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FOREIGN SPENT FUEL STORAGE AND GEOLOGIC DISPOSAL IN RUSSIA: A TECHNICAL PATH FORWARD

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ABSTRACT

The option of storage and eventual geologic disposal in Russia of spent fuel of U. S. origin used in Taiwan provides a unique opportunity that can benefit many parties. Taiwan has a near term need for a spent fuel storage and geologic disposal solution, available financial resources, but limited prospect for a timely domestic solution. Russia has significant spent fuel storage and transportation management experience, candidate storage and repository sites, but limited financial resources available for their development. The U. S. has interest in Taiwan energy security, national security and nonproliferation interests in Russian spent fuel storage and disposal and interest in the U. S. origin fuel. While it is understood that such a project includes complex policy and international political issues as well as technical issues, the goal of this paper is to begin the discussion by presenting a technical path forward to establish the feasibility of this concept for Russia.

INTRODUCTION

A 'Technical and Management Support' program is needed in Russia that would facilitate the transfer of spent fuel from commercial power plants in Taiwan to a storage and geologic repository site near Krasnoyarsk, Russia. This program should define and resolve issues of disposition of Taiwan spent fuel (including US origin fuel) and its implementation would provide revenue for Russia to develop both an integrated spent fuel storage and radioactive waste management system including a geologic repository for foreign, as well as Russian's own radioactive materials. This framework has been developed as a proposed evolution of ongoing LLNL contracts and collaborations with the principal Russian parties. It is suggested that the U.S. fund such a program for the first phase only and Taiwan fund succeeding portions. A three-phase approach over 20 years is proposed: namely, an initial two-year feasibility investigation funded by the U.S., followed by an engineering development phase funded by Taiwan, and then implementation of a dry spent fuel storage site and a geologic repository.

STATEMENT OF OBJECTIVE AND U. S. INTEREST

The objective of the proposed Russian program funded by the U.S. is to facilitate, organize, integrate, lead and manage the technical program required for the timely implementation of an integrated spent fuel storage, transportation and geologic disposal system in Russia capable of receiving, storing and disposing of Taiwan spent fuel with initial shipments by 2007 and a geologic disposal capacity of at least 6,000MT by the year 2020.

The US has several vested interests in this program, including:

1. Development of Russian spent fuel storage and radioactive waste geologic disposal capabilities
2. Funding beneficial activities utilizing Russian nuclear production complex staff and resources
3. Demonstration of international repository technology leadership
4. Final disposition of spent US origin fuel
5. Future energy security for Taiwan

APPROACH

The general approach relies on Russian and Taiwan internal capabilities to the maximum extent possible for activities in Russia and Taiwan, respectively, and on commercially available services wherever available. Existing Russian technologies would be used to the maximum extent possible for transporting, receiving and storing spent fuel within Russia. A formal Russian geologic repository program would be initially focused on the geologic disposal of BWR and PWR spent fuel from Taiwan but would not preclude addition of Russian spent RBMK fuel and vitrified HLW. The primary funding after the Phase-I feasibility studies for the program could be from foreign resources set aside for spent fuel disposition in Taiwan.

This approach utilizes the maximum amount of existing Russian technologies and resources, and will further support the redirection of former weapons complex engineers and scientists in a series of non-defense projects with both a long-term schedule and foreign income. The development of an integrated spent fuel transportation, storage and geologic disposal system in Russia for the spent fuel from Taiwan would provide the foundation for future management and disposition of Russian radioactive materials generated during the Cold War by making incremental additions to this same system. Russian sources of high-level radioactive materials such as RBMK spent fuel; Russian vitrified HLW from Mayak; and other sources, including future spent MOX fuel can be similarly transported, stored and geologically disposed in a geologic repository designed for Taiwan spent fuel. This has major nonproliferation and environmental benefits to Russia, the US and the world. Figure 1 shows a schematic of the major program elements and responsibilities.

