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The risk of nuclear terrorism and how to decrease it

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Summary

We will review, without going into any technical details, the easiest, hence most likely, route for a terrorist group to destroy a city via a nuclear explosion. We will then outline the steps taken and to be taken in order to decrease the probability that such a terrible event happen.
This is a *very elementary* presentation, prepared for an audience *quite ignorant* about these matters.

The difference between nuclear and conventional explosives

The energies involved in nuclear reactions are about *seven* orders of magnitudes (i. e., *ten million* times) larger than the energies involved in chemical reactions (for equal weight of the material consumed, i. e. transformed)

Kiloton, *Megaton*: units of energy (released in a large explosion)

- 1 Kiloton: the energy released in the explosion of
one thousand tons=one million kilograms
of conventional explosive (TNT)

- 1 Megaton: the energy released in the explosion of
one million tons=one billion kilograms
of conventional explosive (TNT)

Hiroshima (August 6, 1945):

- approximately *ten kilotons*

- Uranium bomb: it contained about *60 kg* of Highly Enriched Uranium (HEU)

- the yield was produced by the fission of about *one kilogram* of HEU

- over *one hundred thousand* deaths

- not tested before

[Highly Enriched Uranium: Uranium containing a very high proportion of the isotope U-235 (say, over 90%): see below]

Nagasaki (August 9, 1945):

- approximately *ten kilotons*

- Plutonium bomb

- over *one hundred thousand* deaths

- tested two-three weeks before, at Alamogordo (New Mexico, USA)

“Most people seem unaware that if separated U-235 is at hand it’s a trivial job to set off a nuclear explosion, whereas if only plutonium is available, making it explode is the most difficult technical job I know”. Luis W. Alvarez, key physicist in the Manhattan project, and subsequently Nobel laureate in physics, in his memoirs published in 1987, one year before his death [Luis W. Alvarez, *Adventures of a physicist*, New York, Basic Books, 1987, p. 125].

Some significant facts about nuclear weapons (1)

- Nuclear weapons have never been used in war after August 9, 1945, although enormous arsenals of these weapons have been accumulated during the cold-war era, especially by the two nuclear superpowers, USA and USSR (now Russia), and in spite of the fact that countries possessing nuclear weapons were involved in several armed conflicts and in some cases were defeated, for instance the USA in Vietnam and the USSR in Afghanistan.

Some significant facts about nuclear weapons (2)

- Many *experimental* explosions of nuclear (“atomic”) and thermonuclear (“hydrogen) bombs have been performed, over *one thousand* by the USA (who performed more nuclear-weapon tests than any other country). The largest experimental explosion was performed by the Soviet Union at the time of Krushev: it released in the high atmosphere a yield of over *fifty megatons*, about *five thousand* times larger than the yield released by the Hiroshima and Nagasaki bombs. Only one prototype of this bomb was manufactured, since its yield is too large for any conceivable military use. Hence its explosion was essentially a public relation exercise.

At the moment there is a universal moratoria about nuclear-weapon tests.

Nuclear-Weapon and Non-Nuclear-Weapon States

The Non-Proliferation Treaty (NPT), concluded at the end of the 1960's, has codified the division of all countries of the world in two categories: *five* Nuclear-Weapon States (NWS: USA, USSR now Russia, UK, France, China), and Non-Nuclear-Weapon States (NNWS: all the others). The NPT has been signed and ratified by *all* States except *three*: India, Pakistan and Israel. The first two have tested nuclear weapons and have declared that they possess a nuclear-weapon arsenal; Israel has an official policy of "opacity" with respect to its nuclear-weapon capability, but it is widely believed to possess an operational nuclear-weapon arsenal.
North Korea – whose status under the NPT is now somewhat ambiguous -- also tested a nuclear explosive device.

A bit of nuclear physics

The release of the energy stored in atomic nuclei can occur via two quite different types of nuclear reactions: the *fission* of a very heavy nucleus (for instance the nucleus of a Uranium or Plutonium atom), or the *fusion* of the nuclei of two very light atoms (typically Hydrogen, or its isotopes Deuterium and Tritium). A *macroscopic* release of energy requires a *chain reaction*, involving a very large number of nuclei. If the reaction occurs at a very fast, uncontrolled rate, the release of energy causes an explosion. If it occurs at a slow, controlled rate it can be used to produce useful energy, typically to produce heat and from it electricity or some means of (naval) propulsion.

