120505NWPI.doc

Nuclear Weapon Proliferation, Nuclear Terrorism, and Iran*

by
Richard L. Garwin
IBM Fellow Emeritus
Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598-0218
(914) 945-2555
FAX: (914) 945-4419
INTERNET: RLG2 at us.ibm.com

The world has been spared since 1945 the sight of cities devastated by nuclear explosions. The bombs that destroyed Hiroshima and Nagasaki are the only nuclear weapons thus far used in war, but even these first-generation weapons in the explosive range of 13-20,000 tons of high explosive killed more than 100,000 people each. A larger toll would be expected from such a weapon in a modern city such as Paris or New York, and an explosion at ground level would cause increased deaths due to the intense local fallout that would commit people within an hour to death within a week or two from the radiation-- a phenomenon that was almost absent in the Japanese cities.

None of the more than 400 nuclear power reactors operating in the world today could explode like a Hiroshima bomb. The destruction of a reactor, as in the worst-case accident at Chernobyl in 1986, might kill a few dozen people within a short time (31 in the case of Chernobyl) and commit perhaps tens of thousands to death by cancer over the next generation[1]. Of course the two nuclear weapons that constituted the world stockpile in August 1945 have expanded to ten of thousands, largely in the U.S. and Russian inventories, and a common nuclear yield is 150,000-500,000 tons instead of 10,000 tons of high explosive. The damage in the target country from the use of even a small fraction of these nuclear weapons would result in the total destruction of that country-- hence the absolute urgency to prevent the outbreak of nuclear war and to greatly reduce the number of nuclear weapons in the world.

From the beginning of the nuclear age, it was an important initiative to prevent the proliferation of nuclear weapons to additional states, and there the record has been good. Nuclear weapons do not happen by accident. In general there are two routes to a nuclear weapon, which in both cases involve the rapid assembly of more than a "critical mass" of metal of a nuclear species that can carry out a neutron chain reaction. Of the natural uranium obtained from terrestrial ores, 0.72% is the U-235 isotope (almost all the rest being U-238), which was used in an amount of about 60 kg to stock the Hiroshima bomb. The other conventional approach to a nuclear explosive is to use the artificial isotope plutonium-239, formed only in a nuclear reactor

---

* Draft manuscript of December 5, 2005, edited and published in French in *Diplomatie*, No. 18, pp. 52-57 (Janvier-Février 2006) as "L'Iran et la prolifération des armes atomiques."

[1] Charpak, I, and Journe in our 2005 book, "De Tchernobyl en tchernobyls" estimate that the death toll from Chernobyl will reach about 24,000.

from the U-235 chain reaction that gradually allows some neutrons to be captured on the abundant U-238 isotope to form U-239 that soon decays to neptunium-239 and then to Pu-239.

The normal operation of nuclear power plants fortunately has nothing to do with either material highly enriched in U-235 or Pu-239. And that is key to the rest of this discussion.

A normal power plant, of which France has 58 and the United States 103 contains about 100 tons of uranium-oxide ceramic fuel in the form of thin cylinders sheathed in niobium alloy or perhaps stainless steel, of which about 25 tons is replaced each year. Of these 25 tons, about 4% of the supply (one ton per year) is U-235. After four years in the reactor, about 80% of the U-235 has been converted into fission products (slightly lighter than the fissioned U-235)-- the difference in mass corresponding precisely to the heat and electrical energy generated by the reactor during the year, according to the Einstein equation $E = Mc^2$. Of the 25 tons of fresh fuel fed each year, one ton is fissioned and the resulting mass of fission products is less than one ton by the mass equivalent of three gigawatts times one year—E, or 10^8 gigajoules. Since C is 3×10^8 m/s, $M = E/C^2 = 10^{17}/9x10^{16} = 1.1$ kg. One kilogram of mass has been destroyed by completely converting it into energy; about one-third of it is useful electrical energy.

THE SPREAD OF NUCLEAR WEAPONRY.

The Soviet Union, dedicated rival to the United States, began its nuclear weapon program during World War II, in part on the basis of espionage information from the Manhattan Project in the United States. The first Soviet test explosion occurred in 1949, that of Great Britain in 1952. France tested its first weapon in 1960, and China in 1964. India tested a nuclear explosive in 1974 and again in 1978 followed within two weeks by Pakistan. It is widely believed that Israel has more than 100 nuclear weapons, and North Korea a relatively few plutonium weapons.

