ISOTOPIC SEPARATION REMOTE ADVERTENCY

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Abstract: Данная статья связана с нераспространением применения лазерной технологии обогащения. Лазерная технология обогащения все еще разрабатывается, но есть признаки, что она скоро появится в качестве значительно более дешевого способа производства низкого обогащенного урана для ядерных реакторов и возможно для того, чтобы производить высоко обогащенный уран в целях создания ядерного оружия. Динамика технического прогресса может привести к появлению новых производителей обогащенного урана, угрожая разрушить текущее сравнительное преимущество главных производителей, особенно тех, которые используют центрифужный способ. Однако, существующие основные производители взаимно заинтересованы в ограничении распространения технологий, которые могут привести к развитию способов получения ядерных взрывчатых веществ, дистанционный контроль которых затруднен. Данная работа исследует влияние этих взаимных интересов.

"Remote advertency" refers to the capability to be aware of something at a distance. Despite the numerous security challenges of the nuclear age, remote awareness of enrichment and fissile material production was not a major security problem during the early periods of the nuclear age. A number of early enrichment technologies were experimentally researched resulting in a reliance on electromagnetic separation and gaseous diffusion as the most commonly used means of isotopic enrichment. These two processes were followed by centrifuge separation technology. The use of these three technologies—electromagnetic, gaseous diffusion, and centrifuge—for uranium enrichment on an industrial level was at such a scale and scope that they were relatively easily observable using national technical means such as electronic, photographic or seismic observation conducted at a distance. Very recently a previously abandoned uranium enrichment technology—laser enrichment—has reappeared.

Observation at a distance—remote advertency—has always been an important aspect of non-proliferation verification. International cooperation in nonproliferation verification exists on a number of levels. The basic international agreement is the Nuclear Non-proliferation Treaty (NPT). The NPT recognized two categories of states; those acknowledging possession of nuclear weapons prior to 1967—the nuclear weapon states—and those not acknowledging possession of nuclear weapons—the non-nuclear weapons states. The essence of the treaty consists of three "pillars"; all signatories agree to share the benefits of peaceful nuclear science, to promote disarmament and to prevent proliferation. The specific obligations under the treaty, however, are somewhat different for the two categories. The nuclear weapons states (China, France, Russia, the UK and the U.S) are obligated to prevent nuclear proliferation and to undertake good faith efforts toward nuclear disarmament. The non-nuclear weapon states are enjoined from developing or acquiring nuclear armaments and are additionally required to comply with verification measures to demonstrate they are not seeking to acquire or develop nuclear armaments. Nuclear weapons states are not required by the NPT to comply with verification measures.

The "watchdog" organization established under the auspices of the United Nations, the International Atomic Energy Agency (IAEA) is the primary institution charged with conducting non-proliferation verification on an international basis. In 1990 following the determination that Iraq had skirted verification procedures by secretly undertaking a nuclear weapons development program, the IAEA resolved to enhance verification measures. Two NPT follow-on agreements, the IAEA Safeguards Agreement and the IAEA Additional Protocol, increased the rigor of verification measures. These agreements allow detailed inspections of declared sites and allow the IAEA to carry out environmental monitoring of non-declared facilities in non-nuclear weapon states suspected of proliferation activity. Monitoring can take place to gauge a country's efforts to develop a fissile material program. From the point of view of nuclear power production, two stages in the nuclear fuel cycle are particularly sensitive; the initial production of fissile materials and the reprocessing of spent fuel. Monitoring may attend to either or both of these stages as well as to diversion efforts within the nuclear fuel cycle or from various other applications such as medical use, materials testing, and so on.

