CHAPTER 1

ASSESSING THE IAEA'S ABILITY TO VERIFY THE NPT

A Report of the Nonproliferation Policy Education Center
on the International Atomic Energy Agency's
Nuclear Safeguards System

Henry D. Sokolski

OVERVIEW

Ask how effective International Atomic Energy Agency (IAEA) nuclear safeguards are in blocking proliferation, and you are sure to get a set of predictable reactions. Those skeptical of the system will complain that IAEA inspections are too sketchy to ferret out nuclear misbehavior (e.g., North Korea, Iraq, and Iran) and that in the rare cases when such violators are found out (almost always by national intelligence agencies), the IAEA's board of governors is loath to act. IAEA supporters have a rather opposite view. The IAEA, they point out, actually found Pyongyang, Baghdad, and Tehran in non-compliance with their IAEA safeguards agreements and reported this to the United Nations (UN) Security Council. International inspectors, moreover, were the only ones correctly to assess the status of Saddam's strategic weapons programs. The problem is not to be found in Vienna or in the IAEA's inspections system but in Washington's unwillingness to listen. In the future, the United States, they argue, should rely more, not less, on the IAEA to sort out Iran's nuclear activities and to disable North Korea's nuclear weapons complex.

These two views could hardly be more opposed. There is at least one point, though, upon which both sides agree: If possible, it would be useful to enhance the IAEA's ability to detect and prevent nuclear diversions. This would not only reduce the current risk of nuclear proliferation, it would make the further expansion of nuclear power much less risky.

The question is what is possible? To date, little has been attempted to answer this basic question. Periodic reports by the U.S. Government Accountability Office (GAO) and the IAEA have highlighted budgetary, personnel, and and administrative challenges that are immediately facing the agency.[1] There also has been a 2-year internal IAEA review of how existing IAEA safeguards procedures might be improved.[2] None of these assessments, however, has tackled the more fundamental question of how well the IAEA is actually doing in achieving its nuclear material accountancy mission. Precisely what nuclear activities and materials can the IAEA monitor to detect a diversion early enough to prevent it? What inherent limits does the IAEA nuclear inspections system face? In light of these limits, what new initiatives should the IAEA Department of Safeguards attempt and, even more important, stay clear of? What additional authority and technical capabilities might the IAEA secure to help achieve its nuclear material accountancy goals? In the end, what is or should be protected as being "peaceful" under the Nuclear Nonproliferation Treaty (NPT) or the IAEA charter? What is the proper balance between expanding the use of nuclear energy and making sure it is not diverted to make bombs?

None of these questions admits to quick or easy answers. All, however, are increasingly timely. Will IAEA safeguards be able keep Iran from using their nuclear programs to make bombs? What of IAEA's inspectors' abilities to ferret out all of North Korea's nuclear activities? Will the safeguards being proposed for India effectively prevent U.S. and foreign nuclear cooperation from assisting New Delhi's nuclear weapons program?

Then, there is the long-term problem of nuclear power's possible expansion. Since 2005, more than fifteen countries have announced a desire to acquire large reactors of their own by 2020 (this is on top of the 31 nations that already operate such reactors).[3] Nine of these states—Algeria, Morocco, Tunisia, Libya, Egypt, Turkey, Jordan, Saudi Arabia, and Yemen—are located in the war-torn region of the Middle East. Morocco, Tunisia, Jordan, and Yemen seem unlikely to achieve their stated goal. But the others, with U.S., Chinese, French and Russian nuclear cooperation, may well succeed. What is clear is that most are interested in developing a nuclear program capable of more than merely boiling water to run turbines that generate electricity. At least four have made it clear that they are interested in hedging their security bets with a nuclear weapons-option. For these states, developing purportedly peaceful nuclear energy is the weapon of choice. Will the IAEA, which is pledged to keep these programs peaceful, be able to do so?

In anticipation of these nuclear challenges, the Nonproliferation Policy Education Center (NPEC) began in 2005 to consult with officials from the IAEA, the United States, the United Kingdom, the United Arab Emirates, Germany, and France, as well as outside experts on the effectiveness of the IAEA's safeguards system and how best to improve it. NPEC went on to commission 13 studies on a variety of safeguards-related issues. These analyses were reviewed and discussed at a series of private conferences with senior level officials and outside experts held in Washington, Paris, and London.[4]

A key conclusion of these meetings and research was that the IAEA is already falling behind in achieving its material accountancy mission and risks slipping further unless members of the IAEA board independently and in concert take remedial actions in the next 2 to 5 years. The most important of these measures can be organized around seven basic recommendations:

1. ***Resist calls to read the NPT as recognizing the per se right to any and all nuclear technology, no matter how unsafeguardable or uneconomic such technology might be.*** The current, permissive, mistaken interpretation of the NPT is that all states have a sovereign *per se* right to any and all nuclear technology and materials, including nuclear fuel making and nuclear weapons usable materials, so long as they are declared to the IAEA, occasionally inspected, and have some conceivable civilian application. This interpretation, if not overturned, will guarantee a world full of nuclear weapons-ready states. With only a few more such states, the IAEA's ability to detect military diversions in a timely fashion will be marginal at best. For this reason, as well as a series of legal, historical, and technical reasons, it is essential that members of the IAEA Board of Governors make the IAEA's ability to detect military nuclear diversions in a timely fashion and the economic viability of any nuclear project to be two clear criteria for what is peaceful and protected under the NPT. Nuclear power also should only be considered to be peaceful and beneficial if it makes at least as much economic sense as its nonnuclear alternatives. Thirty years ago, the United States stipulated that in Title V of the Nuclear Nonproliferation Act of 1978 (see Title V, The Nuclear Nonproliferation Act of 1978, P.L. 95-242) Sections 501-503) that the U.S. executive branch should create a series of international technical cooperative programs

to promote the use of non-nuclear and non-petroleum renewable energy sources. The law also required the executive branch to conduct country-specific energy assessments and to report annually on the progress of U.S. and international efforts to employ such energy sources abroad. Unfortunately, since the law's passage, the White House and the U.S. Departments of Energy and State have yet to comply with any of the legal requirements of this title.

Specific Recommendations:

A. The United States and like-minded nations should stipulate in the run up to the 2010 NPT Review Conference that future civilian nuclear energy projects should only enjoy the protection of the NPT if they are:

(1) able to be monitored in non-nuclear-weapon states so as to afford timely warning of military diversions as stipulated by the NPT and the IAEA's own official criteria for what effective safeguards require; and,

(2) economically viable enough to be financed *without* nuclear-specific government subsidies.

B. The U.S. Government should begin full implementation of Section V of the Nuclear Nonproliferation Act of 1978 and urge its closest allies to cooperate in achieving its stated goals.

2. ***Distinguish between what actually can be effectively safeguarded, and what can, at best, only be monitored.*** Currently, the IAEA is unable to provide timely warning of diversions from nuclear fuel-making plants (enrichment, reprocessing, and fuel processing plants utilizing nuclear materials directly useable to make bombs). For some of these plants, the agency loses track of many nuclear weapons-worth of material every year. Meanwhile, the IAEA is unable

to prevent the overnight conversion of centrifuge enrichment and plutonium reprocessing plants into nuclear bomb-material factories. As the number of these facilities increases, the ability of the agency to fulfill its material accountancy mission dangerously erodes. The IAEA has yet to concede these points by admitting that although it can monitor these dangerous nuclear activities, it cannot actually do so in a manner that can assure *timely detection* of a possible military diversion—the key to an inspection procedure being a safeguard against military diversions. In addition, the IAEA's original criteria for how much nuclear material is needed to make one bomb (a "significant quantity"), for how much time is required to convert various materials into bombs ("conversion time"), and what the IAEA's own inspection goals should consequently be ("timeliness detection goals") were set over 30 years ago and need updating.

Specific Recommendations:

A. Require the IAEA Department of Safeguards to distinguish between those nuclear activities and materials for which timely detection of military diversions is actually possible and those for which it is not possible. This could be encouraged by having the nuclear weapons state members of the IAEA do their own individual, national analyses of these questions and make their findings public.

B. In light of the nuclear inspections experience of the last 15 years with North Korea, Iraq, Iran, Egypt, Taiwan, Libya, and South Korea, members of the IAEA Board of Governors should be encouraged to undertake their own national reassessment of what the IAEA's current significant quantities criteria, conversion times, and timely detection goals should be. These reassessments would be driven by what the

IAEA would need to assure timely detection of military diversions—i.e., time sufficient to allow states to intervene to block the possible high-jacking of civilian facilities and materials to make bombs. On the basis of these analyses, the IAEA Board of Governors should instruct the IAEA Department of Safeguards to report back to the Board regarding desirable revisions to the agency's criteria for what nuclear safeguards over different nuclear materials and activities should be.

C. Call for increased monitoring of those nuclear facilities for which such timely detection is not yet possible (e.g., nuclear bulk-handling facilities where nuclear fuel is made and processed and on-line fueled reactors, such as heavy water reactors, where keeping track of the fuel going in an out of the plant is particularly taxing). Such increased monitoring should be designed at least to increase the prospect of detecting diversions *after* they have occurred. The IAEA should make clear that timely detection of diversions (i.e., detection of diversions *before* they are completed) from such facilities is not yet possible. Finally, the IAEA should make the plant operators and owners pay for this additional monitoring. This additional cost should be considered a normal cost of conducting these activities.

D. Avoid involving the IAEA in the verification of a military fissile material cut-off treaty (FMCT). As currently proposed, a FMCT assumes that the timely detection of diversions from declared nuclear fuel-making plants is possible when, in fact, it clearly is not.

E. Call for physical security measures at those facilities where timely detection is not possible that are equivalent to the most stringent standards currently employed in nuclear-weapons facilities in the United

States, Britain, Russia, China, and France. Again, the cost of such additional security measures should be born by the owner or operator.