Different states acquire nuclear weapons for a mixture of purposes-- national pride, undue power of a nuclear establishment, and the desire to obtain nuclear weapons for defense or for national strength. There is always an excuse, given the fact. Many more states, however, have had the ability to build nuclear weapons and have decided against it-- Germany, Sweden, Switzerland, Brazil, Canada. South Africa secretly built six Hiroshima-style weapons and then with the change of government decided that its national security was better served by the destruction of those weapons and the return of the highly enriched uranium to low enriched uranium suitable for feeding reactors. In a very relevant manuscript[2] Jose Goldenberg recounts some of the motivations for nations to acquire nuclear weapons. In particular, in 1990 the newly elected civilian President in Brazil asked Goldenberg to investigate preparations supposedly underway to test a nuclear explosive device near an air force base in Brazil. Goldenberg had suspected that the

---

[2] Jose Goldenberg, “Lessons from the Denuclearization of Brazil and Argentina,” submitted to Arms Control Today, 2005.

secret installations were “in reality a ruse to magnify the importance of the activities and justify budget increases. (He) found out that there was no significant work on nuclear weapons production in any of the military laboratories and duely reported that fact to the President. The rumors persisted, however.”

Full transparency is important not only for creating confidence for other countries, but also for a state itself to have a good understanding of what is going on.

On March 16, 1946, the United States presented the Acheson-Lilienthal Report for the control of the nuclear energy, but by the time this was ready for formal proposal as the Baruch Plan, it was immediately turned down by the Soviet Union. Nevertheless, in addition to the denial of information about building nuclear weapons and the erecting of impediments to the acquisition of enrichment technology for uranium and reprocessing technology to obtain plutonium from reactor fuel, the United States and other nations began a program to provide benefits to those states who did not acquire nuclear weapons. This began with the 1953 announcement of the Atoms for Peace initiative by President Eisenhower, and the 1955 international Atoms for Peace meeting in Geneva. Under Atoms for Peace, states that committed themselves to be Non-Nuclear Weapon States were promised access to peaceful nuclear technology for industry, medicine, and scientific research.

This bargain was formalized in the Non-Proliferation Treaty (NPT) that took effect in 1970, codifying the five nuclear weapon states that had tested by that time, and allowing another category of signatory-- the Non-Nuclear Weapon State (NNWS). Article IV of the NPT:

> "1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with articles I and II of this Treaty.
>
> "2. All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world."

Thus the NWS were committed to help the NNWS according to Article IV. But the NWS had also an obligation under Article VI:

> "Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures

> relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control."

The International Atomic Energy Agency was created by the United Nations to implement the NPT and has two purposes-- the encouraging of the peaceful use of atomic energy, and the conduct of inspections to ensure that NNWS are fulfilling their obligations under the Treaty.

NNWS must declare their nuclear-energy activities, and the IAEA performs routine inspections according to the proliferation potential of the activity. Thus, heavy water reactors such as those manufactured by Canada can discharge spent fuel while remaining in operation; hence IAEA inspectors are continuously present to ensure that the spent fuel is accounted for and not diverted to weapon fabrication.

The first proliferation-relevant portion of the peaceful nuclear fuel cycle is the enrichment of uranium from the 0.72% U-235 in natural uranium to, typically, 4.4% U-235 in fuel for common reactors. The lower limit for the IAEA category of “highly enriched uranium” (HEU) is 20%, and it is impractical to make a nuclear weapon with 20% U-235-- more usual concentrations are 80% or even 95%.

The other proliferation-relevant portion of the peaceful nuclear fuel cycle involves the plutonium in the spent fuel. If the spent fuel is entombed intact in mined geologic repositories, as is the proposal in the United States, it must be followed by the IAEA while it is in storage for decades until it is properly emplaced. If, as in France, the spent fuel is reprocessed to obtain plutonium to serve as reactor fuel itself, that process and the extracted plutonium must be accounted for, until it is put into the reactor as mixed oxide (MOX) fuel. The IAEA control measures are based upon the Significant Quantity (SQ) of Pu as 8 kg and of HEU as 25 kg-- the order of magnitude of metal that would be needed for an implosion weapon of either material.

THE TERRORIST THREAT.

