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Toward the Global Norm: Supporting the Minimization of Highly Enriched Uranium in the Civilian Sector

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Over the past three decades, the United States has led a global effort to minimize the civilian uses of highly enriched uranium (HEU), and to develop related technical and political tools. The international effort took hold because of the dangers posed by HEU, specifically the relative ease with which the material can be used in a nuclear explosive device. Global initiatives to promote HEU minimization assumed greater priority following President Barack Obama's Prague speech in 2009, and gained further support at the 2010 Nuclear Security Summit in Washington, D.C. Nations' commitments made at the 2010 summit, often with assistance from the United States, have done much to accelerate the elimination, conversion, and safeguarding of facilities reliant on HEU. Still, much work has yet to be completed, and the obstacles are numerous. The upcoming 2012 Nuclear Security Summit in Seoul, South Korea, will present an opportunity to improve on commitments made during the 2010 meeting and to set new goals.

Why does HEU matter?

Those seeking to construct a nuclear weapon rely on either HEU or plutonium to form the fissile core of the device. Of the two, HEU poses the most immediate security and proliferation concerns thanks to the relative ease with which the material can be used. The simplest kind of nuclear weapon, a “gun-type bomb”, requires a small amount of HEU. The process is so simple and well understood that the weapon does not require an explosive test; for example, the first nuclear weapon dropped on Hiroshima was a gun-type device and was not tested prior to deployment. A 2007 briefing released by the U.S. Department of Homeland Security further highlighted the modest technical and operational capabilities required to assemble an improvised nuclear device (IND). In the briefing, experts noted the minimal amount of weapons-usable material needed, the availability of information for a gun or implosion system design, and the ease of construction by a small, qualified group of individuals.[1]

Fortunately, naturally occurring uranium does not contain enough of the fissile isotope uranium-235 to be of use in a nuclear weapon. A physical process to “enrich” or increase the amount of uranium-235 relative to the non-fissile uranium-238 is first required. The International Atomic Energy Agency’s Glossary considers uranium enriched to less than 20% uranium-235 to be low-enriched uranium (LEU) and not well suited for weapons use. Enrichment levels beyond 20% are considered highly enriched and therefore potentially suitable for weapons use. HEU materials enriched to 20% or more of uranium-235 are considered “weapons-fissionable material”, while “weapons-grade material” is viewed as close to 90%. The International Atomic Energy Agency (IAEA) considers 25 kilograms of HEU (of any enrichment level) a “significant quantity”, or enough to construct a nuclear weapon.[2] However, the higher the level of enrichment, the smaller the quantity of HEU required for this purpose.

For decades, HEU has been used for both military and civilian purposes. Traditionally, HEU has been limited to four principal uses: nuclear weapons, fuel for research reactors, targets for the production of medical isotopes, and fuel for nuclear navies. Currently the annual use of non-weapons HEU totals nearly 3,900 kilograms: 3,100 (1,900 used by the United States) kilograms for naval propulsion, 750 kilograms for research reactors, and 40-50 kilograms used in the production of medical isotopes.[3] Concerns over the quantity of HEU holdings in civilian facilities are heightened by sometimes inadequate levels of physical security. Many civilian facilities employing HEU, such as universities, have not installed the same security standards as found in military installations.

The presence of HEU, particularly "weapons-grade" material, in these civilian facilities poses several immediate and long-term security risks. Most urgently, HEU stocks available in the civilian sector present opportunities for unauthorized personnel to acquire a significant amount of material, which could then be used in a nuclear weapon or IND. In the long run, it is also possible that HEU in civilian use could be diverted to weapons purposes by the state in question. In short, the simple design of a gun-type bomb, as well as the short- and long-term security and proliferation risks associated with HEU, require the coordinated support of the international community. Further multilateral and bilateral engagement reinforcing the international norm against HEU use will be essential.

HEU and the Nuclear Security Summit

The conclusion of the Nuclear Security Summit in early April 2010 marked an important chapter in efforts to restrict civilian uses of HEU. Endorsed by 47 governments, the final communiqué called on states to "encourage the conversion of reactors from high enriched to low enriched uranium fuel and minimization of the use of highly enriched uranium, where technically and economically feasible."[4] Some states also made more concrete commitments or "house gifts" at the summit. Canada, for example, agreed to return spent HEU fuel from its medical isotope reactor to the United States. Repatriation of the fuel is slated "between 2010 and 2018".[5] In addition to the return, Canadian officials also pledged $8 million in funding to the U.S. Global Threat Reduction Initiative to support two separate projects that will remove HEU from Mexico and Vietnam. Kazakhstan announced a commitment to convert one of three HEU-based research reactors, including the elimination of its remaining HEU stockpile.[6] As part of a trilateral agreement with Canada and the United States, Mexico agreed to convert an HEU reactor and eliminate its remaining HEU stocks. In addition, Vietnam committed to converting its only research reactor to LEU fuel.