3. ***Reestablish material accountancy as the IAEA's top safeguards mission*** by pacing the size and growth in the agency's safeguards budget against the size and growth of the number of significant quantities of special material and bulk handling facilities that the agency must account for and inspect (see Figure 1, p. 20 below). As noted above, the amounts of special nuclear material under IAEA safeguards that go unaccounted for is large and increasing every year. These increases are most worrisome in non-weapons states that are now making nuclear fuel (e.g., Iran, Japan, the Netherlands, Germany, and Brazil). Unfortunately, the IAEA refuses to report anything but aggregate information about these materials: There are no national breakdowns that are publicly available for the different types of nuclear fuels being safeguarded in each country nor a run down of the materials that have gone unaccounted for country-by-country. As already noted, the IAEA is technically unable to meet its own timely detection goals for the safeguarding of plants producing and processing separated plutonium, highly enriched uranium, and mixed oxide fuels. Candor and encouraging restraint is all that can currently be offered to address this safeguards gap. In addition, at most of the sites that it must safeguard, the IAEA lacks the near-real time monitoring capabilities necessary to determine if the agency's own monitoring cameras and other sensors (which are left unattended for 90 or more days) are actually turned on. As such, a proliferator could divert entire fuel rods containing one or more significant quantities of lightly enriched

uranium and nuclear weapons-usable plutonium without the agency finding out either at all or in a timely fashion. Unlike the safeguards gap associated with nuclear fuel producing and processing plants, though, this gap can technically be fixed by installing near-real time surveillance systems that allow IAEA inspectors in Vienna to receive information from the remote sensors it has deployed without being on site. Certainly before the IAEA takes on additional dubious or extremely challenging missions, such as monitoring fissile production cut-offs or searching for nuclear weapons-related activities, it must arrest this growing gap between the amounts of nuclear materials it must safeguard and its technical ability to do so.

Specific Recommendations:

A. Pay greater attention to what the IAEA can clearly do better—count fresh and spent fuel rods—by quickly increasing and optimizing its remote near-real time monitoring capabilities for all of its monitoring systems, and increasing the number of full-time, qualified nuclear inspectors necessary to conduct on-site inspections.

B. Require the IAEA Department of Safeguards to report annually to the public on its safeguards budget and identify not only the number of man-hours dedicated to onsite inspections and the number of significant quantities under the IAEA's safeguards charge, but also the amount of direct-use materials (materials that can be quickly turned into bomb fuel) under its charge by type *for which the agency could not achieve its own timeliness detection goals*, the amount of direct-use materials for which the agency could achieve its own timeliness detection goals; the number and location of facilities under near-real time surveillance; the amount of money dedicated to wide-area surveillance; and the amount of money dedicated to IAEA safeguards research and development. In each case, the IAEA should present national breakdowns of each total.

C. In addition, each member state of the IAEA Board of Governors should routinely conduct its own national analysis of what it believes the proper ways to the address the problems noted above are and publicly identify and explain what it thinks the agency's top safeguards priority should be to improve these numbers.

4. ***Focus greater attention on useful safeguards activities that are necessary, but have yet to be fully developed.*** To assure that the IAEA's material accountancy assets do not risk becoming cannibalized for other urgent missions that might arise (e.g., inspections for India if the U.S.-India nuclear deal should go forward, more intrusive inspections for Iran, and North Korea, etc.), it would be useful for the agency to develop stand-by wide-area surveillance teams for the imposition of sudden inspections requirements. The agency might also usefully do more to account for source materials in processed form, as it was information regarding the shipment of such material from China that originally tipped off the IAEA to suspicious nuclear activities in Iran. The agency also needs fully to fund and properly staff its sampling analysis facilities and its efforts to secure overhead imagery of the sites that it must inspect. Finally, the agency needs to do more to establish what its own safeguards research and development requirements might be.

Specific Recommendations:

A. Members of the IAEA Board of Governors should assess on their own what might be required to conduct wide-area surveillance inspections of Iran and North Korea (i.e., what such inspections would cost to stand up and maintain in terms of dollars and staff), and ask the IAEA Board of Governors to task the IAEA Department of Safeguards to do likewise.

B. The IAEA Board of Governors should ask its members for supplemental contributions to stand up and maintain such surveillance units so that they can be tapped at any time without affecting the IAEA's routine safeguards operations. To the extent possible, the supplemental contributions should be based on a formula tied to the costs of generating nuclear electricity in each member state (as called for by recommendation 5 detailed below).

C. Similar studies should be conducted and supplemental assessments made in support of IAEA efforts to improve the agency's ability to account for nuclear source material and to fund nuclear sampling analyses and of inspections-related overhead imagery and analysis.

5. ***Complement the existing UN formula for raising IAEA funding with a user-fee for safeguards paid for by each nuclear operator.*** The IAEA's director general has repeatedly noted how small the agency's safeguards budget is, but has yet to propose how to increase it. As a stop-gap measure, the United States, European Union (EU), and Japan have been giving token amounts of voluntary, "supplemental" contributions to the agency. Currently, the UN formula used to raise IAEA funds has nations that possess no power reactors, such as Italy, paying more than nations, such

as South Korea, that possess 20 such plants. Countries including the United States, Canada, Brazil, Japan, and India, meanwhile, are taxing the IAEA safeguards system (or soon will be) with nuclear fuel-making and bulk-handling facilities and on-line fueled reactors that are much more challenging to monitor than other nuclear plants. Although the IAEA inspects the nuclear reactors and facilities of nuclear-weapon state members of the NPT far less than they inspect those of the non-nuclear-weapon states, the nuclear-weapon NPT states arguably have the most to gain from IAEA efforts to prevent the further spread of nuclear weapons. Both the insufficiency of the IAEA safeguards spending and the inequity of the way funds are currently raised for this function suggest the need to complement existing country assessments with a safeguards surcharge that is based on the costs of generating nuclear energy in each country. This surcharge is needed to assure the IAEA's budget not only grows significantly above its current level (which is too low by one or two orders of magnitude), but also to keep up with the possible expansion of nuclear power.

Specific Recommendations:

A. The United States, EU and Japan each should base all of their current supplemental contributions to the IAEA safeguards budget on a national formula based on a specific percentage of nuclear generating costs as it relates to the number of kilowatt hours that their civilian reactors generate per year.

B. The United States, EU, and Japan should, then, negotiate among themselves on what an agreed safeguards surcharge formula should be and encourage others to follow suit so that revenues from such a fee would become mandatory for each country contributing to the IAEA and would go exclusively to support the IAEA's Department of Safeguards. The UN formula, meanwhile, would be used to support the IAEA's non-safeguarding activities.

C. The IAEA Board of Governors should instruct the agency's Department of Safeguards to identify those nuclear facilities (e.g., on-line fueled reactors and nuclear fuel making plants) that require the greatest amount of resources to inspect or pose the greatest difficulty in meeting the agency's own timely detection criteria. The IAEA Board of Governors should then ask those countries possessing these identified facilities to pay an additional amount to the IAEA Department of Safeguards to cover the additional costs associated with their inspection. To the extent possible, the IAEA should encourage nations having to pay such additional fees to collect them from the customers or owners or operators of these facilities.

6. ***Establish default actions against various levels of IAEA safeguards agreement non-compliance.*** Currently, any proliferator that violates its IAEA comprehensive safeguards agreement knows that the deck is stacked against the IAEA Board of Governors reaching a consensus to (1) find them in non-compliance, and (2) take any disciplinary action. The key reason why is simple: The current burden of proof regarding any non-compliance issue is on the IAEA staff and the Board of Governors rather than on the suspect proliferator. In the absence of political consensus in the IAEA Board of Governors, the proliferator can be assured that no non-compliance finding will be made, much less any disciplinary action taken. This set of operating assumptions needs to be reversed. The best way to assure this is to establish a set of country-neutral rules regarding non-compliance that will go into effect

automatically upon the Board of Governors' inability to reach a consensus on (1) whether or not a given party is in full compliance with its comprehensive safeguards agreement, and (2) what action to take in the event that a party is found to be in non-compliance.

Specific Recommendations:

A. The United States, EU, and other like-minded nations should announce—independent of Nuclear Suppliers Group (NSG) consensus—that they will suspend transfers of controlled nuclear goods from their jurisdiction to any country that the IAEA Board of Governors has been unable to find in full compliance with its safeguards obligations and urge the IAEA Board of Governors and the NSG to agree to do the same. Under such a regime, the IAEA Board of Governors would be forced to suspend nuclear cooperation from any IAEA member to the suspected state until the Board could unanimously determine that the suspect state was in full compliance.

B. The United States, EU, and other like-minded nations should call on the UN Security Council (UNSC) to pass resolutions prohibiting states found in non-compliance by the IAEA Board of Governors from making nuclear fuel for a decade, and requiring these states to submit to intrusive wide-area surveillance to establish that they are completely out of the bomb-making business.

C. The United States, individual EU member states, and other like-minded nations should take national actions to sanction states that withdraw from the NPT while in violation of the treaty and call on the UNSC, IAEA and the NSG to pass a country-neutral sanctions resolution that tracks these sanctions measures.

D. At a minimum, the United States and like-minded states should adopt national laws and executive orders to establish what sanctions they would be willing to impose against any non-nuclear-weapon state that tests a nuclear device and call on the UNSC to pass a country-neutral sanctions resolution that tracks these national sanctions. The sanctions could be lifted after the testing state has disarmed and demonstrated to the IAEA Board of Governors that they are out of the bomb making business.

7. ***Plan on meeting future safeguards requirements on the assumption that the most popular innovations—integrated safeguards, "proliferation-resistant" fuel-cycles, and international fuel assurances—may not achieve their stated goals or, worse, may undermine them.*** Perhaps the three most popular safeguards innovations—integrated safeguards under the Additional Protocol, proliferation-resistant fuel-cycles under America's Global Nuclear Energy Partnership (GNEP), and international fuel assurances that can be afforded through fuel banks and regional fuel-making centers—are also the most unexamined. Recent analyses conducted by outside think-tanks (including the Council on Foreign Relations, Princeton University's International Panel on Fissile Materials, the Keystone Center, and the U.S. National Laboratories), in fact, conclude that each of these innovations could prove to be ineffectual or even self-defeating. GNEP's proposed proliferation-resistant fuel-cycles, for example, do not appear to be very proliferation resistant especially with respect to state-based proliferation and could easily increase the use and availability of nuclear weapons-usable fuels worldwide. Fuel banks and fuel making centers, if they make fuel available at "affordable" or "reasonable" prices, could easily end up subsidizing nuclear power development in regions where such

activity would not be economical or safe. Fuel-making centers also could end up spreading nuclear-fuel making technology. Finally, integrated safeguards, which reduce the number of inspections per safeguarded facility, could easily become a crutch for the IAEA to evade its material accountancy responsibilities.