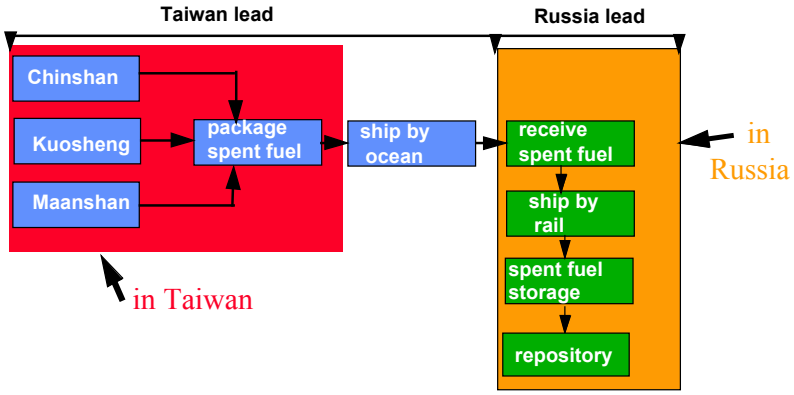

Figure 1. Program elements and lead responsibilities

A program would be conducted in three phases, with tri-party decision points on whether to proceed further at the end of each of the first two phases. The first phase is a two-year preliminary feasibility investigation to validate the potential, identify problems and provide all necessary information to the US, Russia and Taiwan for a decision on whether to initiate the second phase. The second phase includes design and development of the storage and transportation systems needed for receipt of spent fuel and conduct of geologic repository site selection and initial repository design concept studies. Implementation and actual operations would be the third phase, concurrent with completion and start-up of the geologic repository. The goal is for initial shipments for interim storage to begin by 2007, with repository operation following within about 10 years.

It is understood that such a project includes complex policy and international political questions as well as technical issues. The goal of this paper is to begin the discussion by presenting a technical path forward in the hope that presentation of a technical framework might prompt others to consider the policy and political considerations and support the start of the initial phase activities. Further institutional and background issues are discussed by Jardine, Smith and Halsey (1).

TAIWAN SPENT FUEL

Taiwan rapidly exhausting its capacity to store spent fuel at existing reactor sites. Taiwan will have to begin to curtail nuclear generation of electricity in 2007 if no disposition is found for their spent fuel. Very significant financial resources accumulated in their nuclear waste fund will allow Taiwan to finance an international disposition effort.

Table I provides a summary of the current and projected power reactors in Taiwan. The total reactor operating experience in Taiwan is approximately 100 reactor years as of early 1999. The fraction of electric power from nuclear reactors is approximately 25-30%. Figure 2 shows a map of Taiwan with the current reactor sites. Table II provides some estimates of spent fuel inventories by reactor type.

Table I: Current and Projected Power Reactors in Taiwan

Reactor	Type	Net MWe	Operational Date
Currently Operating			
Chinshan 1	GE BWR-4	604	12/78
Chinshan 2	GE BWR-4	604	7/79
Kuosheng 1	GE BWR-6	948	12/81
Kuosheng 2	GE BWR-6	948	3/83
Maanshan 1	W PWR	890	7/84
Maanshan 2	W PWR	890	5/85
Under Construction			
Lungmen 1	GE ABWR	1300	Est. 2004
Lungmen 2	GE ABWR	1300	Est. 2005

Figure 2: Map of Taiwan showing position in the East China Sea and locations of existing reactor sites

Table II: Estimated current spent fuel inventories in Taiwan

	Reactor years	SF (t)	SF (assemblies)
BWR-4	40	800	3500
BWR-6	31	700	3000
PWR	29	600	1100
Total	100	2100	7600

The spent fuel generation rate in Taiwan can be estimated to be approximately 120-150 t/year. This generation rate will increase to about 175-200 t/year when the new ABWRs come on line. The total spent fuel from 8 plants running to end of license is estimated in the range of 7500 t.

Currently, Taiwan spent fuel is stored in pool storage at each reactor, with little flexibility to transfer spent fuel from one site to another. The Maanshan PWRs have expanded and re-racked their pools to accommodate 2160 assemblies each, which gives them capacity to store fuel from their entire 40 years of operation.

