How to Think About Proliferation and Nuclear Power

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It is natural for human beings to want to simplify a problem in such a way that makes it appear tangible, and therefore easily solvable. Tensions surrounding nuclear weapons over the decades have produced some simplistic problem-models, which in turn have produced some simplistic answers. Scientists should be concerned with the spread of nuclear weapons and should see the role that technology can play in mitigating the threat. However, forming a too-simple world model in one's mind can lead to inappropriate, wasteful and even counter-productive solutions. Nuclear proliferation concerns should rightfully place constraints on the growth of nuclear energy, but there are no "quick-fixes" for the problem of proliferation. Scientists are unfortunately often among the worst offenders in seeking the easy answers through a technological fix.

One model of world nuclear proliferation, if taken to its most naïve and extreme form, would hold a view something like the following. The most important driving force for governmental decision-making is preservation of the state's existence. Nuclear weapons enhance a nation's survivability by deterring aggression. Therefore, any nation, especially one that feels militarily threatened, would seek to acquire nuclear weapons. The bottleneck in the process of acquiring nuclear weapons is acquisition of nuclear technology. Promotion of commercial nuclear technology throughout the world then provides the missing ingredient for nations to acquire weapons. The speed at which the weaponization process would occur would therefore increase as nations become wealthier and nuclear technology becomes more widespread. Banning commercial nuclear power (especially in the developing world) therefore is an important part of the solution to the proliferation problem.

Similar thinking had previously led many physicists and others during the 1960's to predict that there would be twenty or more nuclear weapon states by 1980. The failure of this prediction by the early 1980's led some to reevaluate the original model.[2] The main finding was that there exists no fundamental imperative for nations to produce nuclear weapons. For most nations, nuclear weapons have no clear utility for enhancing security, either or as a component in a military strategy or as a political tool. The nations that have pursued nuclear weapons since the 1960's have done so only out of their own myopic world-view.[3]

The correlation of commercial nuclear technology with a nuclear weapon decision was found to be only very slight, because nations who would chose to build weapons will find it easier to build a dedicated weapon-manufacturing infrastructure. A nation must first weigh some huge national security costs and risks if it is to pursue nuclear weapons, and it must come to the conclusion that its security, prestige or bargaining position is enhanced by having the weapons. The actual cost of the weapons is small compared to these considerations.[4] Additionally, the fissionable material in a weapon system is only a small part of the cost, if the entire delivery system is included. The decision to "go nuclear" then is unlikely to be influenced by the cost of only the nuclear component of the system. There would be a weak link between commercial nuclear power and weapons proliferation even if the commercial infrastructure were a good springboard to weapons.

Lastly, if a country decides to build weapons, and it has ratified the Non-Proliferation Treaty (NPT), it would be required to either withdraw from the treaty, which requires giving 90 days notice, or covertly break its safeguards commitments.

Strengthen the Non-proliferation Regime

The NPT is at the center of the international regime to prevent the spread of nuclear weapons; it has been ratified by 187 countries. Discussions of proliferation prevention should focus on this regime. The treaty allows that there is to be a maximum of five nations admitted as nuclear weapon states. These are the US, USSR (now Russia), China, France and the UK. The 182 countries that have ratified the treaty as non-weapon states agree not to develop or otherwise obtain nuclear weapons.

Scientists who are interested in correlations should note that no nation that has ratified the NPT as a non-weapon state has then proceeded to become a weapon state.

The success of the NPT requires that we continue to work towards strengthening the regime, by providing a variety of incentives for countries to stay within the regime. Security guarantees have provided incentives in the past for countries to join and stay within the NPT. How long this can successfully continue is not known, especially if there is a weakening of the US' influence in world affairs someday. Other measures to keep the regime together should be considered.

Only India, Pakistan and Israel are not NPT signatories and the first two are now declared weapon states. Israel is strongly suspected of being one.[5]

In the original NPT bargain, countries committed not to acquire nuclear weapons in return for assistance in developing their civil nuclear power programs. This was an incentive to countries not to defect from the non-proliferation regime, and at the time was a strong non-proliferation argument *for* civil nuclear power.[6] Non-weapon states also agree to place their nuclear activities under a safeguard program with the International Atomic Energy Agency (IAEA) or other organization.

It should be remembered that there was much more optimism about the future of commercial nuclear power when the regime was started; the prospects for nuclear energy were seen as almost limitless. While this incentive was unfortunately not strong enough to entice India and Pakistan to join, it did entice North Korea to join in 1985. Currently, the bargain of the NPT for most countries is thought to be in mutual security and cost avoidance, i.e., by renouncing nuclear weapons, the threat of nuclear attack is reduced without the huge cost of acquiring and maintaining an independent deterrent force. The treaty itself has never been amended.

