NUCLEAR WEAPONS AND NUCLEAR REACTORS

Nuclear Studies & Safety Department

Report No. 77157 August, 1977

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ABSTRACT

This report addresses the tenuous link between nuclear power reactor development and the proliferation of nuclear weapons, particularly with respect to possible terrorist exploitation.

Arguments are presented that contradict the popular image of nuclear weaponry as a "basement project".

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by
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Comment on the Title

The title reflects one of the current problems of the electric power industry. Despite the fact that weapons and reactors have nothing in common there is a ready emotional association between them, at least partly because of the common adjective “nuclear”. The undeniable terrors of nuclear weapons are thereby transferred to nuclear power reactors and are used by those unalterably opposed to installation of facilities whose sole purpose is the production of electricity. It is necessary to examine the actual relationship between nuclear reactors and nuclear weapons in some detail, to reduce the emotional impact that clouds reason, and to attempt to see what influence (if any) the development of this source of electric power might have on the proliferation and possible use of nuclear weapons in the future.

Introduction

This note is a comment on the Energy Probe information submission 38-9 (1) to the Ontario Royal Commission on Electric Power Planning and subsequent "Response to Interrogatory" (2). Some history first. The issue of nuclear weapon manufacture as a possible result of civilian nuclear power programs was raised by Energy Probe in their CANDU Technical Handbook (3). It was clearly implied in that document that nuclear weapons could easily be made from reactor-grade plutonium. This statement was challenged in point 26 of the Ontario Hydro Memorandum 29 (4). All of the 26 points in the memorandum refuted statements made in the Technical Handbook, but only point 26 was challenged.

The information submission 38-9 by Energy Probe consists of a letter from Amory Lovins, pointing out that nuclear weapons can, in fact, be made from reactor-grade plutonium. This fact never has been contradicted by Ontario Hydro. The direct quote from point 26 follows:

> "Plutonium containing high percentages of the isotope 240 is extremely difficult to make into a bomb, and this isotope cannot be easily separated from the plutonium isotopes used in nuclear explosives."

Nowhere is there a claim that plutonium can be denatured by addition of the isotope 240. The statement could, in fact, be simplified to read "plutonium is extremely difficult to make into a bomb." This statement is elaborated below. Before going into these details, the nuclear weapons question must be put into its proper perspective. It is appropriate to list the following as established facts:

1. Any national government, given the desire, time, and money, can gather the expertise and materials necessary to fabricate nuclear weapons. Several nations have already done this more or less independently (United States, United Kingdom, Soviet Union, France, China, India) so it can hardly be questioned as fact. In several cases parts of the necessary body of knowledge may have been purchased or stolen, but this did not remove the necessity for indigenous skills of many types to actually carry out the project; it only reduced the time schedule of the development.

2. A national government can develop nuclear weapons without importing any commodity beyond basic technical knowledge. This statement excludes a few nations whose resources do not include the necessary materials, but does not reduce the number of candidates significantly.

3. A national nuclear weapons capability can be established without the use of any plutonium whatever. The prime evidence for this fact is that the weapon dropped on Hiroshima contained no plutonium. The fuel was enriched uranium that had been produced partly using a mass spectrograph and partly by other methods. This alternative is simpler now than it was in 1945 because of developments in isotope separation whose principles, at least, are now public knowledge

4. The preferred fuel for nuclear weapons is plutonium. The preferred means of obtaining plutonium is from special-purpose, natural-uranium reactors moderated by either graphite or heavy water. The graphite-moderated reactor alternative is relatively easy to manufacture, while the heavy water reactor requires sophisticated

isotope separation techniques to produce the moderator. Both reactors can be designed for on-power fuelling. These reactors can be fitted with electricity-generation facilities, but only with a substantial increase in complexity and cost.

5. The preferred type of plutonium for nuclear weapons is that with a low percentage of the isotope 240. The reason is that, with this material, the chance of achieving high energy yield from a given design is improved. On the other hand, the minimum energy yield from a given design does not depend on the presence or absence of the isotope 240. Facts from which these conclusions can be drawn have been available in the open technical literature for at least 15 years.

6. The minimum energy yield depends on the degree of sophistication in the design. The minimum yield is at least equal to that from the chemical explosive used as a fuse. As the weapon becomes more "successful", demands on the designer's skill and experience increase markedly.

