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Integrating Uranium from Weapons into the Civil Fuel Cycle

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Under a recently-approved agreement, Russia will sell perhaps 500 tonnes of highly enriched uranium (HEU) recovered from its dismantled nuclear weapons to the US Department of Energy over the next twenty years. Blended with natural or depleted uranium to produce low-enriched uranium for reactor fuel, this HEU could displace power consumption in the electricity-intensive gaseous diffusion plants of the US. The sale of the HEU could be done in a way that minimizes uranium market disruptions and benefits both the US and Russia.

INTRODUCTION

Since the birth of the nuclear age, Western nations have made strenuous efforts to separate civil and military uses of the atom. In recent years, this barrier has been eroded from the civil commercial side, resulting in the further proliferation of nuclear weapons and weapons capabilities. Most recently, the collapse of the former Soviet Union and the fading of the Cold War threaten to erode the historic barrier from the other side, with the potential for spread of materials or know-how from weapons programs.

In hindsight, it is clear that the separation between military and commercial uses was essentially institutional and geopolitical, not technical in nature, and was largely an artifice of the West; the Soviet Union did not make such a distinction. With the erosion of the barrier in the West, and the collapse of the Soviet Union, it will be necessary to reconstruct nuclear security regimes. In

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doing so, economic forces—perhaps the ultimate power in the collapsed Union—will play an essential role. The challenge is to align technical and commercial forces in the direction of non-proliferation and global security.

To do so, we must find solutions that—to the extent possible—internalize economic incentives. There are such incentives: massive investments in military programs have produced products that have commercial value. And even where this is not the case, where there are costs to demobilization and cleanup, there are savings to be realized from tackling civil and military nuclear problems in tandem. In short, we need a new structure of security and commercial imperatives and incentives that are *both* security and commercially driven.

Nuclear arms reductions—involving both highly enriched uranium and plutonium— will be a costly process; at the same time, nations are spending large amounts on civil nuclear fuel cycle activities. Would it be possible to find ways to reduce the total combined cost to society of both of these?

As we will show here, the answer is yes, but the mechanisms may not have the simple implications that commercial players may think. For example, some in the civil industry appear to believe that government actions to dismantle warheads—at taxpayer expense—will automatically result in cheap or even free uranium and enrichment derived from the highly enriched uranium (HEU) extracted from nuclear warheads. This is not the case: the products of HEU would need to be sold for substantial amounts to pay for the costs of dismantlement. What can be done is to find an overall cost-minimizing strategy that is good for everyone.

HIGHLY ENRICHED URANIUM*

The way to do this for HEU was proposed by the author more than a year ago† as a way to enhance financial and political mechanisms for the safe dismantlement of former Soviet nuclear weapons; the strategy was subsequently developed in consultation with the US and Russian governments. In effect, HEU from either US or former Soviet warheads can be used to displace power consumption in the electricity-intensive gaseous diffusion plants that still form the backbone of Western nuclear fuel supply. An agreement incorporating this idea was finally given initial approval by both the Russian and US govern-

* The presentation at the Uranium Institute from which this article derives also included discussions of plutonium disposition.

† *New York Times*, 24 October 1991 (Op Ed).

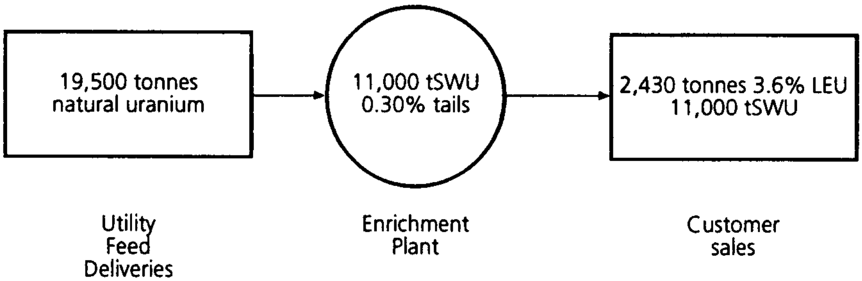

Figure 1: The basic operation of the US enrichment enterprise.

ments in September 1992, providing for the use of perhaps 500 tonnes of Russian HEU by the US Department of Energy (DOE) enrichment enterprise, or its successor, over the next twenty years.

