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HEU-LEU PROJECT: A SUCCESS STORY OF RUSSIAN-US NUCLEAR DISARMAMENT COOPERATION*

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In February 1993 Russia and the United States signed an intergovernmental agreement on the disposition of highly-enriched uranium (HEU) extracted from nuclear weapons.[1] Under the terms of the deal, Russia undertook to downblend 500 tonnes of HEU (enough to build 20,000 nuclear warheads) over a 20-year period. The two sides agreed that the resulting low-enriched uranium (LEU) would be used as fuel by nuclear power plants in the United States - hence the informal name of the program, Megatons to Megawatts.

In January 1994 Russia's JSC Techsnabexport (Tenex) and the United States Enrichment Corporation (USEC), the companies authorized by the two respective governments to implement the deal, signed the contract[2]. According to assessments made at the time, the value of the entire program was expected to reach about 12bn USD. The first 186 tonnes of LEU were shipped to the United States in 1995.

Background

The idea of downblending excess stockpiles of weapons HEU and using the resulting LEU as fuel for nuclear power plants was first proposed by Thomas Neff, a Senior Researcher at MIT's Center for International Studies, in an article headlined 'A Grand Uranium Bargain' in The New York Times on October 24, 1991.[3] The idea was received with great enthusiasm in view of the signing in July 1991 of the Soviet-U.S. START I Treaty[4], which mandated a reduction of the two countries' nuclear weapons stockpiles by approximately 5,000 warheads apiece.[5] Given the difficult economic situation in the Soviet Union at the time, Moscow expressed its interest in Neff's proposal, which had opened up the prospect of billions of U.S. dollars in hard currency earnings being generated as a by-product of implementing the START I Treaty. Some of that money could be used to support the Russian nuclear industry, which was suffering from a sharp reduction in government funding. It is also important to note the significant difference between the HEU-LEU Agreement and the 1992 Agreement on the Safe and Secure Transportation, Storage and Destruction of Weapons and the Prevention of Weapons Proliferation (which provided the legal framework for the so-called Nunn-Lugar Program).[6]

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Under the terms of the latter agreement, the United States was the donor, and Russia the recipient of American financial and technical assistance (including money provided to help Russia implement the reductions agreed in the START I Treaty)[7]. In contrast, the HEU-LEU Agreement was essentially a mutually advantageous commercial deal.

Coming back to Thomas Neff's concept, one has to note his proposal to downblend HEU at the Russian plants and not in the United States with the view of employing as many Russian facilities and people in the post-Soviet nuclear establishment as possible. Such an approach met with the full understanding of the Russian side because, among other considerations, HEU downblending on American territory was unacceptable to Russia for the simple reason that the isotopic composition of this material is classified.

To understand the reaction to such proposals, it is important to recall the situation at the time. This was immediately after the collapse of the gigantic Soviet empire; many Western experts believed that the huge Soviet nuclear arsenal was neither safe nor secure. In addition, a significant part of that arsenal was left on the territory of three newly independent republics – Belarus, Kazakhstan, and Ukraine. The economic and political situation in all three was even worse than in Russia.[8]

There were growing concerns in the Western political circles and in the media that some of the Soviet nuclear weapons could 'fall into the wrong hands' - meaning primarily some of the Middle Eastern states, which were in a state of bitter confrontation with the West. No wonder, then, that Neff's idea received bipartisan support in the U.S. Congress, and later in the U.S. National Academy of Sciences.

Leading Russian scientists, including Yuri Osipov, President of the Russian Academy of Sciences, also gave their backing. Academician Osipov discussed the proposal with the Russian minister of atomic energy, Victor Mikhaylov. After a series of meetings and informal exchanges between Russian and U.S. representatives, in early 1992 the two governments entered into formal negotiations. They also set up a working group, which included 10 Russian and 10 U.S. experts, to undertake comparative analysis of the two sides' proposals regarding the technology of downblending HEU.

The choice of technology

The technology proposed by the Americans was based on liquid-phase downblending, which involved a conversion of HEU and of the blendstock material into uranyl nitrate. The choice of the blendstock was one of the key elements of the whole process.

More specifically, it was necessary to reduce the concentration of the U-234 isotope. This is a light uranium isotope which accumulates during the enrichment process and, being a source of alpha radiation, creates problems during fuel fabrication.[9] The concentration of U-234 in depleted uranium (the waste fraction of the enrichment process) is much lower than in natural uranium. Diluting HEU directly with depleted uranium would achieve a sufficient reduction in the concentration of the U-234

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isotope to comply with the U.S. standards. The downside of that approach is that it wastes a lot of isotope separation work. In other words, the SWU (separation work unit) content of the resulting LEU would be a lot less than the sum of SWU spent on producing the HEU feed and the blendstock. Besides, using depleted uranium as blendstock would produce a much lower LEU yield compared to technologies which rely on adding natural or slightly enriched uranium. (To understand why, consider this: if you have a glass of boiling water, and want to prepare as much lukewarm water as possible through dilution, you should add water which is at room temperature rather than ice-cold). In other words, diluting HEU with depleted uranium rather than slightly enriched uranium would produce less LEU, and therefore generate less revenue for the Russian supplier.