Specific Recommendation: The U.S. Government should create a board of outside experts to serve as a quality-assurance panel to spot the potential downsides of any nonproliferation initiative. This group would be created by and report to Congress on the potential self-defeating consequences of any proposed government "nonproliferation" initiative might have prior to Congress authorizing or appropriating to support it.

Some of these recommendations are easy to act upon; others are not. IAEA member states, though, should begin to act on them now. Certainly, it would be a mistake to wait to see if civilian nuclear energy will expand (a proposition whose demonstration may require another decade or more). The reason why is simple: Even if nuclear power does not expand, the amount of nuclear weapons-usable materials that the IAEA must prevent from being diverted to make bombs is already very large and growing.

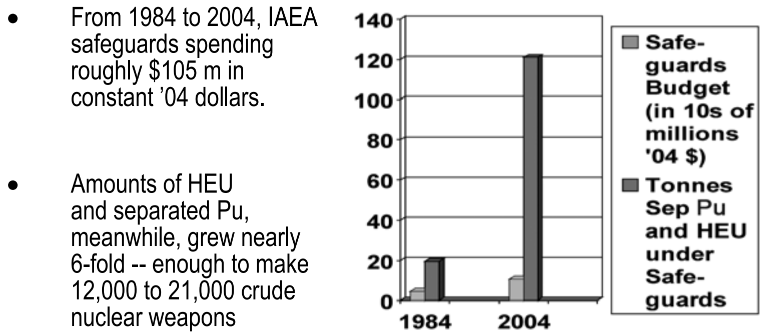
SOME NEGATIVE TRENDS

On a number of counts, the IAEA safeguards system appears to be getting better. After more than a decade of no real growth, annual funding for nuclear inspections finally was increased in real terms from $89 million in 2003 to $102 million in 2004 and to $108 million in 2007. Deployment of advanced remote monitoring equipment is on the rise and implementation of new, more intrusive inspections authority under the Additional Protocol is moving forward. In the future, nuclear power might expand, but most of this expansion will take place in nuclear weapons states or countries that are so trustworthy that it could be argued that few, if any, additional nuclear inspections may be needed. As for additional safeguards requirements—e.g., inspections in India, North Korea, or Iran—they might well be met with additional contributions when and if they arise. From this perspective, current safeguards budgeting and planning could be viewed as being adequate to the task for years to come.[5]

It could, that is, until other, less positive trends are considered. Of these, perhaps the most important concerns the number of significant quantities of nuclear material that the IAEA must safeguard to prevent from being diverted and directly fashioned into bombs. This number is not only growing, but at a rate far faster than that of the IAEA's safeguards budget. The amount of separated plutonium and highly enriched uranium (nuclear fuels that can be fashioned into bombs in a matter of hours or days) that the IAEA inspects, for example, has grown more than six-fold between 1984 and 2004 while the agency's safeguards budget has barely doubled (see the Figure 1 below).

Meanwhile, the number of nuclear fuel fabrication and fuel making plants (facilities that are by far the easiest to divert nuclear material from) has grown in the last 2 decades from a mere handful to 65. Then, there is the number of other plants containing special nuclear material that the IAEA must safeguard: It has roughly tripled to more than 900 facilities today.[6]

These trends have forced the IAEA to work their inspections staff much harder. Over the last 20 years,



HEU: Highly enriched uranium
Pu: Plutonium

Figure 1. IAEA Safeguards Spending vs. Mounting Weapons Usable Material Stockpiles.

the number of days IAEA inspectors have been in the field has nearly doubled from 60 to 70 days to 125 to 150.[7] This doubling has not only cost more money, it is one of the reasons (along with unreasonable employment and contracting rules) for a hollowing out of IAEA's experienced inspections staff. This hollowing out is expected to become acute. As noted by the U.S. GAO, about 50 percent or 30 out of 75 of the IAEA's senior safeguards staff are expected to retire by 2011.[8]

One way to address this inspections crunch is to have the IAEA simply inspect less. This could be done legally by implementing the Additional Protocol. In fact, limiting the number of routine safeguards inspections is one of the incentives the IAEA currently offers countries to sign up to the Additional Protocol. Once a country has ratified the Additional Protocol and the IAEA has established that there "is no indication of undeclared nuclear material activities for the state as a whole," the agency can reduce the number of routine nuclear inspections it makes of that country's nuclear materials and facilities significantly.[9]

The trouble with taking this approach, though, is that initially it actually *increases* the amount of staff time and resources that the IAEA would have to spend to safeguard a given country. It turns out that determining whether or not a country has no undeclared nuclear materials activities takes considerable safeguards staff resources.[10] Over the entire lifetime of a nuclear facility (i.e., 20 to 50 years), then, applying integrated safeguards might reduce the total amount of staff time needed to safeguard a particular set of nuclear plants slightly but in the first few years, more, not less staff time and safeguards resources would be consumed.[11]

Also, the Additional Protocol authorizes the IAEA to conduct wide area surveillance inspections. These would be extremely useful in the case of Iran or North Korea. They also would require significant additional safeguards staff and funding (by one estimate done for NPEC by a seasoned former IAEA inspector, perhaps a plus up in funding constituting as much as 30 percent of the IAEA's entire current safeguards budget).[12] So far, the IAEA has done nothing to establish such an inspections capability.

Finally, relying heavily on integrated safeguards may be unsound in principle. As already noted, they require the IAEA to determine that the country in question has no undeclared nuclear material. Yet, the IAEA's safeguards staff itself has admitted that it cannot yet be relied upon to discover covert nuclear fuel making facilities in the hardest cases (e.g., Iran). Also, reducing the frequency of on-site inspections increases the risks that a member state might divert materials to make bombs without the IAEA finding out until it is too late.

In a detailed study completed for NPEC late in 2004 on the proliferation risks associated with light water reactors, several scenarios were presented under which fresh and spent nuclear fuel rods might be diverted to make nuclear weapons fuel in covert reprocessing or enrichment plants in a matter of days or weeks without tipping off IAEA inspectors.[13] These scenarios were subsequently validated independently by key officials working within the IAEA's Standing Advisory Group on Safeguards, the U.S. Department of State, Los Alamos National Laboratory.[14]

That a country could evade IAEA inspectors in diverting entire fuel rods is disquieting. One would assume that the current crop of IAEA remote nuclear monitoring equipment could be counted upon entirely to warn against such diversions. In fact, they cannot.[15] Most of the currently deployed remote sensors do not allow the IAEA even to know day to day if these systems are on. This is a serious shortcoming. Over the last 6 years, the agency has learned of camera "blackouts" that lasted for "more than 30 hours" on 12 separate occasions. What is worse, it only learned of these blackouts *after* inspectors went to the sites and downloaded the camera recordings as they are required to do every 90 days.[16]

Under new proposed "integrated safeguards" procedures, such "downloading," moreover, would occur as infrequently as every 12 months—a period within which a state could conceivably make a nuclear weapon unbeknownst to the IAEA.[17] The IAEA staff recently proposed to correct this inspections gap by accelerating implementation of near real-time monitoring using satellite communication connections. This effort, though, is still being implemented at an excruciatingly slow pace due to a lack of funds.[18]

STRUCTURAL PROBLEMS

The current gap in the IAEA's near-real time monitoring capabilities may be worrisome but it, at least, can be addressed assuming additional safeguards funding is made available. Far more intractable is the IAEA's inability to detect diversions in a timely manner from nuclear fuel making plants. As already noted, NPEC's earlier study on the proliferation dangers associated with light water reactors highlighted the relative ease with which states might build covert reprocessing plants or divert fresh civilian fuel to accelerate undeclared uranium enrichment efforts.

Additional NPEC-commissioned research detailed just how poorly IAEA safeguards have performed at nuclear fuel plants in Europe and Japan. In his study, "Can Nuclear Fuel Production in Iran and Elsewhere Be Safeguarded against Diversion,"[19] Dr. Edwin Lyman highlights several examples. At a fuel fabrication plant at Tokai-mura in Japan making mixed-oxide (MOX) fuel out of powdered uranium and nuclear weapons usable separated plutonium, the IAEA could not account for 69 kilograms of plutonium. This is enough to make at least nine nuclear weapons (assuming the IAEA's eight kilograms per weapon estimate) or twice that figure (assuming the U.S. Department of Energy's more accurate four kilograms per crude nuclear weapon figure). Only after 2 years, the expenditure of $100 million, and the disassembling of the plant could the operator claim that he could account for all but 10 kilograms (i.e., one to two bombs' worth).[20]

Dr. Lyman details a similarly disturbing incident involving MOX scrap in Japan where at least one bomb's worth of weapons-usable plutonium went missing and another accounting discrepancy at a Japanese reprocessing plant at which the IAEA lost track of between 59 and 206 kilograms of bomb-usable plutonium (but only was able to determine this years *after* the material initially went unaccounted for). Add to these discoveries the many bombs' worth of material unaccounted for (MUF) annually at reprocessing plants in France and the United Kingdom (where the IAEA has employed its very latest near-real time monitoring techniques), and there's cause for alarm.[21]

The picture relating to safeguarding centrifuge enrichment plants is not much brighter. Even at plants where IAEA monitoring and inspectors are on site, there will be times in between inspections during which remote monitoring might be defeated. There also is the constant problem of the operator giving false design, production, or capacity figures.[22]

In any case, the times between a decision to divert and having enough material to make a crude bomb (assuming the IAEA's high estimate of 25 kilograms of highly enriched uranium being required to make one weapon) are so short, even an immediate detection of the diversion, which is by no means assured, would generally come too late to afford enough time to prevent bombs from being made. In the case of a small commercial sized plant, a bomb's worth could be made in as little as 18 hours to 12 days (depending on whether natural or slightly enriched uranium is used as feed).[23]

SAFEGUARDS ASSUMPTIONS

Exacerbating this safeguards gap is the IAEA's overly generous view of how much material must be diverted to make a bomb (referred to by the IAEA as a "significant quantity") and how long it might take to convert this material into a nuclear weapon (known as the "conversion time"). Most of these IAEA estimates were made over 30 years ago. To reassess their accuracy, NPEC commissioned Thomas Cochran, chief nuclear scientist at the Natural Resources Defense Council (NRDC). His analysis and conclusions were revealing. The IAEA estimates it would take eight kilograms of separated plutonium and 25 kilograms of highly enriched uranium to make a crude bomb. These estimates were found to be too high by a minimum of 25 percent and a maximum of 800 percent, depending on the weapons expertise employed and the yield desired (see Figure 2 below).[24]

Weapon-Grade Plutonium (kg)				Highly-Enriched Uranium (kg)		
Yield (kt)	Technical Capability Low	Medium	High	Technical Capability Low	Medium	High
1	3	1.5	1	8	4	2.5
5	4	2.5	1.5	11	6	3.5
10	5	3	2	13	7	4
20	6	3.5	3	16	9	5

Values rounded to the nearest 0.5 kilogram.