Elementary notions about nuclear-weapon technology

There are, *grosso modo*, two types of nuclear explosives: those based on nuclear *fission* (sometimes called “atomic bombs”) and those involving nuclear *fusion* (sometimes called “hydrogen bombs”). The latter are much more sophisticated devices and in any case they require an explosion of the former type to act as trigger: so they generally involve both types of nuclear phenomena, a *fission* trigger then *fusion* reactions and possibly a third stage involving again mainly *fission*. Hence to prevent the proliferation of nuclear weaponry it is sufficient to impede the acquisition of the capability to produce nuclear devices based on nuclear *fission*. The essential “raw materials” available at present for such explosive devices are only *two*: (weapon-grade) *Highly Enriched Uranium* (*HEU*) and *Plutonium*.

Elementary notions about nuclear energy

The production of electric energy via *fission* occurs in nuclear reactors; the main fuel is *Low Enriched Uranium* (*LEU*: Uranium enriched to 3-4% in the isotope U-235). There also are some energy-producing reactors that use as fuel *Natural Uranium* (containing 0.7% U-235, the rest being essentially U-238). And there are smaller reactors, mainly used for research, that use as fuel *Highly Enriched Uranium* (*HEU*). HEU is also used in the (quite compact) nuclear reactors used for naval propulsion, mainly in submarines, and also for some ice-breakers.

Controlled nuclear fusion – that would provide an essentially unlimited source of energy for humankind – has not yet been mastered. Nobody can predict with certainty whether, and especially when, this will happen.

Uranium and Plutonium

Natural Uranium exists in rather abundant quantities in nature: it is radioactive, but its lifetime is very long, several billions of years, so the Uranium produced when the Earth was formed did not have the time to disappear.

Plutonium does not exist in nature (it has a lifetime of a *few tens of thousand* years), but it is produced from *Uranium* in nuclear reactors.

Plutonium (1)

Plutonium is one of the two basic materials for manufacturing nuclear weapons. Manufacturing explosive nuclear devices based on *Plutonium* is much more difficult than manufacturing such devices based on weapon-grade *Highly Enriched Uranium* (*HEU*), but these nuclear weapons have some features that are more appealing from an operational point of view. Therefore States with a sophisticated nuclear-weapon capability possess nuclear reactors specifically dedicated to the production of *Plutonium* for military purposes. The extraction of the *Plutonium* from the spent nuclear fuel is a difficult task because it must be performed at a distance, due to the high radioactivity of the spent nuclear fuel.

Plutonium (2)

Plutonium is produced in *all* nuclear reactors using *Uranium* as fuel, although the *Plutonium* produced in reactors earmarked to civilian applications (i. e., energy production) is less appropriate for manufacturing weapons than that produced in the special reactors earmarked to military employment. The extraction ("reprocessing") of the *Plutonium* contained in the spent nuclear fuel is practiced in certain countries, allegedly in view of its eventual use for energy production, although so far the fuel cycles actually used for the industrial production of energy do not employ *Plutonium*. The stocks of *Plutonium* thus accumulated (also in non-nuclear-weapon countries, for instance in Japan) provide a potential capability for the eventual manufacture of nuclear weaponry.

The difficulty of manufacturing nuclear-weapons

The main difficulty to manufacture nuclear weapons is in the acquisition of the basic materials, weapon-grade *Highly Enriched Uranium* (*HEU*) or *Plutonium*. It is also the aspect of a nuclear-weapon program that is more difficult to hide. Therefore the main barrier against the proliferation of nuclear weapons focuses on preventing the acquisition of *HEU* or *Plutonium*; this is also the main aspect on which the verification -- by the International Atomic Energy Agency (IAEA) located in Vienna – of the respect of the Non Proliferation Treaty (NPT) is based.