During the middle years of the Cold War sophisticated isotopic enrichment technologies using other physical principles were experimented with and put into initial stages of development. Some of these technologies, in particular laser enrichment methods, were considered to have great commercial promise and national security potential. These approaches were widely viewed as beyond the technical or financial capacity of many non-nuclear states. In 2001 one enrichment specialist noted that laser isotope separation "has been regarded as too difficult a technology for a typical proliferating nation in the middle economic rank (100B$/yr) to utilize."[1] Support for these more sophisticated methods diminished among nuclear weapon states because large stockpiles of fissile materials had accumulated during the Cold War period. Comparatively low energy prices contributed to reducing support for research and development in theoretically promising but commercially impractical enrichment technologies. As a consequence, some of these new enrichment technologies remained on the level of research and some of the efforts to transition the technologies to an industrial level were simply shelved.

For several decades the U.S. relied exclusively on gaseous diffusion for uranium enrichment to produce low enriched uranium to be used for reactor fuel commercial purposes.[1] While centrifuge technology offered substantial economic and environmental advantages, existing commercial facilities were retained while research was conducted on more advanced enrichment technologies. Various forms of laser isotope separation (LIS)

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[1] Since the beginning of the nuclear age U.S. facilities have relied exclusively upon gaseous diffusion for uranium enrichment for commercial purposes. No commercial centrifuge enrichment facilities operated in the U.S. until March, 2010 when USEC announced the operation of a cascade of centrifuge machines in a commercial-plant configuration in Piketon, Ohio. A short time afterwards, in June 2010, the firm URENCO announced that it began production of LEU at a centrifuge enrichment facility located in Eunice, New Mexico. In October 2011 the Nuclear Regulatory Commission (NRC) issued a license to AREVA Enrichment Services LLC to construct and operate a gas centrifuge uranium enrichment plant in Bonneville County, Idaho. However, the AREVA project stalled primarily for financial reasons based on future uranium price forecasts.

technology were identified as a theoretically plausible path to isotopic uranium enrichment. A process called AVLIS (Atomic Vapor Laser Isotope Separation) was experimentally demonstrated as a successful physical process at Lawrence Livermore National Laboratory (LLNL) in 1974.[2] Free electron lasers (FEL) have also been used for separation. Other countries around the world were also pursuing LIS technology. The U.S. Department of Energy (DoE) came to regard LIS as the most promising method to provide a low-cost, environmentally sound method to enrich uranium for the U.S. and trading partners. 2DoE saw LIS as a way to replace the aging and energy inefficient gaseous diffusion facilities in the US and, at the same time, skip over the stage of centrifuge separation used in other countries.

The end of the Cold War brought ambitious plans for laser enrichment to a standstill. New U.S. legislation privatized enrichment facilities and turned responsibility for management over to a semi-private corporation created by the U.S. Congress in 1992, the U.S. Enrichment Corporation, USEC. In 1994 USEC renewed the LIS program in the U.S., providing support for further research and development for laser isotope separation methods. However, for financial reasons, in June 1999 USEC withdrew support for LIS research and development. Meanwhile, others continued to research laser technology, pushing it closer to commercial viability. In 1988 in Australia Michael Goldsworthy formed a company to commercialize laser technology under the name SILEX, separation of isotopes by laser excitation.[3] In 1995 scientists Horst Struve and Michael Goldsworthy conducted a "proof of principle" experiment which demonstrated the commercial viability of the proprietary SILEX approach. An Agreement for Cooperation between the United States and Australian Governments was signed paving the way for continued development of the SILEX Technology for uranium enrichment, and facilitating its future transfer to the US. The SILEX methodology was classified in the US and in Australia by the governments.