Figure 2. NRDC Estimate of the Approximate Fissile Material Requirements for Pure Fission Nuclear Weapons.

When presented with these figures, senior IAEA safeguards staff did not dispute them. Instead they argued that the "exact" amount of diverted nuclear material needed to make a crude bomb was not that important. Instead, what mattered most was the IAEA's ability to detect microscopic amounts of weapons-usable materials since securing such environmental samples was the thing most likely to put an inspected party in the international spotlight.[25]

The potential downside of taking this approach, however, is significant. It is these estimates, along with the agency's projections of how long it takes a proliferator to convert uranium and plutonium materials into bombs (i.e., conversion times), that the IAEA uses to determine how often it should conduct its inspections of different nuclear facilities. If these estimates are too high, the frequency of inspections needed to detect military diversions risks is egregiously low. Certainly, what the IAEA defines as desirable "detection times"—the maximum time that may elapse between the diversion of a significant quantity of nuclear material and the likely detection of that diversion—should correspond (according to the IAEA's own guidelines) to the agency's estimated conversion times. If they don't, IAEA-inspected countries could count on being able divert a crude weapon's worth of nuclear material and fashioning it into a bomb before the IAEA could either detect the diversion or have any chance of taking appropriate action to block bomb making.

This worry seems quite real when one considers how high the IAEA's 30-year old significant quantity estimates appear to be and one then looks at how generous the IAEA's estimated conversion times are (see Figure 3 below).

Using the history of the Manhattan Project as a benchmark, the IAEA's first set of estimates regarding the amount of time (7 to 10 days) needed to convert separated plutonium (Pu) or highly enriched uranium (HEU) or ^{233}U metal were judged by Dr. Cochran to be the correct order of time. The key reason why is that in 1945, the plutonium and enriched uranium for the first American bombs had to be shipped thousands of miles from where they were produced to where

Beginning Material Form	Conversion Time
Pu, HEU, or ^{233}U metal	Order of days (7-10)
PuO_2, $Pu(NO_3)_4$ or other pure Pu compounds: HEU or ^{233}U oxide or other pure U compounds; MOX or other nonirradiated pure mixtures containing Pu, U (^{233}U +^{235}U>20 percent); Pu, Heu, and/or ^{233}U in scrap or other miscellaneous impure compounds	Order of weeks (1-3)*
Pu, HEU, or ^{233}U in irradiated fuel	Order of months (1-3)
U containing <20 percent ^{235}U and ^{233}U; Th	Order of months (3-12)

*This range is not determined by any single factor, but the pure Pu and U compounds will tend to be at the lower end of the range and the mixtures and scrap at the higher end.

Figure 3. Estimated Material Conversion Times for Finished Pu or U Metal Weapons Components.[26]

the material was fashioned into nuclear weapons. This transport took several days. If a country making nuclear weapons did not have to ship these distances, the conversion time could be much shorter. However, the conversion times could still be on the order of a day or more.

The IAEA's estimates of how long it would take (1 to 3 weeks) to convert fresh plutonium-uranium fuels (known as mixed oxide fuels or MOX) do not fare as well. Here, Dr. Cochran points out that it would take no more than a week and possibly as little as a few days to convert these materials into metal bomb components. Instead of a matter of weeks, he concludes that the correct conversion time should be measured in a matter of days.

As for the IAEA's conversion time estimates of 1 to 3 months for plutonium, HEU, or ^{233}U contained in irradiated spent reactor fuel, these were also judged to be accurate *only* if the country possessing these materials did not have a covert or declared reprocessing or enrichment plant. If the country in question did, then it could possibly convert the spent fuel into bombs in a matter of weeks rather than months.

Finally, Dr. Cochran agreed with the IAEA's low end estimated conversion time of 3 months for low enriched uranium but, with the increased international availability of gas centrifuge uranium enrichment technology, found the IAEA's high end estimate of 12 months to be totally unwarranted. In fact, as already noted, a country might well be able to convert low enriched uranium into a bomb in a matter of weeks or less.[27]

The policy ramifications of these overly generous IAEA estimates are significant. They directly impact what the IAEA's detection goals should be. In three cases—the conversion of low enriched uranium; the conversion of plutonium, HEU, and ^{233}U metal; and of these materials in spent fuel—the order of time associated with the IAEA estimates is correct. In another three cases, however—the conversion of plutonium, HEU and ^{233}U in MOX; and of these materials in spent fuel; and of low enriched uranium if the inspected country has covert or declared nuclear fuel making facilities—the IAEA's estimates are egregiously high. IAEA conversion times are measured in months when they should be measured in weeks, and in weeks when they should be measured in days.

As a result, the IAEA's timeliness detection goals in many cases are dangerously high. More important, the agency's current detection goals give the mistaken impression that the IAEA can detect military diversions before they result in bombs or even early enough to prevent the diversion from succeeding when this clearly is not the case. Dr. Cochran's analysis highlights that timely detection for plutonium, HEU, and ^{233}U in metal and in fresh MOX is simply not possible. He concludes that countries that do not yet have nuclear weapons should not be allowed to stockpile or produce these materials. He reaches the same conclusion regarding the agency's ability to detect diversions of plutonium, HEU, and ^{233}U in nonweapons states that may have a declared or covert enrichment or reprocessing plant. In these cases, the problem is not that the IAEA's timeliness detection goals are too liberal; it is that the IAEA claims that timely detection is possible at all (see Figure 4 below).

To some extent, these critical conclusions are gaining official support. As the IAEA's former director for safeguards recently explained, when it comes to nuclear fuel making, the IAEA is must rely on its limited ability to ascertain the inspected country's military intent. [28] Even the director general of the IAEA conceded that once a country acquires separated plutonium and HEU, the IAEA must rely on these states' continued peaceful intentions, which could change rapidly. Unfortunately, the IAEA's Board of Governors and major governments, including the United States, do not yet fully appreciate the full implications of these points.

If the IAEA cannot provide timely detection of diversions of weapons-usable HEU and plutonium from centrifuge enrichment, spent fuel reprocessing, and other fuel-making plants, how can it claim that it is "safeguarding" such facilities in Brazil, the Netherlands, Germany, and Japan? How can it

MATERIAL	IAEA Conversion Time	Cochran/ NPEC Commissioned Estimate	Official IAEA Timeliness Detection Goal	NPEC Conclusions and Recommended Timeliness Detection Goals
Pu, HEU, ^{233}U in metal form	Order of days (7-10)	Order of days (7-10)	1 month	Timely detection is not possible
In fresh MOX	Order of weeks (1-3)	Order of days (7-10)	1 month	Timely detection is not possible
In irradiated spent fuel	Order of months (1-3)	Order of months (1-3), if reprocessing - enrichment plant on tap (7-10 days	3 months	For countries with covert or declared nuclear fuel making plants, timely detection is not possible
Low enriched uranium	Order of months (3-12)	Order of weeks to months	1 year	For countries with covert or declared enrichment plants, timely detection is not possible

Figure 4. IAEA's Timeliness Detection Goals and NPEC's Conclusions.

effectively safeguard an Indian reprocessing plant (as is being currently proposed by the Indian government as a way to allow for the reprocessing of foreign fuel for use in an unsafeguarded Indian breeder reactor)? What of the idea of promoting regional nuclear fuel-making centers in nonweapons states, such as Kazakhstan? How might the IAEA prevent diversions?[29]

What of other more ambitious missions for the IAEA? If one cannot keep track of many bombs' worth of nuclear weapons-usable material produced annually at declared civilian nuclear fuel-making plants or assure that the plants themselves would not be seized, how much sense does it make to encourage the IAEA to oversee an even more difficult to verify military fissile production cut-off treaty?[30] Finally, there is the question of large research reactors and nuclear power plants, which require lightly enriched fuel or produce significant quantities of plutonium. If the IAEA cannot reliably ferret out covert nuclear fuel making programs, how safe is it to export such machines to new countries, particularly in war-torn regions, such as the Middle East?

The questions here are all intentionally rhetorical. Yet, many experts and officials within the IAEA and the U.S. and other governments actively support at least one or more of the questionable nuclear initiatives referred to. This needs to change.

One of this report's key recommendations is to encourage governments and the IAEA to reassess the agency's estimates of what a significant quantity is, along with the conversion times for various materials and what the proper detection goals should be for the agency. The most important part of this reassessment would be to clarify precisely what nuclear material diversions the agency cannot be counted upon to detect in a timely fashion. At a minimum, this should include the possible diversion of HEU, ^{233}U, and MOX from storage facilities, reprocessing plants, enrichment plants, fuel fabrication plants and of direct-use materials from large research or power reactors in nonweapons states that might have covert or declared nuclear fuel-making plants.

For these nuclear activities and materials, the IAEA would do well simply to declare that the agency can monitor, but not safeguard them—i.e., that it can mind these facilities and materials but not assure detection of their possible military diversion in a timely fashion. Such an honest announcement would be helpful. First, it would put governments on notice about how dangerous the conduct of certain nuclear activities most closely related to bomb making actually are. Second, it would encourage countries to demand more monitoring and physical security of these unsafeguardable nuclear materials and activities. The primary aim in increasing such security and monitoring would not be to block diversions so much as to increase the chance of at least detecting them after they had occurred. This would help to deter such deeds and to limit further the risks of nuclear theft or sabotage. It is difficult to determine what the optimal level of monitoring and physical security might be for this purpose. But a good place to start would be to upgrade physical security at nuclear facilities that handle or produce nuclear weapons-usable materials to those security standards currently employed at the most secure nuclear weapons production and storage facilities.