7. Plutonium is an exceptionally difficult material to work with, not only because of its radioactivity but also because of its particular chemical and physical properties. Plutonium containing a high concentration of the isotope 240 is not much more difficult to handle than pure plutonium 239.

8. The principles of nuclear weapon design have been known for many years by exactly those individuals who would be expected to take part in a national development project. As evidence of this fact, no one has challenged the competence of the Swedish Ministry of Defense to pass comment on the weapon design put forward by an unidentified MIT student, even though Sweden apparently has not developed their own nuclear weapons.

9. The actual manufacture of nuclear weapons demands very considerable skills and knowledge in a number of fields even if the design is fully specified. Attention must be paid to a number of specific design details in order to assure success.

10. Testing of weapon components is a very important part of any development program, to show which of many specific design details are important to success. A great deal can be learned in such a testing process, but the development time is thereby extended relative to the situation in which these details are known.

11. Testing of even rather small weapons (as opposed to components) leads to almost certain detection.

12. On the scale of devastation that has been experienced in wartime, the effect of a Nagasaki-type bomb is similar to that which occurred in the largest conventional-bomb raids during World War II; there is no doubt that these have been the most devastating single acts of war. However, the Armageddon-like consequences often associated with nuclear weapons are characteristic of thermonuclear or "hydrogen" bombs. These weapons require a second level of sophistication in design and fabrication technology, as well as another "fuel" that is difficult to obtain.

Feasibility of Bomb Manufacture by Terrorists

"The mere designing of nuclear weapons has something in common with climbing the Matterhorn: once thought to be impossible, then considered extremely difficult, and now confidently undertaken by parties of informed and prepared tourists" (5). Carson Mark makes this statement in a discussion of the real and potential accessibility of nuclear weapons. He states that there is ***no*** question that an organization much smaller than a national government could assemble the resources necessary to produce an effective nuclear weapon. Contrary to the mountain-climbing analogy, no reasonable individual would supply guide-books for such an expedition. It is this writer's opinion that, regarding the actual details of nuclear weapons design, the less said the better. Those who know (or who guess) can be fully excused for letting stand any myths, misconceptions, and blind leads that exist. Those who disclose specific details may contribute to nuclear weapons proliferation by answering questions that could occupy a great deal of time and effort in some nation attempting to develop weapons. With this background, it is useful to discuss two possible pictures of how terrorist weapons may be acquired and used.

Sub-national groups have the problem that they do not control the land area that they occupy. This situation is not amenable to a steady, long-lived activity such as developing and producing nuclear weapons. There are very few sub-national groups that attempt local manufacture of even much simpler conventional weapons. Import from a friendly nation is the obvious choice. Hypothetically, the degree of threat that can be posed by a sub-national group by this means is much greater than with conventional weapons, because of the much higher energy yield for a given size (especially since this scenario does not rule out supply by a full-fledged nuclear nation) and consequent relative ease of shipment. The blackmail possibilities are very considerable after credibility is established. This could be done after devices are in place either through an announcement by the supplier nation or by means of a demonstration explosion. The demand could be large: perhaps requiring surrender of territory as a condition for removal of the weapons. The threat would be particularly effective against a nation that did not have nuclear weapons, did not have a rapid means of response against the aggressor, and did not have a strong alliance with an established nuclear state. Indeed, it may be difficult to determine exactly which nation supplied the weapons, so that an effective counter-threat may not be possible.

The consequences of detonation of blackmail weapons, either by accident or as a result of the bluff having been called, certainly would not be as great as those following a full-scale nuclear war. The consequences with respect to human survival on the planet would not be greater than those following atmospheric weapons tests some years back, even though local devastation and death could be considerable. This scene can be presented as the worst that may be achieved by terrorist use of nuclear weapons. One can imagine a group gaining control over some province of a nation by threatening to devastate the nation's capital. They may have smuggled two thermonuclear weapons in from an unidentified source and carried out a convincing demonstration with one of them. If they carry out the threat they lose their venture. If they achieve their objective they have the same problems insurrectionists always have had; namely, control of their own population and defense of borders. These problems are unchanged by their unique means of gaining power, because the weapons that served so well before are useless against both of these threats.