With the passage of 60 years since Hiroshima, and the declassification of a lot of weapon relevant information, as well as the overt efforts under the Atoms for Peace program to train tens of thousands of scientists and engineers throughout the world to deal with the very materials of nuclear weapons-- uranium metal, plutonium metal, and the like-- what keeps individuals or groups from obtaining nuclear explosives is the political will not to do so, and difficulty in access to the HEU or the weapon plutonium—dangerous and formerly valuable materials.

There has been much confusion, especially in the nuclear power industry, about the usability of "reactor-grade plutonium" in nuclear weaponry. It is a disagreeable fact that although this so-called civil plutonium cannot be substituted kg for kg for military plutonium in stockpiled nuclear weapons, a program to build weapons with civil Pu is not much more difficult than with military-Pu. Plutonium in national weapon inventories is typically on the order of 95% Pu-239 and about 4% Pu-240. The Pu-240 is about as fissionable as U-235, but it emits 900,000 stray neutrons per second per kg of Pu-240, so that even 1% Pu-240 is enough to spoil the gun-assembly methods used for uranium at Hiroshima.

In that method two sub-critical masses of uranium (say 30 kg each) are separated far enough so that the likelihood of a neutron escape is sufficient that the reproduction factor is below one. If the two masses are rapidly brought together before a stray neutron is incident, the combination of HEU and a reflector of heavy metal might produce two critical masses, so that the first neutron that enters would then multiply in successive 0.01 microsecond intervals to be 2 neutrons, 4 neutrons, 8 neutrons, 16, and so on. In the Hiroshima bomb, this was sufficient to fission about 0.8 kg of U-235 in less than the microsecond it took for the chain reaction and the explosive disassembly of the mass. About 1.3% of the initial mass was fissioned with corresponding release of 13 kilotons of energy—high-explosive equivalent.

When the first plutonium arrived from the production reactors at Hanford, Washington in 1944, the entire Los Alamos Laboratory realized that the planned gun-assembly plutonium bomb was not feasible, because it would have a sure "fizzle" with an explosive yield of a tiny fraction of the hoped-for kilotons of high-explosive yield. The "implosion method" of assembly was thus devised, powered by high explosive rather than gunpowder, with a much more rapid assembly scheme depending initially simply on the compression of a solid ball of plutonium metal by means of a spherically converging detonation wave in explosive. Converting multiple diverging detonation waves in explosive into a single convergent wave was initially achieved by means of high-explosive lenses.

Both the Hiroshima and the Nagasaki bombs weighed about four tons, but reducing the weight was of primary interest to the United States and the other nations, so that much more powerful weapons are now available in the hundred kg weight class.

Because of the enmity during the Cold War, the nuclear arms race was seen in terms of large inventories and threats from dedicated adversaries. But the lethality of even a single nuclear weapon detonated in a city is such that very small numbers in possessions of states that might use them, or of non-state groups, are of critical importance. After a brief period of toying with active defenses against nuclear weaponry, it was generally accepted that the most effective counter was deterrence-- the availability of secure retaliatory forces that would be used in case of nuclear attack. The target state would suffer enormously, but the attacker would suffer comparably and would presumably be deterred from the initial strike. Of course, a state about to be destroyed in conventional war, but in possession of nuclear weapons, could not be counted upon to accept its annihilation without using its nuclear stockpile.

Although some terrorist groups in the era up to a decade or so ago wanted publicity and political influence, many now appear simply to wish the death of their adversaries, especially in some highly public fashion. Thus, the bus and subway bombings in London in July 2005 killed more than 50 people, apparently at the cost of the lives of three suicide bombers. The events of

September 11, 2001 killed almost 3000 people, at the cost of 19 terrorist lives.

It would surely have been easier to kill more than 3000 people by having 20 terrorists smuggle 20 bombs onto as many aircraft, detonating them approximately simultaneously, thus killing all aboard. So there is something in the goals of Al Qaeda and Osama bin Laden that was satisfied only by thousands of visible deaths in an instant. One of bin Laden's spokesmen has indicated that bin Laden feels that he is entitled to kill more than four million Americans.

