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Lessons of Chernobyl

Bennett Ramberg

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LESSONS OF CHERNOBYL

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SUMMARY

The accident on April 26, 1986, at the Chernobyl nuclear energy facility in the Ukranian province of the USSR is considered in the light of nuclear safety attitudes that existed in the Soviet Union before the accident. The accident itself and its immediate consequences are reviewed and their impact is projected into future operating regulations of nuclear plants. The author concludes that as bad as the accident was, its impact on the future of nuclear plants will be minimal.

ABSTRACT

Dr. Bennett Ramberg discusses the nuclear plant safety attitude leading to the Chernobyl accident, he reviews the accident and its immediate impact, and he then considers its long-term impact on the nuclear power-generating industry worldwide. This paper is based on a talk given by Dr. Ramberg on May 4, 1987, at the Center for National Security Studies of the Los Alamos National Laboratory. The presentation was followed by a question and answer session.

LESSONS OF CHERNOBYL

by

Bennett Ramberg

INTRODUCTION AND BACKGROUND

It's a rather propitious time to talk about Chernobyl. After all, it's been roughly a year since the accident took place. On April 26, 1986, at 1:23 in the morning, two explosions rocked unit number 4 at the Chernobyl nuclear energy facility. Today, I will talk about the immediate roots and some of the underlying causes of Chernobyl; at the end of the presentation I will address some of the other strategic risks posed by nuclear energy.

Among the many questions that arose in the press and other sources were: How could Chernobyl happen? How do we explain Chernobyl? Were the Russians as responsible (as they ought to have been) in addressing nuclear safety issues? Were there generic causes of the accident?

The problem of addressing any particular issue in the public policy domain requires first that an item appear on the political agenda. It arrives in several ways. A policymaker may recognize it as a pressing issue, that is, a peculiarly important matter. Oftentimes our policymakers don't recognize matters as pressing because they're confronted with a multitude of issues. New players will also help matters. Some examples are a new party secretary in the Soviet Union, a new commissioner on the Nuclear Regulatory Commission (NRC), or a new head of the Department of Energy. Alternatively, policy entrepreneurs play an important role. People outside government can, for example, be from the labs, environmental groups, or can be others who try to raise issues. Failing that, windows of opportunities may arise.

The framework of pressing issues, new players, policy entrepreneurs, and windows of opportunity affords a tool to understand Chernobyl — not only for Chernobyl, but for American nuclear energy policy as well.

In the Soviet Union, nuclear energy safety, per se, was never a pressing issue; however, a pressing issue was electrical generation. Contrary to public accounts, the Russians paid serious attention to nuclear safety. Reactors, for example, were designed with emergency core cooling systems and with diesel generators to provide emergency generation in event of a loss of off-site power. But the reactors were not built to withstand incredible accidents. And here's the rub: What is incredible? How should we design reactors? How should the Soviets have designed their reactors? To what extent should we overdesign reactors to compensate for the possibility of "the incredible"? Trying to address the incredible was not a unique Soviet problem. The U.S. program — a nuclear energy program about which we know a good deal more — faced a similar problem over the years. How the United States confronted it provides an interesting point of comparison. I'll return to the Soviet situation shortly.

At the outset of the civil nuclear program here in the United States, nuclear safety, per se, again was not a pressing issue. Electrical generation was paramount. In fact, if you look at the legislative hearings which marked up the Atomic Energy Act of 1954, relatively little attention was paid to safety. This is understandable because there was no civil nuclear energy program in the United States at that time. There were nuclear promoters such as Edward Teller, who raised the issue of nuclear safety. Nonetheless, he said that the benefits of nuclear power outweighed the risks. And he said we should get on with the matter, just as he says we should get on with nuclear electrical generation today. The government was not oblivious to the matter of nuclear safety. There arose a group of people whom I would define as techno-bureaucratic entrepreneurs — nuclear safety engineers and scientists in government and associated weapons and energy labs around the country — who raised safety issues. In 1957 we had the first of a train of famous reports dealing with nuclear safety. WASH-740 raised the specter of a catastrophic release of radiation that could result in the deaths of tens of thousands of people. However, the issue was set aside for more study.

