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Limiting the Hazards of Nuclear Weapons in a World of Nuclear Power

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The previous speakers have provided an excellent view of the serious security problems posed by the existence of nuclear weapons and even by the knowledge of how to build them. These hazards are exacerbated by the fact that nuclear weapons have spread beyond the 5 "official" nuclear weapons states of the NPT, and further by the enormous overhang of excess nuclear weapons in the inventories of the U.S. and Russia, and even a surplus of some hundreds in the armories of the United Kingdom and France.

In this talk I will first deal with the hazard of terrorist nuclear explosives, the link to expanded nuclear power, a regime that de-links nuclear power and nuclear weapons by technology and political mechanisms, and national survival of a terrorist nuclear explosion.

THE HAZARD OF TERRORIST NUCLEAR EXPLOSIVES.

You have heard, no doubt, that although "weapons grade" plutonium is to be preferred for making nuclear weapons, that so-called "civil plutonium" separated from the spent fuel of the power reactors that provide 20% of the world's electrical power can also be used to make nuclear explosives. None of the nuclear weapons states would do so, because civil Pu is inferior in every way to weapon-grade Pu, except that it may be far more readily available to a terrorist or to a state that is not formally an NPT member.

Carson Mark, long head of the Theoretical Division at Los Alamos, made this clear in his 1993 article in Science & Global Security; and the National Academy of Sciences Committee on International Security and Arms Control, of which I was and still am a member, addressed this problem in its book-length reports of 1994[1]. In particular, if the improvised nuclear explosive design satisfactorily deals with the 4-fold greater heat from the civil plutonium, Mark shows that the explosive yield of such a bomb would not be less than one or two kilotons and that more sophisticated design methods could provide a yield equivalent to the full yield of a corresponding weapon made with weapon-grade plutonium.

[1] "Reactor-Grade and Weapons-Grade Plutonium in Nuclear Explosives" pages 32-33 of "Management and Disposition of Excess Weapons Plutonium," Report of the National Academy of Sciences, Committee on International Security and Arms Control, W.K.H. Panofsky, Chair, January 1994. tinyurl.com/2kxmz7

The scale of damage from the ground-level explosion of a 1-kt or a 10-kt nuclear device in a major city is sketched in my paper of 2002[2] and is in the range of 100,000-300,000 dead (mostly by fire and radiation), and the denial of some sq km of land from productive use by virtue of the intense local fallout that was absent at Hiroshima and Nagasaki.

Hiroshima, October 1945

Nagasaki, 20 kilotons

A recent report of the Royal Society of London[3] addresses weapon-use of civil plutonium as an urgent problem, because as of end-2005 the United Kingdom possesses about 105 metric tons of separated civil plutonium, and France has another 50 tons. Japan owns approximately 44 tons and has about 9 tons in Japan.

A terrorist weapon using civil plutonium would require less than 10 kg of plutonium, thus allowing the fabrication of 100 such weapons from a single ton of the 200+ tons of separated civil plutonium in the world.

Far simpler to make than a Pu-implosion weapon would be an improvised nuclear explosive using weapon-grade uranium, which by comparison with Pu is hardly radioactive at all. With ready enough access, a terrorist group might obtain the requisite 60 kg or so of HEU for a "gun-type assembly" in which one portion of the HEU mass is projected at the other at the modest speed achieved in an ordinary artillery piece. But a terrorist weapon to destroy a city need not be packaged to survive delivery by air or even by truck; it might be assembled in place in an apartment or basement room in the highest density or most valuable portion of a city.

We have wasted much valuable time since the demise of the Soviet Union in 1991, and half measures are peculiarly ineffective in securing weapon-usable nuclear materials against theft or diversion. It is not like securing the gold at Fort Knox, where if one ensures that 99% of it cannot be stolen, most of the concern vanishes. Russia[4] has about 800 tons of excess HEU and 90-140 tons of excess weapon Pu, and there are obviously weapons and weapon materials in all of the states with nuclear weapons, the official five plus Israel, India, North Korea, and Pakistan. The available weapon materials would suffice to make some 60,000 nuclear weapons, so that even if 99% of the material was fully secured, there would be 600 weapon-equivalents still cause for concern.

