 HUMAN AND FINANCIAL RESOURCES

Each Contracting Party shall take the appropriate steps to ensure that:

i) qualified staff are available as needed for safety-related activities during the operating lifetime of a spent fuel and a radioactive waste management facility;

ii) adequate financial resources are available to support the safety of facilities for spent fuel and radioactive waste management during their operating lifetime and for decommissioning;

iii) financial provision is made which will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of a disposal facility.

11.9.1 Quality assurance

Each Contracting Party shall take the necessary steps to ensure that appropriate quality assurance programmes concerning the safety of spent fuel and radioactive waste management are established and implemented.

11.9.2 Operational radiation protection

1. Each Contracting Party shall take the appropriate steps to ensure that during the operating lifetime of a spent fuel or radioactive waste management facility:

i) the radiation exposure of the workers and the public caused by the facility shall be kept as low as reasonably achievable, economic and social factors being taken into account;

ii) no individual shall be exposed, in normal situations, to radiation doses which exceed national prescriptions for dose limitation which have due regard to internationally endorsed standards on radiation protection; and

iii) measures are taken to prevent unplanned and uncontrolled releases of radioactive materials into the environment.

2. Each Contracting Party shall take appropriate steps to ensure that discharges shall be limited:

i) to keep exposure to radiation as low as reasonably achievable, economic and social factors being taken into account; and

ii) so that no individual shall be exposed, in normal situations, to radiation doses which exceed national prescriptions for dose limitation which have due regard to internationally endorsed standards on radiation protection.

3. Each Contracting Party shall take appropriate steps to ensure that during the operating lifetime of a regulated nuclear facility, in the event that an unplanned or uncontrolled release of radioactive materials into the environment occurs, appropriate corrective measures are implemented to control the release and mitigate its effects.

11.9.3 Emergency preparedness

1. Each Contracting Party shall ensure that before and during operation of a spent fuel or radioactive waste management facility there are appropriate on-site and, if necessary, off-site emergency plans. Such emergency plans should be tested at an appropriate frequency.

2. Each Contracting Party shall take the appropriate steps for the preparation and testing of emergency plans for its territory insofar as it is likely to be affected in the event of a radiological emergency at a spent fuel or radioactive waste management facility in the vicinity of its territory.

11.9.4 Decommissioning

Each Contracting Party shall take the appropriate steps to ensure the safety of decommissioning of a nuclear facility. Such steps shall ensure that:

i) qualified staff and adequate financial resources are available;

ii) the provisions with respect to operational radiation protection, discharges and unplanned and uncontrolled releases are applied;

iii) the provisions with respect to emergency preparedness are applied;

iv) records of information important to decommissioning are kept.

11.9.5 Transboundary movement

1. Each Contracting Party involved in transboundary movement shall take the appropriate steps to ensure that such movement is undertaken in a manner consistent with the provisions of this Convention and relevant binding international instruments.

In so doing:

i) a Contracting Party which is a State of origin shall take the appropriate steps to ensure that transboundary movement is authorized and takes place only with the prior notification and consent of the State of destination;

ii) transboundary movement through States of transit shall be subject to those international obligations which are relevant to the particular modes of transport utilized;

iii) a Contracting Party which is a State of destination shall consent to a transboundary movement only if it has the administrative and technical capacity, as well as the regulatory structure, needed to manage the spent fuel or the radioactive waste in a manner consistent with this Convention;

iv) a Contracting Party which is a State of origin shall authorize a transboundary movement only if it can satisfy itself in accordance with the consent of the State of destination that the requirements of subparagraph (iii) are met prior to transboundary movement;

v) a Contracting Party which is a State of origin shall take the appropriate steps to permit re-entry into its territory, if a transboundary movement is not or cannot be completed in conformity with this Article, unless an alternative safe arrangement can be made.

2. A Contracting Party shall not license the shipment of its spent fuel or radioactive waste to a destination south of latitude 60 degrees South for storage or disposal.

3. Nothing in this Convention prejudices or affects:
i) the exercise, by ships and aircraft of all States, of maritime, river and air navigation rights and freedoms, as provided for in international law;

ii) rights of a Contracting Party to which radioactive waste is exported for processing to return, or provide for the return of, the radioactive waste and other products after treatment to the State of origin;

iii) the right of a Contracting Party to export its spent fuel for reprocessing;

iv) rights of a Contracting Party to which spent fuel is exported for reprocessing to return, or provide for the return of, radioactive waste and other products resulting from reprocessing operations to the State of origin.

11.9.6 Disused sealed sources

1. Each Contracting Party shall, in the framework of its national law, take the appropriate steps to ensure that the possession, remanufacturing or disposal of disused sealed sources takes place in a safe manner.

2. A Contracting Party shall allow for reentry into its territory of disused sealed sources if, in the framework of its national law, it has accepted that they be returned to a manufacturer qualified to receive and possess the disused sealed sources.

11.10 STUDY OF LONG-TERM ECONOMIC PROSPECTS OF THE PROJECT IN VIEW OF GEOPOLITICAL TENDENCIES

11.10.1 Preliminary Estimations

The preliminary estimations of technical and economic parameters have shown that the costs of domestic implementation of the minimum RW removal program can reach up to $220M-400M per year that should be rather acceptable in connection with importance of the task of clearing the biosphere from dangerous RW. Granting of services in the framework of space burial resolution to other countries, radiating from the global prices for space services, can be expedient.

Created by the CIS, mainly Russia, Ukraine and Kazakhstan, launch vehicles, space boosters, recoverable space vehicles, as well as devices of monitoring and flight control and the available space ports can serve a good base for creation of a space complex capable of RW isolation in space.

Along with solving the basic problem – protection of ecology – initiative on creation of this complex is a perspective development trend of space-rocket branch, which could promote the economic ascent of the CIS.

The international value and high scale of this task requires a global contribution of efforts for its solution by various state and private organizations arranging the necessary financial and technical feasibilities.

The concept of space isolation covers a problem of its preparation and delivery into space, as well as appearance of the space-rocket complex, costs of its creation and international breakdown of activities.

The idea of removal of the dangerous RW from the Earth and its isolation in safe areas of the Solar system attracts the increasing attention of world experts.

Huge potential in rocket-space engineering accumulated in the countries of CIS and in the world, which was not quite claimed due to reduction of strategic arms, could and should be directed to solution of universal problems, in particular, preservation of ecology of the Earth and removal of RW.

As a result, the option considered in this report, namely removal of dangerous RW, has probably no alternative in the near future. At the same time, as the pointed problem has now obtained a primary value for survival and development of our civilization, necessity for resolution of a number of accompanying problems connected to ecological safety does not call any doubts.

11.10.2 Prospects of Removal of Dangerous Nuclear Waste in Space

One of the tasks for space rockets could be removal of waste produced by nuclear reactors. Delivery of waste in space will be completely safe for mankind. Thus, disposal of radioactive waste is a very robust solution for the given problem.

The space age lasted for less than five years when a number of vehicles launched in space reached a couple of dozens. After successful fulfillment of a fundamental task: achievement of the first circular velocity on October 4, 1957, the second circular velocity was achieved in January, 1959, while the Soviet vehicle “Moon-1” was injected to an orbit of an artificial satellite of the Sun, and the first vehicle to research the Venus was launched on February 12, 1961. Unconditionally, the greatest achievement of that phase was the flight of the first astronaut in April of 1961. Among space vehicles launched at that time it is necessary to note several American “Transit” satellites, which were launched in June and November, 1961. Radioisotope Plutonium-238 was used by an electrical system of these vehicles as a power source. Thus, it was for the first time when radioactive materials of terrestrial nuclear power engineering got in space.

Today, after 45 years of development the astronautics became the integral part of daily life for mankind. Among present achievements are about 30 space vehicles with radio-isotope power sources onboard, including spacecraft “Apollo”, on which the Americans have flown to the Moon. During preparation of these flights along with the task of return to the Earth there was another solution found: during the atmosphere impact with the second orbital velocity integrity of ampoules with radioisotope was provided at emergency return to the Earth. The problem of integrity of ampoules was also successfully resolved in USSR at creation of the radio-isotope heating unit for “Lunokhod” (“Moon Rover”), and radio-isotope generators for “Mars-96” vehicles. Radio-isotope power sources have found their application onboard interplanetary space vehicles intended for distant flights to planets of the Solar system: for example, “Cassini” launched in 1997 to the Saturn, has a 33kg load of Plutonum-238.

Another achievement of practical astronautics having a direct relation to the considered problem was creation of nuclear energy installations and their application in space. The first space vehicle with atomic power plant (APP) was injected to the terrestrial orbit in 1965. It was a unique American spacecraft SNAP-10A. Soviet spacecraft with APP “Buk” (“Beech”) on fast neutrons and thermoelectric system of energy conversion worked on the orbit later, as well as "Topol" (same as "Topaz") on intermediate neutrons with thermo emission system of energy conversion.

One more development trend of an astronautics having the extremely important value for the considered problem was development of an electrical rocket engine (ERE). For the first time such engine was used on the interplanetary Soviet spacecraft "Zond-2" (“Probe-2”) in 1964. To the present time more than 200 space vehicles equipped with ERE were launched, which executed orbital correction of the operating spacecraft. Within last several years due to development of powerful high-impulse and resourceful ERE their application for resolution of a new task in space began. It was transportation. The first example of ERE used as a mid-flight engine onboard interplanetary vehicle was the American spacecraft “Deep Space-1”, launched in October, 1998. At launch of domestic satellites “Topaz” in 1987-1988 for the first time in world practice the APP was used to power up the electrical rocket engine.

The idea of RW removal in space has called a large response from both scientists and technicians. In the 70-80th of the last century the numerous researches were conducted by some Russian and foreign engineers. Thus, for example, American contributors have considered a problem of removal as one of the primary tasks for the reusable “Space-Shuttle”. During the 70th some similar researches took place in the Russian Research Center named after M.V. Keldysh. The new splash of interest in RW removal into space has arisen after Chernobyl. In 1990, some of research was done under this concept by a decision of the USSR State Committee of Science and Engineering. The last similar activity was conducted in 1996 in the framework of joint resolution of the Ministry of Atomic Energy of Russian Federation and the Space-Rocket Corporation “Energia” named after S.P. Korolyev with issue of the feasibility report on RW removal in deep space.