ELEMENTS OF THE PROPOSED PROGRAM

Spent Fuel Storage

Russia has reasonably well-developed technologies for spent fuel storage, namely wet spent fuel storage at both Mayak and Krasnoyarsk for many non-defense related spent fuel types. Dry spent fuel storage technologies have been recently developed and continue to evolve for nuclear navy spent fuels and for RBMK spent fuels. These technologies are now being deployed in Russia, but at a low rate. Thus, minimal technical assistance is needed on spent fuel storage technology. The engineering, siting and licensing of spent fuel storage are basically ready for implementation in Russia.

Krasnoyarsk-26 (K-26) was selected by Minatom in 1999 for detailed study as a future dry spent fuel storage facility site. Facility start-up is planned for 2006 assuming adequate funding. The investment justification phase has already been completed (Phase-III of the Russian development cycle[a]). The next phase of generating working designs, drawings, making site preparations, initiating construction and fabricating equipment is now ready to be started once funding is available. The lead Russian design institute and lead scientific institute for dry spent fuel storage have been selected by Minatom. Further development of this storage capacity could be undertaken as an extension of current collaboration on plutonium disposition between LLNL, these institutes and the K-26 site operating company in current contracts, using DOE funds, including assessments of MOX spent fuel and transportation in Russia.

Transportation

There are several technical issues requiring assessments related to transportation of spent fuel from a Russian seaport by railroad to Krasnoyarsk**.** These include identifying an approved rail transportation cask for Russian railroads and determining its compatibility both as an ocean ship transport cask and as a Krasnoyarsk spent fuel dry storage cask. The compatibilities and interfaces must be assessed early and managed carefully so as to minimize secondary cask transfers and unloading operations at either the Russian sea port before rail transport in Russia or after receipt at Krasnoyarsk for extended dry storage prior to geologic disposal. This is a critical area to be assessed early, together with the selection of the proper Russian seaport, identification of seaport docking modifications and the specific Russian rail route. The existing rail routes and two possible seaports (Vladivostok and Vanino) in Russia accessible from Taiwan are shown in Figure 3. These need a systematic technical and economic feasibility assessment.

Figure 3. General map of Russia showing southeastern seaports (e.g., Vanino and Vladivostok), existing rail routes and Krasnoyarsk in Central Russia.

The issues related to loading the Taiwan spent fuel into casks and transporting these casks outside of Russia in international waterways are best managed and handled by Taiwan. Commercial ocean transport services are available (e.g., PNTL, BNFL, COGEMA) for loading and international ocean shipping of spent fuel. Such shipping is routinely carried out between European ports and between Japan and Europe and could be used for Taiwan spent fuel. The Russian interface specifications for the transportation casks, including Taiwan spent fuel technical details, casks will be the major interfaces to be coordinated between Russia and Taiwan to ensure success. Further discussion of ocean transport, port facility interface and institutional issues for shipping are discussed by Jardine, Smith and Halsey (1).

Geologic Repository

Due to lack of funding in Russia, there is no significant active geologic disposal program in Russia, although expert staff and preliminary plans are available for such work at two Russian sites. An active Russian program existed in the 1980's and work was done to select specific sites near both the industrial sites of Mayak and Krasnoyarsk-26. A single integrated Russian repository for all the Cold War high-level wastes was even assessed and a site located in the early 1980's, but was then put on indefinite hold. Plans and proposals now exist to develop the two geologic repository sites, and with funding, completion of the specific site selections, site characterizations, underground laboratories, and design at both the Mayak and Krasnoyarsk sites can be restarted and implemented rapidly. Initial repository studies could evolve from current collaboration between LLNL, a Russian design organization and with the two lead scientific institutes for these two sites regarding geologic disposal for the joint US-Russian plutonium disposition program. A preconceptual design for a repository in a granite massif near Krasnoyarsk-26 is being developed in one contract. The Mayak site preconceptual repository design is under development in another new contract.