Nuclear proliferation and terrorists may be linked, if a state contributes nuclear materials to a terrorist organization or if it does not protect them sufficiently well to prevent their falling onto terrorist hands. This has been a particular concern in post-Cold War Russia and the rest of the former Soviet Union, where the economic and security situation is such that much HEU and even plutonium might well be vulnerable to theft either by those inside the organization or by armed attack. Similarly, the HEU weapons of Pakistan might be vulnerable to a coup overthrowing the current president and transferring the nuclear weapons into the hands of supporters of fundamentalist terrorist groups. Hence there are plans among states and alliances, nuclear and non-nuclear for military action to counter proliferation under such circumstances. Still another aspect of proliferation is exemplified by the 1974 Indian test, which misused nuclear materials provided by the United States and Canada solely for peaceful purposes. This is the general problem that confronts the world now with North Korea and Iran.

Iran is much in the Press these days. Iran has vast oil production and resources, but it should also be noted that by 1979 the Shah had taken very seriously nuclear power and had seen to it that many Iranians were trained in Western universities in nuclear physics, nuclear engineering, chemical engineering, and the like. The United States was looking forward to close collaboration with Iran in the building of many power reactors, to the profit of the American nuclear industry. To those who argued that Iran would better burn the natural gas that it was wasting as a byproduct of oil production, the U.S. nuclear industry responded that hydrocarbons were too valuable to use as fuel, and they should be saved for chemical feed stock. The Shah probably had an interest in building the infrastructure for nuclear weapons even if he had not made a decision to build the weapons themselves. The revolution in Iran changed all that, as did the outbreak of the Iran-Iraq war. Revolutionary Iran was now isolated from the United States and to some extent from the West and it saw Iraq with a program to build and even use weapons of mass destruction, including a substantial program to acquire nuclear weaponry, discovered by the West only after the first Gulf War in 1991.

There has been much interaction and some negotiation in the last two years between Iran and the IAEA, and Iran and the EU-3 (France, Germany, and Great Britain). Iran is a member of the NPT as a Non-Nuclear Weapon State, and has signed the additional Protocol of the IAEA, allowing environmental monitoring and inspections almost anywhere, although Iran has impeded such inspections. Iran has a single full-scale power reactor at Bushehr, constructed by Germany and finished this year by Russia, which needs to be supplied with fuel.

Although it hardly matches the necessary time scale, Iran insists that it has a program to provide indigenous fuel for the reactor-- an initial load of 100 tons and 25 tons per year of 4.4% U-235, for which it needs a supply of natural uranium of about 200 tons annually, a conversion plant to convert the uranium ore to uranium hexafluoride (UF6) that can be used as a gas in an enrichment plant, and it needs a fuel fabrication facility to convert the LEU UF6 gas to uranium oxide ceramic pellets and to encase the precision fuel pellets into pencils (“rods” typically 8 mm diameter by 5 meters long).

The IAEA and the EU-3 (and the United States, which in this matter seems to be fully in accord with the EU-3, although it does not talk with Iran directly) are searching for ways to allow Iran to exercise its "inalienable right" to the peaceful use of nuclear energy-- especially nuclear electric power. Indeed, the NPT recognizes this inalienable right, which existed even before the NPT. But it maintains that every NNWS signatory, including Iran, retains that right, only on condition that it remain a member in good standing of the NPT. And that is the dispute.

For the past 20 years, Iran has often not notified the IAEA, as would have been required, about the "peaceful use" program Iran was undertaking. Nor has Iran been totally candid even in recent years, when its notifications have turned out to be only partial and needed to be amended. The Secretary General of IAEA, Mohamed ElBaradei, has noted that IAEA has as yet no evidence that Iran has been undertaking anything but a peaceful program, but it is easy to build almost all of a uranium-weapon infrastructure without doing anything different from a peaceful program. In fact, nuclear weapons are far simpler to manufacture than is an advanced power reactor such as that at Bushehr.

Iran argues that it was not its fault that it did not properly inform the IAEA of its activities, and that the activities would have been perfectly acceptable if it had so informed the IAEA. Iran argues that the United States had erected sanctions against Iran after the revolution, and that Iran had no choice, in exercising its inalienable rights under Article IV, but to do this clandestinely.

ENRICHMENT NEEDS FOR A NUCLEAR WEAPON PROGRAM VS. A CIVIL POWER REACTOR.

