CHAPTER 5

NUCLEAR POWER, NUCLEAR WEAPONS—CLARIFYING THE LINKS

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It was obvious from the beginning of the nuclear age that nuclear energy for power and nuclear energy for bombs overlapped. The 1946 Acheson-Lilienthal Report said the two were "in much of their course interchangeable and interdependent."[1] Therefore, and this was also understood from the beginning, gaining the benefits of the new energy source without spreading the bomb entailed strict international rules backed up by military force. This coupling did not diminish enthusiasm for developing nuclear energy. The United States proposed international ownership and control of what the report called intrinsically dangerous nuclear activities.[2]

The report contained powerful insights, but the proposal for international ownership was in many ways unrealistic and therefore failed. Less than a decade later, the United States, reluctant to give up the benefits of U.S. nuclear technology—at that time mostly political—reversed course to launch Atoms for Peace. The program promoted nuclear technology worldwide on the optimistic assumption that periodic international inspections would be sufficient to make sure that "peaceful" technology would not be used for weapons. This was the very arrangement the Acheson-Lilienthal Report had said would not work: "No system of inspection, we have concluded, could afford any reasonable security against the diversion of such materials to the purposes of war."[3] Not for the

last time, the immediate attractions of nuclear energy overwhelmed distant security concerns.

Aside from occasional modest adjustment, we have been on that Atoms for Peace course ever since. But concerns about the weapons consequences kept intruding and stoked a continuing argument over whether occasional inspections by the International Atomic Energy Agency (IAEA) were really enough to keep the spread of nuclear electric facilities from contributing to the spread of nuclear weapons.[4] The present arguments over additional controls, especially in relation to reprocessing technology to separate plutonium and uranium enrichment, have their roots in that early history.

MAKING WAY FOR PLUTONIUM FUEL: FROM ATOMS FOR PEACE TO THE NPT

Plutonium is, of course, one of the two important nuclear explosives. Under Atoms for Peace, the United States declassified plutonium fuel technology, and the U.S. national laboratories trained foreign scientists in reprocessing technology.[5] The justification was that a shift to reliance on plutonium fuel was then considered inevitable so that reprocessing was regarded as an integral part of nuclear power operation.[6] A further rationalization, based on the scientifically incorrect argument first made in the Acheson-Lilienthal Report was that plutonium could be "denatured" to make it unusable for weapons.[7]

The other important nuclear explosive is highly enriched uranium (HEU). The United States did not release its uranium enrichment technology, then based on gaseous diffusion, and expected to monopolize it for many years. The United States, however, did ex-

port dozens of research reactors that were fueled with HEU, and ultimately exported over 30 tons of HEU.[8] Initially, the U.S. Government saw the various exports as too small to pose security concerns. Then, as the research and power reactor sizes increased, American and other exporters argued that IAEA inspections, or "safeguards" as they were optimistically called, were sufficient to make sure exports were not used to make material for bombs. The idea behind the inspections was that the threat of being found out and then sanctioned by the international community was sufficient to deter any would-be bomb maker from breaking the rules. The IAEA inspections were then gentlemanly affairs, with scientist-inspectors looking in on fellow scientists, and, in truth, the system was intended more to legitimize nuclear trade than to prevent wrongdoing.

In the late-1960s and early-1970s, the number and size of nuclear power installations increased rapidly. The preferred reactor type around the world was the light water reactor (LWR). Nuclear planners concluded from the large number of LWRs projected by national programs, and the limited then-known world uranium resources, that as early as 1980, the LWRs would have to be replaced by fast breeder reactors fueled with plutonium, thousands of them.

This meant many thousands of tons of plutonium in commercial channels, which gave pause to the security minded, as a bomb only requires a few kilograms. But the enthusiasms about plutonium as the fuel of the future overrode any concerns about its weapons potential. The interest in making way for the breeder reactor was strong enough to influence the negotiations over the Nonproliferation Treaty (NPT). The inspection provisions of the NPT were limited specifi-

cally to alleviate German and Japanese concerns that intrusive inspections would put them at a competitive disadvantage in supplying plutonium fuel for fast breeder reactors.[9]

Most of the less advanced non-nuclear countries saw the NPT negotiations as an opportunity to trade their signature for access to nuclear technology. They changed the NPT, which came into force in 1970, into a deal—or at least portrayed it as one—in which non-nuclear countries pledged not to make bombs in return for essentially unlimited access to "peaceful" nuclear technology. Article III stated that inspections were "to avoid hampering the economic or technological development of the Parties . . . including the international exchange of nuclear material and equipment."[10] Article IV gave NPT members the **inalienable right** to develop and use nuclear energy, and to benefit from the obligation by all parties "to facilitate" the "fullest possible exchange" of nuclear technology.[11] In principle, all these activities had to conform to the overriding and fundamental prohibition on developing nuclear weapons. In practice, "peaceful" came to mean whatever a country said was peaceful and subject to IAEA inspections. In many quarters, that is still how the NPT is interpreted, and the phrase "inalienable right" is still thrown back at anyone who would place restrictions on nuclear technology transfers.