Ukraine's commitment to remove its remaining HEU stockpile was widely regarded as a key summit success. With assistance from the United States, HEU from three separate locations in Ukraine was repatriated to Russia in 2010. In May 2010, 56 kilograms of HEU spent fuel, estimated at more than a third of its total inventory, were removed, which was followed by an additional removal of 50 kilograms in

December 2010. The Ukrainian government has until the next Nuclear Security Summit in Seoul in 2012 to complete the elimination of its remaining stockpile.

Key Outliers: Russia and Belarus

While HEU efforts have gained momentum, two countries in particular could upset the trend: Russia and Belarus. To be sure, Russia has been a strong partner in assisting other states' HEU conversion and repatriation efforts. So far, Moscow has overseen more than 35 shipments of spent and fresh fuel, totaling almost 1,500 kilograms of fissile material. This includes HEU recovery missions in Belarus, Poland, Serbia, and Ukraine. Russia has also agreed to conduct feasibility studies "to explore possibilities for conversion" of six research reactor cores to LEU fuel.[7] However, it is not actually the technical feasibility that is in doubt, but Russia's will to fulfill the commitment, as Russia has to date demonstrated little interest in minimizing HEU use in its own territory.

Moscow is believed to possess the largest civil stocks of HEU in the world, estimated at nearly 30 tons. It hosts 16 research reactors, including 11 civilian reactors, and additional critical assemblies using HEU fuel. For example, two critical assemblies at the Institute of Physics and Power Engineering in Obninsk are reported to hold 8.7 tons of uranium with enrichment between 36% and 90%.[8] Efforts to convert these facilities have been stymied in part by Russian authorities fearful of committing to an expensive LEU-based enterprise and scientists concerned about hampering their scientific productivity as well as a number of other factors.[9] And rather than advance reactor conversion, Russia hopes to take advantage of any lags in the isotope market to increase production of molybdenum-99 (Mo-99) using HEU fuel and targets.[10] Increasing HEU-based production of medical isotopes will make it difficult for new, more expensive LEU-based production to gain a foothold, as well as increase the security risks involving the theft or loss of fissile materials, which could fall into the hands of a terrorist group.

The possibility of participation in the 2012 Nuclear Security Summit appears to have been one incentive that spurred Belarus, which did not participate in the 2010 gathering, to commit to eliminate its HEU stocks. Under 2010 agreements with Russia and the United States, Belarus agreed to remove all of its HEU, which includes both fresh and spent fuel stockpiles. On October 8, 2010, Russia and Belarus reached an intergovernmental agreement on the return of HEU fuel from Belarus to Russia.[11] The agreement was followed almost immediately by secret shipments of non-weapons grade HEU fuel-both fresh and spent-on October 22 and November 28, conducted by Belarus, Russia, the United States, and the IAEA.[12] Subsequent U.S. inducements led to a December 1, 2010, joint statement from U.S. Secretary of State Hilary Clinton and Sergei Martynov, the foreign minister of Belarus, in which Belarus announced its intention to "eliminate all of its stocks" of HEU by the time of the next Nuclear Security Summit in Seoul in 2012.[13] U.S. National Nuclear Security Administration (NNSA) officials said it was anticipated that the shipments of the most dangerous fuel, including 40 kilograms (88 pounds) of weapons-grade HEU,[14] would take place in early 2012, shortly before the summit.[15]

It is not clear, however, if the shipments will actually move forward, given declining relations between Washington and Minsk. U.S. and European complaints that the December 2010 presidential election in Belarus was fraudulent ended a short-lived warming in relations between Belarus and the West; tensions were later compounded by the Lukashenko regime's arrest of opposition presidential candidates. To be sure, Minsk has yet to give any clear indication that it is backing away from the deal: technical cooperation between the two countries on conversion, removal, and other steps has so far continued. Still, concerns persist.

Supporting LEU Use in Medical Isotope Production

Radioisotopes play an important role in medical imaging and diagnostics. The two most widely employed isotopes, Mo-99 and its decay product technetium-99, are used in more than 30 million such examinations around the world each year, with the United States alone accounting for 14 million procedures annually.[16] Four of the largest producers of medical isotopes, based in Canada, the Netherlands, Belgium, and South Africa, provide almost the entirety of the world's supplies of Mo-99.[17]

All four suppliers have traditionally produced these isotopes by irradiating an HEU target inside an HEU-fueled research reactor to produce Mo-99, which decays within days to technetium-99. Since technetium-99m has a half-life of about six hours,[18] it must be produced continuously rather than stockpiled. The annual total world demand for HEU in the production of medical isotopes is around 40 to 50 kilograms,[19] suitable for two bombs each year. While progress has been made in producing isotopes with LEU rather than HEU fuel, it has been more difficult to get producers to switch to LEU targets.