There were people in and out of government who tried to pursue the matter. Paper calculations were made - additional paper calculations beyond WASH-740. But there were a number of complicated problems in bringing these issues to the attention of policymakers. First, there was the problem of cost. To what extent should we overdesign reactors to compensate for the potential of a disastrous accident? Then, there was the problem of conflicting advice, or what I call the fog of expertise. There were conflicting estimates of what could really happen as a result of a major accident. Just before the reactor safety study, WASH-1400 (the Rasmussen Report) was published. Herbert Kouts, who headed the Atomic Energy Commission (AEC) study on nuclear safety, stipulated that the probability of an accident was low indeed. According to Kouts, there was virtually no chance of a major incident. The odds of major catastrophe were 1 in 1 billion to 1 in 10 billion years for a given reactor. Peer review, however, raised a number of issues. And a policy entrepreneur, Frank Von Hipple, emerged. He brought the matter to the attention of the American Physical Society (APS). An APS study was thereafter undertaken by Harold Lewis. The result reestimated the WASH-1400 calculations, but the review never really penetrated into the government. The newly formed NRC, while paying some attention to the issue, didn't implement suggestions put forward by the APS despite the fact that there were actual anomalies in the field. Accidents were occurring, but the accidents were not particularly dangerous. Ultimately, it was an accident — an event, Three Mile Island (TMI) — and not the efforts of policy entrepreneurs or new people entering government that put nuclear safety onto the public policy agenda.

In light of the American experience, it's not surprising that the Soviet Union would not pay more attention to nuclear safety. After all, the Soviets tended to emulate the United States in a variety of ways. Soviet nuclear planners carried on with the same bravado as their American counterparts in dismissing the possibility, or probability, of major nuclear accidents. In 1983, well after Three-Mile Island, for example, one Soviet publication, *Novostii*, reported that Soviet stations were the safest in the world. Echoing Herbert Kouts, the Soviet press reported that the probability of nuclear accidents involving radioactive discharge was less than 1 in 1 million. Workers had as much chance of being struck by lightning. Ironically, in February 1986, several months prior to Chernobyl, an article appeared in *Soviet Life*. It contained a case study of the Chernobyl plant. Petro Borenvenko, one of the Chernobyl operators, was pictured. He is a shift superintendent in the Department of Labor Protection and Safety Review who maintains that working at the plant is safer than driving one's car. We don't know if he survived the accident. But leaving that aside, the report, with the same bravado as that heard from American nuclear engineers, put the odds of a meltdown at 1 in 10,000 years: "The plants have safe and reliable controls that are protected from any breakdown with three safety lines." The report quoted Nicholev Foman, the plant's chief engineer, "who believes that both man and nature are completely safe. The huge reactor is housed in a concrete silo and it has environmental protection systems. Even if the incredible should happen, the automatic control and safety systems would shut down the reactor in a matter of seconds. The plant has emergency core cooling systems and many other technological safety devices and systems." Finally, we have a picture of Soviet plant operators: "The occupational safety and health agency requires that all persons strictly abide by the rules and regulations. In order to hold a job here you have to know industrial safety rules to perfection and pass the exam in them every year." This was the problem. The Soviets simply didn't follow the rules, as we'll see when I provide a case study of what actually happened at Chernobyl.

There were policy entrepreneurs in the Soviet case who tried to raise the issue of nuclear safety. In 1979, for example, in the important theoretical Soviet journal *Kommunist,* two academicians questioned the possibility that there could be a catastrophic accident. They suggested that Soviet plants be located in very remote areas. In 1982 in another Soviet publication, *Soviestia Dosia*, a Soviet nuclear engineer reported that a plant that he was working on in Bolokovo, was receiving piping that was "complete junk." It is uncertain whether these policy entrepreneurs could really reach the ears of the policymakers. As in the United States, it would be events and not the actions of people or others entering government that would be determining. In 1976, A. M. Petrosiants, head of the Soviet State Committee on Atomic Energy, informed his American counterparts that the necessity for hard, reinforced containment was ridiculous. It was simply not necessary.

However, in the aftermath of Three-Mile Island, the Soviets placed heavily reinforced concrete containments over new Soviet construction — over new Pressurized Water Reactors (PWRs). Still, there was no real sense of urgency; older PWRs were not retrofitted with heavy containments, nor were the graphite-moderated, Chernobyl-like reactors. A few months after the TMI accident, for example, Governor Richard Thornberg visited the Soviet Union and spoke to the deputy chairman of the Soviet Committee on Science and Technology. He was told that the safety problem of the Soviet Union was solved. There simply was no safety problem. Three-Mile Island was depicted in the Soviet press as a peculiarly American problem. It reflected the U.S. capitalist system, which put environmental concerns after economics. It would take Chernobyl to force rethinking — to reassess energy.