SECOND THOUGHTS ON PLUTONIUM: INDIA'S BOMB TO 1976 FORD STATEMENT

It was widely believed in the early days of Atoms for Peace that, while a country might decide to make bombs on its own, no country would violate a "peaceful uses" pledge to another.[12] This complacency was

punctured by India's 1974 nuclear explosion. India had obtained the plutonium for its bomb from a small Canadian reactor that used heavy water obtained from the United States. India had agreed to restrict use of the reactor and heavy water to "peaceful uses."[13] After setting off its bomb, India insisted there was no problem, as the bomb was peaceful. This was too much for the U.S. Congress and led to its rethinking of America's permissive nuclear export policy—and ultimately to the 1978 Nuclear Nonproliferation Act, which tightened the rules for U.S. nuclear export and effectively forbade nuclear fuel exports to India because it did not accept comprehensive IAEA inspections.[14]

The experience with India made clear that a country with direct access to nuclear explosives could quickly arm nuclear bombs if it wanted to. For countries with this capacity, one could no longer rely on the IAEA inspection system to provide "timely warning," that is, warning in time to stop the bomb manufacture. To keep nuclear weapons capabilities from spreading, it was necessary—despite the liberal wording of the NPT—to restrict access to fuels that were also nuclear explosives, and therefore also to reprocessing and enrichment facilities that can produce them.

Several of the chief exporting countries met secretly in London, England, in April 1975 to form the Nuclear Suppliers Group to place restrictions on the export of what they now called "sensitive" technology (as opposed to the Acheson-Lilienthal designation of "dangerous"). It appeared that France and Germany were getting ready to sell reprocessing plants to Pakistan, South Korea, Taiwan, and Brazil. The United States set out to block these projects.[15] In September 1975, U.S. Secretary of State Henry Kissinger told the United Nations (UN) General Assembly, "The great-

est single danger of unrestrained nuclear proliferation resides in the spread under national control of reprocessing facilities."[16]

In the course of the 1976 presidential campaign, U.S. President Gerald Ford launched a study on the proliferation dangers of nuclear power programs and what could be done to keep them from contributing to proliferation. The President's October 1976 statement laid out the problem and announced his decisions.[17] It was the most important statement since the Acheson-Lilienthal effort.[18]

"The root of the problem," the President said, was that "the same plutonium produced in nuclear power plants can, when chemically separated, also be used to make nuclear explosives." He believed that nuclear power could proceed economically on the basis of the so-called once-through fuel cycle—without reprocessing spent fuel to extract plutonium and recycling it.

In spite of the view at the time that recycling plutonium was economically beneficial, the President declared:

> The reprocessing and recycling of plutonium should not proceed unless there is sound reason to conclude that the world community can effectively overcome the associated risks of proliferation. I believe that avoidance of proliferation must take precedence over economic interests. . . .[19]

The October 1976 statement also made a number of ancillary proposals that became part of the nonproliferation boilerplate up to the present. It urged nuclear suppliers to provide reliable fuel services instead of providing "sensitive" facilities, and proposed "suitably-sited multinational fuel-cycle centers to serve regional needs." But President Ford added

the condition—often forgotten today—that any such centers had to be **economically warranted**. He raised an economic test again in asking all nations "to turn aside from pursuing nuclear capabilities which are of **doubtful economic value** and have ominous implications for nuclear proliferation and instability in the world."[20] He refused a subsidy to the still unopened Barnwell reprocessing plant and thereby ensured it would not begin operation.

The nuclear industry reacted with considerable antagonism.

THE EMPIRE STRIKES BACK: PLUTONIUM ISN'T A PROBLEM, AND IF IT IS, SO WHAT?

In proposing the once-through fuel cycle, an approach his successor, Jimmy Carter, would endorse, the President was trying to find a way of developing nuclear energy that preserved a safety margin for international security.[21] It was a reasonable approach, but the nuclear devotees saw it as way of postponing indefinitely their dream of moving beyond LWRs to plutonium-fueled fast breeders, in their view the ultimate objective of nuclear energy development.

In reality, Adam Smith's "Invisible Hand" had already moved that dream beyond the horizon. Fast breeder programs had fallen behind overoptimistic schedules, and their estimated costs mounted. Meanwhile, cheap uranium became plentiful and reprocessing turned out to be expensive, so there was no economic incentive to move beyond uranium-fueled LWRs. But the plutonium enthusiasts in government and industry would not relent. To keep the reprocessing efforts on track, they shifted their objective from

recycling LWR plutonium in fast breeders to recycling it in LWRs. It made no economic sense—it was rationalized as a stopgap until breeder development caught up. By the time that became an unrealistic hope, fueling LWRs with a mixture of plutonium and uranium oxides, called mixed oxide fuel (MOX), had taken on a life of its own, with supportive government bureaucracies and industrial contractors.

Defenders of this substitute recycling insisted that it posed no proliferation problem because "reactor grade" plutonium, the plutonium formed in LWRs, unlike that from weapons production reactors, was contaminated with unwanted isotopes and thus unusable for weapons.[22] This echoed the Acheson-Lilienthal Report's denaturing concept, known to be incorrect at the time by those with access to weapons information but still widely believed 30 years later by those who did not. IAEA Director General Sigvard Eklund and his IAEA safeguards staff certainly believed it in 1976, as I discovered in talking to them in Vienna, Austria. Upon returning to Washington, DC, I notified the U.S. National Security Council staff, which arranged for a briefing on reactor grade plutonium at an international meeting Eklund would attend. I sat in and saw Elklund's jaw literally drop when Bob Selden, of the Los Alamos National Laboratory, made clear that the stuff could be used for bombs.[23]