A Russian geologic repository program will have to assess the issues of selecting one or two geologic repositories at Mayak and Krasnoyarsk (a third proposed site at Novaya Zemlya is not currently considered for spent fuel disposal). Technical issues for potential collaboration within this proposed framework include site selection criteria and methodologies, site characterizations, reliance on the natural and engineered barriers, allowing import of foreign, or Russian radioactive waste from other regions of Russia, all requiring resolution and technical assessments.

ROLES AND RESPONSIBILITIES

Development of a tri-party (Taiwan, U.S., Russia) program must recognize the interests and responsibilities of each involved party.

United States

The U.S. interest in energy security for Taiwan, final disposition of spent U.S.-origin fuel and the special relationship between U.S. and Taiwan allows the U.S. to serve the role of facilitator and technical monitor for this program. As a minimum, the U.S. would have to enter into agreements with Taiwan and Russia that provide for successful implementation of the program. This will involve many complex issues and interested government agencies as well as non-governmental organizations. Due to the unique aspects of the relationship between Taiwan and the U.S., the coordination of technical activities in this program requires careful management.[b]

LLNL's proposed role is to assist, integrate and coordinate the Russian and Taiwan activities to develop the spent fuel storage, transportation and geologic disposal systems. Activities could include integrating and coordinating necessary project elements among Russian scientific, design and construction institutes and organizations, coordinating with similar organizations in Taiwan, identifying project management, institutional and technical needs required for implementation,

facilitating and obtaining U.S. or other technical assistance when needed and requested by organizations in Russia and Taiwan. Technical assistance to Russia or Taiwan would be provided by the best organization for the specific need, as identified jointly by organizations in Russia, Taiwan and U.S. Assistance could include nuclear industry vendors for: casks: BWR and PWR spent fuels; nuclear utilities for current dry spent fuel storage operations; and other U.S. national laboratories for transportation, dry storage and spent fuel geologic repository technical issues. Assistance from U.S. regulatory and environmental agencies in the form of lessons learned and licensing, or permitting, are other possible examples. As the lead laboratory for a proposed DOE nuclear materials safety program, LLNL would monitor that international and Russian nuclear safety, MPC&A and transparency standards are achieved in all program elements.

Taiwan

The need for Taiwan to dispose of spent fuel provides the primary motivation for implementation, and the resources set aside in a trust fund for that purpose financially enable the program. Representatives from Taiwan would have to enter into agreements to fund the implementation of this program. Taiwan would need assurance that they would achieve an acceptable final disposition of the spent fuel for their investment. Taiwan would be responsible for contracting shipping and handling of the fuel from the reactor sites, onto suitable ocean transport ships, and delivery to the selected Russian port. Taiwan has in operation the systems and permitting processes for shipment of LLW by ocean ship to a storage site. That experience can be extended to shipments of the spent fuel through international waters, drawing on the commercial experience of the British and French (including the use of existing ships).

Russian Federation

Russia's potential interest to accept foreign development funds and to assess the hosting of an integrated system for the handling, transporting, storage and eventual geologic disposal of radioactive waste and spent fuel provides the opportunity for this program to go forward. The Russian government would have to change some existing laws and enter into agreements with the U.S. government to assure implementation of acceptable final disposal of the Taiwan spent fuel in a geologic repository without reprocessing. The U.S. would enter into agreements with Taiwan (probably through the AIT/TECRO mechanism) to assure implementation of receipt, transportation, storage and geologic disposal. Appropriate Russian institutes and organizations would be responsible for planning, implementing, permitting, constructing and operating the integrated spent fuel and radioactive waste management (storage, transportation and geologic disposal) system. The U.S. role should be to facilitate and monitor these activities and supply technical assistance when needed and requested.

One legal issue is Russian law (Article 50 of the Russian Federation Law about Environmental Protection) which prohibits import of spent fuel for the purpose of disposal. Several proposed amendments to this law have been discussed by various interested parties, and at least one has been introduced to the Russian Duma. At the time of this writing, no action has been taken on this amendment.