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[2] "Nuclear and Biological Megaterrorism," by R.L. Garwin, presented at 27th Session of the International Seminars on Planetary Emergencies, Erice, Sicily, August 19-24, 2002. (A shorter version was published in MIT's Sept. 2002 Technology Review, titled "The Technology of Megaterror" at http://tinyurl.com/33ljnw

[3] "Strategy options for the UK's separated plutonium, "Policy document 24/07," (See wwww.royaloc,.ac.uk)

[4] www.princeton.edu/~aglaser/2007aglaser_sipri.pdf (pp. 562, 567.

Of course, the concern would be maximal if the remaining 600 weapon equivalents were at 600 different places, and the efforts required to provide security for the material would be enormously greater than if the material were consolidated at a single or relatively few sites.

Little Boy and Fat Man, 13 and 20 kilotons

Outline

1. The hazard of terrorist nuclear explosions
2. The link to expanded nuclear power
3. Don't sell deterrence short
4. The unthinkable will happen
5. Summary of threats
6. What to do to limit the spread of nuclear weapons to states and individuals while allowing the expansion of nuclear power

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THE LINK TO EXPANDED NUCLEAR POWER.

Adding to the legacy of separated plutonium and to the problems associated with uranium enrichment plants is the prospect of a greatly augmented nuclear power infrastructure as the number of reactors increases from the 400 or so to perhaps on the order of 10,000 that would make a serious dent in the carbon dioxide emissions. Proponents of nuclear power naturally use the prospect of reduction of greenhouse gas emissions by the substitution of nuclear power for fossil fuels as a selling point, and proponents of advanced nuclear technology put a "proliferation resistant" label on their favorite approach, whether or not on balance it reduces the proliferation hazard from the nuclear power sector.

The DOE Global Nuclear Energy partnership-- GNEP-- takes as its goal the creation of a secure fuel cycle in which most reactor operators (and even countries) would be clients, acquiring their enriched uranium fuel from a relatively few reliable, secure suppliers, so that they would have no native enrichment plants. At the "back end" of the fuel cycle, the highly radioactive spent fuel would be stored for a few years at the reactor site and then shipped in hundred-ton casks to one of the supplier nations for disposal or reprocessing. Actually, GNEP goes off the track here, in my opinion and testimony, in assuming that the spent fuel will be reprocessed and that the plutonium and other transuranic elements will be burned up in specialized "burner reactors", which are just like breeder reactors except that the natural uranium content of the reactor is minimized, so that there is little production of new plutonium for each plutonium destroyed[5]. Unfortunately, there has been no demonstration of a burner reactor that does not make a substantial amount (say 65%) as much plutonium as it burns, so that the burner reactor system would be vastly expensive.

Most of the GNEP energy and proposed expenditure would be for the technology of reprocessing in burner reactors, whereas the benefit would come from a political acceptance of the secure supply of enriched uranium and a competitive, commercial system of mined geological repositories to which the spent fuel could be committed. GNEP appears about to die an early and well-deserved death, but I hope that it does not take with it the concept of secure fuel supply and disposal. Although the leaders of the

[5] "GNEP:Leap before looking" R.L. Garwin, March 27, 2007, http://www.fas.org/rlg/GNEP_ACS_2Hf.pdf

French and Japanese nuclear power programs often argue that reprocessing of spent nuclear fuel in necessary because these countries have no native uranium resources, such an approach to recycling plutonium can save at most 20% of the imported uranium, at a cost of approximately $750 per kg of uranium saved in this way, in comparison with current prices that have been in the range of $40-80 per kg. This would still require the importing of 80% as much uranium as the no-reprocessing approach. Never evaluated, apparently, is the option of "buying ahead" and taking delivery of uranium supplies as much as 10 years in advance, to guard against political pressure or supply interruptions-- protection that the 20% reduction in uranium imports does not provide.

In fact, I strongly favor a future that ultimately has fast-neutron reactors in the form of breeders, but their problems of design and safe operation must be frankly faced because unlike the reactors that operate with slow (so-called thermal) neutrons, a fast reactor can actually have a small nuclear explosion. A nuclear explosion in a nuclear reactor might have a yield of considerably less than a ton of high explosive equivalent, but it could be highly significant in view of the enormous amount of radioactivity not created during the explosion but liberated during the explosion from its generation over the years of operation of the reactor. This was, for instance, the case at Chernobyl, which had an ordinary steam explosion and not a nuclear explosion, but nevertheless liberated much of the radioactivity in the form of fission products produced by the operation of the power reactor over the previous few years. If nuclear reactors are to play a substantially increased role in the provision of electrical energy, beyond the present 20% of the world's electricity, it is essential that accidents be rare and that an accident now and then, even leading to melting of the core and liberation of much of the radioactivity, not provoke a worldwide shutdown of nuclear power. In the future, such shutdown would be impossible to achieve because of the dependence of society on the continued production of electrical energy by means of nuclear reactors. It is impossible now in France, where 80% of the electrical supply comes from nuclear fission.