LWRs can be an even more useful source for nuclear explosives than described in Selden's briefing. LWR plutonium is not necessarily heavily laden with unwanted isotopes, as would be the case if it came from spent fuel irradiated for the three fuel cycles, or about 5 years, that LWR fuel normally spends in the reactor. If the fuel is removed after one refueling, at about 18 months or earlier, the plutonium it contains is quite good even for low-technology bombs.[24]

The nuclear industry then took another tack to defend commercial reprocessing. In 1977, with the encouragement of the Electric Power Research Institute, an expert team at the Oak Ridge National Laboratory designed a small reprocessing plant that a country with minimal industrial base could build quickly and secretly. The Oak Ridge exercise's objective was to show that even if power reactor plutonium could be used for bombs, it was not going to do any good to ban commercial reprocessing, because a country could quickly build a small clandestine reprocessing plant, using essentially off-the-shelf components, and use it to produce militarily significant numbers of warheads.[25] An essential point is that an amount of plutonium (or HEU) that is commercially insignificant can be highly significant militarily.

The idea, of course, was to undermine the Ford-Carter anti-reprocessing policy. But it also undermined the Ford-Carter assumption that LWRs with no commercial reprocessing was a safe proposition. If a country with LWRs but no commercial reprocessing could secretly build a small "quick and dirty" plant to reprocess LWR spent fuel, then—contrary to conventional wisdom—it could rapidly separate enough plutonium for nuclear weapons, likely before the IAEA inspection system could set off a timely alarm.

FAST-FORWARD TO THE PRESENT: THE CENTRIFUGE AND OTHER PROBLEMS

If we fast-forward to the present, an important addition to proliferation concerns is the commercialization and wide distribution of gas centrifuge enrichment technology and the realization that centrifuge manufacturing capabilities are widespread, too. Un-

like gaseous diffusion, gas centrifuge enrichment uses small amounts of electric power and lends itself to small-scale operation, which makes it easier for many states to get into small-scale enrichment. It also means that a small plant, likely difficult to spot from outside, could produce militarily significant quantities of HEU.

A country could build such a plant quite apart from any nuclear power program, but the presence of nuclear power plants would be advantageous. It would obviously provide a useful cloak to mask some of the clandestine activities and provide a source of trained personnel, but most importantly, it could provide a source of low enriched uranium fuel. The use of such feed material would reduce (either in size or duration) the enrichment effort to produce HEU by as much as a factor of five. Any such effort would also require ancillary conversion facilities for uranium compounds, which would make secrecy more difficult, but the presence of a nuclear power program would amplify the possibilities for small-scale clandestine HEU production. This provides another reason, in addition to the concern about small clandestine reprocessing, why LWRs by themselves are not necessarily a safe proposition from the point of view of proliferation.

We know that some countries, including NPT members, have cheated on their "peaceful uses" commitments, so one cannot exclude that possibility. Nor can we be confident that clandestine facilities would be found in time by the IAEA or even by national intelligence means, as it took years to find a number of secret nuclear facilities (the latest being the secret Syrian reactor).

Identifying clandestine weapons activities would become much harder if nuclear power programs expanded significantly, especially if many new coun-

tries adopted such programs, and even more so if these new countries were in the less stable parts of the globe. The IAEA bureaucracy would be faced with a larger and more complex job. It is unclear whether it could scale up effectively.

So far, the prospects are low for a large worldwide expansion in nuclear power installations. Such an increase has been held back by the nuclear power plants' extremely high cost, which is likely to be increased further by the lessons learned from the 2011 Fukushima, Japan, accident. Still, in recent years, the major nuclear bureaucracies have dedicated themselves to a worldwide nuclear "renaissance." The U.S. Congress, with the support of President Barack Obama, has voted large subsidies for U.S. nuclear plants. The nuclear vendors press their wares throughout the world, and quite a few countries, including a number in volatile regions in Asia and Africa, have expressed interest, and some of them may be willing to foot the steep bill to enter the nuclear power ranks.[26]

There is another ominous note—the nuclear "renaissance" movement includes efforts to revive commercial reprocessing. In 2007, the George Bush administration launched the Global Nuclear Energy Partnership, a crash futuristic reprocessing and recycling program. The advertised purpose was to "solve" simultaneously the nuclear waste and proliferation problems by having the United States and other major nuclear supplier countries provide a full range of fuel services. It was a poorly thought-out scheme based on exotic reprocessing and fuel technology that did not exist in practicable form.[27] The real purpose was to rekindle the nuclear dream of a fast reactor future and to start by reversing the Ford/Carter reprocessing restrictions, which always rankled the nuclear

research and development (R&D) community. The enthusiasts sold President Bush on their idea, and on the occasion of signing the 2006 U.S.-India nuclear agreement, he said, "I don't see how you can advocate nuclear power . . . without advocating technological development of reprocessing."[28] The Obama administration continued a slowed down version of the Bush program with a new name, International Framework for Nuclear Energy Cooperation, but with the same basic purpose: "mainly in relation to closing the fuel cycle by reprocessing used fuel and burning actinides in fast reactors."[29] This effectively takes us back to the pre-1976 policy.

The 2006 U.S.-India agreement, proposed by former President Bush but supported by President Obama, by carving out a generous exception for India, which fought the NPT for 40 years, has seriously diminished the Treaty, and with it respect for what used to be called the nonproliferation regime. The U.S.-India agreement explicitly allows India to operate several of its nuclear power plants as part of its weapons complex.[30]

The United States also uses civilian power reactors to support its nuclear weapons program—the Department of Energy uses Tennessee Valley Authority's Watts Bar power reactor to produce tritium for warheads. When the arrangements were first announced and drew criticism, U.S. Department of Energy Assistant Secretary for Nuclear Energy Ben Rusche said the difference between civilian and weapons applications was only "psychological."