The following remarks from the Soviet report to the International Atomic Energy Agency (IAEA) capture the "business as usual" attitude — and inertia — the accident may have had to overcome. Quoting the report, "The developers of the reactor installation did not envision the creation of protective systems capable of preventing an accident in the presence of premeditated diversions of technical protection facilities and violation of operating regulations which occurred since they considered such a set of events impossible." Finally it dawned on the Soviet decision makers that the incredible was credible. That it took an incident of this magnitude to force Soviet reconsideration of nuclear safety clearly supports the "body in the morgue" theory advanced some years ago by two nuclear cassandras, Arthur Tamplin and John Goffman. These cassandras, whom I would call ineffective policy entrepreneurs, contended that the AEC would only take remedial measures to make nuclear energy safe in this country after people were hurt. In the aftermath of Chernobyl and TMI, the contention seems plausible across political systems. In both countries, it would take a major accident to overcome overconfidence in technology, the inability of dissent to reach policymakers, the drive to expand nuclear energy rapidly, and the absence of political entrepreneurs. Bureaucratic inertia, cost, and pride are further underlying causes of Chernobyl.

CIRCUMSTANCES

Now let's look at the accident with greater focus. The Chernobyl accident is situated roughly 60 miles north of Kiev in an agricultural region. It is not a particularly productive region. It produces rye and dairy products. The population around the Chernobyl plant includes the city of Pripyat with 49,000 people and a city closer to the reactor itself, Chernobyl with 12,000 people.

The area has a number of scattered villages with populations of roughly 500 to 700 people. Roughly 135,000 people lived in an 18-mile radius of the plant. The city of Chernagov, with a population of about 210,000 people, is situated roughly 60–70 miles north of Chernobyl, and Kiev, with about 2.3 million people, is to the south. Nuclear energy supplies about 11 percent of Soviet electrical generation today — of that generation the Chernobyl-like reactors supply roughly half. Chernobyl unit 4, the reactor at which the accident occurred, went into operation in 1986. It was one of four units at the plant. Two additional units were under construction, each producing 1000 megawatts of electricity.

Why was there an accident at Chernobyl? The accident is now well understood as a result of the Soviet report, of investigations in the United States, and studies by the IAEA. The Soviets were concerned, as we have been concerned, about the probability or possibility of a loss of off-site power. They sought to address the possibility that emergency diesel generators might not come on line automatically. They wanted to test a device which would allow the turbine generator of the plant to supply roughly 30 to 40 seconds' worth of electricity in the event of a loss of off-site power. The Soviets began the test at one o'clock in the afternoon on April 25th. Emergency cooling pumps were disengaged, suggesting sloppiness in Soviet procedures — I mean considerable sloppiness — although this did not contribute to the accident. At two o'clock in the afternoon of April 25th, a dispatcher said that consumers down the line needed more electrical generation so the Soviet plant — unit 4 — was put back on the line. At eleven o'clock in the evening, 9 hours later, the plant was taken off the grid to conduct this experiment. One purpose for performing the experiment then was that annual maintenance was scheduled. From this point on, the reactor suffered reactivity problems. To stabilize the reactor at one point, control rods were raised very high; only eight rods were in reserve. According to Soviet procedures, at least 15 rods and, better yet, at least 30 rods were to be held in reserve. A number of automatic safety systems were disengaged to allow the experiments to proceed. About a minute or two before the experiment, reactor operators were informed by computer printout that the reactor itself was in a potentially unstable situation.

Nonetheless, the operators proceeded. The rationale: reactor operators were tired. After all, they had been working at the plant since the previous afternoon. They wanted to get on with the experiment; they were concerned about the reaction of superiors if they failed to perform; they looked forward to the coming May Day holiday. So they engaged the test at 1:23 in the morning on April 26th. Power levels accelerated rapidly. Thirty-six seconds into the test the operator realized that the reactor was out of control. He tried to engage the control rods: they failed. The reactor was subjected to, according to some accounts, a steam explosion followed by a hydrogen explosion. Two explosions occurred, lifting a thousand-ton steel plate above the reactor; roughly a quarter of the core was thrown from the reactor. Up to 30 fires burned around the reactor. Immediately the Soviets tried to put the inferno out. A team of firemen arrived within 90 minutes after the initial explosions. The Ukranian Minister of Internal Affairs led the team. The area was sealed off. About 6:30 a.m., the fires around the reactor were doused, but the reactor core, the graphite core, continued to burn and would burn for roughly 14 more days.