That is why Russian experts proposed an alternative approach which relies on gas-phase dilution by mixing HEU hexafluoride with hexafluoride of slightly enriched uranium. The blendstock used in that technology is depleted uranium produced by uranium enrichment plants and later enriched to 1.5 per cent. Such a solution had three advantages. First, it reduced the U-234 content to a level deemed acceptable under U.S. standards. Second, it reduced the wastage of separation work. And third, it made it possible to achieve a compromise with the United States regarding the amount of LEU to be bought by USEC, with a good balance struck between the size of the U.S. market and the amount of spare separation capacity in the Russian uranium enrichment industry.

Most importantly, for the following 20 years the HEU-LEU Agreement kept the Russian enrichment plants busy producing the slightly enriched blendstock. Measured by SWU, that was roughly equivalent to the amount of work that would have been necessary if Russia were to supply the United States with the same quantity of LEU produced from natural uranium.

After discussing the two proposals, the working group of experts agreed that the Russian technology was preferable because it made more sense economically. Another interesting detail is that the HEU-LEU Agreement also allowed for the possibility of using the Russian technology to downblend America's own excess stocks of HEU.[10]

LEU production in Russia

The first 186-tonne batch of LEU, which required 1.1m SWU and 2,500 tonnes of natural uranium component to produce, was made in 1995 at the Urals Electrochemical Combine (Novouralsk, Sverdlovsk Region). It used about 6 tonnes of HEU downblended in a 1:30 proportion. In other words, Russia had used up 6 tonnes of HEU and 180 tonnes of slow enriched uranium as a blendstock; the Americans paid for 186 tonnes of the resulting LEU.

The aforementioned natural uranium component of LEU is an important part of the deal. Essentially, it represents the amount of natural uranium (with 0.7 per cent U-235 content) which would have been required to produce a given amount of LEU by regular enrichment rather than by downblending HEU. According to the terms of the

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deal, there were two separate lines in the contract for the price of the natural component and the price of SWU; these were based on the market prices at the time. But during the actual implementation of the agreement the two sides ran into trouble with that particular part of the deal - more on that later.

Another three Russian enrichment plants, which were run by the Ministry of Atomic Energy (now by the State Atomic Energy Corporation 'Rosatom'), joined the program at a later stage: the Siberian Chemical Combine (Seversk, Tomsk Region), the Electrochemical Plant (Zelenogorsk, Krasnoyarsk Territory), and the Angarsk Electrolysis Chemical Combine (Angarsk, Irkutsk Region). As a result, by 2000 Russia was downblending 30 tonnes of HEU every year, and producing 900 tonnes of LEU in the process, charging the United States for about 5.5m SWU and 12,000 tonnes of natural component. By the time the Agreement completed later this year, Russia will have downblended 500 tonnes of HEU, and produced a total of 15,200 tonnes of LEU, using up 200,000 tonnes of natural component and 92m SWU in the process.

The precise technology of downblending HEU at the Russian plants is as follows. At the first stage of the process, metallic uranium weapons components are milled into chips, which are then turned into oxide powder of highly enriched uranium in a high-temperature furnace. The next stage is conversion of the powder into uranium hexafluoride, which is then blended with slightly enriched uranium hexafluoride; the latter is produced by enriching depleted uranium to 1.5 per cent. The precise enrichment ratio of the resulting blend can be adjusted depending on the requirements of the U.S. customer. The final stage is pouring LEU hexafluoride into transportation containers, which are then brought to the St. Petersburg Sea Port and shipped to the East Coast of the United States. Upon delivery, the material is de-converted into uranium dioxide powder and the latter is used to manufacture fuel pellets and fuel assemblies for power reactors.

Under the terms of the HEU-LEU Agreement, the United States has the right to monitor the HEU downblending process. In practice that translates into quantitative monitoring of the flow of uranium hexafluoride in three technological pipes; the Americans also record the U-235 enrichment ratio in each of these pipes. At the early stages, the monitoring was conducted by American inspectors who visited the Russian facilities involved in the program. Later on, however, the American partners developed and installed a remote monitoring system at the downblending facilities, thus eliminating the need for regular visits.