Despite these setbacks in anti-proliferation policy, there has been no letup in discussions over anti-proliferation measures because everyone knows there is a problem. Perhaps the most talked about, but also

the most ineffectual, such measure is the recurring proposal for a "fuel bank" that would assure nuclear fuel supplies to countries with nuclear power plants to dissuade them from pursuing reprocessing or enrichment technology.[31] This rationale takes at face value the excuse countries give—that they worry about "security of supply"—to mask other reasons. In reality, existing commercial contracts provide a high level of assurance.[32] The talk about fuel banks allows governments to maintain the illusion of measures to control proliferation without having to incur any political costs.

A number of other proposals fall in the same category, for example, a much stricter and more intrusive IAEA inspection regime. Such an expanded and intrusive IAEA is unlikely to be realized because it would be inconsistent with industrial operations and national sovereignty and would be costly. However, an additional problem—a considerable leap from information to international action—exists. There are conflicting interests among the major states that impede a rapid response, and sometimes countries do not even want to know about illicit nuclear activities precisely because such information would force them into actions they do not want to take.[33] In other words, in an international complex of nuclear power programs, one cannot count on IAEA inspections or even national intelligence revelations leading reliably to enforcement. To maintain a decent margin of safety, there needs to be some limitation on the nuclear facilities in place.

THE LAST REFUGE: CLAIMING NUCLEAR POWER HAS LITTLE TO DO WITH PROLIFERATION

When all is said and done, the nuclear power lobby's ultimate argument against strict anti-proliferation rules for commercial nuclear facilities is that these facilities do not contribute to the proliferation problem, and so placing restrictions on commercial nuclear power programs would do little to affect proliferation. As the Nuclear Energy Institute puts it: "All nuclear weapons programs have either preceded or risen independently of civilian nuclear energy," and any future bomb makers would likely do the same because this would still be the easiest approach.[34]

As it was, of course, the nuclear age started with weapons rather than power plants, and the first five NPT weapons states did indeed start with dedicated weapons facilities. Civilian applications then piggybacked on weapons facilities and designs. The British and French built dual-purpose reactors to produce plutonium for warheads and also generate electricity.[35] The U.S. enrichment complex, built to produce highly enriched uranium for bombs, was later used to produce low enriched fuel for reactors.[36]

But would future bomb programs follow this historical pattern? Suppose, for example, that the historical sequence were reversed, and nuclear power facilities had been in place before World War II. Would the belligerents not have used them to obtain nuclear explosives for weapons? If the most readily available source of nuclear explosives will be in the commercial sector, then that is likely where bomb makers will go.

When the next group of countries—Israel, India, Pakistan, South Africa, and North Korea—decided,

over the next 30 years, to build nuclear weapons, they did not yet have domestic power plants and fuel facilities that could supply nuclear explosives. They did have small nuclear research reactors that provided a focus for training a nuclear cadre.[37] At the same time, after the early-1960s, they had to cope with the fact that the international scene had become significantly less accepting of overt weapons programs. To build the larger "research" facilities they needed, the would-be bomb makers advanced secretly, or cloaked their weapons preparations in claims that they were only engaged in research directed toward "peaceful" nuclear power programs.[38]

The current situation is now different again. All the non-nuclear weapons countries are members of the NPT. A country intending to make nuclear weapons would have a choice of withdrawing from the NPT, and thus inviting a hostile reaction, or cheating under cover of the NPT. Unless we believe that this could never happen, we need to take this possibility seriously.

If a country is going to cheat—and we know that countries that were members of the NPT have cheated—it will want to limit the period of maximum vulnerability from the time its bomb program is evident, or might be discovered, to when it has bombs in its armory. The quickest future access to nuclear explosives for a country with a nuclear power program, and especially one with associated fuel facilities, is likely to be in some way related to that ongoing program.

WHAT THIS ADDS UP TO: CURB YOUR ENTHUSIASM

It is clear that countries enriching uranium for fuel, or separating plutonium from their spent fuel in order to recycle it as nuclear fuel, have the means to produce nuclear explosives for bombs. (There is not much argument about this, although some people still cling to the notion that plutonium from commercial facilities is effectively unusable for bombs). With the general advance of technology and spread of information, the list of candidate countries that could, if they wanted, design and manufacture bombs given the necessary nuclear explosives continually expands. It is less obvious but nevertheless true that even countries lacking commercial enrichment or plutonium separation plants still have quite a leg up on making bombs if they have nuclear power plants or related research reactors.[39]

Ted Taylor, a former Los Alamos weapons designer, put it aptly:

> The connections between nuclear technology for constructive use and for destructive use are so closely tied together that the benefits of the one are not accessible without greatly increasing the hazards of the other.[40]

So far, we have not developed the technology or the international institutions to break this connection.

To cope with the hazards of proliferation in the face of weak international restraints on national nuclear programs—basically IAEA inspections and export controls—we seem to be slipping into reliance on greatly increased national intelligence operations, both to gather information and to carry out black op-

erations to sabotage worrisome nuclear programs, and keeping open the possibility of air attacks.[41] That, at least, is what the Iran experience appears to suggest. In a sense, this is the logical consequence of expanding nuclear power around the world, one foreseen in the 1946 Acheson-Lilienthal Report. After all, someone has to enforce the NPT rules. In this respect, nuclear energy is the only electric energy source that poses major military risks if it is in the wrong hands, and that requires constant surveillance by highly alert intelligence operations with an enforcement backstop of military force. At the same time, it is difficult to imagine the current intense intelligence focus on Iran and the open option of large-scale violence as a workable model for the broader problem of proliferation. It is not even clear it will work in Iran.