Figure 1 shows the basic operation of the US enrichment enterprise without HEU or other complications. Each year, under existing contracts, utilities deliver about 19,500 metric tonnes of natural uranium to DOE. At a transaction tails assay of 0.30 percent, DOE supplies about 11 million kilograms-SWU and delivers about 2,400 metric tonnes of low-enriched product (at an average assay of about 3.6 percent U-235) to utilities for fabrication into reactor fuel. Matters have actually been a bit more complicated than this as DOE has been forced to find ways to reduce its costs. But the basic example here is correct.

Now suppose that one can provide some of the product delivered to utilities by blending down HEU (say at 93.5 percent U-235) with natural or depleted uranium to make low-enriched uranium (LEU). As is shown at the top of figure 2, ten tonnes of HEU can be blended with natural uranium to make about 321 tonnes of LEU, or about 13 percent of DOE deliveries. This avoids the production of about 1.45 million SWU, which would otherwise require consumption of about 3.6 billion kilowatt-hours of electricity. If the avoided cost to DOE were $50 per SWU, this would mean a savings of about $70 million, equivalent to about $7,000 per kilogram of HEU.

From this sum we must deduct the cost of converting, transporting and blending HEU into LEU. Estimates of this cost are still quite uncertain but probably lie between $2,000 and $3,000 per kilogram of HEU. We will assume a cost of $2,500, in which case, the net value of the HEU for this direct commercial use would be about $4,500 per kilogram.

However, this picture is not complete. Under their contracts with DOE, utilities would be delivering about 2,300 tonnes of natural uranium that

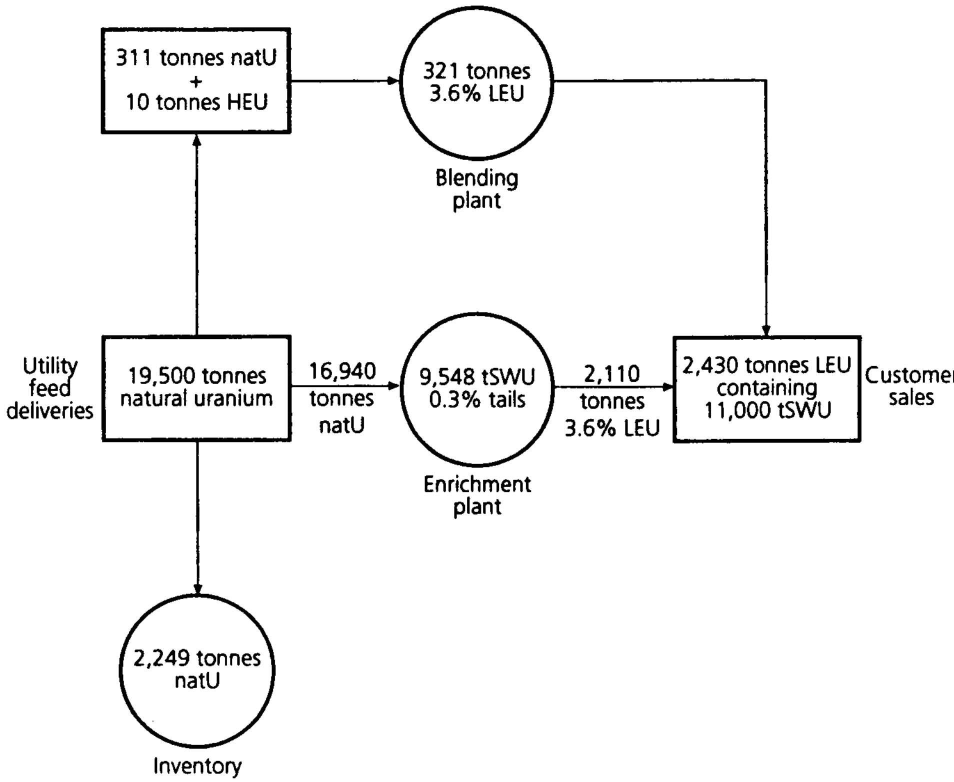

Figure 2: Blending natural uranium and HEU with no overfeed; displacing 1,452 tonnes SWU.

would be displaced by the use of HEU (note that only a small amount of feed is required for blending). In figure 2, we have assumed that this material is simply put into DOE inventory.

But there is a better use for this feed, one that significantly increases the amount that might be paid for the HEU. If the "surplus" feed is used to "overfeed" the enrichment cascades, it can further reduce the number of SWU that must be generated and the power that must be purchased. Overfeeding consists of operating the gaseous diffusion plants at a tails assay higher than the contract level of 0.30 percent. Such overfeeding will increase the amount of natural-uranium feed used to produce a kilogram of product and reduce the amount of separative-work units required (see figure 3). Calculation shows that all of the "surplus" feed delivered by utilities can be absorbed by operating the DOE plants at 0.355 percent tails assay.