The task of removal of radioactive waste in space requires the answer to three interconnected basic questions:

1. What RW has to be removed?
2. Where it has to be removed?
3. What means should be used to remove it?

Obviously, removal of all available RW into space is impossible and inexpedient at the same time. The significant part can be successfully used or buried on the Earth. Only extremely dangerous RW are considered, sine they are formed at fission of highly toxic radionuclide with a large half-life period. These are supertransuranic elements such as neptunium, curium and americium, as well as fission products of uranium: zirconium, technetium and iodine. In the beginning of 90th the forecast was made that by 2000 the annual output volume of the listed nuclides from domestic processing plants should make about 10t, while the global volume increase by 100t per year. Thus, a total weight of the RW together with capsules and various safety means would be from 500 to 1000t per year, and freight traffic to LEO together with carriers should be then 2500-5000t per year. The existing freight traffic to LEO is estimated within the limits of 500-800t per year, which was much lower that required. The modern forecast of RW accumulation in the first quarter of this century is shown in Tab. 1 (the calculation was made at the rate of summarized quantity of RW in a volume of 66kg/year according to 1GW of electrical power produced by APP). According to the weight of protective facilities, the freight traffic to LEO in this case was estimated approximately to 750t per year.

Table 1 – FORECAST OF RW ACCUMULATION IN THE 1ST QUARTER OF THE XII CENTURY (tons)

LOCATION	2010	2025
COUNTRIES OF CIS	5	5
GLOBAL	10* – 17	20* – 30

* Without taking into account a number of reactors in the USA, Canada, Sweden and other countries, which are not oriented to recycling

Tab. 2 represents some typical considered locations for accommodation of RW in space and their comparative characteristics. The listed ranking of locations with preference to the Solar Orbit is commonly used in all researches carried out during the beginning 70th and up to the middle 90th. Dropping of the RW on the surface of the Sun in all times was fairly considered due to extremely large required energy. Near-Earth and Lunar Orbits are excluded because of their low stability. It is rather clear that removal of dangerous RW from the Solar System is more preferable in comparison to injection into the Solar Orbit due to a high level of guaranteed isolation from the biosphere. Thus, a problem of stability is solved in this case.

Table 2 – POSSIBLE LOCATIONS FOR REMOVAL OF RW INTO SPACE

Description	LEO	Lunar Orbit	Lunar Surface (smooth landing)	Solar Orbit	Outside Solar System	Dropping onto Solar Surface
Accrual velocity, km/s	4.00	4.25	6.05	4.45	8.75	24.00
Lifetime of the system, days	<1	6	6	180	<1	<1
Typical location	Circular Orbit 55000 km	Circular Orbit 21700 km	Lunar Surface (back side of the Moon)	Orbit 0.85 a.u. with 1° inclination	-	-
Expected number of orbital maneuvers	2	5	5	2	1	1

Advantages	easy to recover; easy to return; lowest accrual velocity	capable of recovery; capable of return; low accrual velocity	capable of recovery; capable of return; permanent isolation on celestial body; no orbital stability problems;	permanent isolation; very high orbital stability (>107 years)	permanent isolation; high eligibility potential; easy to implement	permanent isolation; easy to implement
Disadvantages	unstable orbit; low eligibility; non-permanent isolation	unstable orbit; rather complicated flight mission	potential pollution of Lunar surface; low eligibility; complicated flight mission	significant system lifetime required; difficult recovery	high accrual velocity; hard recovery; return to the Earth impossible	very high accrual velocity; very small quantity of RW returns to the Earth

Up to the middle 90th, due to use of traditional chemical boosters the required accrual velocity was not possible during removal of the RW outside the Solar System. The situation has fundamentally changed in the second half of the 90th after creation of powerful ERE. Engines powered by a nuclear reactor are currently being developed by a number of Russian institutions according to the newly ratified "Convention of space nuclear energy in the Russian Federation" of February, 1998.

Another important astronautic achievement of the present time was creation of an international commercial sea-based automated launch site for efficient launching of spacecraft from near-equatorial area of the Pacific, operated by Russia, Ukraine, USA and Norway. Besides its advantages this launch site allows injection into space with a minimum possibility of impact to inhabited areas of the Earth, as well as minimal radiation exposure for the staff at pre-launch preparation.

Obviously, one of the main tasks in the framework of this project is safeness of the removable RW during its isolation in space. The performed activities are based on the 40-year's experience in astronautics, including manned missions and use of radioisotope power-units onboard various spacecraft. It allows the required integrity of the RW ampoules almost at every emergency situation, as well as prevention of radiation exposure to the biosphere due to implementation of the multi-barrier protection system.

Russian project on creation of the Lander with RW onboard anticipates for implementation of the multi-barrier protection. Radioisotope with a total mass of 150g is isolated in a multilayer metal capsule. Inner casing is manufactured from tantalum-wolfram alloy with a fusion temperature of 3050℃, which is much higher than any possible overheating temperatures at any emergency situation. The outer casing manufactured from rhenium-molybdenum alloy allows safe sealing in case of impact of the capsule onto granite surface with a maximum velocity of 120 m/s. The ampoules are placed in the separate graphite multilayer casings with thermal protection and then installed into graphite matrix, located inside the metal container, which ensures a complete radiation shielding in addition. Special thermal protection of the Lander preserves the container from external overheating, while the onboard shock-absorption system eliminates any possible damage at its collapse onto the ground. The special compartment ensures flotation of the vehicle during its splash-down. Probability of the biosphere impact at a solitary launch is estimated to $3.5 \cdot 10^{-8}$.

None of the researches on RW removal was done without any econometric study. According to materials obtained in 1996, the project on space isolation of the RW into GSO by means of traditional launch facilities should require about $12M – 15M. In total, during a 20-year operation period the costs should be estimated to $65 – 110 billion. (The same amount stands for creation and 15-year operation of the ISS). During this time there will be about 600t of dangerous RW isolated in space. Any possible rise in prices for energy produced by an APP due to implementation of this project was estimated to 0.12 – 0.14 cents per kW/h. At the current price of energy produced by any APP in the USA of 2.5 – 3.5 cents per kW/h this rise should assume about 3 – 4%. Since the costs in domestic rocket industry are much lower than anywhere in the world, removal of the RW into space would be commercially favorable for the Ukrainian enterprises. Nevertheless, implementation of this project is possible only on international level due to rather high capital outlays.

Hence, the very important role in a final solution is played by removal of toxic and long-living components of the RW into space. Current state and available potential of the nuclear science, as well as space rocket industry, allow considering of econometric models for the removal complex and engineering concept of removal outside the Solar System aiming at the guaranteed permanent isolation.

11.10.3 Joint Convention on Safe Processing of Used Fuel and Radioactive Waste

The Joint Convention is one of the first international tools engaging problems of safety during processing of radioactive waste in countries with own nuclear programs. Furthermore, it deals with a significant improvement and toughening of the existing regime of nuclear safety under aegis of IAEA, as well as development of the international standards for this industry. The Convention is aimed at maintenance of the hi-tech works with the RW in order to create some operational mechanisms for safety and prevention of nuclear pollution.

The Convention concerns problems of safety of radioactive waste being a yield of activity of civil nuclear objects. Besides, it concerns problems of RW safety on military objects, in case these materials are delivered for use within the framework of any civil program.

The text of this Convention includes an appeal to the participants upon revision of safety regulations and analysis of ecological factors considering the existing nuclear objects, as well as the developed. The Convention serves as a basis for legislation and regulatory documents aiming at control of nuclear safety. It establishes the rules and conditions of transportation, according to which the participant countries must obtain the required administration and technical facilities, as well as regulatory institutions supervising any possible works with the RW according to this Convention. The Convention obliges the exporter to undertake the required activities on recovery of the exported materials on its own territory if they could not be transported according to prescribed rules.

Participants of the Joint Convention on Safe Processing of Used Fuel and Radioactive Waste

Country	Date of Signing	Form of Submission	Depositary Date
Argentina*	December 19, 1997	ratification	November 14, 2000
Australia	November 13, 1998	ratification	August 5, 2003
Austria	September	ratification	June 13, 2001

	17, 1998		
Belarus	October 13, 1999	ratification	November 26, 2002
Belgium*	December 8, 1997	ratification	September 5, 2002
Brazil*	October 31, 1997		
Bulgaria*	September 22, 1998	ratification	June 21, 2000
Canada*	May 7, 1998	ratification	May 7, 1998
Croatia	April 9, 1998	ratification	May 10, 1999
Czech Republic*	September 30, 1997	approval	March 25, 1999
Denmark	February 9, 1998	admission	September 3, 1999
Estonia	January 5, 2001		
Finland*	October 2, 1997	admission	February 10, 2000
France*	September 29, 1997	approval	April 27, 2000
Germany*	October 1, 1997	ratification	October 13, 1998
Greece	February 9, 1998	ratification	July 18, 2000
Hungary*	September 29, 1997	ratification	June 2, 1998
Indonesia	October 6, 1997		
Ireland	October 1, 1997	ratification	March 20, 2001
Italy	January 26, 1998		
Japan*		joining	August 26, 2003
Kazakhstan*	September 29, 1997		
Republic of Korea*	September 29, 1997	ratification	September 16, 2002
Latvia	March 27, 2000	admission	March 27, 2000
Lebanon	September 30, 1997		
Lithuania*	September 30, 1997	ratification	March 16, 2004
Luxemburg	October 1, 1997	ratification	August 21, 2001
Morocco	September 29, 1997	ratification	July 23, 1999
Netherlands*	March 10, 1999	admission	April 26, 2000
Norway	September 29, 1997	ratification	January 12, 1998
Peru	June 4, 1998		
Philippines	March 10,		

	1998		
Poland	October 3, 1997	ratification	May 5, 2000
Romania*	September 30, 1997	ratification	September 6, 1999
Russian Federation*	January 27, 1999		
Slovakia*	September 30, 1997	ratification	October 6, 1998
Slovenia*	September 29, 1997	ratification	February 25, 1999
Spain*	June 30, 1998	ratification	May 11, 1999
Sweden*	September 29, 1997	ratification	July 29, 1999
Switzerland*	September 29, 1997	ratification	April 5, 2000
Ukraine*	September 29, 1997	ratification	July 24, 2000
Great Britain*	September 29, 1997	ratification	March 12, 2001
USA*	September 29, 1997	ratification	April 15, 2003
TOTAL	**42**	**34**	**34**

* Countries with at least one nuclear reactor (APP)

11.10.4 Ten Essential Facts on RW

1. The used nuclear fuel (RW) is extremely dangerous and hot "cocktail" representing a mixture of huge number of fission-fragment elements, various isotopes of uranium, plutonium and other supertransuranic elements and decay products.