It would be an especially problematic approach if the number of countries with nuclear programs, and the number of facilities, expanded significantly. Of course, there may not be any such expansion in view of nuclear power's high cost, now likely to go higher after the Fukushima accident. But increased worldwide reliance on nuclear energy remains a goal of the United States and other industrial countries. So politically powerful is this idea that President George W. Bush made a point of saying he would not object to Iranian nuclear power plants if Iran gave up enrichment. Meanwhile, Iran's example has provoked interest in nuclear power in a number of Middle Eastern and African countries.

One of the more naïve aspects of the Acheson-Lilienthal proposal was to distribute dangerous nuclear facilities owned by an international authority among the various countries with the thought that this would best dissuade countries from seizing the facilities for

national weapons use. The idea was that each country would be deterred from doing so because it would know that other countries could do the same. Whatever deterrent value this arrangement had, it also had the intrinsic potential for massive failure with an avalanche of weapons decisions. Yet, that is essentially the arrangement that we are drifting toward today.

Up to now we have allowed, over and over, the interest in gaining the benefits of nuclear power to trump bomb worries. It is time to return to the principle stated 35 years ago by President Ford that, if a choice had to be made, "nonproliferation objectives must take precedence over economic and energy benefits." This would also likely mean holding up nuclear energy expansion worldwide until—to generalize President Ford's statement on plutonium use—"The world community can effectively overcome the associated risks of proliferation."

Restraining further expansion of nuclear power would not eliminate the possibilities of additional nuclear weapons countries, but it would limit the dangers—whose outlines we barely understand—inherent in further expansion, and it would be an important first step in coping with the international security implications of nuclear energy.

ENDNOTES - CHAPTER 5

1. *A Report On The International Control Of Atomic Energy*, Washington, DC, March 16, 1946. President Harry Truman appointed Under Secretary of State Dean Acheson to head a committee to set forth U.S. policy on what was then called atomic energy. The other members were scientists James Conant and Vannevar Bush, who headed the office that controlled the Manhattan Project; John McCloy; and General Leslie R. Groves, the military officer in charge of the Manhattan Project. Acheson ap-

pointed a board of consultants chaired by David Lilienthal, chairman of the Tennessee Valley Authority. J. Robert Oppenheimer, head of the Los Alamos during WWII, was the most influential member. The committee's report became known as the Acheson-Lilienthal Report. (Hereafter Report.)

2. "We were given as our starting point a political commitment already made by the United States to seek by all reasonable means to bring about international arrangements to prevent the use of atomic energy for destructive purposes and to promote the use of it for the benefit of society." Report, Sec. I.

3. Report, Chap. V.

4. The Agency was founded in 1957.

5. Soon after announcement of the Atoms for Peace program, Soviet Foreign Minister Vyacheslav Molotov asked U.S. Secretary of State John Foster Dulles why the United States wanted to spread nuclear weapons capabilities through the program. Dulles had no idea what Molotov was talking about, and when he returned to Washington, asked his assistant, Gerard Smith, to confirm that Molotov was wrong. As he later told me, Smith had to explain to the surprised Dulles that Molotov's question was a valid one. For example, Indian scientists trained in reprocessing at Oak Ridge, TN, became the nucleus for the Indian reprocessing program and hence the production of plutonium for bombs.

6. What this really means is that uranium-235, the fissionable isotope that makes up less than 1 percent of uranium, was thought to be too rare to fuel nuclear power plants for long and therefore use would have to be made of the abundant isotope, uranium-238, that with the addition of a neutron can be converted into plutonium.

7. It appeared in the Acheson-Lilienthal Report and in fact was central to the Report's conclusion that certain plutonium activities could be conducted on a national basis: "U 235 and plutonium can be denatured; such denatured materials do not readily lend themselves to the making of atomic explosives, but they can still be used with no essential loss of effectiveness for the peaceful applications of atomic energy." See Report, Chap. V. In the

case of uranium, the Report had in mind the use of low enrichment uranium fuel, as in today's LWRs. This material cannot be used for weapons without upgrading in an enrichment facility. In the case of plutonium, it meant what we would now call "reactor grade" plutonium, material that had been irradiated sufficiently to increase the fraction of unwanted isotopes. This is a much iffier concept, as plutonium of pretty much any composition can be made to explode. Robert Oppenheimer, the intellectual force behind the Report, pushed the denaturing concept, key to the whole Acheson-Lilienthal scheme, hoping it could be made to work but probably knowing it was wrong. The Report adds the following qualification: "It is not without importance to bear in mind that, although as the art now stands denatured materials are unsuitable for bomb manufacture, developments which do not appear to be in principle impossible might alter the situation."

8. That amounts to over a thousand bombs' worth. (IAEA-TECDOC-1452) Initially, the U.S. Atomic Energy Commission (AEC) did not even keep track of what was exported and where it went. The agency left this to private firms. The AEC commissioners became aware of this in the course of investigations around 1966 after the loss of about 100 kilograms of HEU at a fuel plant in Pennsylvania that could not be accounted for and was feared to have ended up in Israel. It is hard to understand why the United States was so casual about the export of HEU.