Nuclear weapon proliferation

A breakdown of the current nuclear-weapon nonproliferation regime, entailing the spread of nuclear weaponry to many more countries, would put at risk the very survival of our civilization.
Recently there are worrisome symptoms of the possible occurrence of such a breakdown, which might have a catastrophic, “domino-like” development. Indications of this risk are the recent, overt acquisition of nuclear weapons by India and Pakistan, the erratic behavior of North Korea in nuclear-weapon matters, the continued tension in the extended Middle East region where the nuclear-weapon capability of Israel – in spite of its low profile – constitutes a sore point, and, last but not least, the reluctance by the nuclear-weapon states to take seriously their commitment – article VI of the NPT – to eliminate their own nuclear arsenals.

The risk that terrorists get hold of a nuclear weapon (1)

The more nuclear weapons are around, the more serious is the risk that terrorists get hold of one or more of them. This risk is obviously enhanced by the proliferation of nuclear weaponry to more States, especially when significant sectors of the political leadership of these States – and/or of their military forces and security personnel -- are significantly infiltrated by elements sympathetic to terrorist groups.

From this point of view more worrisome are the so-called “tactical nuclear weapons” earmarked for “battlefield use”, especially when they are deployed in the periphery, away from central control centres, and especially if they are not equipped with “protective action links” (PALs), namely electronic devices physically impeding the unauthorized explosion of these warheads.

The risk that terrorists get hold of a nuclear weapon (2)

On the other hand it is reasonable to presume that *all* nuclear weapons are carefully accounted for and well protected. From this point of view their “quantized” character is of course helpful. On the contrary the key materials for the manufacture of explosive nuclear devices – such as Highly Enriched Uranium – are more difficult to keep proper account of, especially when they are processed and then stored as a large number of small subunits (pellets) or as a liquid or a powder. Indeed all techniques used to manage and produce these materials involve significant quantities of Materials Unaccounted For (MUF) -- due, for instance, to their dispersal when flowing through pipes. This of course provides many more possibilities of clandestine diversions of these materials.

The difficulty for terrorists to manufacture an explosive nuclear device (1)

The *explosive nuclear device* likely to be manufactured by terrorists in order to destroy a city is very different from a *nuclear weapon*.

A *nuclear weapon* must be sturdy and compact enough to be *transportable* and it must be mated to a delivery vehicle, it must be *reliable* (in particular, its yield must be *predictable*), it must be *safe* (most unlikely to explode *accidentally*), and it must be part of a *nuclear arsenal* (it makes hardly sense for any State to possess just one such weapon).

The explosive nuclear device likely to be manufactured by terrorists in order to destroy a city need not be transportable (it will be assembled in a rented locale in the target city), it will not be reliable (its yield will be unpredictable, but with a significant probability to be of Hiroshima type), it need not be safe (but its manufacture will involve no health risks, and its explosion shall be triggered by a timer allowing an easy getaway), and of course a single such device will be sufficient to produce a catastrophic damage way beyond anything so far achieved by terrorists.

The difficulty for terrorists to manufacture an explosive nuclear device (2)

It is unfortunately quite easy for a small group of terrorists to manufacture such an explosive nuclear device, provided they can get hold of a sufficient quantity of weapon-grade Highly Enriched Uranium (HEU). All the other materials needed are easily available in the open market, except possibly for some conventional explosives (if they are at all needed) easily obtainable in the black market. Bringing clandestinely all these materials to the locale where the device will be manufactured is also quite easy. And all the information needed to project such a device is easily available from open sources, available for instance via internet. Hence no specific nuclear-weapon know-how will be required – although it might ease the task.

The difficulty for terrorists to manufacture an explosive nuclear device (3)

Manufacturing an explosive nuclear device using *Plutonium* rather than *Highly Enriched Uranium* (*HEU*) as basic material is much more difficult. It requires a substantial program of research and development, which most States would be able to manage, but that no terrorist group is likely to be able to organize clandestinely.

Hence the main barrier preventing terrorists from destroying a city via a nuclear explosion is the difficulty for them to acquire a sufficient amount of weapon-grade *Highly Enriched Uranium* (*HEU*).

The acquisition by terrorists of *Plutonium* is in any case to be avoided, because this material is quite convenient to manufacture a Radioactive Dispersion Device (so-called “Dirty Nuclear Bomb”).