2. There are no technologies in the whole world (and not anticipated in the near future) allowing safe processing of the RW. All available technologies are characterized by terrible environmental pollution with a great volume of liquid radioactive waste (LRW). They end-up in pumping-in under the ground of Krasnoyarsk-26 (by the Yenisei River) or Tomsk-7, and dumping in open reservoirs as one at the "Mayak" facility (Chelyabinsk area).

3. The existing technologies provide only two possible ways of RW processing:

– Storage or burial;
– Processing (regeneration).

Uranium and plutonium extracted at processing are used for preparation of fresh fuel, including the mixed uranium-plutonium glue-fuel. There is a huge amount of waste formed during regeneration, which still needs to be buried.

Processing of the RW in civil purposes is fulfilled only by 3 countries in the whole world – Russia, France and the Great Britain. The existing global tendency determines that the majority of the countries choose the direct burial without any processing.

1. Until July, 2001, import of RW produced by foreign APP was allowed in Russia only with purpose of processing with its subsequent return. On June 6, 2001, Russian government has ratified a law on modification of the Law of RSFSR «Protection of Environment», which allowed "import of irradiated heat-generating assemblies of nuclear reactors for implementation of temporal technological storage and (or) their processing on the territory of the Russian Federation».

2. In 2001, Russian Duma (the Parliament) has approved an administration bill on import of foreign RW, which allowed burial of radioactive waste formed as a result of its processing on the territory of Russia. The feasibility report for the project does not actuate any costs on re-export of the majority of regenerated fuel and radioactive waste. Creation of a burial place for these dangerous LRW serves as evidence. It means that the RW will stay in Russia forever.

3. If the project on import will be implemented, there will be about 200t of plutonium formed as a result of processing. Russia already has about 30t of plutonium stored after its domestic processing. This plutonium does not find its application for different reasons including the economic. Industrial utilization of plutonium is not available. Storage of plutonium is very problematic and extremely expensive.

4. The costs of Russia at import of foreign RW will superimpose the profit of the project. According to Rosatom (Russian Agency for Nuclear Energy), construction of a plant will cost about $1.96 billion. However, costs of the similar enterprise in Sellafield (Great Britain) with 2 times less power were estimated to $4.35 billion (1994). In Japan the similar plant was estimated to $17 billion. The project does not include any costs on transportation of a significant part of the regenerated uranium fuel and radioactive waste back in the country-supplier, as well as eliminating of storage and processing facilities, etc.

5. It is supposed, that the profit on import of RW will be ostensibly spent for ecological purposes. Thus, within 40 years the “nuclear” officials did not solve a problem of resettlement for inhabitants of the polluted “Mayak” area in Chelyabinsk. People are still living on radioactive ground. Moreover, the medical experiment to study the influence of small radiation dozes on human body is carried out there. Even in case of successful submission of the project there are no warranties that this money will be used on the announced purposes.

6. There is no market, neither market pricing for such services on storage of the RW in the world. France and the Great Britain process the RW on the basis of previous contracts, which are not a subject of market relations. Besides, due to economic unprofitableness, as well as ecological danger and social unacceptability the expediency of processing of RW was put under a doubt by these countries.

7. According to public poll, the majority of the Russians stand against import of foreign RW.

These 10 facts make it easy to understand, that it is safer and economically expedient to remove the available RW into space than neutralize them.

11.10.5 Treatment of RW in Finland: Policy; Last and Present Experience; Plans for Future

Finland has processed about 1700t of uranium from the four available APP power generating units, which were put into operation in the beginning of 1970 up to 1980. Initially the RW policy was based on the centralized international facilities due to rather small scale of nuclear program. After acceptance of the correction to the Act on the nuclear energy in 1994, this policy was revised for the benefit of a burial in domestic geological storehouses; for today it was the unique technology.

About 300t of uranium from APP at Lowiis was sent for processing to “Mayak” Complex in Russia, but since 1996 this initiative has stopped pursuant to the mentioned correction of the law. Today, the RW is stored on territory of the APP up to its final burial. The storage is done in pools; thus, some good in-service experience was accumulated.

Finland successfully implements an advanced program of burial. It began more than 20 years ago. The general sanction, including designation of a site, was given by the

Government and approved by the Parliament. In the middle of 2004, installation of the underground facility began; it should be a part of a storehouse area. It was supposed, that the license for construction of hermetic sealing and burial place will be submitted in 2012, while the operation license – in 2020.

Though the current policy of Finland in relation to the RW is based only on a single-use technology, we still monitor all the developments of fuel cycles and make estimations. Due to the prolonged storage before the final burial, the issue of using the other technology still remains open here.

11.10.6 International Storehouse for Commercial Nuclear Fuel and Toxic Waste

Within many years there were numerous measures undertaken on development of the acceptable solution on safe RW processing. The most recent were approved during the first meeting of the Parties under the Joint Convention on Safe Processing of Used Fuel and Radioactive Waste. As more countries decline to a geological burial and conduct activities on termination of operation and disassembly, the government of the USA considers it one of the most actual issues.

It is hardly necessary to emphasize on any national or global character of the problem. For countries, which have found the solution of salvaging unacceptable, the development and implementation of multinational solutions has its positive alternative. At the same time it is necessary to note, that this research should not endanger any current national program.

In the USA there are some requirements established by the legislation and policy on any procedure of international storage and salvaging of American RW. In particular, there are some certain problems concerning the capability induced by the Russians in 2001, as well as numerous similar proposals. These factors essentially complicate a problem of international cooperating and salvaging of the nuclear fuel and toxic waste.

11.11 CURRENT SITUATION

11.11.1 Requirements of the Joint Convention

The final responsibility for safety of the nuclear fuel and radioactive waste is born by the State. This is confirms by the Preamble to the Joint Convention. The Convention also recognizes a principle of responsibility for safety of the nuclear fuel and radioactive waste of its producer. The Convention has come into force on June 18, 2001. On September 29, 1997, the USA has signed the Convention. On April 9, 2003, the USA has become the thirty first country to ratify the Convention, and July 14, 2003, it became by the full-part participant. Now there are 42 Parties in the Convention, which have signed it, and 34 participants.

This document actuates the principles important for all states. It provides and magnifies the culture of global safety.

Regarding the primal responsibility of the producer of nuclear fuel and nuclear waste, as well as salvaging on the own territory, the Convention recognizes that in some circumstances the safe and effective liquidation of radioactive waste should be stimulated by the agreements between the Parties on use of the available facilities, in particular, where the waste occurred as a result of the joint programs.

Any proposal on international storage or liquidation of the RW should be considered separately in each case. IAEA has issued the Code on Foreign Transportation of Radioactive Waste. The most important rules positions of the Code have found their reflection in the Joint Convention. This Code and the Joint Convention provide a technical management, which any state can use at determination of its participation or nonparticipation in the international storage or transportation of nuclear fuel or waste. The principle of primary action anticipates that an exporter should transport the waste only upon received consent of an importer and obligatory after ensuring that the receiving state has obtained all administrative and technical feasibilities, as well as the governing structures necessary for control over safety of the RW. At the same time, an importer should agree on a reception of waste only in the event of meeting the specified requirements. It means that dispatch of the RW is under jurisdiction of the state and reflects its governmental policy. At importance of the technical factors for estimation of the proposal, the political issues should also have a large value at decision-marking process.

11.11.2 US Cooperation in Area of Control over Liquidation of Waste

USA supports the very idea of convention for the countries of the region for collective solution of nuclear problems. This current initiative is similar to American Waste Compact Program (Convention on Wastes), according to which some of the US states have integrated for determination of a burial place for the underactive wastes on one specific territory instead of disposing a number of separate storehouses. A certain progress was reached in this direction.

One of the examples is the agreement between Luxembourg and Belgium, on which Belgium agrees to import radioactive waste of Luxembourg. Other example is the announcement by Slovenia at the first Meeting of the Parties of the Joint Convention about the first steps undertaken in support of the regional approach, expressed in meeting of the Commonwealth of Independent States (CIS). From the time of this announcement some of annual meetings have passed. The third example is the announcement in March, 2004, by the European Commission on financing of EUR50000 in the feasibility report on European Regional Utilization Facility. Thus, if the collective solution concerned with a steep suspicion, now a new joint solution gears up.

The USA conducts a strong program of international cooperation in liquidation of radioactive waste and renders assistance to other states in this area. For example, meetings of the US Committee on Nuclear Cooperation with Taiwan and the Republic of Korea were conducted accordingly more than 15 and 25 years, and the problems of utilization have occupied an agenda of the majority of these meetings. Many states have managed to find understanding in the US Department of Energy on similar scientific programs.

At the same time, any country should not expect that the USA would consider import of the irradiated fuel with American origin back for storage and/or salvaging, for example in Ukka Mountain or somewhere else. According to the law on non-proliferation ratified in 1978, any plans on return of such a fuel should correspond to the stringent conditions, including submission of the proposal to the Congress having the right to reject it. The Congress, accordingly, has forbidden the executive branch to spend money for revision of such plans.