9. Wolf Haefele, the chief technical advisor to the German NPT delegation, believed that the economic opportunities were going to lie in manufacturing fast breeder fuel rather than in building the reactors themselves. ("It's the razor blade not the razor.") He thought Germany was well positioned to compete on fuel technology but worried that it would be at a disadvantage if, as a non-nuclear state, it was subject to more intrusive international inspection and was thus more vulnerable to industrial espionage. He convinced the Japanese to join in Germany's complaints. As a result, the Treaty Preamble encourages inspecting "the flow of source and special fissionable materials by use of instruments and other techniques **at certain strategic points**." (Emphasis added.)

10. Treaty on the Non-Proliferation of Nuclear Weapons, July 1, 1968. (Hereafter NPT.)

> Article III 3. The safeguards required by this article shall be implemented in a manner designed to comply with Article IV of this Treaty, and to avoid hampering the economic or technological development of the Parties or international cooperation in the field of peaceful nuclear activities, including the international exchange of nuclear material and equipment for the processing, use or production of nuclear material for peaceful purposes in accordance with the provisions of this article and the principle of safeguarding set forth in the Preamble of the Treaty.

11. NPT:

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

12. The IAEA inspections were not seen as performing a police function to catch wrongdoers, but rather verifying material balances to add confidence that agreements were being observed.

13. The 1956 India-U.S. heavy water contract restricted the reactor to "peaceful uses." When finally called on this, India said there was no problem because its bomb was peaceful. The American position was not as clear as it could have been. At the time, the United States had a program on so-called peaceful nuclear explosives. That was bad enough, but its real purposes were clouded. In a 1964 briefing I attended, Director of the Livermore weapons

laboratory John Foster explained that the real purpose of the program was to get the public used to nuclear explosions so that the military could get a release for battlefield use in wartime.

14. When congressional hearings raised questions, the U.S. State Department, intent on protecting nuclear exports, tried to hide the existence of the U.S.-India heavy water contract, and then lied about whether U.S. heavy water was still in the Indian reactor. It ultimately led to the Nuclear Nonproliferation Act of 1978, which required tightening nuclear cooperation agreements, including the one with India that covered the General Electric-built reactor at Tarapur. The United States essentially gave the nuclear station to India in order to introduce IAEA inspections into India. It was a unique agreement that tied Indian acceptance of IAEA inspections to the U.S. supply of fuel. The 1978 Act forbade fuel supply to countries that did not accept full-scope IAEA inspections, which India did not. The State Department scurried to find a replacement fuel supplier.

15. But neither the United States nor the other exporters ever publicly addressed the tensions in the NPT between prohibitions on bombs and liberal promises of technology, so the NPT's ambiguities remained.

16. Kissinger's apparent concern has to be put in context. When the State Department staff learned of the Indian explosion, they assumed the United States would react firmly. Kissinger cabled back from the Middle East, rejecting any strong reaction. He was apparently in the process of putting together a nuclear deal of his own that he did not want upset. In the 1975 speech to the UN, he pointed to the dangers of reprocessing conducted under national auspices and proposed a multilateral approach. This became a standard "solution" to the problem of reprocessing. It is unlikely that Kissinger understood that the activity made no economic sense at all. He would have looked at it in purely political terms. In a talk at the RAND Corporation in Santa Monica before he assumed his role in the Richard Nixon administration—I was then a department head—he said, "Never underestimate the superficiality of important people."

17. Gerald R. Ford, "Statement on Nuclear Policy," October 28, 1976.

18. And we are still waiting for the third one.

19. It subsequently became clear that plutonium reprocessing and recycling were highly uneconomic. At the time, I also accepted that plutonium recycling was marginally economic. I calculated that the advantage was about 3 percent of the cost of power, and planned to say so in a speech. I showed the draft to a fellow commissioner—Richard Kennedy. His reaction said a lot about the extent to which the nuclear community at the time was invested in the idea of plutonium recycle. He told me I had every right to deliver the speech saying the plutonium advantage was only 3 percent. But he wanted me to know that if he had wanted to kill U.S. nuclear power, that was what he would say.

20. Gerald R. Ford, "Statement on Nuclear Policy," October 28, 1976. Emphasis added.

21. The restriction would apply to HEU as well, but hardly any power reactors used this material for fuel—it was mainly used in research reactors. The United States proposed shifting these reactors to lower enrichment fuels. After a lot of foot dragging, most of these reactors have now been converted, although some, including the research reactor at the Massachusetts Institute of Technology (MIT), still resist.

22. One claim is that a bomb made of this material would "fizzle." Using the technology in the first bombs, the yield of such a fizzle would still be on the order of a kiloton.

23. The top German officials who were exporting the technology to Brazil shared the same belief that the plutonium separated from LWRs would be unusable for weapons, or at least professed to believe that. The Selden briefing was described in a memorandum for the commissioners of the U.S. Nuclear Regulatory Commission (NRC) from James Shea, director of the NRC Office of International Programs. He wrote:

> From November 15 to 19 ERDA [Energy Research and Development Administration, DOE's predecessor] conducted a series of briefings, presented by Bob Selden (Livermore) and Carson Mark (Los Alamos), directed at convincing in-

> terested international VIP's attending the ANS-AIF-ENS [American Nuclear Society-Atomic Industrial Forum-European Nuclear Society] International Meetings that reactor grade plutonium is highly useful for constructing nuclear explosives.