Although one can imagine but probably not achieve totally safe nuclear reactors, even if there were an absolute commitment to their use reactors of existing type and even the existing reactors themselves will be with us for a long time.

The design of reactors to be absolutely safe is to be encouraged, but safety depends also on proper maintenance, and that is imperiled in the industry by the supremacy of the profit motive over the requirements for safety, as attested in the October 2003 meeting of the World Association of Nuclear Operators-- WANO-- where those who actually operate and profit from nuclear power testified as follows:

"A terrible disease" threatens nuclear operating organizations from within, and it begins with "loss of motivation to learn from others ... over confidence ... (and) negligence occurs in cultivating a safety culture due to severe pressure to reduce costs following the deregulation of the power market." WANO Chairman Hajimu Maedae went on to warn that these troubles can be "like a terrible disease that originates within the organization ..." and can lead to "a major accident ..." that could "destroy the whole organization."[6]

Even without the profit squeeze on safety, it would be difficult to fight human nature, and two recent occurrences in the U.S. nuclear security arena provide a sobering lesson. The first occurred on August 29, 2007, when six advanced cruise missiles, complete with their nuclear warheads, were loaded onto the wing of a B-52 bomber at Minot Air Force base in North Dakota and flown to Barksdale Air Force Base in Louisiana, without anyone's knowledge that the missiles were nuclear armed. For 36 hours, the nuclear weapons were without the special supervision and guard always associated with them.

[6] Nucleonics Week, article by Ann Maclachlan, October 16, 2003

The second problem surfaced more recently[7] when it was revealed that the commander of a U.S. Navy nuclear-powered submarine and his crew had schemed to falsely document the required daily inspection of the reactor, which never took place. It is apparently an unsolved problem how to motivate the individuals who are responsible to look after the safety of us all. What is perfectly clear, though, is that punishing those who did not fulfill their day-to-day responsibility will not solve the problem. One needs to move up the ladder to those who devised the measures for safety and security and judged them adequate, and those who have been responsible, in principle, for evaluating in a timely manner the compliance with those measures.

It will probably take a terrorist explosion to bring the world to the shared commitment that such a thing should never happen again, and that nuclear war with large numbers of nuclear weapons would not be a good idea either.

THE FUTURE OF NON-PROLIFERATING NUCLEAR POWER

When that commitment does exist, the International Atomic Agency-- IAEA-- will have its budget for safeguards and enforcement multiplied by five or ten from the current $109 M per year. Enrichment facilities will either be openly operated under the control of IAEA and a supporting coalition of nations, or they will be shut down and dismantled. The secure fuel cycle will operate with competitive, commercial, mined geologic repositories in various countries of the world, to reduce the amount of aged spent fuel potentially available to terrorists or proliferators, and far better security will be provided to the fresh fuel and to the spent fuel in cooling ponds near reactors,

Almost all nations, then as now, will have signed the Nonproliferation Treaty as a non-nuclear-weapon state, but those who have nuclear power or research reactors will sign a new Additional Protocol to the NPT, so that nuclear facilities and materials produced while an NPT member could not be retained by the country, if it left the NPT, and there should be adequate enforcement with backup troops from a special UN-operated force, that could deploy rapidly as required to supplement normal security forces. Will the nations of the world ever have this commitment, together with one to reduce national holdings of nuclear weapons and, as a step on the way to their entire elimination, to have a relatively few at the service of an appropriate international authority?