FUNDING

As already noted, the IAEA's inspections of safeguardable nuclear materials and activities could be enhanced in a number of ways. More near-real time monitoring could significantly enhance the agency's ability to detect the diversion of fuel rods. Retention and increasing the numbers of experienced nuclear inspectors could help assure the IAEA actually meets its timelines detection goals and is able to analyze remote sensing information and imagery properly. Full support for the IAEA's environmental sampling activities would enable it to replace its aging Safeguards Analytical Laboratory and help the IAEA shorten the time needed to analyze samples from months to days or weeks. Much needed work to develop new safeguarding research capabilities and equipment could proceed much more quickly if more funds were made available.[31] Similarly, with proper funding, the IAEA could muster reserve inspections staff and resources to meet unexpected demands and to provide the agency with deployable wide-area surveillance capabilities.

The first step to address these current gaps is simply to admit that they exist. For years, the IAEA has avoided doing this publicly. At the very outset of NPEC's investigations, early in 2005, the IAEA's safeguards planning staff briefed NPEC that it believed safeguards funding for the mid-term (i.e., the next 5 years) was sufficient. It conceded that it had given little or no thought to what funding agency safeguards might require beyond this period.

Fortunately, in the last 2 years, the agency's approach to safeguards planning has improved. Most recently the IAEA's director general highlighted the agency's lack of safeguards funding to deal with urgent inspections requirements associated with monitoring the shutdown of the reactor in North Korea. In a statement he made on July 9, 2007, IAEA Director General Dr. Mohamed ElBaradei explained that the IAEA was having difficulty paying for the nearly 4 million euros needed to cover the monitoring costs. He went on to note:

> The DPRK case clearly illustrates the need for the agency to have an adequate reserve that can be drawn upon to enable it to respond promptly and effectively to unexpected crises or extraordinary requests, whether in the areas of verification, nuclear and radiological

> accidents, or other emergencies. The agency's financial vulnerability is also demonstrated by our current cash situation, which indicates that unless some major donors pay their outstanding contributions by the end of next month, the agency will have to draw from the Working Capital Fund in order to continue operations. And unless contributions are received by September, that Fund would be depleted. Finally, let me stress that the recent process of preparing and getting approval for the programme and budget for the next biennium has once again highlighted the urgent need for adequate resources to ensure effective delivery of the entire programme that you have requested. As I made clear during the last Board, even with the budget originally proposed by the Secretariat, the agency remains under-funded in many critical areas, a situation which, if it remains unaddressed, will lead to a steady erosion of our ability to perform key functions, including in the verification and safety fields.

At the conclusion of this statement, the director general then announced that he had initiated a study to examine the IAEA's "programmatic and budgetary requirements" over the "next decade or so." In addition, he announced his intention to create a high level panel to study options for financing the agency's requirements.[32]

The director general's announcement accords almost precisely to the recommendations Dr. Thomas E. Shea made to a select group of U.S. and European officials, including Dr. ElBaradei's top scientific advisor, Andrew Graham, at an NPEC-sponsored conference held in Paris, France, on November 13, 2006.[33] In his brief, "Financing IAEA Verification of the NPT," Dr. Shea argued that North Korea "provides a clear justification" for additional safeguards funding and that to secure it the director general "should convene a council of wise men to assist in determining how best to respond in this matter."

As has been noted, the IAEA's funding is based on a United Nations formula that weights a country's gross domestic product and other factors. This formula may be sensible for raising general funds, but for nuclear safeguards purposes it produces several anomalies. Countries with no large reactors (e.g., Italy) are sometimes asked to pay in more than countries that have a score or more of them (e.g., the Republic of Korea). The UN assessment method also overlooks the actual inspections requirements particular nuclear facilities impose that are significantly higher than the norm. Nuclear fuel-making plants of any type, reactors that are on-line fueled (i.e., fueled constantly while they are operating, e.g., heavy water and gas-cooled reactors, versus off-line fueled reactors, e.g., light water reactors), and fast reactors all impose additional inspections challenges that are significantly higher than other types of nuclear facilities. Inspecting or monitoring these facilities costs much more than it does for other nuclear plants, yet the operator or owner pays no premium to cover these additional expenses.

Finally, because the IAEA's current approach to assessing its members for contributions fails to raise enough money for the Department of Safeguards, the agency must depend on additional voluntary contributions of cash and technical assistance. Almost all of voluntary contributions come from the United States (amounting to roughly 35 percent of the IAEA's safeguards budget). That so much of the safeguards budget is paid for voluntarily by the United States is politically awkward, since the agency's most challenging inspections cases—e.g., India, Iran, North Korea, Taiwan, and South Korea—are all of special interest to Washington.[34]

Dr. Shea suggests several ways to increase funding for safeguards—from setting up an endowment to selling bonds. All of them are worth pursuing, but one of his ideas is particularly deserving: the customer (i.e., the inspected party) should pay. There already is a precedent for doing this. Taiwan, which the IAEA does not recognize as being an independent, sovereign nation does not pay as other nations do but instead pays what the IAEA estimates it costs the agency to inspect Taiwan's plants.

This report recommends that the United States take the lead getting the IAEA to help fund its safeguards activities with a user fee. The United States should continue to make its voluntary contributions but instead of making them as it currently does, Washington should justify them as representing a specific percentage of costs associated with generating nuclear electricity annually in the United States. Japan, which also gives voluntary contributions, should be urged to do likewise. Agreement might subsequently be reached on an international standard and this surcharge should be tacked on to the cost of electricity or other products these civilian plants produce. The last step would be to make the surcharge obligatory and assign all of the funds so raised to the IAEA's Department of Safeguards.

In addition to these funds, the agency should consider assessing an additional charge for the monitoring of unsafeguardable nuclear materials or facilities (e.g., nuclear fuel-making plants and nuclear weapons or near-nuclear weapons-usable fuels, etc.). Finally, an additional fee might be levied against nuclear facilities or plants that are particularly costly for the IAEA to meet its own timeliness detection goals (e.g., for on-line fueled reactors).

RIGHTS

Some countries, of course, are likely to bridle at these proposals, arguing that imposing surcharges would interfere with their right to peaceful nuclear energy. These arguments, however, should be rejected. The exercise of one's right to develop, research and produce peaceful nuclear energy hardly extends to not paying what it costs to safeguard these activities against military diversion. Also, the premise behind these arguments is a dangerously distorted view of the nuclear rules—that so long as states can claim a nuclear material or activity has some conceivable civilian application, any country has a right to acquire or engage in them even if they are unprofitable commercially, bring their possessor to the very brink of having bombs, and cannot be safeguarded against military diversion. The danger of this over-generous interpretation of the NPT is obvious: It risks, as U.N. General Secretary Koffi Anan explained to the 2005 NPT review conference, creating a dangerous world full of nuclear fuel-producing states that claim to be on the right side of the NPT, but are, in fact, only months or even days from acquiring nuclear weapons.[35]

Luckily, as research conducted for NPEC makes clear, this interpretation of the NPT is wrong.[36] The NPT makes no mention of nuclear fuel making, reprocessing, or enrichment. Spain, Romania, Brazil, and Mexico all tried in the late 1960s to get NPT negotiators to make it a duty under Article IV for all of the nuclear supplier states to supply "the entire fuel cycle" including fuel making, to nonweapons states. Each of their proposals was turned down.[37] At the time, the Swedish representative to the NPT negotiations even suggested that rules needed to be established to *prevent* nations from getting into such dangerous activities, since there seemed no clear way to prevent nations that might make nuclear fuel from quickly diverting either the fuel or the fuel making plants very quickly to make bombs.[38] They certainly were not interested in protecting uneconomical propositions that are unnecessary and that could bring states to the brink of having bombs.[39]

A clear case in point was the NPT's handling of peaceful nuclear explosives, which turned out to be so dangerous and impossible to safeguard that the treaty spoke only of sharing the "potential benefits" of peaceful nuclear explosives that would be supplied by nuclear weapons states. No effort, however, was ever made to request or to offer such nuclear explosives because they were so costly to use as compared to conventional explosives and no clear economic benefit could be found in using them.[40]

Finally, in no case did the framers of the NPT believe that the inalienable right to develop, research or produce peaceful nuclear energy should allow states to contravene the NPT restrictions designed to prevent the proliferation of nuclear weapons. These restrictions are contained in articles I, II, and III of the treaty. Article I prohibits nuclear weapons states "assist[ing], encourage[ing], or induc[ing] any non-weapons state "to manufacture or otherwise acquire" nuclear weapons. Article II prohibits non-weapons states from acquiring in any way nuclear explosives or seeking "any assistance" in their manufacture. Together these two prohibitions suggest that the NPT not only bans the transfer of actual nuclear explosives, but of any nuclear technology or materials that could "assist, encourage or induce" nonweapons states to "manufacture or otherwise acquire" them.[41]

If there was any doubt on this point, the NPT also requires all nonweapons states to apply safeguards against all of their nuclear facilities and holdings of special nuclear materials. The purpose of these nuclear inspections, according to the treaty is "verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons."[42] It was hoped at the time of the treaty's drafting that a way could be found to assure such safeguards. It, however, was not assumed that such techniques already existed.[43]

CONCLUSION

It would be useful to remind members of the IAEA of these points. The most direct and easiest way to begin is to make clear what can and cannot be safeguarded—i.e., what can and cannot be monitored so as to detect a military diversion *before* it is completed. Beyond this, the IAEA should have the owner, operators, and customers of nuclear facilities bear the costs associated with monitoring and safeguarding them. The hope here would be that the poor economics associated with large nuclear power reactors and nuclear fuel making plants might help some nations reconsider the desirability of acquiring them. Making sure that the full external costs of IAEA inspections are carried by each inspected party would be useful. The NPT, after all, is dedicated to sharing the "benefits" of peaceful nuclear energy, not money losing programs that bring countries to the brink of having bombs.[44]