What is the value of this overfeeding, and what does it mean for the amount that might be paid for HEU? As figure 4 shows, the combination of

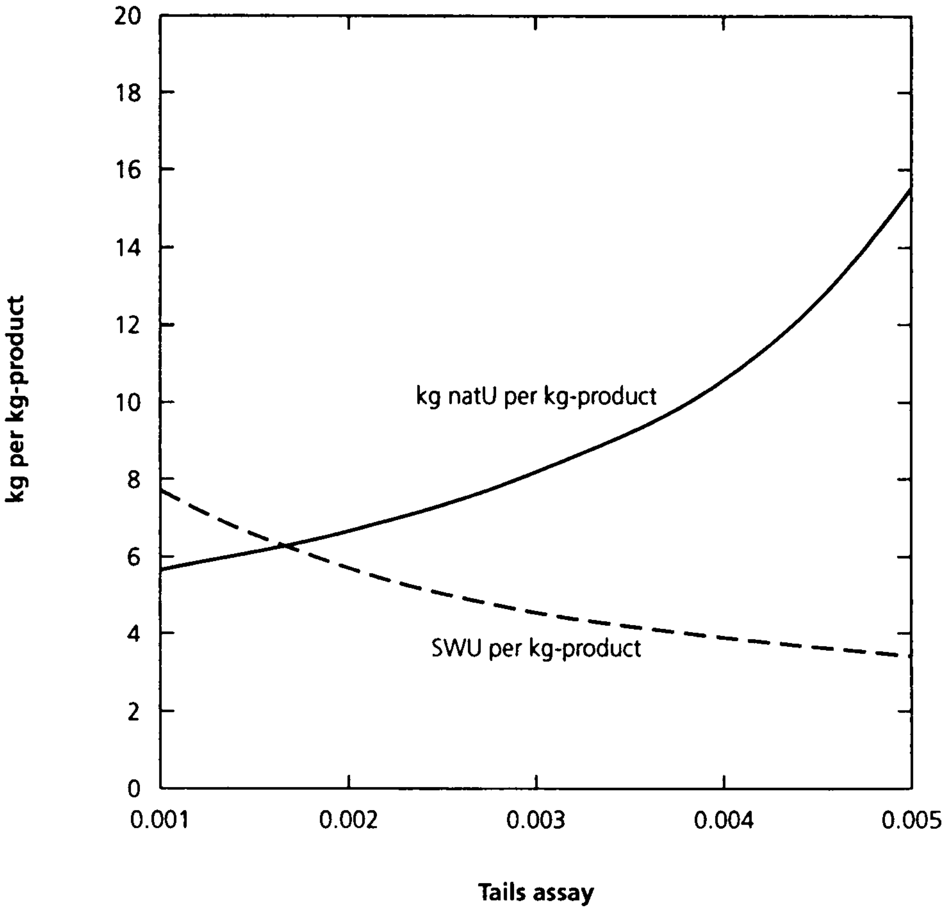

Figure 3: Kilograms of natural-uranium feed and kilograms of separative work units required per kilogram of 3.6 percent LEU for different enrichment-tails assays.

overfeeding and blending possible with an HEU purchase results in avoidance of nearly 2.4 million SWU, about a million more than results just from blending alone. With our assumed avoided cost of $50 per SWU, overfeed results in a savings of an additional $45 million dollars, or about $4,500 per kilogram of HEU. Note that this is a pure savings since no HEU conversion costs are involved. The overfeed savings is thus just as large as the direct savings from HEU blending.

We summarize the SWU savings from these two sources, and the financial implications, in table 1. The total savings from using 10 tonnes HEU (with associated overfeed and net of conversion and blending costs) is more than $90