Randall Forsberg, initiator of the nuclear freeze movement that peaked in 1982 died October 19, 2007. I hope that she was cheered by the January 4, 2007 article in the Wall Street Journal by Henry Kissinger, Sam Nunn, Bill Perry, and George Shultz, endorsing the goal of eliminating nuclear weapons and steps toward that goal. This emerged as a majority view of an October 2006 Reykjavik II meeting at the Hoover Institute at Stanford University, spearheaded by Sidney Drell and George Shultz. A follow-on meeting just took place October 24-25, 2007, with a speech from Arnold Schwarzenegger, from which I quote:

"The most dangerous consequences of nuclear weapons, however, are here and now. They are of this hour and time. A nuclear disaster will not hit at the speed of a glacier melting. It will hit with a blast. It will not hit with the speed of the atmosphere warming but of a city burning. Clearly, the attention focused on nuclear weapons should be as prominent as that of global climate change. After he left office, former Vice President Gore made a movie about the dangers of global warming. I have a movie idea for Vice President Cheney after he leaves -- a movie about the dangers of nuclear proliferation. If you Google 'global warming,' you will find 6,690,000 entries. If you Google 'Britney Spears,' you will

[7] "Nuclear Submarine Commander Removed" Associated Press, October 26, 2007 (http://tinyurl.com/2tqfdg)

find 2,490,000. If you Google 'nuclear disarmament,' you will get 116,000 entries. And if you Google 'nuclear annihilation,' you will get 17,400. Something is wrong with that picture."

Such a regime, together with its enforcement cannot coexist with United States "exceptionalism," but only if the United States takes the lead in helping to create and to abide by a mandatory regime.

My own view began with more than 57 years of working with nuclear weapons-- initially 8 long summers at Los Alamos where I helped improve fission bombs and introduced new techniques for obtaining detailed information in nuclear explosion tests, and then provided the specific design for the first test of a hydrogen bomb-- almost 1000 times the explosive yield of the highly enriched uranium bomb that destroyed the city of Hiroshima. Beginning in 1953, I worked with scientists in Cambridge, MA, on defense of North America against Soviet bombers armed with their nuclear or thermonuclear weapons. I argued that by the time any of our improvements in air defense could see the light of day, the threat would be intercontinental ballistic missiles, against which we had no defense.

DON'T SELL DETERRENCE SHORT

For decades I evaluated for the President proposed ballistic-missile defenses, as a member of the Strategic Military Panel of the President's Science Advisory Committee. They wouldn't work, and with one exception they were not deployed. Their ineffectiveness did not arise from any lack of will to make them work, but primarily because the advantage lies with the offensive side, that can overwhelm, overfly, or outfox the defense. The missile defense currently being deployed at the cost of some $10B per year has these same problems; against even a few ICBMs it will fail if the attack includes balloon decoys in the mid-course phase, where the intercepts are to take place, with the warhead enclosed in its own aluminized balloon to look like one of the decoy balloons-- "antisimulation".

The defense against nuclear weapons had better be perfect, because the destruction of a city by nuclear attack is such an enormous loss. That is why deterrence of attack has been so important, despite its questionable morality, and why it is so important to keep nuclear weapons or improvised nuclear materials out of the hands of undeterrable terrorists.

THE UNTHINKABLE WILL HAPPEN

There will be reactor accidents and melt-downs. With enough nuclear weapons and a long enough time horizon, unless year-by-year the safety and surety of nuclear weapons everywhere is improved continuously, there will be an unintended nuclear explosion or a terrorist nuclear explosion somewhere. In fact, in my opinion, we are so far behind in the necessary measures that I believe that there is more than a 50% probability that there will be a terrorist nuclear explosion in a major city sometime in the next ten years. Former SecDef Bill Perry has expressed a similar view. [Added after the talk:] In his MIT Ph.D. thesis[8], "Guardians at the Gates of Hell, Estimating the Risk of Nuclear Theft and Terrorism and Identifying the Highest-Priority Risks of Nuclear Theft" Matthew Bunn provides an analysis of the probability of each step on the way to a successful terrorist detonation in a target city. It does not do justice to the depth and breadth of the analysis, but a quotation will give the flavor and an example that happens to be about 3% per year for a terrorist nuclear explosion in a city:

> *"Thus, assumptions similar to these would support estimates of a 30-50% probability of nuclear terrorism over the next decade that have been made by some analysts. (By chance, the 29% over 10 years estimate in this numerical example is identical to the average estimate of the*

[8] at http://dspace.mit.edu/handle/1721.1/39006

probability of a nuclear attack anywhere in the world over the next ten years in a poll of selected international security experts by Senator Richard Lugar in 2005.)"

Even with a potential death toll of 300,000 people, such an event would kill about one person in 1000 in the United States, but could lead to the self-destruction of the country-- either through the measures that would be taken in the name of security in the immediate follow-on, or in the physical and economic collapse of the country because measures were not taken to be able to maintain its operation in the face of loss of the hardware, the software, and the data that would be destroyed or made inaccessible by such an event.