In this regard, it is worth noting that a popular idea to promote nonproliferation that enjoys IAEA support—assuring supplies of nuclear fuel at "affordable" or "reasonable" prices with fuel banks and the construction of fuel making centers in nonweapons states—could, under certain circumstances, actually undermine the NPT's intent. If these assurances come with subsidies, more countries may be enticed to develop large nuclear programs that may not be economically viable. If these assurances come, as they now do, with repeated pledges that the recipients of the fuel retain a per se right to make nuclear fuel any time they wish, then, there also is a danger that after bootstrapping themselves up with fuel assistance, recipient nations will simply proceed to make fuel on their own. Finally, if the assurances result in building fuel-making centers in countries that do not yet have nuclear weapons, the risks of nuclear weapons proliferation will surely increase.[45]

Unfortunately, there is no technical fix yet for the dangers associated with declared and covert nuclear fuel making activities. Initially, one of the claims of the U.S. Global Nuclear Energy Partnership (GNEP) initiative was that it would make it possible to recycle spent fuel in a proliferation resistant manner and, thereby, strengthen the international nonproliferation regime. NPEC commissioned two leading national nuclear experts at MIT and Princeton to examine these claims.[46] Their conclusion—that these assertions do not hold up and that the recycling technology would be more not less difficult to monitor—now is closer to the view that even the Department of Energy itself is making. Its official strategy document now warns against spreading its "proliferation resistant" uranium extraction (UREX) system for fear it, too, might be diverted to make bombs.[47]

Finally, routine inspections alone are unlikely to deter states from breaking the rules. One of the key reason why is that after the agency's experience with Iraq, Iran, and North Korea, it is no longer clear what might happen to the next nation that breaks its IAEA safeguards agreement or the strictures of the NPT. Pierre Goldschmidt, the former IAEA Deputy Director who headed up the agency's Department of Safeguards, knows this first hand: He had to deal with Iraq, Iran, and North Korea where the burden of proof for misbehavior was laid at IAEA's doorstep rather than with the suspect party. NPEC was fortunate to be able to commission Dr. Goldschmidt to review what might be done to correct this. His recommendations, which consist of developing a set of country-neutral rules that come into play when the IAEA is *unable* to clarify suspicious behavior or when a majority of the IAEA board finds a nation to be non-compliant or attempting to break free from the NPT before it is found to be in compliance, are among the ones contained in this final report.

Adoption of these recommendations, along with the others, is essential to give the IAEA the resources and authorities it needs to succeed. Beyond this, member states must stop pushing the IAEA to safeguard nuclear materials and projects that are both unnecessary and so close to bomb making that no agency, national or international, could credibly safeguard them against military misuse. The balance, in short, that must be struck is to give the agency much more to do its job and to back off demanding that it tackle the impractical.

ENDNOTES – CHAPTER 1

1. For the latest of these, see U.S. Government Accountability Office, *Nuclear Nonproliferation: IAEA Has Strengthened Its Safeguards and Nuclear Security Programs, but Weaknesses Need to Be Addressed*, GAO-06-93, Washington, DC, October 7, 2005, available from *www.gao.gov/new.items/d0693.pdf*.

2. Upon the suggestion of the United States, the IAEA Board of Governors agreed in 2005 to create a special committee to advise how best to strengthen the IAEA's current nuclear safeguards system. In private interviews, NPEC has learned that the confidential recommendations of this committee were almost entirely administrative and quite modest in scope. None of the recommendations, which were made in the spring of 2007, have yet been acted upon.

3. These states included Algeria, Tunisia, Morocco, Libya, Egypt, Turkey, Jordan, Saudi Arabia, Yemen, Vietnam, Australia, Indonesia, Bangladesh, Vietnam, and Nigeria.

4. For a list of experts who participated in NPEC's IAEA safeguards workshops, go to Appendix I.

5. This line of argument was actually presented to NPEC's executive director in a private briefing by the IAEA safeguards planning staff in Vienna early in 2006.

6. For data on the IAEA's safeguards budget obligation in current—not constant—U.S. dollars, see *The Agency's Accounts for 1984*, GC(XXIX)/749, p. 26; and *The Agency's Accounts for 2004*, GC(49)/7, p. 47. For data on the amount of nuclear material safeguarded by the IAEA, see *Annual Report for 1984*, GC(XXIX)/748 (Vienna, Austria: IAEA, July 1985), p. 63; and *Annual Report for 2004*, GC(49)/5, Annex, Table A19.

7. Private interviews with safeguards staff and former IAEA safeguards inspectors at the Los Alamos National Laboratory, Los Alamos, NM, May 12, 2005.

8. See Gene Aloise, Director Natural Resources and Environment, U.S. Government Accountability Office, "Nuclear Nonproliferation: IAEA Safeguards and other Measures to Halt the Spread of Nuclear Weapons Materials," testimony before the Subcommittee on National Security, Emerging Threats and International Relations, Committee on Government Reform, House of Representatives, September 26, 2006.

9. For a more detailed discussion of the Additional Protocol see Richard Hooper, "The IAEA's Additional Protocol," *Disarmament Forum*, "On-site Inspections: Common Problems, Different Solutions," 1999, No. 3, pp. 7-16, available from *www.unidir.ch/bdd/fiche-article.php?ref_article=209*.

10. For example, in the case of Japan, the IAEA needed five years to determine it had no undeclared nuclear material activities and estimates that it will need about as much time to make the same determination for Canada. See U.S. GAO, *Nuclear Nonproliferation,* pp. 12-13.

11. According to IAEA internal analyses, the average lifetime savings in safeguards resources likely implementing integrated safeguards may be no more than five percent. See C. Xerri and H. Nackeaerts on behalf of the ESARDA Integrated Safeguards Working Group, "Integrated Safeguards: A Case to Go Beyond the Limits: Consequences of Boundary Limits Set to the Reduction of "Classical Safeguards Measures on Efficiency and Resources Allocation in Integrated Safeguards" produced in 2003 for the IAEA, available from *esarda2.jrc.it/bulletin/bulletin_32/06.pdf*. For an official overview of the various safeguards resources required to implement the Additional Protocol, see Jill N. Cooley, "Current Safeguards Challenges from the IAEA View," an IAEA document produced in 2003, available from *esarda2.jrc.it/events/other_meetings/inmm/2003-esarda-inmm-Como/1-paper%20pdf/1-1-040127-cooley.pdf*.

12. See Garry Dillon, "Wide Area Environmental Sample in Iran," available from *www.npec-web.org/Essays/WideAreaEnvironmentalSampling.pdf*.

13. See Victor Gilinsky, Harmon Hubbard, and Marvin Miller, *A Fresh Examination of the Proliferation Dangers of Light Water Reactors*, Washington, DC: The Nonproliferation Policy Education Center, October 22, 2004, reprinted in Henry Sokolski, ed., *Taming the Next Set of Strategic Weapons Threats*, Carlisle, PA: Strategic Studies Institute, U.S. Army War College, 2006, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=20041022-GilinskyEtAl-LWR&PDFFolder=Essays*.

14. See, e.g., Andrew Leask, Russell Leslie and John Carlson, "Safeguards As a Design Criteria—Guidance for Regulators," Canberra, Australia: Australian Safeguards and Non-proliferation Office, September 2004, pp. 4-9 available from *www.asno.dfat.gov.au/publications/safeguards_design_criteria.pdf*.

15. For more detailed discussion of how fuel diverted from different commercial and research reactors could help accelerate a country's covert bomb program, go to Appendix II of this report.

16. See J. Whichello, J. Regula, K. Tolk, and M. Hug, "A Secure Global Communications Network for IAEA Safeguards and IEC Applications," IAEA User Requirements Document, May 6, 2005.

17. The problem of states "losing" fuel rods, it should be noted is not limited to countries intent on diverting them to make bombs. The U.S. civilian nuclear industry, which has a clear industrial interest in keeping track of its nuclear fuel, has had difficulty keeping proper account of all of it. On this point, see U.S. Government Accountability Office, "NRC Needs to Do More to Ensure Power Plants Are Effectively Controlling Spent Fuel," GAO O5-339, April 2005, available from *www.gao.gov/new.items/d05339.pdf*.

18. Only about a third of the facilities at which the IAEA currently has remote sensors have near-real-time connectivity with Vienna or other regional headquarters and almost all of these facilities are in countries that are of minimal proliferation risk. This information was presented at a private IAEA Department of Safeguards briefing of NPEC's executive director at Vienna, Austria, IAEA Headquarters, January 30, 2006.

19. See Edwin Lyman, "Can Nuclear Fuel Production in Iran and Elsewhere be Safeguarded Against Diversion," presented at NPEC´s Conference "After Iran: Safeguarding Peaceful Nuclear Energy" held in London, UK, October 2005, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=Paper050928LymanFuelSafeguardDiv&PDFFolder=Essays*.

20. This incident received only scant public attention. See, however, Bayan Rahman, "Japan 'Loses' 206 kg of Plutonium," *Financial Times*, January 28, 2003, available from *news.ft.com;servlet/*

ContentServer?pagename=FT.com/StoryFT/FullStory&c=StoryFT&cid=1042491288304&p=10112571727095.

21. *Idem*. Also see "Missing Plutonium 'Just on Paper,'" *BBC News*, February 17, 2005, available from *news.bbc.co.uk/1/hi/uk/4272691.stm*; and Kenji Hall, "Missing Plutonium Probe Latest Flap for Japan's Beleaguered Nuclear Power Industry," *Associated Press* (Tokyo), January 28, 2003, available from *www.wise-paris.org/index.html?/english/othersnews/year_2003/othersnews030128b.html&/english/frame/menu.html&/english/frame/band.html*.

22. These points have been long recognized by outside experts. See Paul Leventhal, "Safeguards Shortcomings—A Critique," Washington, DC: NCI, September 12, 1994; Marvin Miller, "Are IAEA Safeguards in Plutonium Bulk-Handling Facilities Effective?" Washington, DC: NCI, August 1990; Brian G. Chow and Kenneth A. Solomon, *Limiting the Spread of Weapons-Usable Fissile Materials*, Santa Monica, CA: RAND, 1993, pp. 1-4; and Marvin Miller, "The Gas Centrifuge and Nuclear Proliferation," in *A Fresh Examination*, p. 38.

23. See *idem*. and the comments of the former chairman of the IAEA's Standing Advisory Group on International Safeguards, John Carlson, Australian Safeguards and Non-Proliferation Office, "Addressing Proliferation Challenges from the Spread of Uranium Enrichment Capability," Paper prepared for the Annual Meeting of the Institute for Nuclear Materials Management, Tucson, Arizona, July 8-12, 2007. Copy on file at NPEC.