Despite of the US policy against import of nuclear fuel, there is a certain system of international salvaging in the States, which accepts some used fuel from research reactors back for further salvaging. This system was created according to the program on reduction of use of highly enriched uranium, which successfully results in transition of the majority research reactors to other forms of fuel. The majority of the used uranium will be repatriated before the actual completion of this program in 2009. USA also conducts a similar activity with Russia and IAEA including return of the used uranium and nuclear fuel produced by research reactors during the Soviet time back to Russia.

11.11.3 Eligibility of the Common Repository

The main problem faced by all international waste repositories is their public acceptance. If this was not a problem, then there could be some regional nuclear repositories already created, as the concept itself was more than 25 years old. However, it is inevitable, that such repositories will be created at least in some regions of the world. Today, almost 34 countries including Taiwan will have to utilize their nuclear waste, instead of processing it. It is difficult to imagine the 35 separate geological repositories. Moreover, almost every nuclear reactor represents a long-term repository itself. It is even more difficult to imagine the consequences of such situation in a tight community, where all the different countries have their own waste produced by several reactors. These states should take an advantage of at least one common dump-ground for protection of their environment.

11.11.4 General Factors Influencing the Nuclear Policy

It was a lot of proposals on international repositories or salvaging of used nuclear fuel in the last several years. But all of the attention was given to novel capabilities provided by new Russian legislation on temporal RW storage or processing. Before we address to the given problem, let us consider some general factors.

11.11.5 Cooperation Agreement

Any special nuclear materials are exported from the US pursuant to the agreement on cooperation, negotiations on which were conducted under requirements of Art.123 of the Law on Nuclear Energy and according to its corrections. These requirements concern not only the exported materials, but also nuclear materials manufactured from them or use of technologies, exported from the USA. These materials are referred to as a “nuclear material of American origin”. The requirements are as follows:

1. Guarantee of peaceful use / non-use for explosive purposes;
2. Application of full guarantees for countries not possessing the nuclear weapons;
3. Maintenance of the adequate physical protection;
4. Approval received from the USA on secondary processing or enrichment of nuclear materials, as well as modification of any irradiated fuel containing these materials;
5. USA has a full right to require the return of these material in the US under certain conditions;
6. USA has a full right to approve any repository for plutonium or enriched uranium;
7. Consent of the USA is required for international transportation of the RW.

Negotiations are conducted by the State Secretary at technical assistance of the US DOE with advices from the Commission on Nuclear Regulation. The agreement is submitted by the State Secretary and Minister of Energy to the President, who transmits it to the Congress. It should be further considered there within 90 days of a current session, and then the Cooperation Agreement comes into force in case of its confirmation by the both chambers of the Congress. In case of a cancellation by the President of one or two of the above-stated requirements, the Agreement needs an affirmative of the Congress. Until now none of the presidents have rejected any of the required rules. Currently, the USA has several agreements on nuclear cooperation with EUROATOM, IAEA, Taiwan and 22 other countries in addition.

11.11.6 Application of the US Law Pursuant to the Made Contracts

Today there are almost 33K metric tons of used nuclear fuel available outside the United States containing materials of the American origin, which, accordingly, fall under action of the US law under the contract. The list of the countries, which fall under these regulations, includes the countries of EU, Brazil, Czech Republic, India, Japan, Republic of Korea, Mexico, Switzerland, Yugoslavia, and Taiwan. Among countries supporting the idea of an international repository are Taiwan and Korea, since both of them have accumulated a great volume of used nuclear fuel, from which they would like to get rid of. These countries also have the required funds, due to which any proposal on repository could become potentially attractive for exporters. All used nuclear fuel from Taiwan and majority of Korean fall under action of the US regulations under the contract, which makes a fulfillment of these rights by the United States one of the important issues in any proposal on international repository or utilization of RW. It is necessary to note, that nuclear waste received as a result of secondary processing does not fall under action of the same right of the USA.

According to Article 131 of the Law on Nuclear Energy of 1954, and corrections made pursuant to the made contract, transportation of the used nuclear fuel is implemented on a legally established procedure and acting standards the US DOE on the basis of a separate process called the Consecutive Organization (Scheme). In addition to approval of the State Secretary and advices from the Department of Defense and Commission on Nuclear Regulation the Minister of Energy is obliged to provide a written determination, that the Consecutive Scheme would not severe for the general defense or safety. The notice on the offered Consecutive Scheme and its determination should be published in the Federal Register at 15 days prior to its submission. At repeated import of the used nuclear fuel with the purpose of secondary processing, the Consecutive Scheme should be considered by the Congress within 15 days. According to Article 127 of the above mentioned law it is required that import of nuclear materials of the American origin should be authorized by an importer agreeing on the US control requirements.

11.11.7 Political Factors

11.11.7.1 Utilization Instead of Repeated Processing

The policy of Bush Administration consists in opposition to the global accumulation of plutonium. According to requirements of the Consecutive Scheme any statement on import of the used fuel containing nuclear materials of American origin should be supported by conformation of the USA that these materials are intended for their complete liquidation, instead of for secondary processing. The permanent repository is not necessary during transportation, and the long-term storage can be just one of the components for the Scheme. But the Scheme should also actuate some particular plans on engagement of sufficient resources for development of geological repository. USA assumes to use its consent implying from the made contract against secondary processing or transportation of the RW.

11.11.7.2 Safe and Ecologically Justified Equipment

Besides obtaining the warranties on final salvaging, the warranties on safety and ecological reliability of temporal storage and final repository will be necessary for the United States. The technology of storage is rather detailed. An example to that are the numerous nuclear power plants and also repositories located far from the actual rectors in Canada, Russia and Sweden. The US Commission on Nuclear Regulation has come to a conclusion that the used reactor the fuel could be safely stored for at least 100 years, and there were at least some commercial suppliers of the necessary technology. In any case, we can expect taking part in a scientific estimation of any installation for storage and salvaging to ensure its construction on the basis of ecological reliability.

The recommendations given by the Minister of Energy on Ukka Mountain as scientifically justified site for salvaging of nuclear waste and the following notice of the Congress on adequate sanction to construction are the testimony of large scope of work carried out there. The pilot installation for conservation of waste in New-Mexico City has become the first stake of development of geological repository in 2000, and definitely a huge step forward. Sweden and Finland have also entered the path of geological repositories. The United States have shared their experience accumulated in Ukka Mountain and New-Mexico City at the first meeting of the Parties of the Joint Convention. USA also undertakes various efforts on exchange of experience with the cooperating parties. While the events of September 11, naturally, call a certain concern on safety of nuclear fuel from the terrorists, Minister Abraham has noted the advantage of eternal storage under the “lock of nuclear fuel” in comparison with its storage in various other places.

11.11.7.3 Safe Transportation

Before the actual import the United States prefer to receive some warranties on safe handling of a material during its transportation. Sea-transporting of radioactive materials is performed on a regular basis with an extremely high degree of safety and pursuant to the stringent standards of the IAEA and International Marine Organization. Nevertheless, such transport is extremely inconsistent, and the both coastal and small-island states often raise an issue of regulation or direct inhibit. Any attempts on transporting through the international locations, such as the Panama Channel, Malaccan Channel, Bosporus and Dardanelles can result in attempts of one-side restrictions or even interception by the protesters. The large-scale transportation of nuclear materials from a seaport to places of storage on automobile or railway can result in potential danger for infrastructure of many nations and become just one more pretext for numerous protests. However, the technology of transport canisters is quite safe and any predicted incidents can hardly become a threat for safety.

11.11.7.4 Warranties of Necessary Resources

The requirements on safety as already spoken should last for a long period of time. Before granting the approval on transportation, the United States should receive some warranties on presence of organizational (private or state-operated) mechanisms for maintenance of the requirement on safety. In particular, these mechanisms include maintenance of the appropriate control and reporting on financial resources, the majority from which are the advance payments; and their availability to control of the used nuclear fuel on time of the utilization program. Term of theses obligations can appear much longer than any commercial structure was able to guarantee.

11.11.7.5 Capabilities of Russian Repositories

As to a particular subject of a number of presentations made on this section, the United States are rather interested in capability of safe and reliable storage in Russia. Among other technical problems raised above, the US DOE has already launched a program on cooperation with Russia for scientific study of geological repositories. It should become an excellent basis for further cooperation on the possible utilization site.

11.11.7.6 Transportation Issues

Use of Russian western ports can be quite problematic for transportation of the foreign RW. The access through politically dependent marine paths and loading facilities is required. Transportation of the RW to the Pacific port can be dangerous due to a rather old railway path of the Transsiberia Railway unable to handle the heavy rail canisters. Nevertheless, it is possible to develop a new railway.

11.11.7.7 Problem of Salvaging

The final salvaging of the RW often raises large difficulties. While in USA the open path for liquidation is required, according to Russian legislation the used nuclear fuel can be accepted only for temporal storage or processing, but not utilization. Temporal storage, and especially long-term storage, would definitely reduce the acuteness of a political problem arising at filling of repository capacities, which can result in a premature stop of the reactors. Temporal storage can also facilitate scientific analysis and final construction of a big repository site, for example, study of thermal control and behavior/corrosion of materials. At the same time, at utilization of the RW construction of a very expensive geological repository is required, which would definitely reduce a value of such temporal site.

11.11.7.8 Warranties of the IAEA

Another problem can possibly be caused by the requirements of the IAEA in connection with the used fuel transferred to Russia. According to the US law there are no requirements on export or import of special nuclear materials in Russia, since the state is possessing nuclear weapons. Moreover, USA considers a diverse application of warranties to Russia should not have any special importance for IAEA. In addition, Russia has no sufficient resources to meet its obligations under the stated warranties. USA also doubts that IAEA is able to spend its own funds. Nevertheless, some of the non-nuclear states can express their wish for such warranties to apply the fuel, which they export. At the existing Guarantee Agreement applied to Taiwan, the official warranties on any kind of the used nuclear fuel are required.

11.11.8 International Companies Dealing with the RW

***International Agency on Atomic Energy (IAEA)* –** www.iaea.org

The main purpose of its activity, created within the framework of U.N.O. in 1957, is propagation of peaceful application for atomic energy. Today IAEA headquarters is in Vienna and integrates 132 countries. One of its priorities is development of standards for safety of storage, processing and transporting of used nuclear fuel and radioactive waste, as well as implementation of programs on utilization of nuclear submarines.