For instance, if the normal financial system broke down so that individuals throughout the country could not be paid, the shipment of food to cities would collapse almost immediately, and people would surely starve, in view of the long distances most of the necessary food travels in our modern society. Similarly, manufacture would grind to a halt; fuel would not be available for transport. Obviously these social and economic phenomena would be met by martial law, in the hope that the system could run on autopilot, and immediate collapse would be prevented. But imagine the public outcry if the agencies of the US government began to study how best to implement martial law, if it became necessary.

Of course, Washington, DC, is unique in being the seat of the federal government, and of almost all those who would succeed the President if he or she were lost in a nuclear attack. But I am more concerned with New York, or even with some unique manufacturing capability such as the enormous plants for manufacture of integrated circuits, and of the knowledge required to rebuild them. Unlike the confrontation with the Soviet Union, when we risked that destruction of the majority of the people, structures, and capability of our country, the physical threat now is only to a tiny fraction-- just the job, you might say, for an insurance policy. But this is not 1918, when the Spanish Flu killed 700,000 of the US population of 105 million-- a 2.5% mortality rate compared with the 0.1% typical of seasonal flu. At that time, all recorded information was in books or ledgers, not in specialized computer form; and the society was far less specialized. An insurance policy for your house will build you a new dwelling in case of fire, but it may not be able to replace a unique facility or personnel lost to terrorist nuclear attack.

Nor can one depend on the private owner of the semiconductor factory or even of elements of the financial system to provide assurance to the level required if the nation is to survive such a shock. It is clear that "economy of scale" can be a very false economy if it results in a single or even two facilities rather than a larger number of smaller and slightly less efficient plants, and this is so even on the mundane level of a 2000 megawatt generator for a large coal-fired power plant, as contrasted with 4 500-MW machines. What is needed now is not panic over the prospects of loss but a real analysis, sector by sector, of necessary redundancies and of the way to fund, build, and test them. The purpose is "continuity of business," for society as a whole. This is not defeatism but prudence, just as one should plan for one's own demise, but that is another story.

While recognizing security threats and the necessity to reduce their likelihood and to mitigate their consequence, it is essential not to destroy the society preemptively by compromising civil liberties and the rule of law, which has been severely strained in recent years.

SUMMARY OF THREATS.

Although not the most probable use of nuclear weapons in the foreseeable future, the most devastating would be for a substantial fraction of the 5000 or so U.S. nuclear weapons and a similar number of the Russian weapons to be used inadvertently or by a catalytic action in which a third party may intentionally aim for the destruction of much of the world that it could not otherwise provoke. Surely this hazard would decline very substantially if numbers of Russian and American nuclear weapons were

limited to the range of a few hundred, instead of 10 or 20 times that number. After all, that is the message of the January 2007 article by Henry Kissinger, et al. Just recently in a Wall Street Journal article of November 19, 2007, John Deutch and Harold Brown take on Kissinger, et al with an article titled "The Nuclear Disarmament Fantasy," arguing that nuclear weapons are real and that they are needed for deterrence, although "the lowest number needed for the purpose of deterrence is likely to be considerably below the present stockpile of over 8000 weapons." They go on to argue that other states will acquire nuclear weapons for their own security purposes, and not just because the United States and Russia have a very large number. Indeed, that is widely argued to be the case, especially after 1991 when a number of commentators from various nations observed that the lesson from the 1991 Gulf War was that no state should face the United States without having its own nuclear weapons.

This enormous residue of potential damage is one of the problems we face, with some clear support for retaining much of the massive arsenal of nuclear weapons, as indicated by the Brown/Deutch article.

Another problem, discussed already, is the terrorist acquisition and use of nuclear weaponry.

A third is the task for greatly expanding energy from nuclear reactors without expanding access to material useable for nuclear weaponry.

And a fourth problem is that we will not be able to solve any of the substantive problems because we may have already so lost an effective operating government that we will be concerned with self-dealing, propaganda, and diversions that keep us from recognizing and solving these problems.

WHAT TO DO.