A radioactive dispersion device

Much has been made about the risk involved by the possibility that terrorists get hold of radioactive materials and deliberately contaminate with them inhabited areas (cities). A terrorist act of this kind is likely to create widespread panic -- also due to the inability of humans to sense radioactivity, hence the widespread fear of it – and to cause a significant, possibly enormous, economic impact. It is on the other hand unlikely to cause many immediate deaths because it is extremely difficult to spread sufficient quantities of radioactivity to cause serious radiation sickness possibly resulting in death. Hence such an event, while quite unpleasant, is incomparably less dramatic than an actual nuclear explosion of Hiroshima type.

The most appropriate countermeasure is, of course, to monitor carefully all radioactive materials, and to educate the public at large about radioactivity including the ease to measure it, making largely available simple instruments to do so.

The difficulty for terrorists to acquire a quantity of HEU sufficient to manufacture easily an explosive nuclear device (1)

One hundred kilograms of weapon-grade Highly Enriched Uranium (HEU) – i. e., HEU adequately uncontaminated and containing, say, over 90% U-235 – is more than sufficient to manufacture easily a nuclear device likely to yield an explosion of Hiroshima type. Carrying clandestinely this amount of HEU – the volume of which is less than *ten litres* -- to the target city is a trivial task, indeed trying to defend a country by erecting barriers capable to intercept such transfers is a useless waste of resources.

The enrichment of Uranium is a difficult technological task – certainly beyond the capabilities of any terrorist group, indeed few countries master this task.

The difficulty for terrorists to acquire a quantity of HEU sufficient to manufacture easily an explosive nuclear device (2)

Unfortunately enormous quantities of (weapon-grade) Highly Enriched Uranium (HEU) have been accumulated during the cold war, especially in the Soviet Union (now mainly stocked in Russia) and also in the United States.

No more HEU is now produced in the *five* nuclear-weapon States (as defined by the NPT: USA, Russia, United Kingdom, France, China), although it has not been possible until now to agree on a Treaty codifying, and verifying, this commitment.

But in Russia alone there probably still are as much as *one million* kilograms of HEU, and substantial quantities of HEU also exist in the USA -- where a large stock of this material has been set aside for future employment as fuel for nuclear-propelled submarines.

The difficulty for terrorists to acquire a quantity of HEU sufficient to manufacture easily an explosive nuclear device (3)

Up-to-date information on the stocks of Highly Enriched Uranium (HEU), and also of Plutonium (and nuclear weapons), existing worldwide are provided by the Global Fissile Material Report 2007, the second report issued by the International Panel on Fissile Material (an international group of independent experts) "Developing the Technical Basis for Policy Initiatives to Secure and Irreversibly Reduce Stocks of Nuclear Weapons and Fissile Materials": see www.fissilematerials.org (quoted below as GFMR07).

The International Panel on Fissile Materials (IPFM)

“The International Panel on Fissile Materials (IPFM) was founded in January 2006. It is an independent group of arms-control and nonproliferation experts from sixteen countries, including both nuclear weapons and non-nuclear weapon states.

The mission of the IPFM is to analyze the technical basis for practical and achievable policy initiatives to secure, consolidate and reduce stockpiles of highly enriched uranium and plutonium. These fissile materials are the key ingredients in nuclear weapons, and their control is critical to nuclear disarmament, halting the proliferation of nuclear weapons, and ensuring that terrorists do not acquire nuclear weapons.”

“The Panel is co-chaired by Professor R. Rajaraman of Jawaharlar Nehru University in New Delhi and Professor Frank von Hippel of Princeton University. Its members include nuclear experts from Brazil, China, France, Germany, India, Japan, South Korea, Mexico, the Netherlands, Norway, Pakistan, Russia, South Africa, Sweden, the United Kingdom and the United States…” www.fissilematerials.org.