The European Nuclear Society (ENS) – www.euronuclear.org

The European Nuclear Society (ENS) was founded in 1975. It represents association of 27 nuclear communities from 26 countries of the world. Incorporating the Russian Nuclear Society, ENS has a point-to-point communication with the Pacific Nuclear Council. ENS has signed the agreements on cooperation with Nuclear-Power Association of Argentina, American, Canadian and Chinese Nuclear Societies.

ENS integrates more than 20000 of experts with representatives from business, industry, power engineering, as well as technologists, scientists and teachers. Corporate members of ENS are national and transnational corporations engaged in space engineering, manufacturing of nuclear fuel and equipment for enterprises of a nuclear industry. ENS executes activity on development of science and engineering in the field of peaceful use of nuclear energy, consolidation of international technological community for resolution of problems of safe applications for nuclear energy, including safe handling of radioactive waste.

***Agency of Nuclear Energy (NEA)* –** www.nea.fr

The structure of the Agency of Nuclear Energy includes 27 countries of Europe, Northern America, Asia and Pacific region. It is created within the framework of Organization on Economic Cooperation and Development (OECD). The Agency headquarters in Paris and executes tight cooperation with IAEA and EC. Among the programs implemented by NEA there are activities on rendering assistance to its members in control of radioactive areas, development of a nuclear safety system, as well as strategy of accommodation of the used nuclear fuel, active waste and waste obtained at operation of nuclear objects.

***Global Association of Nuclear Stations Operators (GANSO)* –** www.wanomc.ru

The Global Association integrates all operators of APP in the world. The organization is created for exchange of in-service experience and team working directed on achievement of the best level of safety and reliability at operation of APP. In the framework of GANSO all organizations can communicate and interchange any information with each other in atmosphere of cooperation and openness, which allows each operator to learn some lessons and gain experience, as well as solve problems and practice for achievement of the final purpose – increase of safety. GANSO is a noncommercial international organization with no political barriers and interests. GANSO is not a supervising institution. It does not give any advices on problems of design. It is not a financial organization as well and does not belong to any lobbyist circles.

World Nuclear Association (WNA) – www.world-nuclear.org

The World Nuclear Association with central office in London integrates the companies of global manufacture of atomic energy and uranium. Members are producers of nuclear fuel and companies specializing on transportation of radioactive waste from operating nuclear objects.

Global Partnership "Group of Eight" (G8)

Foreword

During the Summit in Kananaskis on June, 2002, the Federal Chancellor of Germany G. Schroder and the President of Russian Federation V. Putin together with their G8-partners have founded the "Global Partnership against Distribution of Weapons and Mass Destruction Materials"

Russia and Germany cooperate in two key areas of the Global Partnership: annihilation of reserves of chemical weapons and construction of safe long-term storage sites for radioactive waste produced by nuclear submarines of the Naval Fleet of Russia. These two areas were designated by the leaders of G8 among other priorities of the Global Partnership. Utilization of submarines thus coincides with the integrated program providing rehabilitation of coast bases and treatment of the irradiated nuclear fuel.

Contributions within G8

Germany and Russia participate along with a number of the largest donors of the world. Today all of the partners have contributed their obligations (March, 2004):

USA	– $10 billion;
Russia	– $2 billion;
Germany	– $1.5 billion;
EU	– $1 billion;
Italy	– EUR 1 billion;
Great Britain	– $0.75 billion;
France	– EUR 0.75 billion;
Canada	– 1 billion Canadian dollars
Japan	– $0.2 billion.

During the G8 Summit in 2003, some new donors were accepted: Norway (EUR 0.1 billion), Finland (EUR 10M), Sweden (EUR 10M + $20M), Switzerland (15 million Swiss franks), Poland ($100K), and Netherlands (EUR 4 billion). Russia spends annually more than 180 millions on utilization of submarines and about 65 million dollars on annihilation of chemical weapons.

Joint Russian-German Projects

Germany and Russia have gained a significant experience in the field of disarmament:

– Since 1993 both countries cooperate in annihilation of chemical weapons in Saratov area;

– Since 1995 they work on increasing the level of physical protection for nuclear installations.

The gained experience has induced the Federal Government of Germany to concentrate financing on the three of the most important projects:

– Creation of liquidation site for chemical weapons in Kambark and further financing of utilization Gorniy (up to EUR 300M);

– Salvaging of nuclear submarines at facility of long-term storage in Sayid (EUR 300M);

– Rendering of assistance on physical protection of nuclear material (allocation of EUR 170M by 2009).

The projects on destruction of chemical weapons and physical protection are supported by the Federal Ministry of Foreign Relations of Germany, while utilization of nuclear submarines is handled by the Federal Ministry of Economy and Labor. From the Russian party there are two institutions engaged: the Federal Industrial Agency and the Federal Agency of Atomic Energy.

Additional participation of Germany in NDEP

Germany also participates in the International Program on Environmental Protection "Northern Dimension Environmental Partnership" (NDEP). It was founded by the Scandinavian countries and aimed, in particular, at problems of nuclear and radiation safety and salvaging of nuclear submarines.

Financing of the program is done at the expense of the fund controlled by the European Bank of Renovation and Development (EBRD) in London. In addition, Germany supports the Fund of Nuclear Safety "Nuclear Security Fund" (NSF) of the IAEA. German contribution is EUR 1M. This fund was created under German initiative after September 11, which should enable IAEA to counteract any threat of terrorism to nuclear objects and radioactive sources.

Legal Basis

The legal fundamentals of the Russian-German projects are set by the bilateral Intergovernmental Agreement of December 16, 1992, on cooperation for safety control at liquidation of nuclear and chemical weapons, as well as interdepartmental agreements between the German Federal Ministries supervising implementation of the projects and Russian partners.

The problems of responsibility for nuclear damage were separately settled by the Intergovernmental Agreement of 1998. The project on utilization of nuclear submarines is executed, in particular, pursuant to the Framework Agreement on multilateral nuclear-ecological program in Russian Federation of May 21, 2003. It simultaneously determines the legal frameworks for the NDEP projects.

Financial and Technical Monitoring

In interests of transparency and controllability the Federal Government pays special attention to competent financial and technical monitoring of the projects within the framework of Global Partnership. Along with monitoring carried out by the Accounting Chamber of Germany, the projects implemented by the Ministry of Foreign Relations are controlled by the Federal Department of Military Engineering and Supplies (BWB) in Koblenz. All transactions and financial monitoring are executed by the Major Finance Administration in Erfurt, and engineering control is implemented by the Federal Department of Research and Materials (BAM).

Utilization of Nuclear Submarines

In connection with strict terms of operation, and according to the international contracts on disarmament, Russia has begun the mass utilization of submarines since the 90^{th} of the last century. For today, there are 193 nuclear submarines retired. Basically, at expense of Russian budget there were 96 submarines already utilized.

In the northern regions of Russia there were 117 nuclear submarines retired and 63 utilized. 22 submarines are are being utilized at the moment and 32 are stored and still waiting for their turn.

The storage of a big number of submarines and reactor units creates significant risk for safety and environment. Russian Federation engages the considerable funds in liquidation, but still requires a certain help. Germany has promised to assist by allocation of financial assets on implementation of these projects (about EUR 300M).

Joint Russian-German Project on Utilization

Preparation of all reactor compartments for their long storage is conducted by “Nerpa” plant, which is about 25 km from the planned repository site. Today, as a result of utilization there are about 40 three-block reactor units and 9 submarine hulls stored floating at the piers at Sayida. The available there bays are completely loaded. Lack of sites for long-term storage can possibly stop the further utilization.

“Nerpa” has a capability to improve the technical infrastructure for salvaging of nuclear submarines. There are 5 hulls of nuclear submarines and three-cut-off reactor units stored on the territory of the plant. The one-cut-off units are sealed and preserved, while a biological protection is set with the purpose of safe and ecological storage within 70 years. Germany provides “Nerpa” with the equipment for effective utilization and conservation of reactor of units for long-term storage.

The Russian-German project on utilization has a complex character. It has many participants, while carried out for a long term and establishes high specifications. Russian and German engineering is applied simultaneously. Activities are implemented in different locations of Russia and Germany. Climate of Russia is rather cold, and any work there should be conducted during summer only. It is especially important to show mutual understanding and good will for fruitful cooperation.

The main supervision over the project is executed by the Russian-German Control Committee, working on a constant basis.

Project Management

Energiewke Nord GmbH (EWN) is responsible for coordination of the project in Germany.

In Russia, Kurchatov Institute is responsible for implementation of the project and facility control, accompanied by “Nerpa” Plant responsible for disassembly of submarines and preparation of the reactor units for their long-term storage.

For solving of the most important technical and organizational problems, German and Russian participants cooperate on a basis of the joint technical committee. Its resolutions are mandatory.

Russian organizations execute their functions as the customer, while Germany performs its activity on those issues, which are not restricted by Russian law.

Implementation

The Russian and German enterprises execute their activities pursuant to the contracts signed by organization in control of the project from the German Party. Joint supervising groups from the German and Russian Parties monitor the fulfillment of activities. Upon successful completion of activities EWN pays the appropriate German and Russian enterprises directly.

Control

Chief Control Experts execute the control over the project in various stages of its implementation. The control management from the German Party is a subject of control from the Federal Department of Research and Materials in Erfurt.

Financing

Germany allocates EUR 300M for implementation of this project. The Russian Party takes up the expenses on the necessary sanctions and licenses.

Achieved Results

Within 2003, a good progress of the project was reached. Since January till September the General Agreement was developed and signed on October 9, 2003, by the State-Secretary A. Takke on behalf of the Federal Ministry of Economy and Transactions of Germany and the Deputy Minister Dr. C. Antipov on behalf of the Ministry of Atomic Energy of Russian Federation.

After signing of this Agreement, the Executive Arrangement was signed at the end of October, 2003, in Moscow.

In November, 2003, the first five contracts for the total amount of EUR 18M with “Nerpa” Plant were signed.