The treaty has been at risk over the last decade especially from clandestine activity within two signatory states. One (Iraq) was discovered to have operated clandestine nuclear programs in defiance of its NPT obligations. The other country (North Korea) continues to resist the IAEA's efforts to verify its compliance with its safeguard agreement pursuant to the NPT.

In other ways, too, the treaty appears to be at risk. Egypt, a party to the NPT, has stated that it cannot continue to show restraint on nuclear weapons if Israel does not also become a party to the treaty. Egyptian withdrawal from the NPT would be a terrific blow to the treaty and perhaps would stimulate other nations, such as the Arab nations that have only recently adhered to it, to withdraw also. It has been said that the willingness of the US to ignore Israel's proliferation has undermined the norm the NPT strove to achieve.[7]

Some parties to the treaty have complained about the slow rate of progress in nuclear disarmament as required by Article VI of the treaty. Multilateral negotiations among the nuclear weapon states to further reduce nuclear arsenals remain elusive. Despite this, the 1995 NPT extension enabled the five nuclear powers to maintain their positions as holders of nuclear weapons. This extension was adopted under the condition that the nuclear powers carry out negotiations for nuclear arms reductions in good faith, based on Article VI of the NPT. For that reason, the enforcement of the Comprehensive Test Ban Treaty (CTBT) lays important groundwork for strengthening the NPT. The US Senate should ratify the treaty as soon as possible.[8]

Safeguards

International safeguards are designed to provide credible assurance that States are complying with their NPT commitments and not diverting declared materials to a nuclear weapon program. The IAEA safeguards system makes diversion of materials from declared commercial facilities to weapons purposes extremely difficult.

Because of the problems with Iraq and North Korea, the safeguards system has started to evolve in new directions. There will be a shift in emphasis to a flexible state-level approach with a greater emphasis on transparency, rather than simply inspecting declared facilities. In other words, inspectors will visit sites that are not part of a state's declarations.

Satellite surveillance stands out as an approach that will increase cost-efficiency of safeguard systems. The US government has assisted private companies many times in space ventures and it should be equally as generous with the IAEA. The US intelligence community still has access to technology that would enable the IAEA to better do its job and sharing more of this technology would be in the national interest.

Effective international enforcement of non-proliferation will also probably rely heavily on special inspections. For these to be effective, it is essential that the IAEA be able to send inspectors to a suspect site with a minimum delay. This implies, among other things, permanent visas for some IAEA inspectors so that they may enter the territory of the state with no delay. These inspections stress the resources of the IAEA, and the US and other nations should be more generous in supplying adequate funding to the agency. The investment could pay for itself in terms of national security at a far better rate of return than many portions of the US military budget.

Nuclear Power

No country has successfully started a nuclear weapon program beginning with civil nuclear power facilities. On this basis, one may form the simplistic conclusion that there is no link between nuclear power and proliferation. However, several countries (such as India, Pakistan and Israel) have used a civil nuclear programs as a cover story to justify establishment of weapon activities or to buy items on the international market. In other words, there is a link, but it is very fuzzy link.

As the decades have gone by, the Pressurized Water Reactor (PWR) has become the favorite reactor design for most nations. A variant of the PWR is the Boiling Water Reactor (BWR), a somewhat simplified design which uses fewer layers of isolation for the reactor core. These two basic designs, when lumped together, are called LWRs (for Light Water Reactor). Although Russia, England and France each had their own power reactor designs that evolved out of their weapons programs, these designs have each been abandoned in favor of the PWR. The only other reactor that is considered to be current technology is the Canadian heavy-water reactor design called CANDU.

During LWR or CANDU operation, some of the uranium content is converted to plutonium that is wholly contained within the uranium fuel matrix. Some of this plutonium undergoes fission, which helps stretch the fuel utilization. If the fuel is discarded after its useful life is over, no separated fissionable materials are ever produced.

It was once thought that the continued use of nuclear power would require reprocessing, recycle and a buildup of separated plutonium inventories in order to fuel a generation of plutonium breeder reactors. Governments and some businesses invested in the reprocessing infrastructure in anticipation of large demand growth for nuclear power accompanied by rising uranium prices. Because nuclear demand has not grown as anticipated, the original plan of reprocessing can only be called a mistake. Such mistakes are common in economic affairs, but in the European, Japanese and Russian nuclear reprocessing businesses, these ventures have been shielded from market forces by governmental subsidy.