In the Introduction it was stated as fact that almost any national government can develop nuclear weapons, with or without assistance from other nations and with or without nuclear-electric power plants. It is obvious that, within the limits of smugglers' ingenuity, it is possible for a sub-national group to import such weapons from its allies and use them for blackmail purposes. In the following it will be argued that, by comparison with this potential (which has existed for many years and will increase as the number of nuclear-weapons nations increases), the threat that a sub-national group will fabricate effective weapons inside a nation is insignificant.

Local Manufacture of Weapons

The minimum number of well-informed individuals who might build a weapon can be set at six, to give the correct impression that it would be extremely unlikely for an individual to succeed, but also to indicate that the task no longer requires a "small army" as was true in the original effort. The precise number is unimportant: the recruiting of one individual with considerable prior knowledge (such as that displayed by Amory Lovins in Reference 1) would decrease the number. Beyond the minimum amount of money required, additional funds would not make much difference to the job because (in common with other development tasks) success or failure depends mostly on individual knowledge, intelligence and skill. The existence of some definite time schedule or a project involving several weapons would increase the number of persons required.

Rather than discuss the actual case, it is much easier and less likely to be informative to anyone interested in nuclear weapons technology if we speak in terms of an analogy. The analogy must include an objective, a chosen means of achieving it, a technological challenge of roughly the right order, and the disapproval of existing authority. It must be a task that has been accomplished before, but whose precise technological requirements are not known. Shipment of ten kilograms of heroin from Toronto to Montreal by means of a home-built rocket provides a suitable framework for discussion. The immediate reaction is that there are many easier ways to accomplish the objective of delivering the heroin. This is one element in forming the correct overall impression from the analogy. Delivery of ten kilos of heroin to Montreal is not as serious (nor, one suspects, as rare) as the surrender of a free society to the demands of a small minority. Also, the explosion of such a rocket is not as horrifying as the death and devastation that could follow explosion of a nuclear weapon. Both of these "scale-down" factors may prove useful to rational discussion by reducing the emotional content of the argument.

When the group of six rocket designers assembles, the first task is to set the functional requirements for the rocket. Given the required payload and known distance, what lift-off thrust and weight are required? What propellant is both suitable and available? What are the guidance requirements? Target accuracy? Should the rocket be of the cruise type or the ballistic type? What materials can be used to meet stress and temperature demands? The questions go on and on, and the unknown answer to one question often reveals the next question. The rocket design group first should do a survey of available literature. (This method has repeatedly proven more effective than re-invention of rocketry). The scope of available literature ranges from science fiction to popular mechanics to the Model Racketeer's Handbook, to NASA Tech Briefs, and finally perhaps to a classified document that one of the designers picked up some years back. In addition there is the broad general literature of mathematics, physics, chemistry, metallurgy, engineering, and specialized trades (such as precision metalworking). The designers must organize and make sense of the literature, then form a conceptual design. They may choose a design near to one that has been successful, even though it may not fit the current objective. It is unlikely that they will have the detailed technical specifications and drawings, so they will have to use good judgment in many areas. It is most important that they ask all of the right questions, and be able to distinguish which of the answers are essential to their success.

The next step is to obtain the materials. Many of these are quite easy to obtain or can be substituted by others. Each substitution may affect the design, so each must be checked. The fuel is a very special problem. The designers may decide to manufacture their own fuel. In this case, a chemical plant is necessary. This plant must be designed, built and operated without detection for some time. The second choice is outright theft. In this case, the designers must evade pursuit after the theft for sufficient time to load fuel and launch the rocket. The third choice is subversive theft, in which the thief attempts to divert fuel in small amounts from a rocket fuel manufacturing plant. This forces the designers to include an "inside man" in their group. The recruiting and setting-up of a team member in an insider's position may take years, and is subject to disruption through periodic staff reassignment. Detection is a constant risk.

By the time the final design is complete, all materials should be pretty well in hand. Construction of the rocket involves some highly specialized parts that must be fabricated by the designers. Fabrication of special items involves sophisticated operations in chemistry and metallurgy as well as precision tools and the skills necessary to operate them. As each subsystem of the rocket is completed, it should be tested to improve the eventual chance of success. Some systems can be tested easily, but some, such as the guidance system and the engine, cannot be tested without serious risk of detection.

When the rocket is completed it must be set up in a suitable launch location, thereby risking detection. Loading of the fuel and arming of the engine ignition system exposes the designers to considerable personal risks. Again we will assume success.