Civil defense initially was delayed in part because of the absence of an adequate civil defense program. People were advised to stay indoors. Soviets engaged a number of measures to minimize the consequences. They distributed potassium iodide to the population in the vicinity of the plant. Silver iodide was sprayed over rain bearing clouds to prevent a rain out. Thirty-six hours into the accident the first buses from Kiev arrived and a 20-kilometer train of buses carried the population from Pripyat and Chernobyl out of the area. But it took up to 9 days to carry people from rural areas surrounding the plant out to the 18-mile radius. The graphite fire was finally smothered with roughly 5000 tons of sand, boron, and dolomite. The reactor plume spread in a northwesterly direction toward Sweden, then through central Europe and western Europe.

Prevailing westerly winds hoisted it aloft. Some of the radiation extended south over the Arabian peninsula, but the residue crossed Siberia and was detected in the air space above Japan and later over the western United States.

What are the costs of Chernobyl? The immediate costs were 31 dead: 2 people lost their lives as the result of the immediate explosions and 29 people as the result of radiation thermal burns. Numerous issues have been raised about the long-term health costs. I interviewed a number of people about this matter. The estimates varied extraordinarily, I think in part because of political motives. For example, Richard Wilson, a strong proponent of nuclear energy, suggests the late cancers will range from 210 people to 2100 people. For Marvin Goldman of the University of California at Davis, who heads the Department of Energy's Chernobyl biological evaluation program, the figures range from zero to about 4600. The Nuclear Regulatory Commission's estimates, according to Frank Congel, were from 20,000 to 40,000. The current estimate of the NRC is 14,000 fatalities worldwide. According to the Natural Resources Defense Council, as many as 210,000 people might lose their lives. John Goffman continues to hold that his estimate is correct, that anywhere from 500,000 to 600,000 people in the end will lose their lives. And Sternglass, of the University of Pittsburg, suggests the figure stands at 1,000,000 people.

The scientific problem of trying to establish the consequences of the Chernobyl accident relates to our lack of knowledge about the impact of low-level radiation. What's striking in the interviews I conducted was the fact that it seemed to be politics rather than science that dominated the estimates.

In addition to the human loss or the potential human costs of the accident, the Soviets confront economic costs. This may be the world's most expensive industrial accident. The Soviets and others estimate the accident will cost anywhere from 3 to 5 billion dollars. Some recent estimates suggest 9 billion dollars will be lost to Soviet economy as a result of the lost reactor, lost electrical generation, relocation, decontamination, and other problems, including medical costs.

NUCLEAR STRATEGIC RISKS WORLDWIDE

Let's look at Chernobyl in a broader context, that is, in the context of other nuclear strategic risks. Even before Chernobyl, the world confronted a serious nuclear energy slump. There are roughly 380 reactors in operation around the world in 26 nations, with 118 new plants scheduled for operation in 17 countries by 1990. What happens beyond the mid-1990s is uncertain. Until the turn of the century we are unlikely to see any major new construction for most of the world outside the Soviet Union and Japan. If nuclear energy is to survive, it has to address a number of strategic risks, accidents included. Between 1971 and 1984, the General Accounting Office (GAO) reports that there were 2 significant and 149 potentially significant accidents in 14 industrialized countries (they failed to define significant and potentially significant). But among the accidents or potential accidents was an event that occurred in 1984 at a French nuclear reactor where a failure of an electrical component and the emergency diesel generator, coupled to operator error, almost resulted in another Three-Mile Island.

Beyond reactor accidents, the nuclear industry confronts the possibility of terrorist sabotage. Between 1970 and 1984 there were a number of such acts, including a bazooka attack against a reactor in France. No sabotage to date has resulted in any significant release of radiation or any other significant plant damage. Still, the inadequacy of government regulation is striking. According to the U.S. code, reactor operators need not protect plants against more than one internal or three external attackers; nor are reactor operators required to protect nuclear facilities against foreign enemies of the United States. Recent Congressional hearings point out that certain nuclear defense facilities are particularly vulnerable to terrorist acts. In addition to sabotage, there is the problem of diversion of nuclear materials. By the 1990s there will be roughly 350 to 400 metric tons of plutonium separated in the West — notably in Japan, Germany, England, and France. Finally, there's the issue of military attacks on reactors. Nuclear plants are likely to be attractive targets in time of war. The consequences are likely to be significantly greater even in a conventional war than what we saw in Chernobyl for several reasons. First, it's conceivable that all reactors co-located could be destroyed in a wartime scenario. Second, as we saw at Chernobyl, the Soviets had to mobilize essentially their entire country to try to put the Chernobyl fire out. In wartime, resource mobilization will be much more difficult.