The Russian Federation has the right to monitor the use of supplied nuclear material in the United States to make sure it is not being diverted to weapons purposes. But Rosatom seldom exercises that right because the inspection visits are quite costly, and under the terms of the Agreement the party which conducts the inspection bears all the costs.

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The natural uranium component problem

Under the terms of the HEU-LEU deal, the United States has agreed to pay in full for the SWU and the uranium component required for the production of the downblended material. SWU accounts for about two-thirds of the final price of the product, and the uranium component for the remaining third. Such a state of affairs remained until April 1996, when a bill was passed on the privatization of USEC[11], the U.S. Executive Agent under the Agreement. The bill introduced strict quotas on sales of natural uranium component on the U.S. market; essentially, it made it impossible for the US side to pay for that natural component under the HEU-LEU Agreement.

Russia and the United States were forced to begin lengthy negotiations to find a mutually acceptable solution. The talks took almost two years to complete. There were times when the situation seemed completely hopeless, and the Agreement itself was on the brink of collapse. The problem was exacerbated by the fact that Russia and the United States had yet to sign an Agreement for Cooperation in the Field of Peaceful Uses of Nuclear Energy (the so-called 123 Agreement)[12]. The absence of that document complicated the return to Russia of the natural component which could no longer be sold in the United States.

A way out of the deadlock was finally found in March 1999. It was agreed that USEC would return to Russia an equivalent of the natural uranium component, and pay only for the SWU content. Also, under the terms of an Agreement Concerning the Source Material Transfer to the Russian Federation signed in March 1999 between the Russian Ministry of Atomic Energy and the U.S. Department of Energy, Washington made an exception for the HEU-LEU natural component and allowed its return to Russia without signing the 123 Agreement[13]. The Americans also allowed the purchase of 11,000 tonnes of natural component accumulated on U.S. territory for 325m USD, at an above-market price. At the same time, Techsnabexport and a group of Western companies, *Areva, Cameco,* and *Nukem,* agreed to sign an option for the purchase between 2002 and 2013 of the Russian natural component that was being accumulated on U.S. territory.

The following figures can be cited to illustrate that the arrangement has been a success: by June 2011, the Russian treasury had received 9.9bn USD under the HEU-LEU Agreement, including 6.9 bn USD paid by the Americans for SWU, and 3bn USD for the natural component supplied to the aforementioned group of Western companies. In addition, over the reported period the United States had physically returned back to Russia more than 30,000 tonnes of natural component worth more than 3.6bn USD – that is the material that cannot be sold, and is required to produce the blendstock.

According to a preliminary assessment of sales of the natural component to the group of Western companies and the return of some of the natural component to Russia (taking into account the LEU shipments to the United States due before the end of 2013), the overall revenue the HEU-LEU Agreement has generated for Russia could

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be as high as 17bn USD, with about 13bn USD in hard currency going directly to the treasury.[14]

Prospects for sales of Russian uranium products in the United States after the completion of the HEU-LEU Agreement in 2013

Russia has no intention to extend the HEU-LEU Agreement; senior Rosatom executives have made it clear on more than one occasion. The remaining Russian HEU stockpiles will be required by Russia's own nuclear energy industry. There was a lot of uncertainty over continued Russian supplies of uranium products to the United States after 2013, taking into account the restrictions imposed by Agreement Suspending the Antidumping Investigation on Uranium signed by the Russian Ministry of Atomic Energy and the US Department of Commerce in October 1992[15].

After the break-up of the Soviet Union, Russia and several other former Soviet republics dumped a lot of uranium products on the U.S. market at very low prices. In response, Washington imposed an anti-dumping tariff of 115 per cent, essentially closing the door to the U.S. market for Russian suppliers. That door was partially reopened after the signing of the 1992 agreement, which made an exemption for the SWU contained in the LEU shipments supplied under the HEU-LEU Agreement via USEC. But as a result, commercial supplies of uranium became all but impossible because they were not covered by the quota exemption.

In an effort to resolve that problem, in February 2008 Rosatom and the U.S. Department of Commerce signed Amendment to the Agreement Suspending the Antidumping Investigation on Uranium From the Russian Federation, allowing Russian nuclear industry to supply up to 20 per cent of the U.S. market demand for uranium products in 2014-2020 by signing contracts directly with NPP operators, bypassing USEC[16]. As of January 2013, the Russian portfolio of contracts signed with American energy companies was worth about 6bn USD.