In 2006 GE Energy entered a partnership with the Australian firm SILEX Systems to develop the third-generation SILEX process. In the U.S., GE Energy partnered with Hitachi, forming GE-Hitachi. In July 2007, GE-Hitachi submitted a license amendment request to the U.S. Nuclear Regulatory Commission (NRC), seeking approval for research and development associated with laser enrichment to be conducted at its Global Nuclear Fuels-Americas (GNF) facility in Wilmington, NC. The GNF partnership led to the development of an industrial level "test loop" and, following that, to an industrial pilot "lead cascade". In mid 2008 Cameco bought into the project, acquiring a 24% share, alongside GE (51%) and Hitachi (25%). GE-Hitachi is currently operating the test loop at Global Nuclear Fuel's (GNF) Wilmington, North Carolina fuel fabrication facility. GNF is a partnership of GE, Toshiba, and Hitachi. In addition, in June 2009, GE-Hitachi submitted a license application to construct a commercial laser enrichment plant in

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2 Laser isotope separation using photo-disassociation (LIS) is based on the fact that different isotopes of the same element, while chemically identical, have different electronic energies and therefore absorb different colors of laser light. The isotopes of most elements can be separated by a laser-based process if they can be efficiently vaporized as atoms. In the laser system used for the LIS uranium enrichment process electrons from the ^{238}U atoms are separated, leaving positively charged ^{235}U ions that can be easily collected for use.

Wilmington, NC. The NRC staff is reviewing that application and expected to reach a decision in September 2012. [4]

Electromagnetic and gaseous diffusion technology uses large amounts of electricity. In the past it has been quite easy to observe from a distance the functioning of these facilities. Similarly, centrifuge technology uses considerable electricity but also produces a signature that are easily distinguishable as a result of the distinctive vibration produced by equipment that runs at such a high number of revolutions per minute. However, laser enrichment technology does not share these features. The fact that LIS technology is so much more compact and free of distinctive industrial signatures has led scientists to immediately question the proliferation implications.[5] Some have raised questions whether laser technology might be of particular interest to states or groups intent upon proliferation. [6]

The advertency (remote observability) of LIS depends upon a number of factors. [7] Researchers have challenged the NRC position on the issue of reviewing the GNF proposal without including a formal process of non-proliferation assessment. [8] Researchers have objected that a formal non-proliferation assessment should be included as a component of the review of the GNF license application. [9] GNF voluntarily offered a specialist assessment of the non-proliferation implications of the LIS technology. The details of the assessment have not been made public, but the conclusion of the assessment was that LIS technology did not present non-proliferation implications that involved risks exceeding those of other enrichment technologies. Because the details of the process are not public, without more information it is difficult to accept the report's conclusion. If it is true that the LIS process requires UF6 as the basic feedstock, then the uranium conversion process would be observable by existing means. 3 Furthermore, if the LIS process requires turnable dye lasers which are still on the forefront of laser technology and easily observable through existing dual-use priority categories, then international acquisition as well domestic research and development programs would be observable. However, as technology advances the observability could be expected to decline. Furthermore, unexpected breakthroughs in technology might quickly exceed present oversight capacities.

Conclusions and Recommendations

Certain types of technology are required and may be either internationally acquired as components or in part. Laser programs are known to require tunable dye lasers and the associated equipment necessary to measure output. Uranium needs to be vaporized. Sputtering, platings and coatings for advanced materials qualities to resist highly corrosive substances are required.

Calling a moratorium on research on LIS technology is at best a temporary palliative. The history of enrichment technology and, more generally, the history of science in general suggest that once a technology is known to have been moved from the theoretical to the practical plane, it is futile to attempt to impose upon other countries the

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3 Milled uranium ore—U_3O_8—is moved through a conversion process resulted in uranium hexafluoride—UF_6 to be used as the gaseous process medium.

cessation of further research. In general it is futile and counterproductive for nuclear weapon states to either individually or jointly intercede in scientific development and industrial adoption of laser enrichment technology. Laser enrichment offers a path to less expensive and more environmentally sustainable production of reactor fuels.

At the same time, the proliferation implications of laser technology are an order of magnitude more disruptive to current non-proliferation monitoring and verification efforts. The further development of laser technology calls for a more robust and focused dialogue among nuclear weapon states of measures to enhance monitoring and verification. This dialogue should be aimed at consensus based standards and principles regarding remote observation.

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