As a result of the mistake, as of 1995, about 185 tonnes of plutonium have been separated for commercial use worldwide, but only about 50 tonnes of this have been recycled. The UK-owned inventory of over 50 tonnes is expected to continue increasing slowly, reaching a level of more than 100 tonnes by 2015. Yet there are no reactors in UK that can burn plutonium. The 175 tonnes of plutonium that are in store for commercial purposes, mostly in France, the UK and Russia are in addition to the worldwide military stocks of comparable size.

Should these stockpiles be of great proliferation concern? Most countries that stockpile separated plutonium for commercial purposes are weapon states, and most of these countries are not actively seeking more weapon material. Additionally, if they were, they would not rely on commercial plutonium, which is much less suitable for weapon use because of its higher content of the isotope 240. Japan also stockpiles plutonium under IAEA safeguards but has no weapon program. There is no evidence that Japan has incorporated a nuclear weapon option in the design of its nuclear fuel cycle facilities. It also does not use its commercial plutonium stockpile in the international political realm as a "latent" weapon capability, for instance by threatening to convert to a weapons path. It has also acted as a leader in the community of nations with respect to non-proliferation objectives, for instance by being one of the first countries ratify the Comprehensive Test Ban Treaty (CTBT). It is clear that commercial plutonium stockpiling is not interpreted by Japan as giving it access to nuclear materials for weapon purposes.

There is no immediate reason to be concerned about the existing commercial stockpiles of plutonium, provided that the proper protection measures stay in place. These measures typically involve the "three G's" - guns, guards and gates, connected both in series and in parallel. Of the three G's, the most serious concern is with the guards. A discontented guard force could lead to access of nuclear materials for terrorist organizations or for nations that otherwise could not afford the nuclear infrastructure for weapon material acquisition. Such access has been the concern of international organizations and the US government since the dissolution of the Soviet Union and the economic difficulties that have followed there.[9] The great majority of reported theft incidents have involved materials from weapon facilities, research facilities, or naval fuel facilities and not commercial power facilities, but there are some important lessons for the future of commercial nuclear power from these incidents.

The crisis in nuclear material management in the Former Soviet Union that has resulted from societal and economic disruption is a clear indicator that the world cannot rely solely on institutional measures such as armed-guards to protect fissionable materials. Social disorder tends to arise in every part of the world at one time or another. For example, although Japan and France are two of the most stable countries in the world, some portions of these countries were in utter chaos during this last century. Certain portions of the US were in the state of anarchy during the Civil War, which was less than two centuries ago. It appears (at a glance) that a period of one hundred years without some major economic political or economic disruption is rare for any country.

The commercial fuel cycle certainly should be configured to make theft by terrorists or criminal organizations as difficult as possible. This is independent of any perceived threat of national diversion of fissionable materials to weapons purposes. For this reason alone, discouraging the production of separated weapons-usable fissionable material should be undertaken now on a worldwide basis. These materials should be locked in spent fuel, but there will always be some small risk of theft during transportation or storage of this spent fuel. As an international anti-theft measure, consolidated surface storage of spent fuel at a few internationally sanctioned sites would be better than the present widely dispersed storage at nuclear stations and fuel cycle facilities. It would be better for transparency, accountability, security and control and it should be pursued.

Power Reactor Fuel Cycle Choice

The continued utilization of the LWR without recycle is compatible with a phasing-out of separated weapon-usable materials, and it meets the need for international uniformity in selection of fuel cycle options. For the relative near term (next couple of decades at least) this fuel cycle should be retained for its proliferation resistance and good economics. Further increases in LWR fuel utilization are possible with the so-called Radkowsky fuel cycle (without reprocessing), which employs both uranium and thorium in the fuel.

Some claim that a strategy that relies on the once-through fuel cycle is doomed to produce a uranium shortage in the future and that plutonium recycle is inevitable to avoid escalating fuel costs due to resource depletion. While there is some appeal to the simple logic that all resources are finite and therefore must be conserved, technological changes will occur which make the cost of mining and extraction decline. In any case, an upper limit on the cost of uranium would be the cost of extracting it from seawater, which is thought to be ~$100/lb, roughly eight times the current, depressed price. If this were to happen, the cost of nuclear electricity would increase by no more than 20%. Thus, the economic case for reprocessing, even in this extreme case, would not be compelling.[10]

At some time in the future, if recycle is utilized, fissionable materials must be entrained with intensely radioactive fission products and possibly some neutron-absorbing species.[11] Accumulation of plutonium even under these conditions should be avoided by recycling the plutonium at the same rate it is recovered. From an environmental perspective, these reactors offer the advantage of a greatly reduced need for mining of uranium ore. However, an economically sound start date for this is many decades in the future, if ever. There are also other (potentially less expensive) reactor designs that could be a replacement for the LWR, including the high temperature gas cooled reactor. One proposed design uses a core lifetime equal to the reactor lifetime and so the system can be completely sealed. Nuclear fusion may someday be economical and should not be forgotten.