Preventing terrorists from acquiring the capability to destroy a city by a nuclear explosion

The key step is to ensure that terrorists do not acquire a quantity of Highly Enriched Uranium (HEU) sufficient to manufacture easily an explosive nuclear device. To achieve this goal it is necessary to secure all existing stocks of HEU, and it is obviously expedient to eliminate these stocks as soon as possible and as completely as possible. The elimination is of course a more efficient measure, since it solves the problem drastically -- while securing the stocks of HEU requires a permanent vigilance, entailing an endless investment of funds, advanced technology and reliable personnel.

Securing the nuclear weapons of the former Soviet Union

After the break-up of the Soviet Union there was much concern about the security of its enormous nuclear arsenal -- including *tens of thousands* of tactical nuclear weapons -- and its very large stocks of nuclear materials, including enormous quantities of Highly Enriched Uranium. Fortunately all the tactical nuclear weapons were withdrawn to the territory of Russia before the dissolution of the Soviet Union -- while the strategic nuclear weapons deployed in Belarus, Kazakhstan and Ukraine were eventually dismantled when these new independent countries acceded to the Non Proliferation Treaty (NPT) as Non-Nuclear-Weapon States: a major positive development made possible by the existence of the NPT.

Securing the nuclear materials of the former Soviet Union

After the disintegration of the Soviet Union there was much concern in all informed circles about the risk that nuclear materials – especially Highly Enriched Uranium (HEU) – stored in Russia and in the other New Independent States might get lost, ending in dangerous hands. Substantial funds were invested, mainly by the USA – due to an initiative spearheaded by the US Senators Lugar and Nunn – to assist Russia in securing these materials. In spite of initial difficulties to collaborate in such a sensitive field, these Nuclear Threat Reduction programs have been quite successful. The United States has invested substantial funds -- almost one billion US dollars per year over many years – and other countries (Europe, Japan, Canada) have also contributed, although much less. Presumably the situation has by now considerably improved, also thanks to the consolidation of the political and economic situation in Russia. A considerable amount of co-operation in this field continues, in spite of the unfortunate recent chilling of the relations between Russia and the USA (and other Western countries).

Eliminating Highly Enriched Uranium

From the *technological* point of view the elimination of Highly Enriched Uranium (HEU: containing generally over 90% U-235) is an *easy* task: by mixing it with Natural Uranium (containing only 0.7% U-235) or Depleted Uranium (a by-product of the enrichment of Natural Uranium containing *less* than 0.7% U-235), Low Enriched Uranium (LEU: generally containing from 3% to 5% U-235) is *easily* obtained. This is the fuel utilized in most nuclear reactors for energy production hence it is a *quite valuable* commodity.

The reverse process – enriching Uranium, to produce, from Natural Uranium, Low Enriched Uranium (LEU) or Highly Enriched Uranium (HEU) -- is instead a *difficult* and *costly* technology, mastered by private corporations or public institutions in only few States. And the *same* technology yielding LEU -- whose acquisition can therefore be justified in the context of a civilian nuclear energy program -- can also be used to produce HEU, with only a, relatively minor, additional investment of energy and time. Hence quite intrusive verification is required in order to ensure that enrichment installations ostensibly meant to produce LEU are *not* used to also produce HEU clandestinely. Or such capabilities -- having been developed to produce LEU in the context of a peaceful nuclear program -- might be used to produce HEU by a country *immediately after* forsaking its nuclear nonproliferation commitment.

Eliminating the large stocks of Highly Enriched Uranium in Russia

After the dissolution of the Soviet Union Russia found itself in possess of a huge stock of Highly Enriched Uranium (HEU), that was also later increased by the dismantlement of nuclear warheads that took place in the context of the limited nuclear disarmament that Russia – as well as the USA, the United Kingdom and France – performed after the end of the cold war. Although no official announcement was ever made, it is believed that this stock exceeded *one million* kilograms of weapon-grade HEU.

At the beginning of the 1990's – also in the context of the serious economic crisis in Russia – the Russian Parliament agreed that *half a million* kilograms of HEU were excess to the security needs of Russia, and this opened the way to downblending this material to produce LEU to be then sold to American utilities.