PATH FORWARD

Phase-I Preliminary Feasibility Investigation

Prior to commitments to large-scale development of this program, preliminary scoping and feasibility studies should be conducted including interactions with all interested parties. Initial funding for the first two years is proposed to be from U.S. DOE, with the potential for further support from Taiwan. The goal of this two-year preliminary feasibility investigation period would be to further define the issues, opportunities and activities needed to implement this program. Program activities and schedules, the state of development of process descriptions and facility concepts would be documented. National and international concerns, interests and institutional requirements requiring resolution would be explored and documented. This would provide in an integrated plan the information needed for tri-party policy- and decision-makers to decide whether to pursue further development.

Phase-I would include both formal and informal interactions with Taiwan and Russian representatives. Formal negotiations regarding potential terms for implementation would involve Russia, Taiwan (AIT), DOE and other U.S. agencies. Technical topics and contracts would be addressed by lab-to-institute methods. The U.S. technical participant would be responsible for coordinating and delivering the final integrated plan developed by Russian participants. Participation in preliminary investigations by Russian organizations would be funded initially by the U.S. DOE through lab-to-institute contracts. Taiwan participation would be funded by Taiwan sources. Taiwan funding of U.S. and Russian activities (via the U.S.) would be developed when appropriate.

To achieve the goal of providing initial storage capacity for Taiwan by 2007, an opportunity for an early decision is provided by end of FY-02. By beginning this preliminary investigations in FY-00, a decision to proceed to Phase-II could be made in FY-01. If required, a mid-phase evaluation of preliminary feasibility potential could be scheduled for late FY-01.

Phase-I Activity Descriptions

Six specific Phase-I activities have been identified.

Russian Spent Fuel Handling and Storage Facility Concept: Technical evaluation of the requirements and design concepts for receiving and storing Taiwan spent fuel for up to 40 years at Krasnoyarsk with dry storage technologies. Maximize use of existing Russian expertise, staff and facilities. Issue Russian contracts for technical studies and planning. Prepare schedule and budget estimate for development program.

Feasibility Study of Russian Rail Transport: Assess options for transport of spent fuel shipping casks from a Russian port to Krasnoyarsk. This includes interface with the ocean transport system, rail transport and handling. Issue Russian contracts for technical studies and planning. Provide schedule and budget estimates for development, including rail cash needs.

Technical Survey of Krasnoyarsk Repository Site: Prepare a preliminary evaluation of the technical approach to development of a Russian geologic repository. Contract with Russian organizations responsible for geologic repositories to obtain technical studies, schedules and plans. Assemble the existing Russian documentation on the potential repository sites. Outline a site characterization program, a conceptual design and an institutional plan. This information will provide the basis for a realistic schedule and budget for Russian repository development.

Feasibility Study of Taiwan Shipping, Handling and Ocean Transport: Work with organizations in Taiwan to assess technical and institutional requirements for loading spent fuel into transport casks and transfer to ocean transport system. Consider commercially available services. Prepare schedule and cost estimates for development.

Review of National and International Regulations and Requirements: Review laws, regulations, requirements, policies and other institutional issues to understand the implications for going forward with this tri-national program. U.S., Taiwan, Russian and International issues must be considered. Contract for Russian regulatory studies. Prepare a roadmap for regulatory path forward.

Development of Phase-II Program Plan, Schedule and Documentation: Prepare Phase-II plan documentation. Manage the activities including schedule, budget and plans. Provide regular status reports and final documentation from Phase-I.