In 2003, the total amount of the implemented work was EUR 4.6M. In 2004, this amount has reached EUR 50M.

In 2005, the following stages of the projects are completed:

1. Activities of “Nerpa” Plant:

– Works on preparation of the new stockpile plate for formation of single reactor units;
– Disassembly of the five multi-compartment hulls of nuclear submarines, disassembly of the three-compartment reactor units and formation of single reactor units units;
– Delivery of German automated mobile equipment;
– Design and licensing of the repository;
– Manufacture of the floating tanks for the liquid radioactive waste.

2. Development of the Transportation System located in the Cape Sayida by “Nerpa”:

– Integrated research of the coast site and water areas;
– Development and design of the hydraulic keel-block elevators.

3. Preparatory activities at the Cape Sayida:

– Relocation, extension and putting into operation of the piers;
– Cleaning of a coast zone from the trash and old hulls;
– Manufacturing of the pontoons.

4. Creation of the storage facility at the Cape Sayida:

- Topographical research of the site;
- Obtaining the sanction on construction;
- Projecting activities and preparation of construction;
- Preparation of a building site and the required equipment equipment;
- Beginning of construction of the berthing facilities and the repository;
- Ecological monitoring;
- Designing of the monitoring system.

According to the Master Schedule of the Project, by the end of 2006, the first reactor units will be delivered to a coast site for their long-term storage. The Complex thus will be put into operation. Up to the end of 2008, it is stipulated to finish all the complex activities under the project operated by Germany with technical contributing from Russia.

12. WP 5000 - FLIGHT TEST DEFINITION

12.1 LIST OF ABBREVIATIONS

APP	–	atomic power plant
CSCU	–	control system and communication unit
SRC	–	space rocket complex
RM	–	reboost module
MRAW	–	module with capsules with radioactive wastes
ODS	–	orbital disposal stage
UNF	–	used nuclear fuel
TB	–	transition bay
HARAW	–	highly active radioactive wastes
ILV	–	integrated launch vehicle
SRS	–	space rocket system
LV	–	launch vehicle
RAW	–	radioactive wastes
ES	–	escape system
CS	–	control system

12.2 PROPOSALS ON EXPERIMENTAL CONFIRMATION OF CAPSULE SAFETY

For experimental confirmation of safety of capsules with RW in emergency situations it is expedient to use launch vehicle of light type, for example LV «Dnepr».

LV «Dnepr» launch it is possible to simulate the hardest emergency case when simulator of capsule with RW enters the atmosphere and falls to earth. It is expedient to launch module with capsule with RW to ballistic trajectory with point of falling in area of the Russian Federation polygon «Cura». Parameters of entry (entry angle θ, entry velocity Va) are chosen in such a way that at movement in atmosphere and following falling to Earth there was realized influence on capsule with RW more serious than in emergency case in normal flight.

It will allow to get experimental data for optimization of mass of removed RW and mass of orbital stage of removal.

Besides, such demonstration of safety of capsule with RW can essentially increase project investment attractiveness.

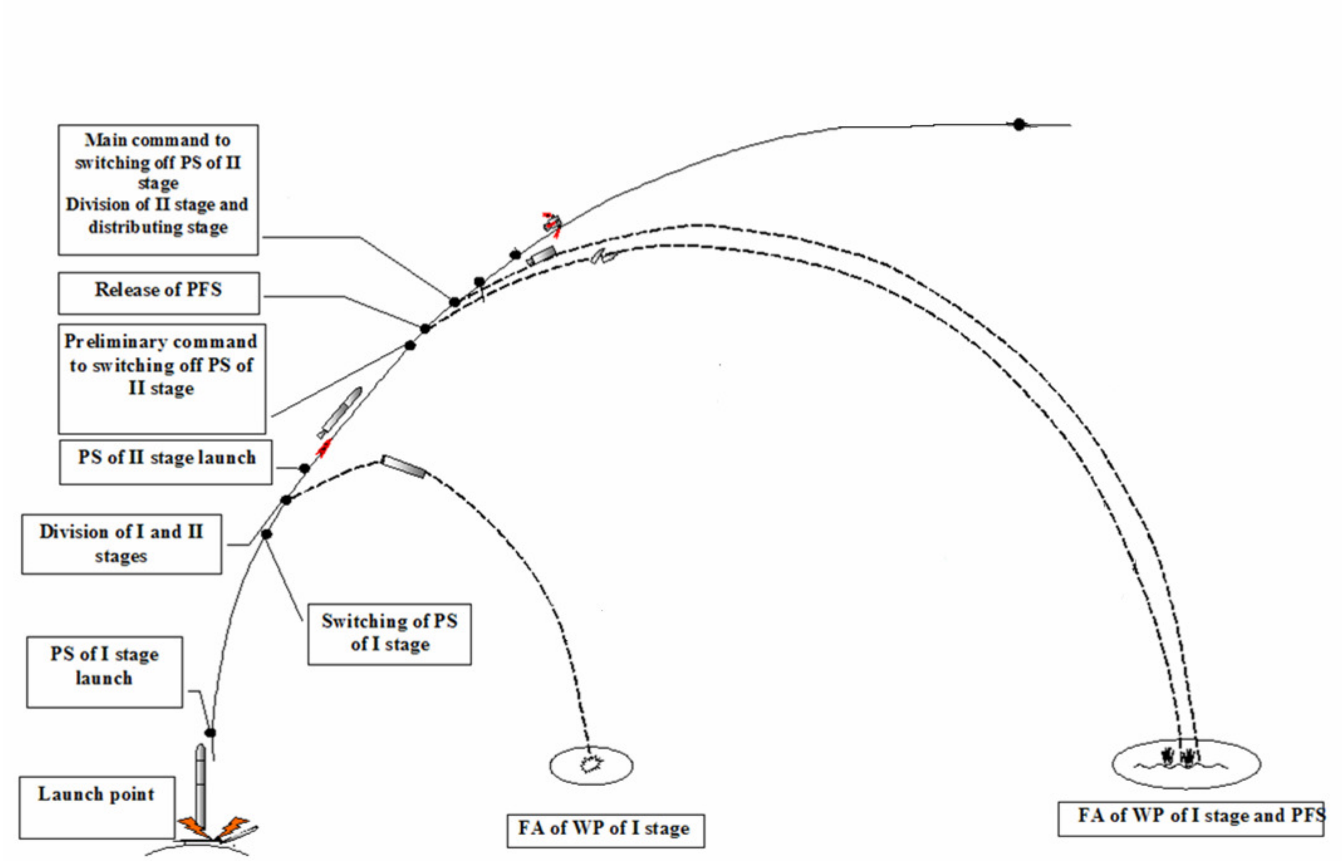
12.3 EXPERIMENT DEMONSTRATION

The development of the relevant LV system could follow two parallel activities:

1. Development of the waste removing orbital stage and demonstration of its reliability and safety with the potential use of the LVs based at Baikonur cosmodrome.

2. Creation and experimental-industrial exploitation of the LV for removal of highly radioactive waste on the basis of "Zenit-M" Space Rocket Complex at Baikonur cosmodrome.

In the next picture is presented the injection by the launch vehicle “Dnepr” of experimental module on the trajectory simulating failure with falling down to the Earth



12.4 SPACE PAYLOAD UNIT

Space payload unit (SPU) in modification for the SC launching (scheme which is given in the Figure…) consists from of:

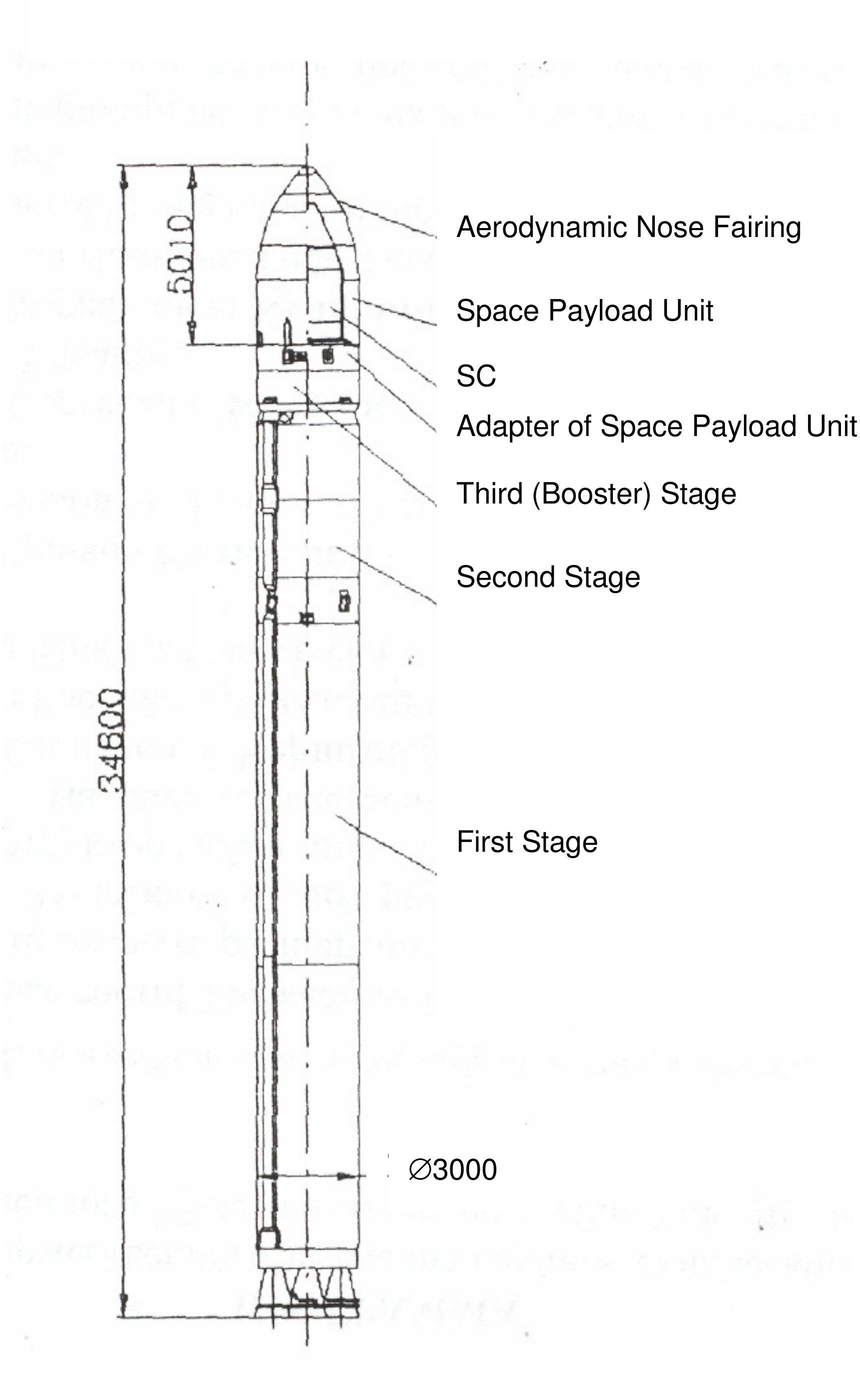
- Fairing, borrowed from the PC-20 missile composition;
- Body, consisted of the « Б » story (with up-dated), new cylindrical spacer and the “A” up-dated story;
- Adapter, of new structure, created for conditions of the SC configuration;
- SC.