The HEU Deal (1)

This deal, concluded by the Russian State Nuclear Agency with an American Corporation -- the, just at that time privatized, United States Enrichment Corporation (USEC) – envisaged the downblending in Russia of *half a million* kilograms of Highly Enriched Uranium (HEU) to Low Enriched Uranium (LEU), the transfer of this LEU to the United States and its sale to American utilities who would use it to produce nuclear electricity. The envisaged income to Russia was expected to reach *twelve billion* US dollars – to be entirely paid by the electrical utilities (the deal was advertised as entailing "no cost to the American taxpayer"). But unfortunately this important deal – concluded in 1993 – although motivated by obvious security considerations, was eventually transformed -- consistently with the private character of USEC -- into a commercial affair in which security considerations took the back seat. So its implementation was spread over *twenty years* (mainly to minimize its impact on the market price of LEU), and was moreover beset by recurrent delays due to haggling about its commercial aspects. Now the deal seems to be implemented smoothly, eliminating

thirty tons = thirty thousand kilograms

Russian HEU ***every year***; over *300 tons* have already been eliminated, *500 tons* (advertised by USEC as corresponding to *twenty thousand* nuclear weapons) shall be eliminated by 2013. Already *$4.6 billion* have been paid to Russia, and it is expected that *$7.6 billion* shall have been paid by 2013. For up-to-date information see the entry "Megaton to Megawatts" in the USEC website: http://www.usec.com .

The HEU Deal (2)

This is a positive result, although much more could and should be done, indeed a faster rate of elimination (by as much as a factor of *five*) would have been feasible – certainly technologically and probably also in terms of Russian willingness – provided adequate funds were available to support an acceleration of the elimination of the *500 tons* of HEU declared excess by Russia. An extension of the project so as to eliminate *additional* quantities of Russian HEU can also be envisaged, perhaps via a different sort of financial arrangement (see below). Unfortunately – and in my opinion most unwisely -- the USA and other affluent countries do not seem as committed to address this question as it should be implied by the lip service paid to the risk of nuclear terrorism, for instance at the meeting of the G8 group of nations (or G7+1: Canada, France, Germany, Italy, Japan, UK, USA + Russia) held at Kananaskis over a year ago, where the formula 10+10/10 (*ten plus ten over ten*) was advertised, meaning an agreement "in principle" to devote *10 billion US dollars* by the USA, plus *10 billion US dollars* by the other countries, over the next *10 years*, to promote various developments meant to alleviate the risk of the use by terrorists of means of mass destruction. But these commitments have not been and are not being fully implemented.

It is also doubtful whether Russia would now be willing to eliminate additional quantities of HEU – although it certainly could do so without in any way compromising its security (rather, improving it!).

Additional initiatives

A study, advocating faster progress in the elimination of Highly Enriched Uranium (HEU) and suggesting political and financial arrangements to this end has been completed some years ago. It originated in the Pugwash context, and it was eventually commissioned by the Swedish government and performed by an international expert group: it is available on the Pugwash website [www.pugwash.com]. The hope was that the Swedish government would take it up and promote it in the international, and especially in the European, context; this has not really happened for various unfortunate reasons, including the assassination of the Swedish Foreign Affairs Minister. The main idea of that study is to offer financial incentives to Russia (and possibly to other countries of the former Soviet Union; but most of the HEU is in Russia) in order to promote additional elimination of Russian HEU besides that already agreed with the USA.

Eliminating Highly Enriched Uranium in the USA

“In the United States, a total of 87 tons of excess HEU had been blended down as of mid-2007. None of this HEU was weapon-grade. The United States plans to blend down or otherwise dispose of 147 additional tons of HEU, some from weapons, over the next few decades.

Russia and the United States retain for weapons a combined total of 600 to 1200 tons of HEU – sufficient for 25,000 to 50,000 nuclear warheads. The United States has set aside almost all its excess weapon-grade uranium for use as naval-reactor fuel – enough for 5,000 more nuclear warheads. Russia and the United Kingdom also have large reserves of HEU for naval fuel. These naval HEU stockpiles, and their vulnerable processing and transport links, would be eliminated if the three countries followed France’s example and moved to naval reactors fuelled with LEU.” [quote from GFRM07, page 3]