There was another important problem which had to be resolved after the Swiss company Noga tried to seize Russian state-owned assets on the basis of a decision by the Stockholm Chamber of Commerce Arbitration. In order to protect the Russian assets involved in the implementation of the HEU-LEU Agreement from arrest and seizure by a third party, in 2000 the U.S. President signed an Executive Order (which is now renewed every year) making it impossible to seize such assets. The Executive Order cites the exceptional importance of the HEU-LEU Agreement for American national security.[17]

Criticisms of the HEU-LEU Agreement

In the late 1990s some of the Russian media outlets (most of them left-leaning) launched a campaign of sharp criticism against the HEU-LEU Agreement. They quoted 'reputable experts' as saying that the terms of the deal were daylight robbery; the claim was that the price Russia was getting for the 500 tonnes of HEU being downblended to LEU was an order of magnitude lower than it should have been.

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Critics also argued that the Agreement undermined Russian national security because it reduces the country's strategic stockpiles of HEU.

That rhetoric culminated in 1999 during a special hearing launched by the Russian State Duma Committee on Geopolitics. The MPs which presided over the hearing invited representatives of the Ministry of Atomic Energy, the Foreign Ministry and the Ministry of Defense to give evidence. In his opening remarks, the Committee's chairman, Alexey Mitrofanov (then member of the nationalist LDPR party) essentially repeated the arguments outlined above. He said that the Duma should discuss the question of Russian withdrawal from the Agreement because the deal ran counter to Russian national interests.

The Foreign Ministry representative who attended the hearing delivered a stiff rebuttal, saying that the criticisms were completely groundless. He said that, to begin with, selling 500 tonnes of weapons-grade uranium downblended to produce LEU would barely have any detrimental effects on Russian defense capability because the country would still have, according to Western assessments, another 700 tonnes left in reserve. (These figures are classified in Russia, so no official data available for public discussions; foreign scholars estimate that Soviet Union had accumulated about 1,200 tonnes of weapons-usable uranium).[18] The American HEU reserves are estimated at about 700 tonnes; in addition, Washington has declared 209 tonnes of HEU as being surplus to its national security requirements, and is planning to eliminate that amount of HEU unilaterally over the next few years. Available reports suggest that the United States has already converted about 119 tonnes of HEU to LEU.[19]) The second argument cited by the Foreign Ministry representative was that the hard currency revenues generated by the HEU-LEU deal were a vital source of additional funding for the Russian nuclear industry, which was facing a serious deficit of state financing. The third argument was that safe and secure storage of all the HEU being extracted from nuclear weapons dismantled under the START I Treaty would be very costly. Finally, the Foreign Ministry official said, the overall value of the Agreement was set at 12bn USD based on the global market prices at the time of the signing of the deal (i.e. the average price of 1kg of LEU, adjusted by the two sides depending on the market situation). Of course, Moscow in theory could have tried to find a more generous buyer for its weapons-usable uranium (such as Saddam Hussein). But being a depository of the Nuclear Non-Proliferation Treaty, Russia has a commitment 'not in any way to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.' These arguments were echoed by the Ministry of Defense and Ministry of Atomic Energy representatives.

In the end, the LDPR party initiative to withdraw from the HEU-LEU Agreement was not backed by the Russian parliament; the Agreement will be completed later this year, as originally scheduled.

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Conclusion

The implementation of the Russian-U.S. Agreement on disposition of highly enriched uranium extracted from nuclear weapons has become an effective instrument of irreversible nuclear disarmament. As a party to the Agreement, Russia has converted 500 tonnes of its HEU stockpiles into low-enriched uranium suitable for use as power reactor fuel. The final LEU shipment to the United States under the HEU-LEU deal is scheduled for the fall of 2013.

The importance of the HEU-LEU deal for the United States can be illustrated by the following figures: for almost 20 years LEU supplies under the Agreement with Russia have accounted for about 50 per cent of the nuclear fuel consumed by the American NPPs. Up to 10 per cent of American electricity is generated from uranium supplied under the HEU-LEU program.[20]

The revenue generated by the program, especially in the 1990s, made a substantial contribution not only to the Russian nuclear industry's bottom line, but to the Russian treasury as well. In 1999, a year after the 1998 financial crisis, proceeds from the HEU-LEU Agreement made up almost 3 per cent of the Russian federal government's revenues.[21] The money was partially used to finance programs to improve safety at the Russian nuclear power plants, defense industry conversion, and clean-up of contaminated areas.[22]

The implementation of HEU-LEU Agreement has created a favorable climate for the United States to adopt a reciprocal decision to downblend, on a voluntary basis, some of the American HEU stockpiles, thereby making their weapons use impossible. Some 119 tonnes of American HEU has already been downblended.

The HEU-LEU Agreement has been a useful platform to demonstrate the possibility of using commercial approaches in the implementation of disarmament initiatives. It has also enabled the Russian and American nuclear industries to gain useful experience of working together, which will facilitate further cooperation in commercial uranium enrichment services. As of January 2013, the Russian portfolio of nuclear contracts signed with American energy companies was worth about 6bn USD.

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