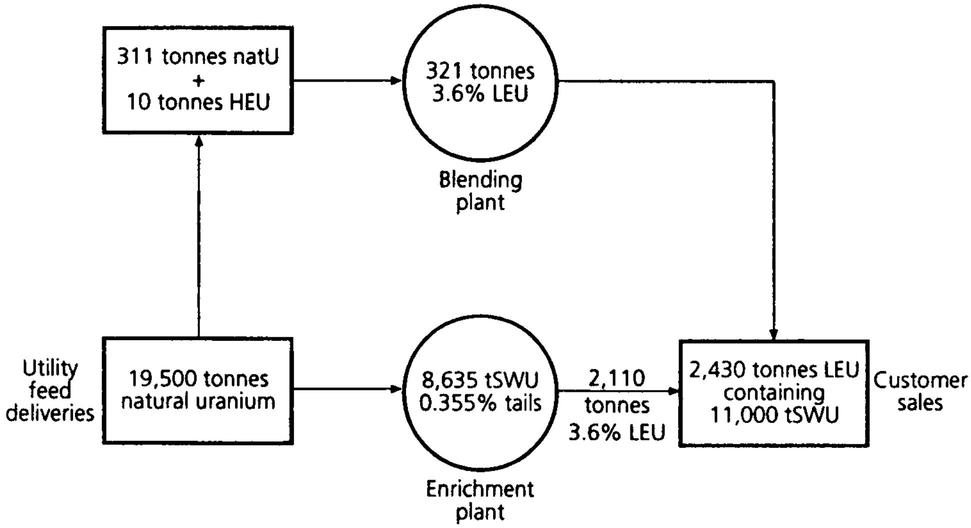

Figure 4: Blending natural uranium and HEU with overfeed, displacing 2,362 tonnes SWU.

million dollars, or $9,000 per kilogram of HEU. This money can be used by Russia to finance dismantlement, with surpluses used for other purposes, such as reactor safety improvements.

It is the present US intention to purchase HEU from Russia with the money saved in the enrichment activity. That is, it must be "budget-neutral" and based on avoided cost. In practice, the calculation of avoided cost is not an obvious matter, being wrapped up in arcane matters of government accounting as well as direct power costs. Our $50 per SWU value may be slightly high, or significantly low, depending on how one does the accounting. DOE (or the Office of Management and the Budget) may also use other formulas for estimating avoided cost. Similarly, the actual cost of converting and blending HEU may be less or greater than assumed here.

However, it is essential for fuel market participants to understand that half or more of the value of the HEU comes from displaced uranium feed and that use of deliveries for overfeeding—or at least payment for the uranium resulting from displacement—is central to economic feasibility. The direct blending of HEU provides less than half the value, as illustrated in table 1. Thus the proposed deal cannot succeed commercially without the overfeeding of surplus uranium by the enrichment enterprise.

Those who see the HEU deal as resulting in freeing up of uranium and increased supply in the market are thus mistaken. If uranium were displaced into the market, the economic and policy realities of the US-Russian deal would not permit it to take place in the first place.

Table 1: Enrichment avoided cost calculation.[a]

Source	**SWU savings**	**Value**	**HEU**
	mt SWU	*\$ million*	*\$ kg^{-1}*
HEU blending	1,452	72.6	7,260
less cost		(25.0)	(2,500)
Net from blending	1,452	47.6	4,760
Overfeed	910	45.5	4,550
Total	**2,362**	**93.1**	**9,310**

a. $50 per SWU avoided cost; 11,000 mt SWU deliveries; 10 mt HEU @ 93.5% U-235. Cost is for conversion, transportation, and blending.

As may be seen from table 1, the amounts paid for Russian HEU, under our assumption of $50 per SWU avoided cost, would be equivalent to sale of the products of HEU for $50 per SWU and $7.80 per pound of uranium oxide (about $45 million for 2,300 tonnes natural uranium as overfeed). Russia could blend down its own HEU and sell it in the open market, but the impact of large amounts of such sales (especially in a thin enrichment market) would quite likely be to drive prices below those that might be obtained from DOE, based on avoided cost (if avoided cost for enrichment is at the level assumed, or higher).

Russia and the US have common interest in reducing the market impacts of weapons dismantlement, to avoid cannibalizing their own regular sales of uranium and enrichment services and further depressing their remaining industries and employment in them.

What is interesting about the HEU deal is that it is possible to combine disposition of Russian military HEU with commercial imperatives of the DOE civil enrichment enterprise in such a way as to benefit both parties. That this can occur with no market impact is truly remarkable. It is also remarkable that use of HEU on an avoided cost basis would not change the competitive structure of the enrichment supply industry, since DOE costs would not change appreciably.

If the volumes of HEU grow very large, it becomes more difficult, but not technically or economically impossible, to use the combination of blending and overfeed to reduce costs. To do this at 30 tonnes HEU per year, it would be necessary to increase tails assay in figure 3 to about 0.46 percent U-235 and to reduce actual SWU production to about 5.5 million SWU per year. DOE enrichment plants have operated at such tails assays in the past, but the reduced demand on the enrichment plants could eventually require closing Portsmouth or Paducah. If DOE were to expand SWU sales, or stockpile excess feed, it would be feasible to absorb even larger amounts of HEU.