Eliminating Highly Enriched Uranium worldwide

"HEU also has been used as a fuel for research reactors worldwide since the 1960s. The United States is leading a global effort to clean out often insecure civilian HEU. Thus far, HEU in both fresh and spent fuel has been completely removed from sixteen countries. Twenty-eight, however, still have enough civilian HEU to make at least one nuclear weapon. Russia, which has half of the world's 140 HEU-fueled research reactors, has no policy with regard to HEU cleanout at home." [quoted from GFMR07, page 3]

A world without Highly Enriched Uranium

It is plain that the long-range future of our civilization cannot coexist with the availability of a material that provides to a very small group of people – possibly even to a single individual – the capability to destroy a city. Eventually Highly Enriched Uranium (HEU) shall have to be *completely eliminated*. This does not entail the phasing out of nuclear energy, which only requires the availability of Low Enriched Uranium (LEU). But it does require that all capabilities to enrich Uranium shall be closely monitored by the IAEA, indeed it suggests the desirability that they shall eventually all have a *multinational* management.

A world without Plutonium (1)

It appears moreover desirable (although opinions about this differ) that the future of our civilization be free of Plutonium – so that, to the extent fission nuclear energy will be part of humanity's future, this should be on the basis of nuclear fuel cycles forsaking the reprocessing and recycling of Plutonium. This also suggests – for the immediate future – the desirability of eliminating the existing Plutonium via immobilization and its inclusion in nuclear waste disposal rather than via its use for instance as MOX fuel in nuclear reactors. But these as well are very controversial matters.

A world without Plutonium (2)

When the risk is emphasized that terrorists manufacture an explosive nuclear device with Highly Enriched Uranium (HEU), hence the advisability is stressed to invest funds in order to eliminate this dangerous material, often someone intervenes to emphasize the analogous risk arising from the possible availability of Plutonium – ignoring or downplaying the much greater difficulty for a terrorist group to manufacture an explosive nuclear device with Plutonium rather than with HEU. In my experience those who so argue tend to come from countries – and sometimes even to be on the payroll of companies – who stand to gain considerably from international investments earmarked to the elimination of Plutonium (for instance by burning it in nuclear reactors in the form of MOX fuel, produced by these companies in these countries), rather than to the elimination of HEU (that, in economic terms, entails essentially channelling funds to Russia).

The relevance of nuclear disarmament

"Nothing would reduce the nuclear threat to civilization and increase the credibility of the nuclear nonproliferation regime more than the United States and Russia cutting their weapons and associated fissile-materials stockpiles much more deeply.

There are well developed proposals for how the United States and Russia could quickly reduce the number of warheads in their nuclear stockpiles to 1000 each. Deeper cuts to about 200 weapons each could be made if other nuclear weapon states joined the arms limitation process. Such deep cuts would make it possible to eliminate most of the global stockpile of weapons HEU and plutonium." [quoted from GFMR07, page 4]

A world without nuclear weapons

Some of us have been arguing since long ago that it is imperative to begin and think seriously about the eventual complete elimination of nuclear weaponry, indeed the 1995 Nobel Peace Prize was jointly assigned to Joseph Rotblat and to Pugwash "for their efforts to diminish the part played by nuclear arms in international politics and in the longer run to eliminate such arms."

I cannot therefore refrain from ending this talk by mentioning this topic – obviously somewhat connected with the main focus of my presentation – in view of the significant developments that occurred quite recently on this front, in the guise of interventions by individuals carrying considerable political weight at least as advisors undoubtedly belonging to the "realist" (rather than the "utopian") camp. I limit this contribution to listing a few references.

A world without nuclear weapons (some recent references)

- George P. Shultz, William J. Perry, Henry A. Kissinger and Sam Nunn, "*A World Free of Nuclear Weapons*", The Wall Street Journal, January 4, 2007.
- Mikhail Gorbachev, "*The Nuclear Threat*", The Wall Street Journal, January 31, 2007.
- Arnold Schwarzenegger, "Governor Schwarzenegger's Nuclear Disarmament Remarks", October 24, 2007.
- George Bunn and John B. Rhinelander, "Reykjavik Revisited: Towards a World Free of Nuclear Weapons", World Security Institute, September 2007.

All these recent papers – and many others on this topic -- are easily googable.

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