24. See Thomas B. Cochran, "Adequacy of IAEA's Safeguards for Achieving Timely Warning, " paper presented before a conference cosponsored by NPEC and King's College, "After Iran: Safeguarding Peaceful Nuclear Energy," October 2-3, 2005, London, United Kingdom, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=Paper050930CochranAdequacyofTime&PDFFolder=Essays*.

25. Interview of senior advisors to the IAEA Director General, IAEA Headquarters, Vienna, Austria, January 30, 2006, and January 17, 2005.

26. IAEA, *IAEA Safeguards Glossary,* 2001 Edition, Paragraph 3.13, Figure 3 here is identified as Table I in the IAEA glossary.

27. Cf. the low-end conversion time estimates for low enriched uranium of John Carlson in note 22 above, which for a small commercial enrichment facility range between 18 hours and 12 days.

28. See the testimony of Pierre Goldschmidt before a hearing of the House Subcommittee on National Security and Foreign Affairs of the House Committee on Oversight and Government Reform, "International Perspectives on Strengthening the Nonproliferation Regime," June 26, 2007, Washington, DC, available from the subcommittee upon request.

29. See Ann Mac Lachian, Mark Hibbs, and Elaine Hiruo, "Kazakh Buy-in to Westinghouse Seen as Win-win for Kazakhs, Toshiba," *Nucleonics Week*, July 12, 2007, p. 1; and Kenneth Silverstein, "As North Korea Gives Up Its Nukes, Kazakhstan Seeks a Nuclear Edge," *Harper's Magazine,* July 2007, available from *harpers.org/archive/2007/07/hbc-90000549*.

30. On the challenges of verifying a military fissile production cut-off treaty, see Christopher A. Ford, "The United States and the Fissile Material Cut-off Treaty," delivered *at t*he Conference on "Preparing for 2010: Getting the Process Right," Annecy, France, March 17, 2007, available from *www.state.gov/t/isn/rls/other/81950.htm*.

31. For a detailed discussion of what specific new safeguards capabilities the IAEA Department of Safeguards is investigating, see N. Khlebnikov, D. Parise, and J. Whichello, "Novel Technology for the Detection of Undeclared Nuclear Activities," IAEA-CN148/32, presented at the IAEA Conference on Safeguards held in Vienna, Austria, on October 16-20, 2006, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=20070301-IAEA-NovelTechnologiesProject&PDFFolder=Essays*.

32. See IAEA Director General Dr. Mohamed ElBaradei, "Introductory Statement to the Board of Governors," July 9, 2007, Vienna, Austria, available from *www.globalsecurity.org/wmd/library/news/dprk/2007/dprk-070709-iaea01.htm*.

33. See Thomas E. Shea, "Financing IAEA Verification of the NPT," paper presented before a conference sponsored by the Nonproliferation Policy Education Center and the French Foreign Ministry, "Assessing the IAEA's Ability to Verify the NPT," November 12-13, 2006, Paris, France, available from *www.npec-web.org/Essays/20061113-Shea-FinancingIAEAVerification.pdf*.

34. See U.S. GAO, *Nuclear Nonproliferation,* pp. 34-40.

35. See Statement of UN Secretary General Kofi Annan, Statement to the Nuclear Nonproliferation Treaty Review Conference, May 2, 2005, UN Headquarters, New York, available from *www.acronym.org.uk/docs/0505/doc11.htm*.

36. Robert Zarate, "The NPT, IAEA Safeguards and Peaceful Nuclear Energy: An 'Inalienable Right,' But Precisely To What?" presented at *Assessing the IAEA´s Ability to Safeguard Peaceful Nuclear Energy*, a conference held in Paris, France, on November 12-13, 2006, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=20070509-Zarate-NPT-IAEA-PeacefulNuclear&PDFFolder=Essays*.

37. See "Mexican Working Paper Submitted to the Eighteen Nation Disarmament Committee: Suggested Additions to Draft Nonproliferation Treaty," ENDC/196, September 19, 1967, in U.S. Arms Control and Disarmament Agency, *Documents on Disarmament, 1967*, Publication No. 46, Washington, DC: U.S. Government Printing Office, July 1968, pp. 394-395; "Romanian Working Paper Submitted to the Eighteen Nation Disarmament Committee: Amendments and Additions to the Draft Nonproliferation Treaty," ENDC/199, October 19, 1967, in *ibid.*, pp. 525-526; "Brazilian Amendments to the Draft Nonproliferation Treaty," ENDC/201, October 31, 1967, in *ibid.*, p. 546; and "Spanish Memorandum to the Co-Chairman of the ENDC," ENDC/210, February 8, 1968, in U.S. Arms Control and Disarmament Agency, *Documents on Disarmament, 1968*, Publication No. 52, Washington, DC: U.S. Government Printing Office, September 1969, pp. 39-40.

38. See "Statement by the Swedish Representative [Alva Myrdal] to the Eighteen Nation Disarmament Committee: Nonproliferation of Nuclear Weapons," ENDC/PV. 243, February 24, 1966, in U.S. Arms Control and Disarmament Agency,

Documents on Disarmament, 1966, Publication No. 43, Washington, DC: U.S. Government Printing Office, September 1967. p. 56.

39. See Eldon V.C. Greenberg, "NPT and Plutonium: Application of NPT Prohibitions to 'Civilian' Nuclear Equipment, Technology and Materials Associated with Reprocessing and Plutonium Use," Nuclear Control Institute, 1984, Revised May 1993.

40. See *Report of Main Committee III*, Treaty on the Nonproliferation of Nuclear Weapons Review and Extension Conference, May 5, 1995, NPT/CONF.1995/MC.III/1, Sec. I, para. 2, emphases added, available from *www.un.org/Depts/ddar/nptconf/162.htm*, which states: "The Conference records that the potential benefits of the peaceful applications of nuclear explosions envisaged in article V of the Treaty have not materialized. In this context, the Conference notes that the potential benefits of the peaceful applications of nuclear explosions have not been demonstrated and that serious concerns have been expressed as to the environmental consequences that could result from the release of radioactivity from such applications and on the risk of possible proliferation of nuclear weapons. Furthermore, no requests for services related to the peaceful applications of nuclear explosions have been received by IAEA since the Treaty entered into force. The Conference further notes that no State party has an active programme for the peaceful application of nuclear explosions."

41. See Greenberg, "NPT and Plutonium"; and Henry D. Sokolski and George Perkovich, "It's Called *Non*proliferation," *Wall Street Journal*, April 29, 2005, p. A16.

42. NPT, Art III, para. 1.

43. For example, see "British Paper Submitted to the Eighteen Nation Disarmament Committee: Technical Possibility of International Control of Fissile Material Production," ENDC/60, August 31, 1962, Corr. 1, November 27, 1962, in U.S. Arms Control and Disarmament Agency, *Documents on Disarmament, 1962*, Publication No. 19, Vol. 2 of 2, Washington, DC: U.S. Government Printing Office, November 1963, pp. 834-852.

44. On these points, see Henry Sokolski, "Market-based Nonproliferation," testimony presented before a hearing of the

House Committee on Foreign Affairs, "Every State a Superpower?: Stopping the Spread of Nuclear Weapons in the 21st Century," May 10, 2007.

45. On these points, see Charles Ferguson, *Nuclear Energy: Balancing Benefits and Risks*, New York: The Council on Foreign Relations, April 2007.

46. See Frank von Hippel, "Managing Spent Fuel in the United States: The Illogic of Reprocessing," January 2007, an NPEC-commissioned paper published as Research Report No. 3 by the International Panel on Fissile Materials, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=20070100-VonHippel-ManagingSpentFuel&PDFFolder=Essays*; Richard K. Lester, "New Nukes," *Issues in Science and Technology,* Summer 2006, pp. 39-46, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=20060600-Lester-NewNukes&PDFFolder=Essays*; and Edwin Lyman, "The Global Nuclear Energy Partnership: Will It Advance Nonproliferation or Undermine It?" presented at the annual meeting of the Institute of Nuclear Materials Management, July 19, 2006, available from *www.npec-web.org/Essays/20060700-Lyman-GNEP.pdf*.

47. See U.S. Department of Energy, Office of Fuel Cycle Management, *Global Nuclear Energy Partnership Strategic Plan*, Washington, DC: U.S. Department of Energy, GNEP-167312, Rev. 0, January 2007), p. 5, where the DoE notes that "there is no technology 'silver bullet' that can be built into an enrichment plant or reprocessing plant that can prevent a country from diverting these commercial fuel cycle facilities to nonpeaceful use. From the standpoint of resistance to rogue-state proliferation, there are limits to the nonproliferation benefits offered by any of the advanced chemical separations technologies, which generally can be modified to produce plutonium. . . ."

APPENDIX I

NPEC IAEA SAFEGUARDS WORKSHOP PARTICIPANTS, 2005-2007

Graham Andrew,
Special Assistant to the Director General for Science & Technology, Office of the Director General - IAEA

Andrew Barlow,
Foreign and Commonwealth Office, United Kingdom

Patrick Beau,
National Defense General Secretariat of France

Wyn Bowen,
King's College London

Martin Briens,
Sours-Directeur Du Désarmement et De La Non-prolifération Nucléaires, French Ministère des Affaires étrangères

Lisa Bronson,
Deputy Undersecretary of Defense for Technology, Security Policy, and Counterproliferation, National Defense University

Kory Budlong-Sylvester,
NNSA - Department of Energy - USA

John Bunney,
Former Adviser to the Department of Safeguards, IAEA

Ed Burrier,
Professional Staff, Subcommittee on International Terrorism and Nonproliferation

Doug Campbell,
Office of Congressman Berman, USA

Thomas B. Cochran,
Chief Nuclear Scientist, Natural Resources Defense Council

Leland Cogliani,
Government Accountability Office

Garry Dillon,
International Atomic Energy Agency (retired)

Bruno Dupre,
Ministry of Defence, France

Jack Edlow,
President, Edlow International

Steve Elliott,
Department of State, Chief of Staff, Office of the Under Secretary of State for International Security

Phillipe Errera,
Députe Director du Centre d'Analyse et de Prevision Ministère des Affaires étrangères

Steve Fetter,
Dean, School of Public Policy, University of Maryland

Mark Fitzpatrick,
International Institute for Strategic Studies

Jeff Fortenberry,
Congressman, United States House of Representatives

Paul Fouilland,
État-major des armées, France

Thomas Göbel,
Ministry of Foreign Affairs, Germany

Jose Goldemberg,
former Brazilian Secretary of State for Science and Technology

Pierre Goldschmidt,
former Deputy Director General, Head of the Department of Safeguards, IAEA (Retired)

Bruno Gruselle,
Fondation pour le Recherche Strategique, Paris

Thomas Guibert,
Ministère des Affaires étrangères

Erwin Häckel,
German Council on Foreign Relations

Glenn Hawkins,
Department of Trade and Industry, U.K.