All these advanced nuclear energy systems will also unfortunately have potential (but unlikely) use in the clandestine manufacture of weapon material. This is because nearly all systems envisioned so far either rely on a neutron flux to induce nuclear fission, or produce a neutron flux as a by-product of nuclear fusion.[12] In all cases, safeguards will be required to verify that nuclear weapon materials are not being produced in the flux.

Improvements in safeguard cost-effectiveness and security could be achieved in the future through standardization and integration with nuclear design. Facilities that are non-standard or unique tend to take far more man-hours of inspection time per year per unit of power output than standard designs.

A Nuclear Power Expansion Without Proliferation?

It is important to address the need of developing countries for increased energy supplies. To reduce the reliance of these countries on fossil fuels, it is desirable for the developed world to share nuclear technology with them, under proper safeguards, as stipulated in Article IV of the Non-Proliferation Treaty. Now is the time to cautiously consider the greater use of nuclear energy under the most stringent safeguards standards. Power reactors could be provided (at below cost) to recipient nations under a "clean development mechanism" within the UN framework on Climate Change.[13] Other forms of energy production could also be exported under this mechanism, with the choice of technology left to bilateral agreement. However, the recipient would be required to ratify the NPT and accept the most recent IAEA safeguards in order to receive subsidized reactors. A comprehensive set of initial inspections would be required. Fuel cycles which produce weapon-usable material anywhere in process would be disallowed from receiving the financial incentives.

If there is to be growth of nuclear power in the US, it could also be focused in ways to prevent nuclear proliferation or theft of nuclear materials in other countries. For instance, the US should welcome imports of nuclear power components and systems from manufacturers throughout the world, but should constrain the imports so that they originate only in countries that will allow comprehensive IAEA inspections.

Peaceful cooperation between nations is a potential benefit that has been recognized since the Atoms for Peace era. Much has been learned since Eisenhower made his speech in front of the UN

General Assembly, and much has changed in the world political system. These experiences and changes should be integrated into a new program, one that is centered on strengthening the NPT and promoting a comprehensive safeguards regime.

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[1] This article was written while the author was on sabbatical leave during 2000 at Stanford University. The opinions are those of the author only.

[2] S. M. Meyer, "The Dynamics of Nuclear Proliferation," University of Chicago Press, Chicago, 1984.

[3] P. Bidwai and A.Vanaik, "A Very Political Bomb," Bulletin of Atomic Scientists, June/July, 1998.

[4] May, M., Nuclear Weapons Supply and Demand, American Scientist 82, pp 526-537, November-December, 1994.

[5] Cuba also has not ratified the treaty but it belongs to the Treaty of Tlatelolco, which defines Latin America as a Nuclear Weapon-Free Zone.

[6] H. Feiveson, Princeton University, personal communication, 2000.

[7] K. C. Bailey, "Doomsday Weapons in the Hands of Many," University of Illinois Press, 3.

[8] S. Gotoh, "CTBT is Indespensible for Establish Nuclear Non-Proliferation Regime," Plutonium, 1999, 2.

[9] M. Bunn, "A Detailed Analysis of Urgently Needed New Steps to Control Warheads and Fissile Material", chapter 7 of "Repairing the Regime: Preventing the Spread of Weapons of Mass Destruction", J. Cirincione, Ed., Routledge Press, New York, 2000.

[10] R. L. Garwin, "The Nuclear Fuel Cycle: Does Reprocessing Make Sense?", in Nuclear Energy Promise or Peril, a Peer Review Workshop of the Pugwash Conference, Paris, Dec 4-5, 1998, Published by World Scientific Publishing, Inc., 1999, pp 139-151.

[11] See, for instance, "The ALMR: A Decade of LMR Progress and Promise, Washington DC Nov 11-15, 1990, American Nuclear Society Press, La Grange Park, IL.

[12] One exception being a reactor that relies exclusively on ^3He + ^3He fusion, which produced no neutrons.

[13] UNFCCC web page is http://www.unfccc.de/.