Phase-II Engineering Development

Engineering development in Phase-II would proceed if a favorable decision based on the information developed in Phase-I was made to proceed. Phase-II could begin in late FY-02 and would last approximately 5 years. Funding would be primarily from Taiwan resources. The detailed activities for Phase-II will be developed during Phase-I. The goals include design and construction of spent fuel handling and storage facilities, site characterization and preliminary design of a geologic repository and documenting the interfaces needed to provide confidence that the program will be successful in disposition of Taiwan spent fuel. Activities would include regulatory development in Taiwan and Russia; demonstration of shipping and handling capability in Taiwan; development, permitting and fabrication of rail cask transport system in Russia, including port facilities; and design, siting, permitting and construction of handling and storage facilities at the site selected in Russia. To meet the working goal for initial shipments by 2007, the transportation and storage capabilities must be sufficiently developed to provide confidence that shipments could commence in a timely manner following a decision to proceed with implementation. To provide confidence that final geologic disposition will be achieved, the repository program in Russia should achieve a site recommendation decision that documents expectation that a viable repository can be developed and operated in Phase-III. It is estimated that Phase-II costs, including construction, would be in the hundreds of million dollars.

Phase-III Implementation

Implementation of shipping, storage and disposal would follow favorable decisions at the end of Phase-II. The activities cost and schedule for Phase-III implementation will be preliminary in Phase-I and fully developed in Phase-II. The goal for initial receipt of Taiwan spent fuel for interim storage is 2007. Further storage capacity will be needed until operation of the geologic repository begins. The schedule for repository operation cannot be accurately known until appropriate regulations are developed and site investigations have been carried out. A preliminary goal is to have the geologic repository operational prior to 2020, but this schedule will be determined in Phase-II. It is estimated that full implementation costs would be in the billion-dollar range, probably dominated by the fee charged by Russia (cost/ton) for storage and final disposal of the Taiwan spent fuel.

SUMMARY AND CONCLUSIONS

This proposed two-year Russian Phase-1 feasibility program represents a unique opportunity to define and develop, under the control of the U.S.DOE, the concept of Russian disposition of foreign spent fuel and development of an integrated spent fuel and radioactive waste management system in Russia, including a geologic repository. This program would resolve the Taiwan spent fuel disposition issue and utilize Taiwan funds to achieve this and other goals. Russia would develop the facilities and capabilities for geologic disposal of their own spent fuel and radioactive materials from the Cold War, while providing jobs and new direction for former Russian nuclear weapons scientists and engineers.

By initiating the early start of the preliminary studies discussed above, the information basis would be developed to allow U.S., Taiwan and Russian policy makers to make a future decision on implementation in a timely manner.

FOOTNOTES

a) Note: there is a formal Russian governmental nuclear project engineering and construction development process and an approval process somewhat equivalent to the U.S. NEPA/ROD and licensing process that must be followed.

b) Shortly after the United States Government changed its diplomatic recognition from Taipei to Beijing on January 1, 1979, the American Institute in Taiwan (AIT) was established as a non-profit, private corporation. The Taiwan Relations Act (PL 96-8) of April 10, 1979, authorized the continuation of "commercial, cultural and other relations between the people of the United States and the people on Taiwan." It also provided that "any programs, transactions, or other relations conducted or carried out by the President or any Agency of the United States Government with respect to Taiwan shall, in the manner and to the extent directed by the President, be conducted and carried out by or through the American Institute in Taiwan." The Department of State, through a contract with the Institute, provides a large part of AIT's funding and guidance in its operations. Congress, in passing the Taiwan Relations Act, also assumed an oversight role with respect to the Institute's operations.

Since Taiwan has no diplomatic representation in the US, commercial and cultural relations with the people of the U.S. are maintained through a private instrumentality, the Taipei Economic and Cultural Representative Office (TECRO) with headquarters in Taipei and field offices in Washington and 12 other U.S. cities.

Through AIT and TECRO, the United States and Taiwan have 21 bilateral agreements on science and technology issues. These include scientific and scholarly cooperation, exchange of technical information, cooperation in nuclear regulation and research, as well as agreements covering disease control, environmental protection, atmospheric science, physical sciences and wildlife protection.

REFERENCES

1. L. J. Jardine, C. F. Smith, W. G. Halsey, "Vision and Framework for Technical and Management Support to Facilitate Foreign Spent fuel Storage and Geologic Disposal in Russia," UCRL-ID-134762, Lawrence Livermore National Laboratory (1999).