Brian Jenkins,
RAND Corporation

Joanna Kidd,
King's College

Bernadette Kilroy,
Director, Strategic Planning Office, Department of State, USA

Michael Knights,
The Washington Institute for Near East Policy

Michael Levi,
King's College London

Ed Levine,
Senior Professional Staff Member, Senate Foreign Relations Committee

Edwin Lyman,
Union of Concerned Scientists

Cécile Maisonneuve,
Assemblée Nationale, France

Jim McNally,
U.S. Department of State

Quentin Michel,
EU Commission, Expert National Détaché on dual use export controls

Thomas Moore,
Majority Staff, Senate Foreign Relations Committee

Raphaële Pailloux,
Delegation General for Armaments (DGA) of France

Florian Riendel,
First Secretary (Political), Embassy of Germany

Guy Roberts,
NATO, Deputy Assistant Secretary General for WMD

Henry S. Rowen,
The Hoover Institution, Stanford, former member of the U.S. Presidential Commission on he Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction

Wolfgang Rudischhauser,
German Foreign Ministry

Guillaume Schlumberger,
Fondation pour le Recherche Strategique, Paris

Thomas Shea,
Pacific Northwest National Laboratory

Henry Sokolski,
Nonproliferation Policy Education Center

Pam Tremon,
U.S. Embassy, London

Robert Zarate,
Nonproliferation Policy Education Center

APPENDIX II

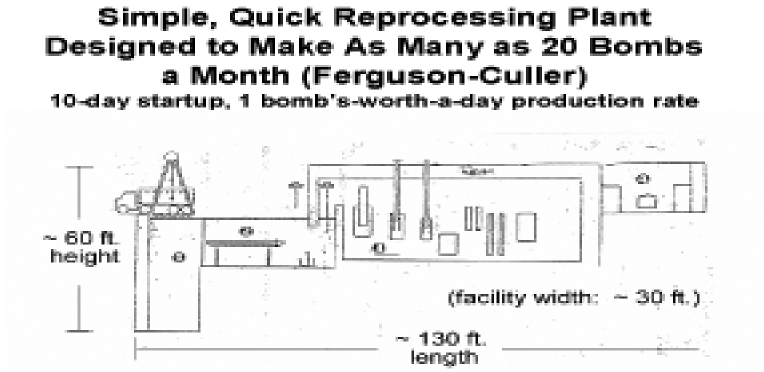
THE PROLIFERATION DANGERS OF LWRS

Adding to the IAEA's nuclear inspection challenges is the continued spread of large research and power reactors to countries like Egypt, Algeria, and Iran that require lightly enriched uranium as fuel and produce a significant amount of plutonium-laden spent fuel—materials, which, as has already been noted, could be seized to accelerate the production of weapons-usable uranium or plutonium. Most of these reactors are off-line fueled and so are considered to be "proliferation resistant" because their fuel cannot be removed or inserted without shutting the entire reactor down and because they are fueled with slightly enriched uranium that only a handful of advanced nuclear nations can produce. This makes inspections against possible diversions or misuse of the fuel easier than with graphite or heavy-water moderated reactors like those found in Israel, India, and North Korea where the reactor is fueled "on-line," i.e., while the reactor is still operating with natural uranium, a fuel that, unlike lightly enriched uranium, is much easier to produce indigenously.[48]

But with the development in North Korea and Iran of covert enrichment and reprocessing facilities, the proliferation resistance of even these "peaceful" reactors now is far less than advertised. In fact, one could seize all, or a portion, of the many tons of fresh lightly enriched uranium fuel that normally sits outside of most power reactors for safety reasons.[49] divert it to a covert or declared enrichment plant, open the fuel rods, crush the uranium oxide fuel pellets, heat them, and run fluoride gas over the material. The result would be the quick production of massive amounts of uranium hexafluoride without ever having to mine and mill uranium ore, or use a complicated hexafluoride production plant. More important, the enrichment of the uranium produced would reduce five-fold the amount of effort otherwise required to enrich natural uranium for use in nuclear explosives. This would significantly reduce the amount of time required for a country to produce its first uranium bomb.[50]

Yet another way that would-be bomb makers could exploit the operation of large reactors would be to divert the reactor's spent fuel either from the reactor itself, or from its spent fuel pond. Spent fuel is laden with plutonium—itself a nuclear fuel, which—once chemically stripped from the other spent fuel by-products, can make nuclear weapons of any yield. In fact, during the normal operation of large light water reactors of the sort Iran is building at Bushier, the reactor will produce 330 kilograms of near-weapons grade plutonium—enough to make over 50 crude nuclear bombs.[51]

As for chemically separating the plutonium from spent fuel, this could be accomplished in a facility as small as 65 feet by 65 feet (small enough to be built and hidden within an existing large warehouse). This plutonium separation plant also need not be elaborate. Yet another "quick-and-dirty" design plant, detailed by the nuclear industry's leading experts in the late 1970s (measuring 130 feet by 60 feet by 30 feet, see Figure 5 below), employs technology little more advanced than that required for the production of dairy products and the pouring of concrete.



Source adapted from D.E. Ferguson "Simple Quick (Re)processing Plant" Memorandum to F.L. Gulier, Oak Ridge National Laboratory, August 30, 1977; and J.A. Hassberger, "Light-Water Reactor Fueling Handling and Spent Fuel Characteristics," Fission Energy and System Safety Program, Lawrence Livermore National Laboratory, circa February 25, 1999.

Figure 5.

These relatively compact plutonium chemical separation plants could be built within other larger buildings undetected, would not send off any signal until operated, and could separate a bomb's worth of plutonium each day after the first 10 days of operation. Assuming the country in question had already perfected a working implosion device,[52] the separated plutonium could be inserted to make a bomb directly—i.e., much more quickly than any outside party could act to block the diversion.

ENDNOTES – APPENDIX II, CHAPTER 1

1. An additional argument often offered to explain why light water reactors are proliferation resistant is that the plutonium they produce is "reactor" grade rather than "weapons" grade. This argument is specious. Reactor-grade plutonium will normally

contain about 25 percent "even isotope" plutonium (Pu 240 and Pu 242). This even isotope plutonium reduces the predictability of the precise weapons yield of any explosive device that uses it but reactor-grade plutonium can be relied upon to produce bombs with a minimum yield of at least one kiloton. Reactor-grade plutonium is also more hazardous to handle than weapons-grade plutonium, which normally contains no more than 6 percent even isotope plutonium. Still, for most national weapons efforts, the disadvantages of reactor-grade plutonium can be surmounted with proper weapons design adjustments to make a weapon of any yield. On these points, see J. Carson Mark, "Explosive Properties of Reactor-Grade Plutonium," *Science and Global Security*, 4 (1993), p. 111 and U.S. Department of Energy, *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives* Washington, DC: U.S. Department of Energy, DOE/NN-0007, 1997, pp. 37-39.

2. For a large power reactor of the size of Iran's Bushier reactor, it is customary to keep one reload, a third of a core consisting of 20 tons of lightly enriched uranium fuel, at the reactor site.

3. For additional details on how fresh light water reactor fuel could be used to accelerate a uranium weapons program, see Victor Gilinsky, Harmon Hubbard, and Marvin Miller, *A Fresh Examination of the Proliferation Dangers of Light Water Reactors*, Washington, DC: The Nonproliferation Policy Education Center, October 22, 2004, pp. 35-41, reprinted in Henry Sokolski, ed., *Taming the Next Set of Strategic Weapons Threats*, Carlisle, PA: Strategic Studies Institute, U.S. Army War College, 2006, available from *www.npec-web.org/Frameset.asp?PageType=Single&PDFFile=20041022-GilinskyEtAl-LWR&PDFFolder=Essays*.

4. This near-weapons-grade material is referred to as "fuel" grade plutonium and contains no more than 14 percent even-isotope plutonium. For a detailed discussion of the weapons utility of reactor and fuel-grade plutonium as compared to weapons-grade, see, Gilinsky, *A Reassessment,* pp. 21-33; and Harmon W. Hubbard, "Plutonium from Light Water Reactors as Nuclear Weapons Material," April 2004, Washington, DC: The Nonproliferation Policy Education Center, available from *www.npec-web.org/projects/hubbard.pdf*.

5. Although developing a working implosion device that can be used with either uranium or plutonium nuclear fuel is much more challenging than perfecting a working gun device, which can only be used to make a uranium bomb, it should no longer be assumed to be a major technical hurdle for most nations. Saddam Hussein's scientists perfected a working implosion device over 15 years ago. Working, tested designs have also been shared with at least Pakistan, Israel, and Libya by the French, United States, China, and Pakistan. For more on these points, see Barton Gellman, "Iraqi Work Toward A-Bomb Reported U.S. Was Told of 'Implosion Devices'," *The Washington Post,* September 30, 1998, p. A01; Carey Stublette, "Pakistan's Nuclear Weapons Program Development," January 2002, available from *nuclearweaponarchive.org/Pakistan/PakDevelop.html*; BBC News, UK Edition, "China 'Link' to Libya Nuke Design," February 16, 2004, available from *news.bbc.co.uk/1/hi/world/middle_east/3491329.stm*; and Avner Cohen, *Israel and the Bomb*, New York, NY: Columbia University Press, 1998, pp. 82-83; and Steve Weissman and Herbert Krosney, *The Islamic Bomb: The Nuclear Threat to Israel and the Middle East,* New York: Times Books, 1981, pp.114-117.