Because a UF6 molecule containing U-235 and one containing U-238 are chemically identical, it is their physical properties that must be used in the separation, and this is a relatively small difference in molecular weight. Every fluorine atom weighs 19 atomic mass units (about 19 times as much as a hydrogen atom) so that the 6 fluorines weigh in at 114 amu. The light molecule then weighs in at 349 amu and the heavy at 352 amu-- about 1% different. The United States during World War II used "gaseous diffusion" through a porous barrier to separate the light isotope from the heavy isotope; fundamentally this depends on the relative speed of the gases in a mixture at the same temperature, which differs only about 0.5%. Many, many stages of separation, with intermediate pumps and recompression are required even to go from 0.72 to 1% or 4.4%, and many more stages (handling less material) to go to 95% U-235. Although the United States still uses gaseous diffusion, much of the world's capacity for enrichment now is satisfied by gas centrifuges, small machines turning in a vacuum at very high speed. Through very clever design, these centrifuges can be used in an internally regenerative mode so that a lot fewer stages are required, and only about 2% as much power is needed for a given output of enriched uranium in a gas-centrifuge plant as in a gaseous diffusion plant. Other approaches include the so-called electromagnetic process, even more profligate of energy than gaseous diffusion, but we discuss centrifuge here because that is Iran's plan of record.

Iran has built a large hall at Natanz to accommodate 50,000 gas centrifuges. If these are to be the P1 centrifuges of Pakistan, each produces about two "separative work units-- SWU" per year. A SWU on the commercial enrichment market costs about $100, so such a centrifuge can't be very expensive if it has a product of only $200 per year, which needs to provide not only cost reimbursement but profit. From fundamental thermodynamic considerations, one kg of U-235 as 4.4% U-235 requires the investment of about 150 SWU, beginning with natural uranium at 0.72% U-235 and discarding "tails" at 0.25% U-235. Thus to obtain the one ton per year of U-235 for operation of Bushehr (after the initial investment), one would require about 150,000 SWU per year, whereas Natanz could only produce about 100,000. Perhaps Iran counts on replacing the P1 centrifuges by P2 centrifuges with substantially better performance.

Our point here, however, is to note that 95% U-235 contains only 220 SWU per kg of U-235, beginning with natural uranium, so that a Natanz-like plant at 100,000 SWU/yr would produce about 450 kg of U-235 as 95% HEU. Taking the SQ of HEU as 25 kg, one sees that a Natanz hall of P1 centrifuges could produce on the order of 18 uranium implosion weapons per year, each of which would likely have a yield somewhat greater than the Hiroshima bomb. So a facility that is inadequate for a single power reactor would be of great importance in building a military inventory.

Iran maintains that it has a right to the full fuel cycle, and to a "research reactor" with heavy water moderator and natural uranium fuel, but of 40 MW (electric) size so that it could be used to produce weapon plutonium in the amount of 40kg per year. Iran maintains, in principle, that it is entitled to reprocess fuel from its power reactor, and to have the full front-end of the fuel cycle, from conversion to UF6 at Isfahan to enrichment, and to fabrication of the fuel rods. In the negotiations with IAEA and the EU-3, however, Iran has agreed not to exercise its right to reprocess fuel from Bushehr, and not to exercise its right to the heavy water reactor. But it has insisted on enrichment, and the Parliament in Iran has passed laws limiting greatly the power of Iranian officials to negotiate with the IAEA and the Eu-3.

At the same time, Iran's new President Ahmadinejad has not yet advanced constructive proposals, but has commented (October 26, 2005) that Israel should be "wiped off the map" and that the "realization of the world without America and Israel is both possible and feasible." Iran's supreme leader, Ayatollah Khamenei, commented a few days later that Iran "will not commit aggression towards any nations. We will not breach any nation's rights anywhere in the world."

ElBaradei (and, independently, U.S. President George W. Bush) have proposed generally in 2005 that most nations deploying power reactors should have a guaranteed supply of fabricated fuel and should give up the spent fuel for reprocessing or disposal under an international or multi-national contract. I and my coauthors, Georges Charpak and Venance Journe, emphasize the desirability of IAEA-approved competitive, commercial mined geologic repositories that will accept spent fuel from any nation, if it is in accord with IAEA standards. Thus, Iran would not be singularized in the treatment of its Bushehr reactor or the five or six others that Iran shows an interest in building.