The attendees at these meetings included Sir John Hill (UK Atomic Energy Authority), Mr. Andre Giraud (Alternative Energies and Atomic Energy Commission-France), Dr. S. Eklund and R. Romettsch (International Atomic Energy Agency), Dr. Daennert (Fundamental Research Grant-Ministry of Research and Technology), and Dr. Imai (Japan Atomic Power Company), and others from Japan. See also "ERDA says reactor grade plutonium can make powerful, reliable bombs," *Nucleonics Week* November 16, 1976. The story included the following:

> Most recently NRC commissioner Victor Gilinsky said that reactor grade plutonium would make a bomb of 1-10 kilotons yield. A source said that ERDA provided Gilinsky with the material for his statement. The ERDA source stated that such bombs would be variable [in yield] but certainly not unreliable.

24. At the end of its first refueling, a new LWR contains about 300 kilograms of plutonium that is quite suitable for weapons by any standard. That would be enough for about 50 warheads. Of course, it first would have to be separated.

25. It was promoted by Chauncey Starr, Electric Power Research Institute's head, and by Floyd Culler, one of the developers of PUREX reprocessing at Oak Ridge. See *www.npolicy.org/article.php?aid=172&rt=&key=fresh%20&sec=article*.

26. A sign that conventional opinion is changing is evident in an October 6, 2011, opinion editorial by Jim Hoagland: "In short, the proliferation of nuclear reactors across Asia is certain to facilitate and encourage nuclear weapons proliferation as well." Jim Hoagland, "Nuclear energy after Fukushima," *The Washington Post*, October 6, 2011.

27. For a discussion on the program's technical flaws, see "A Minority Opinion: Dissenting Statement of Gilinsky and Macfarlane," *Review of DOE's Nuclear Energy Research and De-*

velopment Program, Washington, DC: National Academy Press, 2008, pp. 73-76, available from *www.nap.edu/openbook.php?record_id=11998&page=73.*

28. "President, Prime Minister Singh Discuss Growing Strategic Partnership," New Dehli, India, March 2, 2006. The U.S.-India agreement approved by Congress in October 2008 waived U.S. export restrictions on India, which has fought the NPT regime for 40 years. It makes a mockery of NPT compliance. In effect, with Democratic congressional support, Bush drove a truck through the NPT. A related U.S.-sponsored Nuclear Supplier Group waiver gave India access to the international nuclear trade. The Indian government succeeded in steamrolling the very U.S. and international criteria that were put in place in response to its initial pursuit of the bomb—without giving up anything.

29. See *www.ifnec.org*.

30. "Taking Stock of the U.S.-India Nuclear Deal," Remarks of Geoffrey Pyatt, Principal Deputy Assistant Secretary, Bureau of South and Central Asian Affairs, Mumbai, India, September 30, 2011.

> First, India agreed to draw a clear line between its civilian and military nuclear facilities, and to voluntarily place its civilian nuclear facilities under IAEA safeguards. India's 2005 Separation Plan identified 14 thermal power reactors, as well as a number of upstream and downstream facilities, and nine research facilities for the safeguarded side of India's nuclear complex. . . .

But the separation leaves several power reactors on the military side. Pyatt also makes clear the motivation for making an NPT exception for India:

> And we are open for business. In fact, U.S. companies representing the full spectrum of commercial nuclear activities have participated in six commercial trade missions to India in the past few years, including: . . . I should note—unequivocally—that all of our companies involved in these missions have the strong support of the United States government. . . .

31. See, for example, one of the recommended actions arising from the 2010 NPT review conference:

> Continue to discuss further, in a non-discriminatory and transparent manner under the auspices of IAEA or regional forums, the development of multilateral approaches to the nuclear fuel cycle, including the possibilities of creating mechanisms for assurance of nuclear fuel supply, as well as possible schemes dealing with the back-end of the fuel cycle without affecting rights under the Treaty and without prejudice to national fuel cycle policies, while tackling the technical, legal and economic complexities surrounding these issues, including, in this regard, the requirement of IAEA full scope safeguards.

NPT/CONF.2010/50, 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Final Document, Vol. I.

32. India is mentioned as the classic example (but I believe it is the only such example) of a country that faced a halt in uranium fuel shipments from its supplier. But this happened after it exploded its 1974 bomb in violation of a peaceful uses pledge and then refused to accept comprehensive IAEA inspections as required by the 1978 U.S. export law. Even so, the U.S. State Department found an alternative supply for India, and there was no gap in its fuel shipments.

33. As was the case in 1969 at the start of the Nixon administration when Henry Kissinger decided it would be best if the United States did not know whether Israel had built nuclear weapons.

34. "Preventing the Proliferation of Nuclear Materials," Nuclear Energy Institute, October 2011, available from *www.nei.org/Master-Document-Folder/Backgrounders/Fact-Sheets/Preventing-the-Proliferation-of-Nuclear-Materials*:

> Uranium enrichment facilities that produce fuel for commercial reactors pose no risk of proliferation . . . Used nuclear fuel, which contains plutonium generated as a byproduct of the commercial fuel cycle, poses little risk of proliferation . . . All nuclear weapons programs have either preceded or risen independently of civilian nuclear energy.