Reducing nuclear weapons to the range of 1000 to 100 would be a good start, and it would require a focus at the highest level on this task. It would need to mobilize not only the White House but also the Department of Energy and the Department of Defense if it is to have a chance of going forward. Secretary of Defense Robert Gates in a speech November 26, 2007, at Kansas State University argued for a great increase in the annual $36 B budget of the State Department in order to rebuild "soft power," public persuasion, and negotiation capabilities in the interest of U.S. security. That is a start of focusing on the problem. As part of this addition to US capabilities, we need to have a greatly expanded focus on substance-- on "research" that will, for example, use the modern capabilities of computer modeling and simulation to evaluate the arguments for nuclear weapons as a "deterrent." It is important not simply to restate the arguments on either side, but analysis as to the extent to which 8000 nuclear warheads provide more deterrence than 200 nuclear warheads. In this regard, a recent paper by Ivan Oelrich, responding to Brown and Deutch is instructive[9] This will significantly reduce the security and financial burden on our countries, as well as helping to solve the problems of proliferation and of terrorist use of nuclear explosives. As for proliferation, it is important not so much to reduce the flow of weapon-usable material as to reduce the availability of such flows-- primarily by consolidation and by eliminating all unnecessary uses of weapon-usable material, such as in research reactors, unnecessary reprocessing of spent civil reactor fuel, and the like. In fact, I am a great supporter of breeder reactors, ultimately, for which reprocessing is essential, but I am an equally devoted critic of their deployment until they are safe and economical. Specifically, I have mentioned GNEP and I believe that the soft-power aspect of GNEP should go forward in the way of assured availability of low-enriched uranium fuel for the reactors of existing type, and the availability of competitive, commercial, mined geologic repositories in various nations, under the supervision of the IAEA and the protection of the United Nations. There should also be a substantial and perhaps collaborative world laboratory that would do design studies on several types of fast breeder reactors, advancing the state-of-the-art of safety analyses and of assessment of reactor

[9] http://www.fas.org/blog/ssp/2007/11/a_rebuttal_to_brown_and_deutch.php

design, specific fuel forms, and appropriate reprocessing for that reactor and that fuel. It should be expected that a lot of radioactivity from long-lived fission products would remain in the fuel throughout the processing cycle, so as to bar access to it. And breeders would be widely deployed when they could compete with light-water reactors.

The reduction to a small fraction of nuclear weapons foreseen for Russia and the United States would energize those governments and populations to a new level of intolerance of a new state's joining the nuclear weapon club, and the tool there would be a new Additional Protocol that would have states renouncing the possibility, after they might leave the Nonproliferation Treaty, to use the facilities or the materials acquired under the NPT as a non-nuclear weapon state for pursuing nuclear weapons or for any other purpose.

That leaves terrorist use of nuclear explosives, and there one can only hope to reduce the likelihood and not to eliminate it. To reduce access to weapon-usable material it would be useful to buy up not only the excess highly enriched uranium, but also to convert it promptly into fuel for light-water reactors. Although in the 20-yr $12 B deal between the United States and Russia for 500 tons of excess weapon HEU, blending down was done only as the material was delivered, in this case it should be done up front. It is much cheaper to blend to 19.9% than to blend to 4% and has the further advantage that the specific enrichment of the product does not need to be determined at that point. Cheaper to blend because for every 1 kg of U-235 only 5 kg of uranium altogether need be put through the blending plant; for 4% U-235 25 kg of uranium needs to go through the blending process. So the capacity of a blending plant should be approximately five times as large for the 20% intermediate product. The 19.9% material could remain in Russia or it could be bought far in advance by those wishing to hedge against an increase in price of uranium.

And, as indicated previously, reprocessing of spent civil reactor fuel should be done only when necessary and certainly not when uneconomical. The argument of France and Japan that it is essential for them to reprocess light-water reactor fuel because they are devoid of native energy resources is specious or self-deluding. I think specious because neither country has been willing to listen to argument, primary among which is that no one aims for more than a 20% reduction in uranium demand by the substitution of mixed-oxide (plutonium-uranium) fuel, and that for far less than the cost of reprocessing, one could import raw uranium in advance, or low-enriched uranium, and save money over the option of fuel sparing through reprocessing, until the price of raw uranium increased to about $700 per kg, compared with the current $80/kg or so.

The final problem is the most serious and that is that our competence and motivation in government may no longer be sufficient to address real problems-- even such pressing problems as provision of affordable health care. I think that this is an extremely serious matter, but I have no monopoly on expertise or dedication to this topic. I think it would be a series well worthwhile-- National Security and Government Competence.

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