Nevertheless, Iran maintains its inalienable right to enrichment, but has nevertheless mentioned that it would be willing to limit for awhile its enrichment capability to 3000 centrifuges.

As we have noted, 3000 P1 centrifuges operating for a year would provide 6000 SWU of separated work, and could produce from natural uranium about 6000/220 = 27 kg of HEU for weapons. Worse, beginning with a stock of 4.4% U-235, about 80 kg of HEU could be produced-- even more if the tails were allowed to climb to several percent so that only a small fraction of the U-235 would be in the HEU product.

THE ONE-MAN PROLIFERATION MACHINE.

Dr. A.Q. Khan of Pakistan, who stole the Urenco centrifuge design for Pakistani use, is widely regarded in Pakistan as the hero who gave Pakistan the bomb. But in the last two years it has been revealed that he did much more than that, and that he undertook to sell packages of centrifuges materials, and even nuclear weapon plans to Libya and to other countries, probably including North Korea and Iran. Thus it has been disclosed in recent weeks that Iran has had plans from Pakistan for casting hemispherical shells of natural and enriched uranium-- something for which there is no perceptible peaceful purpose. Iran had not revealed this to the IAEA.

If Iran were truly interested to begin operation of its Bushehr reactor, it should accept the IAEA and the EU on the offer to allow Russia to provide fuel. The objective guarantee of the fuel availability might be achieved if there could be an excess amount of fuel stored in Iran, but with a limited grant of sovereignty so that not only would the IAEA control (verify) the amount of the fuel on a daily basis, but U.N. Security Council-sponsored forces could provide security against theft or diversion, supported, as usual, by voluntary contributions from U.N. members. If Iran insisted on mastering the enrichment program, perhaps 200 P1 centrifuges operating would provide the relevant experience, without advancing significantly the date at which a nuclear weapon could be available. These centrifuges would, of course, be verified as producing LEU of no more than 5% U-235, and in any case, even if turned to HEU production, they could produce no more than 400 SWU per year or about 2 kg of HEU annually[3]. Even 10 years of unsafeguarded

[3] For clarity, "It could hardly be said that even 10 years..." has been replaced by "Even 10 years ..." April,2006.

operation to produce one SQ of HEU would do little to advance Iran's capability, in view of what they could do by expelling the inspectors and building centrifuges as rapidly as possible. Of course, if Iran accepted such a 200-centrifuge temporary limitation only as very temporary and insisted on going within a year to 3000 and within two years to 50,000 centrifuges, the nonproliferation benefit of this very limited enrichment capacity would not be worth the effort to negotiate it.

THE FLAW IN THE NPT.

It is now widely recognized because of the Iran and North Korea crisis that it is entirely feasible for a state to build a large "peaceful use" infrastructure, declaring every element of an enrichment plant, for instance, that would be adequate to fuel six power reactors per year, but that if at a later time the decision was made to produce HEU, it would be a matter only of switching some valves in the enrichment cascade so that the gas centrifuges produced HEU instead of LEU, and a six-reactor enrichment system would then produce about 4.5 tons of HEU per year, enough for almost 200 nuclear weapons annually.

Apparently, it would be useful to have states sign a further additional Protocol, committing them to return all materials and equipment obtained under the NPT as an NNWS state, if they later made a decision to pursue nuclear weaponry. This would need to be backed up by the willingness of the nations of the world to use economic and even military sanctions to enforce the commitment undertaken by that individual state. It should be emphasized, however, that in no way would the assured fuel cycle—guaranteed supply of fuel from a multi-national fuel bank, and guaranteed commercial competitive acceptance of spent fuel—impede the development of a commercial power sector. In fact, it would very much aid that development by eliminating major uncertainties that would otherwise beset the industry. Although some states might contribute LEU to the fuel bank with certain conditions, others (perhaps Russia) would not set these conditions, and there would always be the prospect for buying large amounts of LEU fuel—as uranium-oxide powder, or even as fabricated fuel rods years in advance, to provide buffer time for creating a domestic industry, if that were desirable.

On the other hand, 4 years of fresh fuel for 6 reactors would correspond to about 24 tons of contained U-235, a good fraction of which would be available for enrichment to HEU at less than one-third the SWU requirement beginning with natural uranium. So there must be absolute guarantees that this LEU fuel would never be diverted to military uses.

--End of manuscript of December 5,2005--