The obstacles have been economic, not technical. A 2009 National Academies of Science study commissioned by the U.S. Congress to consider the production of medical isotopes without HEU found that there are "no technical reasons that adequate quantities [of medical isotopes] cannot be produced from LEU targets in the future."[20] The study committee report indicated that the costs to producers of converting reactors to LEU could be considerable (about a 10% climb in the price of Mo-99) but that any such increase would have a negligible effect on the final prices paid by patients. Similar conclusions were reached by an Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency High-Level Group in 2010, which said that the growth of processing facilities also appears to have been limited by a lack of market incentives, including government reimbursement rates for isotopes that do not reflect the full costs of processing and other production.[21]

One of the four major Mo-99 producers, the South African Nuclear Energy Corporation (NESCA), has committed to operate its medical isotope production facilities solely on the basis of LEU (i.e., both LEU fuel and targets), with financial support from the NNSA.[22] A consortium led by NESCA and including Australian producer ANSTO, another smaller LEU-based supplier, was awarded $25 million from the U.S. government to supply the United States with medical isotopes produced using only LEU. NESCA shipped its first FDA-approved shipment of Mo-99 made entirely with LEU to a U.S.-based technetium-99m supplier in December 2010. By June 2011 the consortium was supplying one-third of the U.S. demand for Mo-99.[23] Additionally, countries like Argentina and Australia produce LEU targets for production, but so far only operate on a small scale, although Australia has indicated a desire to increase production to support larger-scale operations.[24] Given the proliferation risk HEU poses, and the absence of a technical need of HEU targets in the production of medical isotopes, the other major producers should follow suit.

HEU Management Guidelines

In addition to efforts to convert facilities and minimize HEU use, France has pushed the idea of HEU Management Guidelines, in order to mitigate the dangers associated with HEU while it remains in use. France has drafted a non-paper on the subject for consideration of the countries involved in the 2012 Nuclear Security Summit in Seoul.[25] The guidelines draw on plutonium guidelines developed in the 1990s and initial suggestions by the James Martin Center for Nonproliferation Studies, and are a set of voluntary measures undertaken by states, covering material control and accounting of HEU, physical protection, security during transportation and international transfers, and HEU management policies.[26]

To be effective, the final HEU guidelines would have to cover all uranium enriched over 20% in peaceful uses, including in materials that have been irradiated (such as critical assemblies and medical isotope production targets). This wide definition of the material covered is crucial, since lightly irradiated items like medical isotope targets may contain as much as 90% uranium-235, and can be handled with relative safety just a few years after their removal from the reactor.[27] Such items, if not covered by security provisions prescribed by the guidelines, could be vulnerable to theft and illicit use.

Like plutonium, HEU would have to be subject under the guidelines to national material control and accounting systems, using verified physical and book inventories. A national regulatory agency should be charged with gathering this information and reporting it to the IAEA using a standard form, a process that would ensure that reliable information on HEU holdings is publicly available.

The guidelines would also provide for uniform security measures to be applied to HEU in storage, transit, and transfers across borders. This would be a central benefit of internationally agreed-upon HEU guidelines, since current international agreements can leave gaps permitting national security policies to vary.[28] For example, the guidelines could require that HEU be secured at the level recommended by the IAEA in the document INFCIRC/225 in domestic storage, transit, and during international transfer. It would be particularly important to pay attention to language in the current revision (Rev. 5), which indicates that states should consider higher levels of protection for irradiated HEU if they face the threat of suicidal terrorists.[29]

Next Steps: 2012 Nuclear Security Summit and Beyond

The Washington, D.C., Nuclear Security Summit in April 2010 was conceived as the first step in a process, with the next conference scheduled for 2012 in Seoul. With support from the United States, South Korea, and other major actors, participating states should use each summit to hold each other accountable to their prior commitments, and to encourage further progress on securing and minimizing fissile material. States must be encouraged to support the adoption of HEU guidelines, and pressure should be applied to facilitate their full adoption, with provisions that ensure that the guidelines support the elimination, not just the management, of HEU. Additionally, participating states ought to consider adding a commitment to phase out HEU in the civil sector by 2020, or agree at least on that date for ending HEU-based medical isotope production. Further financial and expert support will likely prove critical.

In line with this stance, countries can offer additional support for research reactor conversion, consolidation, and downblending, as well as promote further repatriation of HEU spent fuels and stockpiles. Movement toward improved reporting on research reactors and HEU holdings, to be compiled in an IAEA database, would also be welcome. Many of the recommendations provided could be discussed and agreed to in this setting, which enjoys high-level political involvement. World leaders should use this forum to forge consensus on difficult issues that cannot be resolved at a lower level. South Korea, a country that has "cleaned out" its HEU, has developed innovative LEU-based fuels, and is hosting this important international event, can play a leading role.

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