Table 1.1 – Main Specifications of the Dnepr-1 Launch Vehicle

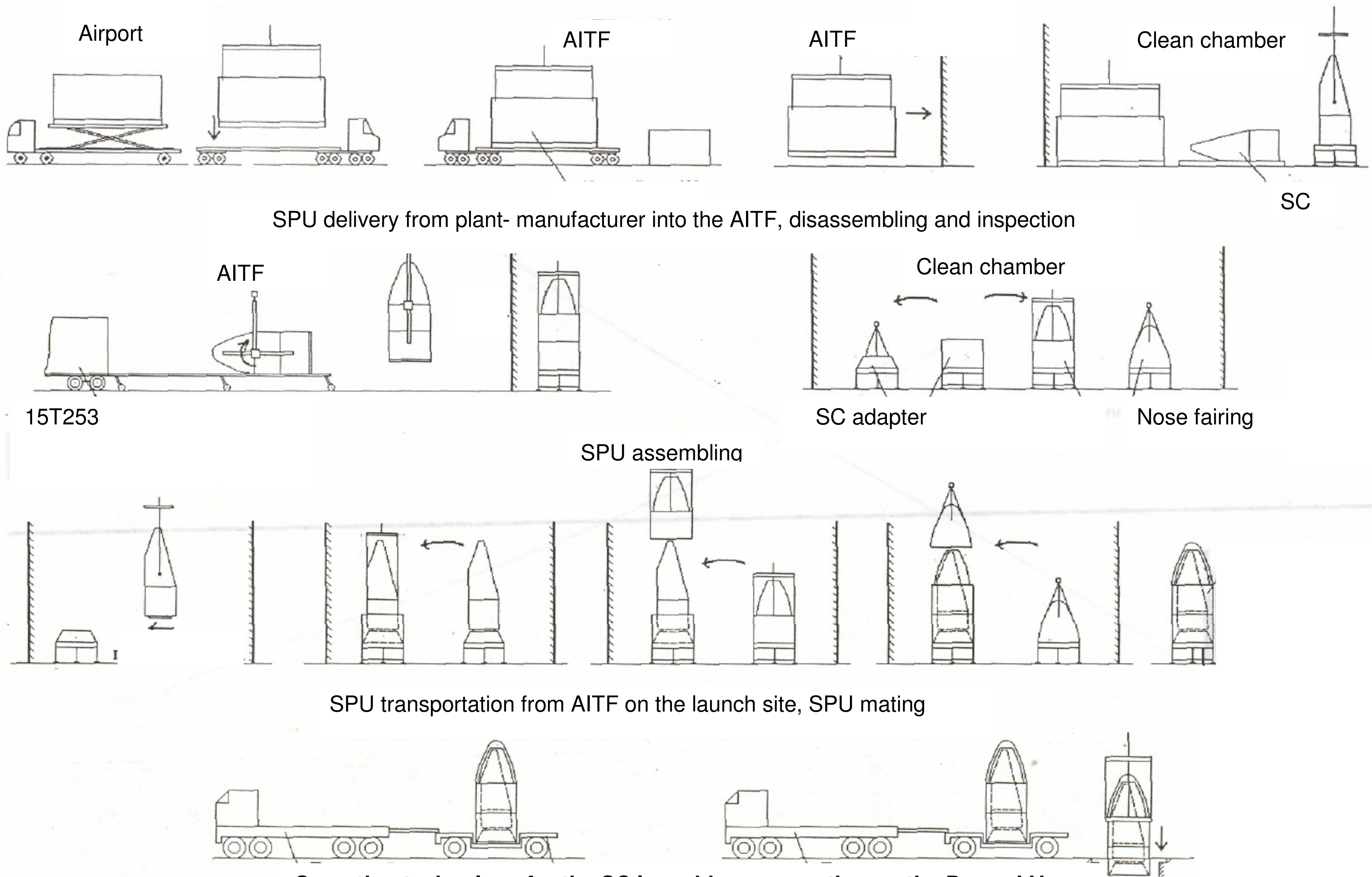
Specification Names	Values	
	Modification 1 of the SC installation	Modification 2 of the SC installation
1 SC mass, kgf		
2 LV launching mass, kgf		
of the first stage	208987	209292
of the second stage	47462	47767
of the third stage	6345	6650
3 Operational propellant reserve, kgf		
of the first stage	147908	
of the second stage	35743	
of the third stage	1910	

4	Engines vacuum thrust, kgf of the first stage of the second stage of the third stage	 461160 77540 2060/862
5	Propellant components on all of the LV stages; oxidizer fuel	 nitric tetroxide unsymmetric dymethilhydrazine
6	LV outline dimensions, mm length diameter	

General View of the Launch Vehicle with SC



Unloading in airport and delivery (in AITF – assembly, integration and test facility) of containers with SC and equipment

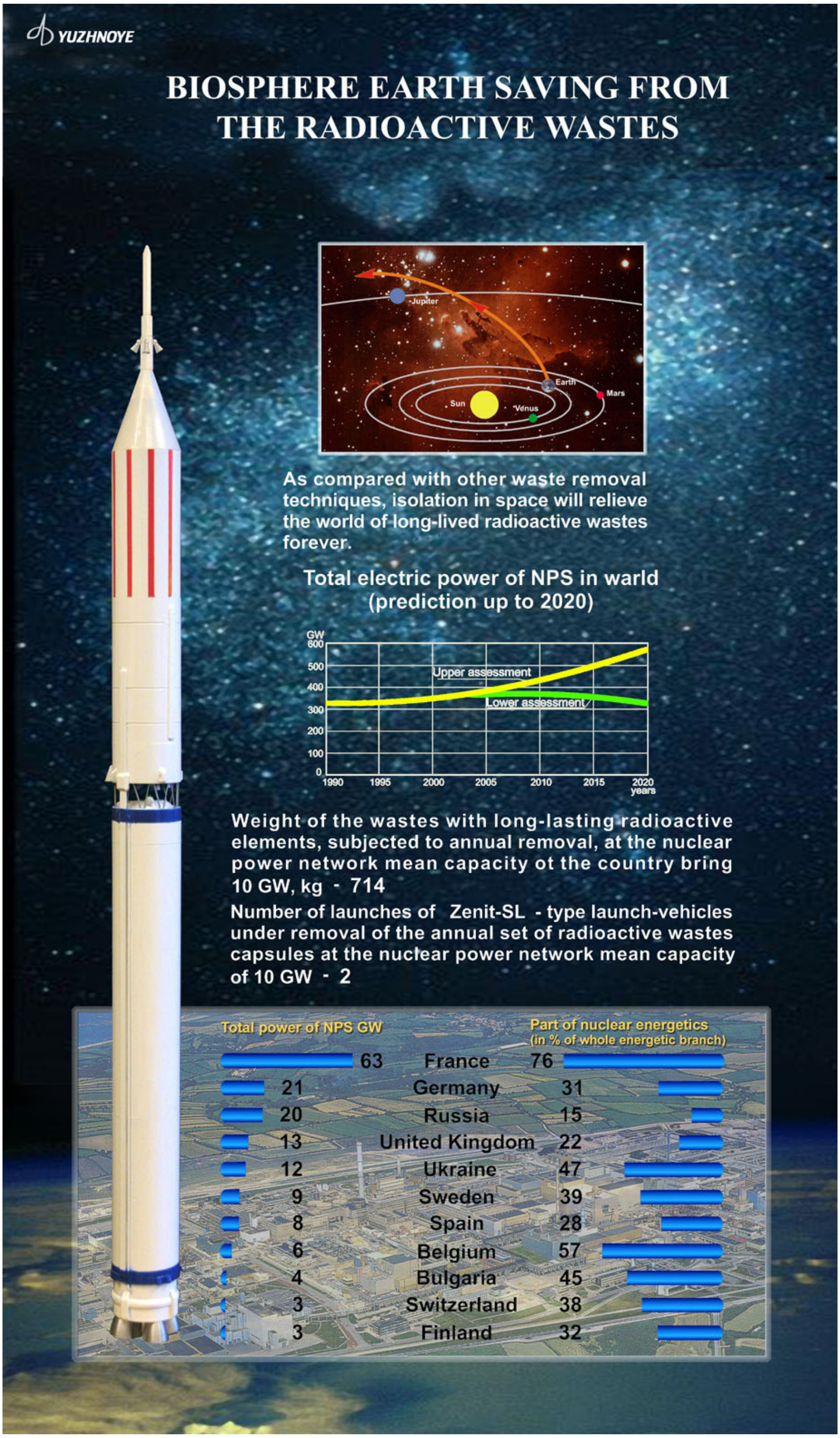


Operation technology for the SC launching preparation on the Dnepr-LV

12.5 CONCLUSIONS

1. The analysis of the ecological situation connected with the increasing amount of NPS wastes shows that the issue of isolation of radioactive wastes will be very urgent for the mankind in the nearest future.
2. At present there is a technical capability of creation of the space rocket complex on the basis of Zenit-2SLB ILV (Zenit-3SLB ILV) that can-be used for radioactive wastes removal into the deep space with a sufficient safety level for the environment.
3. Continuity of the power production process at APP leads to a necessity of constant removal of high-active and toxic radioactive wastes in the industrial technology; it will provide the increasing demand and profitability of the space rocket complex proposed.