"Safeguards to Prevent Nuclear Proliferation," World Nuclear Association (WNA), April 2012, available from *www.world-nuclear.org/info/Safety-and-Security/Non-Proliferation/Safeguards-to-Prevent-Nuclear-Proliferation*:

> Civil nuclear power has not been the cause of or route to nuclear weapons in any country that has nuclear weapons, and no uranium traded for electricity production has ever been diverted for military use. All nuclear weapons programmes have either preceded or risen independently of civil nuclear power. . . . No country is without plenty of uranium in the small quantities needed for a few weapons. . . . There is no chance that proliferation will be solved by turning away from nuclear power.

The same WNA document, however, continues in a more insightful mode:

> While nuclear power reactors themselves are not a proliferation concern, enrichment and reprocessing technologies are open to use for other purposes, and have been the cause of proliferation through illicit or unsafeguarded use. . . . The NPT does not adequately deal with the issue of SNT [sensitive nuclear technology]. It refers to the 'inalienable' right to use nuclear energy, but certainly does not guarantee the right to develop SNT. Nor, however, does the it explicitly limit the development of SNT, other than by the fundamental obligations of Non-nuclear Weapons States not to acquire (or seek to acquire) nuclear weapons, and to place all their nuclear material under IAEA safeguards.
>
> Current approaches to control the spread of SNT have focused on measures against the transfer of equipment, components, special materials and technology, through national export controls and multilateral coordination within the Nuclear Suppliers Group (see below). However, these approaches do not fully address the problems of illicit acquisition of enrichment technology and development of indigenous enrichment technology. A way is needed to assess the international acceptability of enrichment projects.
>
> Concerns about SNT programs are not addressed simply by having these activities placed under safeguards. Safeguards

> are an essential part of international confidence building, but safeguards alone cannot provide assurance about a country's future intent. An enrichment or reprocessing facility under safeguards today could be used as the basis for breakout from non-proliferation commitments in the future. In the case of enrichment, a large centrifuge plant, using LEU feed, could produce sufficient HEU for a nuclear weapon in a matter of days. An essential aspect of non-proliferation is minimising the risk of breakout occurring, through limiting the countries with SNT facilities to those regarded as presenting a low proliferation risk.

35. The Soviet-designed RBMK reactors were used for both plutonium and power production, but it is unclear whether the plutonium was ever used for weapons.

36. It is also significant that the U.S. light water reactors, ultimately the basis for essentially all the world's reactors, grew out of the U.S. Navy's submarine reactors developed by Admiral Hyman Rickover.

37. Israeli Research Reactor 1 (IRR1), started in 1960, was donated by the United States under Atoms for Peace. The 5-megawatt ton (MWt) reactor used HEU fuel. India claims to have built a 1-MWt research reactor that went critical in 1956. Canada supplied the CIRUS, started in 1960, which was a 40-MWt heavy water moderated and light water cooled reactor fueled by natural uranium. The United States supplied the heavy water under a contract signed in 1956. Pakistan's PARR-I Reactor was supplied by the United States. The 5-MWt reactor used HEU fuel and went critical in 1965. South Africa's SAFARI-1 20-MWt reactor was commissioned in 1965. The U.S.-supplied reactor used HEU fuel, initially operated at 6.75-MWt, and was upgraded in 1968. North Korea's IRT-2000, an 8-MWt (2-MWt from 1965-74, 4-MWt from 1974-86) heavy-water moderated research reactor, was supplied by the Union of Soviet Socialist Republics in 1965.

38. Israel was the first of these countries to develop nuclear weapons. Israel lied to President Kennedy about the purpose of the Dimona reactor, claiming it was for peaceful purposes. Had Israel tested full-scale when it built its first bombs in the late-1960s, it might have qualified as one of the original nuclear weapon

states under the NPT. India drew the plutonium for its 1974 nuclear explosion from CIRUS, a small Canadian-supplied research reactor that used U.S. heavy water. India had given both countries "peaceful uses" assurances. When challenged, India replied that its bomb was peaceful. The U.S. State Department did not press the issue. India then continued to stockpile CIRUS plutonium for weapons. Pakistan also claimed its enrichment was for peaceful uses. No one actually believed this, but the United States looked the other way to keep Pakistani assistance in Afghanistan. South Africa claimed its Valindaba enrichment plant was built to supply fuel for its research reactor. The North Korean weapons program started in the 1980s with a nuclear reactor at Yongbyon. In 1985, under Soviet pressure, Pyongyang agreed to join the NPT, but refused to sign a safeguards agreement with the IAEA. Iran claims its enrichment program is intended to supply enriched uranium for its power and research reactors. Time will tell whether this is true.

39. Victor Gilinsky, Marvin Miller, and Harmon Hubbard, "A Fresh Examination of the Proliferation Dangers of Light Water Reactors," Washington, DC: Nonproliferation Policy Education Center, October 22, 2004, available from *www.npolicy.org/files/20041022-GilinskyEtAl-LWR.pdf.*

40. Theodore B. Taylor, *Nuclear Power and Nuclear Weapons,* Santa Barbara, CA: Nuclear Age Peace Foundation, July 12, 1996, available from *www.wagingpeace.org/nuclear-power-and-nuclear-weapons/.*

41. A fuller list of the steps envisioned in current anti-proliferation doctrine would include: Count on only a few countries being interested in nuclear weapons; apply the various mild restrictions and inspections to intimidate those who worry about getting caught; make compromises on access to fuel technology that delay weapons capabilities, even if it means shaving the security safety margins; ramp up IAEA inspections and (mainly) national intelligence; concentrate on hostile states that do not yet have bombs; in the last analysis, count on sabotage, assassinations, and bombings; let the future take care of itself; and hope for the best.