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Editors' Note

This issue of *Science & Global Security* contains three articles exploring fissile material production technologies that could challenge existing nonproliferation monitoring and safeguards arrangements. These technologies include a new means to enrich uranium using lasers, a possible way to conceal plutonium production reactor operation, and fast reactors with core blankets able to breed plutonium. This issue also contains a research note explaining the origin and technical basis of the 20 percent uranium-235 concentration criterion to demarcate weapon-usable highly enriched uranium from non-weapon-usable low enriched uranium.

In "A Proliferation Assessment of Third Generation Laser Uranium Enrichment Technology," Ryan Snyder provides a detailed analysis of the physical principles and operationalization of uranium isotope separation through laser excitation and preferential condensation repression of uranium-235 hexafluoride. The SILEX (Separation of Isotopes by Laser Excitation) system that was licensed for commercialization in the United States by General Electric, Hitachi, and Cameco as the Global Laser Enrichment project may be based on such a mechanism.

The article provides a model laser enrichment cascade able to produce enough weapon-grade highly enriched uranium (90 percent uranium-235) for at least one weapon per year, and a preliminary assessment of key associated signatures—the physical space, energy consumption and technical skills required for such a cascade—suggesting that these may be less than for an analogous centrifuge-based set-up. Lasers that could be used in such a system are described in an online supplement that also details aspects of the enrichment mechanism, associated enrichment factor (which may be significantly larger than for centrifuges) and cascade model. The results highlight the need for a formal public proliferation assessment of laser enrichment technologies such as SILEX and the Global Laser Enrichment project with access to actual design information and key operating parameters and signatures.

"Potential Signatures and the Means of Detecting a Hypothetical Ground Source Cooled Nuclear Reactor" by Lance K. Kim, Rainer Jungwirth, Guido Renda, Erik Wolfart, and Giacomo G. M. Cojazzi examines monitoring options should a state seek to suppress the heat signature from the operation of a plutonium production reactor to reduce the likelihood of detection by avoiding cooling towers or surface reservoirs such as lakes or rivers. They examine a hypothetical system of wells separated by distances of a few hundred meters to several kilometers (depending on the aquifer) that extract groundwater to cool a production reactor of a few tens of megawatts of power and inject the heated water back below the sub-surface. The authors suggest that, in principle, under some conditions, a single extraction well may suffice if the heated water from the reactor cooling system can be pumped back directly into an aquifer.

A reactor cooling system based on groundwater wells would have its own signatures and the article includes a review of possible visual, thermal, seismic, chemical, and radiological markers and a discussion of how these may be suppressed or concealed. The signatures include well construction, pumping and power systems, changes in surface morphology, temperature and seismicity from groundwater pumping activities, the thermal plume caused by the reinjected water and accidental releases, as well as radiological contamination and chemical alterations to the aquifer from injection. These may require new monitoring techniques.

Bernadette K. Cogswell and Patrick Huber in their article "Detection of Breeding Blankets Using Antineutrinos" assess the possibility of determining from outside a reactor containment building whether a plutonium-fueled fast breeder reactor is operating with a uranium blanket around the core. France is believed to have used its *Phénix* breeder reactor to make plutonium for weapons. This scenario is now important since Russia is committed to verifiably disposing of 34 tons of excess weapons plutonium as fuel in its BN-600 and BN-800 breeder reactors as part of the Plutonium Management and Disposition Agreement with the United States—under this agreement the BN-600 is to have its radial blanket removed. The question also has relevance for the operation of India's Prototype Fast Breeder Reactor (PFBR), which is purportedly part of the electricity generation program but could produce an estimated 140 kg a year of weapon-grade plutonium in its blanket, and may become operational in 2016. It will not be under International Atomic Energy Agency safeguards, but India could offer some kind of monitoring to provide assurances that it is not producing plutonium for weapons.

The article offers a new challenge and area of focus for antineutrino detector builders. The proposed detection method relies on unpacking the reactor's antineutrino spectrum to discriminate between antineutrinos emitted by fission and antineutrinos produced by neutron capture on uranium-238 and successive beta decays to plutonium-239, and the effects of neutrino scattering from nuclei. The analysis suggest that it may be possible to determine the presence or absence of the blanket around the core with a hypothetical detector containing 100 kilograms of detector material with a measurement period of 90 days at a distance of 25 meters from the core (assuming perfect efficiency). Estimating the amount of plutonium in such a blanket could be feasible with this type of detector, with large uncertainties, while estimating the isotopic composition of the plutonium in such a blanket would require additional data that such a detector could not provide.

The research note "On the Origins and Significance of the Limit Demarcating Low-Enriched Uranium from Highly Enriched Uranium" by Andrew Brown and Alexander Glaser casts light on an important historical and technical puzzle: how and why did uranium enriched to 20 percent uranium-235 (Highly Enriched Uranium, or HEU) come to be designated as weapon-usable material? The answer, they show, is to be found in a key memorandum from 1954 that was part of the U.S. government's efforts to implement the vision of nuclear technology and material sharing offered in the Atoms for Peace speech by President Eisenhower in 1953.

Discovered in the National Archives by historian Andrew Brown, the memo by Lawrence R. Hafstad, the director of reactor development at the United States Atomic Energy Commission, lays out the technical basis to limit the enrichment and quantity of uranium to be exported as fuel for foreign research reactors so as to minimize the risk of such material being used to make a nuclear weapon. The research note unpacks and explains the assessment about the enrichment level and amounts of material that would be "not suitable for any practical weapon" and the resulting guidelines for constraining exports proposed in this memo. As Brown and Glaser point out, United States policy soon began ignoring the enrichment and quantity limits it laid out, however. The subsequent exports of HEU-fueled research reactors, some with large inventories of weapon-grade material (enriched to over 90 percent uranium-235) have proven to be an enduring problem for the international community.