13. WP 6000 – PERSPECTIVES AND FINAL REPORT



13.1 PROBLEM ACUTENESS

The analysis of the ecological situation on the Earth related to the increasing volume of waste from nuclear power plants (NPP), shows that the question of processing and the safe management of spent nuclear fuel and radioactive waste (RW) will get more and more serious for mankind in the near future.

The traditional approach to solve the problem of RW storage lies in the burial in stable geological formations However, this storage has two major limitations: *first*, the approach proved to be very costly (e.g., 3 billion dollars were spent only for research works on building of national storage in Nevada State); *second*, even gigantic investments do not guarantee success in geological burial because scientists-geologists show that the Earth's inner core is slowly moving with regard to its surface layers; in such a case it can be doubtful that the soil in any place of the Earth could be stable beyond period of time estimated at hundreds years.

The progress reached in the leading countries of nuclear industry during the last years in the field of processing of low-active and middle-active parts of RW allows to reduce, to some extent, the acuteness of the problem. However, in opinion of experts this minimizes volume of non-storable waste but does not solve the problem as a whole. Whatsoever the way the used nuclear fuel is processed, small volume of extremely long half life high radio-activity elements remains, and it presents a great threat to the Earth biosphere.

The prospective new mission for rocket-space technologies is disposal of the most dangerous man-caused waste out of the Earth's biosphere. This is variant of cardinal way of forever release of the Earth from dangerous man-caused waste.

There are three approaches to solving of the problem of treatment with used nuclear fuel (UNF):

- treatment at radiochemical plants with the purpose of extraction of useful components (including for working nuclear fuel) and decrease of activeness of isolated radioactive waste;
- direct burial without treatment;
- long-lasting burial at which choosing of way of UNF treatment is postponed to longer term.

At the present time France, Great Britain and Russia take as a basis the way of UNF treatment at radiochemical plants.

These countries treat their own UNF and UNF of other countries. After treatment working nuclear fuel is returned to the first country. There is subject to returning waste after treatment of USF which are to be isolated from the environment that is very serious problem.

13.2 THE PROPOSED APPROACH

The "long-life high activity" (with half-life period of hundreds of thousands of years) waste (LRW) might be stored in space with the help of Launch Vehicle (LV) systems. This will allow to forever free the Earth's biosphere from the most harmful part of RW. While waste with rather small half-life period will still be subject to vitrification and packing in special containers for geological burial, accumulation of LRW will stop in future geological repositories.

The problem of RW removal into space by means of LV systems requires joint efforts of experts from nuclear industry and the ones in the field of space industry. The first should ensure that LRW after processing at radiochemical plants is separated from waste with small half-life period. Then, the LRW should be placed in capsules to be transported and inserted in containers for LV removal. Once LRW is packed into containers for LV removal, the following sequence of operations could be implemented:

1. The LV inserts special waste removing orbital stage (with LRW) into reference circular orbit around the Earth.

2. An orbital upper stage system provides injection to Earth escape trajectories.

13.3 ANALYSIS OF THE CURRENT SITUATION

According to estimations, the investigated volume and mass of highly active radioactive waste (HRW) which is subject to removal in space do not exceed 2.5 percent of volume and mass of used nuclear fuel processed at radiochemical plants (data from Russian sources).

In this case for disposal of HRW there are needed relatively small of launches of launch vehicles and solving of problem of protection of personnel at treatment with containers of rocket removal.

In the table, the number of "Zenit" type LV launches necessary to remove HRW corresponding to an annual work cycle of NPPs in function of their capacity is shown.

For variant of removal of 2.5 % of UNF.

Country	NPP Capacity, GW	Number of launches by “Zenit” LV (Land Launch option)	Number of launches by “Zenit” LV (Sea Launch option)
France	63	30	27
Germany	21	9	8
Russia	20	9	8
Great Britain	13	6	6
Ukraine	12	5,2	5
Bulgaria	4	1,8	1,6
Czech Republic	3	1,5	1,3
Slovakia	2	1,0	1,0

Total per year		64	58

To the present moment it does not seem to be rational.

13.4 PROPOSED SOLUTION

That is why it is proposed to separate HRW into two parts during the process of treatment at radiochemical plants:

- “long-life”;
- rather small half-life period (SHLP).

At this it is supposed that volume and mass of LRW do not exceed one per cent of volume and mass of used nuclear fuel processed at radiochemical plants.

Remaining 2 % of SHLP is subject to vitrification and packing in special containers for geological burial.

In this case there is solved the problem of protection of maintenance personnel at working with LRW both at transportation to place of putting into containers of rocket removal (CRR) and at works with launch vehicle.

The "long-life high activity" (with half-life period of hundreds of thousands of years) waste (LRW) might be stored in space. This will allow to forever free the Earth's biosphere from the most harmful part of highly radioactive waste.

While waste with rather small half-life period (SHLP) will still be subject to vitrification and packing in special containers for geological burial, accumulation of LRW will stop in future geological repositories.

The problem of RW removal into space by means of LV systems requires joint efforts of experts from nuclear industry and the ones in the field of space industry:

- LRW after processing at radiochemical plants is separated from waste with small half-life period.
- Then, the LRW should be placed in capsules to be transported and inserted in containers for LV removal (containers of rocket removal).

Taking into account the specificity of the problem of RW removal into space, a choice of launch bases and launch vehicles has been considered encompassing the following technical and economic characteristics:
- presence of ground infrastructure;
- degree of automation of works on preparation of LV and payload;
- reliability and high enough thrust characteristics of LV.

The outcomes of the study feature that there are various available LVs types that can be used to solve the problem of removal of LWR in space, e.g. the "Zenit" family is mostly corresponding to these criteria. Considering the experience of their exploitation at the Baikonur cosmodrome, the use of the two-stage or three-stage "Zenit" variants for RW removal from our planet will be the best appropriate option. The baseline for this study will be the modified "Zenit-2" LV of Land Launch and "Zenit-3SL" LV of Sea Launch.

The table below features the preliminary forecast of RW volume which modified LV of "Zenit" family can lift-off in space.

	Zenit-2SLB	Zenit-3SLB
LV lift-off mass, t	462	468
Mass of the waste removing orbital stage in the reference orbit H≈200 km, t	14	
Mass of the waste composition to be removed containing highly active radioactive waste, t *	0,9	1,2

* Preliminary analysis shows an opportunity to increase waste removal by 20-30 %

In the next table, the number of "Zenit" type LV launches necessary to remove LRW corresponding to an annual work cycle of NPPs in function of their capacity is shown.

Country	NPP Capacity, GW	Number of launches by “Zenit” LV (Land Launch option)	Number of launches by “Zenit” LV (Sea Launch option)
France	63	10	9
Germany	21	(3,15)	3
Russia	20	3	(2,9)
Great Britain	13	2	2
Ukraine	12	(1,8)	(1,6)
Bulgaria	4	(0,6)	(0,6)
Czech Republic	3	(0,5)	(0,5)
Slovakia	2	(0,3)	(0,3)
Total per year		21 (21,35)	20

Once in orbit, the following options have been identified for the LRW stage:

- Removal of waste out of the Sun system;
- Disposal of waste on a stable orbit around the Sun
- Destroying (total destruction) of waste at the expense of its delivery to the Sun;
- Burial of waste in asteroids, orbits of which never pass near the Earth.

The development of the relevant LV system could follow two parallel activities:
1. Development of the waste removing orbital stage and demonstration of its reliability and safety with the potential use of the LVs based at Baikonur cosmodrome.
2. Creation and experimental-industrial exploitation of the LV for removal of highly radioactive waste on the basis of “Zenit-M” Space Rocket Complex at Baikonur cosmodrome.

13.5 ECONOMICAL ASPECTS

- The results of the project may serve a basis for launching a global program to remove the long-living radioactive waste from the Earth;
- The cost of such a global program’s implementation is estimated to be about 1 billion US dollars;
- The expected profit is over 2 billion US dollars.

Three main directions of the project’s future developments should be taken into consideration.

Conceptually, one should convincingly show to the target audience that in case of realization of the LRW removal in space, the controversial issue of closing of radiochemical plants will cease to be so acute as the accumulation of LRW in the Earth biosphere will stop. As a result, growth of nuclear energy-generating industry will be provided in accordance with regulations to preserve the environment. Processing of waste of nuclear industry will progress, as well as the LV market. Removal of already buried LRW in the Earth’s storehouses might also be implemented.

Technically, to prove the feasibility of the proposed approach, a capsule which will provide perfect safety of waste removal into the space should be designed, produced and demonstrated. Taking into consideration the long experience of Yuzhnoye SDO in creation of rocket-space technologies, this problem will be successfully solved in the course of the further project development.

From the organizational perspective, it is absolutely expedient to get all the major stakeholders involved as early as possible. They include not only the experts from nuclear and space industries, but also environmentalists, legislators, state and regional public authorities, lawyers (in particular, specialists in the Space Law), insurance companies etc.

13.6 CONCLUSIONS

The analysis of the ecological situation connected with the increasing amount of NPS wastes shows that the issue of isolation of radioactive wastes will be very urgent for the mankind in the nearest future.

At present there is a technical capability of creation of the space rocket complex on the basis of Zenit-2SLB ILV (Zenit-3SLB ILV) that can-be used for radioactive wastes removal into the deep space with a sufficient safety level for the environment.

Continuity of the power production process at APP leads to a necessity of constant removal of high-active and toxic radioactive wastes in the industrial technology; it will provide the increasing demand and profitability of the space rocket complex proposed.