The final step, the delivery, might go smoothly and lead to the undesirable objective being achieved. In this alternative ending, no one gets hurt except the final users of the drug. The actual damage to society that results from this occurrence is debatable. The rocket might malfunction in any one of a number of ways (recalling the early days of the US space program). If the project goes awry in the worst possible way, the rocket might explode and kill a number of people. Failure is as disastrous to the designers as it is to their victims, because it exposes their existence and their means without their having accomplished their objective. The maximum size of explosion, and the number of deaths depend on the size of the fuel charge, the sophistication of the fuel design, and on the special circumstances of the explosion. However, the crash of even an unsophisticated rocket into a populated area could kill several people. This alternative ending results only from failure of a plan. In recent terrorist events, the third alternative, a compromise, has been the outcome in most instances.

Conclusions From the Analogy

1. To the extent that the writer understands it, a single nuclear weapon project is on roughly the same level of difficulty as the hypothetical rocket project. It is reasonable to assign to both tasks an "extremely difficult" label. So far as national policy is concerned, the fact that someone may claim to have designed a weapon by sketching it on paper, or even by constructing a facsimile, deserves about the same response as some rocket enthusiast who claims to have built a V-2 missile when he has a papier-mâché model in his backyard.

2. The politically-motivated terrorist group has many ways in which to go wrong by attempting to build a nuclear weapon, and a small chance of success. Any failure provides an ideal justification for the government of the day to eliminate them as a political element inside the nation.

3. The threat to explode a nuclear weapon is an effective terror-inspiring action in itself, but only for a very few repetitions unless an actual demonstration is conducted.

The totally irrational individual (whose only objective may be to blow something up to achieve notoriety) is highly unlikely to succeed in this project. Safeguard measures (use denial of nuclear materials) can be extremely effective in this case.

Overall Conclusions

1. It is possible that an individual could fabricate a nuclear weapon. It can be stated that this is extremely unlikely.

2. A sub-national group has a reasonable chance of success in a blackmail attempt if it imports weapons from another country. Such a capability exists now and will increase in likelihood as the number of nuclear-weapon nations increases. The rate of increase in this

number can be affected only slightly by elimination of nuclear-electric power programs because of the widely-spread knowledge of basic principles and widely dispersed uranium deposits in the world.

3. A sub-national group is very unlikely to succeed in a blackmail attempt using the means of local fabrication of nuclear weapons. The main reasons are the multiple chances for detection and the sheer difficulty of doing the job right the first time under very restrictive conditions. In a nation with a nuclear-electric power program, rather simple material safeguards are available that make the job doubly difficult.

4. A sub-national group has many ways of terrorizing the population if it suits their ends. They can use chemical or biological weapons of proven effectiveness, with little risk to themselves. A nuclear weapon threat has the very high fear factor that exists after three decades of cold war. (This fear was recently and aptly described as "atom angst"). Atom angst already has been exploited by groups whose apparent purpose is to stop development of nuclear- electric power by whatever means they find at hand.

Overview

The most dramatic event in the electric power industry during the past year was President Carter's announcement that the US will stop the reprocessing of commercial nuclear fuels. The apparent reason was to reduce nuclear weapons proliferation in the world. Several authorities (6, 7, 8, 9) already have commented on the ineffectiveness of this policy. It seems likely, in fact, that the announcement had much more to do with US domestic politics than it did with weapons. Proliferation problems are at least as difficult as disarmament problems, but they are not changed by the presence or absence of nuclear-electric power plants.

The terrorist threat discussed in this article is more imaginary than real. Nevertheless, considerable additional protection is being put into place in the form of security against theft of nuclear materials. (Whether or not this expenditure should be made to counter an imaginary threat is another matter). Very effective means exist for denying access to potential terrorists (10).

Finally, even if the "implacable critics" reject these conclusions, they must face the prospect that the human race is approaching drastic changes in our means for survival. The real issue is not the growth of energy use in the future but rather it is the level to which that use may decrease. If the decrease is large, or relatively small but rapid, the risk to world society is very great. We must try to understand the actual risks of each alternate path, and choose the one for which these risks are least. Cheap and abundant electricity from nuclear reactors is one feature of this minimum-risk path.

Acknowledgement

The author wishes to thank J. Carson Mark, for very useful discussions and for his comments on the manuscript.

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