What are the remedies to the world? We have an International Atomic Energy Agency and a regime of norms centered around it. The IAEA began in 1957, and over the years it acquired an inspectorate function to verify that sensitive nuclear materials would not be diverted. It's interesting to note the Soviet Union initially opposed the international safeguards function. In the early debate the Soviets argued that an inspectorate would be a "spider's web that would catch the scientists of the world." By the late 1950s and early 1960s, the Soviets recognized the proliferation danger in light of their experience with China, but IAEA efforts to promote nuclear safety came more slowly. Today the IAEA has safety guidelines, but they are guidelines only; they're not enforceable. Still, at the invitation of host countries, the Agency can send safety inspectors to civil nuclear power plants.

FUTURE IMPLICATIONS

In the aftermath of Chernobyl, there were proposals for greater scrutiny of all nuclear facilities around the world. Director Blix of the IAEA and Chancellor Kohl of West Germany called for an institution to prescribe safety standards and to verify implementation. The best we've done to date is accident warning and assistance conventions. Joe Pilat of Los Alamos helped negotiate them. I believe there should be in place a more intrusive mechanism to verify plant safety and other nuclear risks. Perhaps the following scenario is worth looking at. All countries are concerned about nuclear safety. No country wants a nuclear accident. Perhaps we could use the issue of safety to encourage a more enforceable comprehensive regime. Inspecting plants for safety could be a ruse to verify that plants are secure in other regards. For example, through a safety audit you could verify that the plant's sabotage protection was in place, that plants were not used to manufacture weapons-grade material to prevent another Israeli-like strike.

How likely are we to have a more secure nuclear regime? Not likely, I think. Why? First, Chernobyl was not bad enough to compel more stringent safeguards; only 31 people lost their lives. In Bhopol, by comparison, 2000 to 3000 people lost their lives immediately. Chernobyl pales by comparison. Second, the incident occurred in the Soviet Union. Had it taken place in Western countries, the press coverage would have been so intense that there would have been extraordinary political pressure to do something drastic.

What are the long-term prospects for nuclear energy? They're somewhat uncertain. As I indicated before, several countries will continue to rely on nuclear energy and will continue new construction, notably the Soviet Union and Japan. What are the alternatives to nuclear energy? Are they satisfactory? In the United States, it's coal. Is this satisfactory? Given the problem with pollutants, perhaps not. The bottom line is — there is no free lunch. And that's the problem we confront as we look into the future.

QUESTIONS AND ANSWERS

Q. Looking at the matter of arms control, I have become convinced, rightly or wrongly, that confidence-building measures are a very important component of that issue. Now do you see an opening here to establish a multinational capability to deal with national disasters such as Chernobyl as one means of fostering confidence-building, which everybody will understand as a universal good; as something that all nations should be in favor of?

A. I'll address your question in several ways. First, there is the matter of nuclear safety. Clearly if you have an intrusive, an honest inspectorate, capable of verifying nuclear safety and dealing with other strategic risks that I addressed, you'll have a confidence-building regime in place. And this is all to the good. The problem is — notwithstanding Chernobyl, notwithstanding TMI — that countries are reluctant to have their sovereignty infringed. There're different safety standards in each country. Some countries don't perceive the risk as great as others. The question is, what standard are you likely to employ? Is it a minimum standard? Is that satisfactory? The IAEA is trying to address the matter through safety guidelines.

Second, I would endorse confidence-building measures more generally. As you know, in September 1986 we negotiated the Stockholm confidence-building accords. This is a positive step. It's surprising that the press paid so little attention to the agreement. I think it is an important step in confidence-building and in the theory of arms control more generally. But going back to nuclear energy, per se, the reasons Israel attacked the Iraqi nuclear facilities in 1981 lay in the fact it lacked confidence that the IAEA was verifying that the Iraqis were not going to use the plant to manufacture weapons material. And it's hard for people outside, that is academics, to address how scrupulously the IAEA has applied safeguards. We have the famous congressional testimony of Roger Richter, an IAEA inspector, who came forward after the bombing of the Iraqi plant and suggested the IAEA was not scrupulous at all. He never visited the Iraqi plant; he based his assessment on reports he saw, or rumors or whatever; it's uncertain what was the foundation for his statement to the Congress.

He said he provided the following scenario: You go to a country such as Iraq to verify the plant is properly under safeguards. You're not allowed access to certain rooms. The Iraqis, for example, tell you that in a particular room where sensitive nuclear material is stored, the lights are out, or the key can't be found. You're supposed to disregard these telltale signs that something is amiss. You come back to Vienna, you write your report stipulating that everything is fine, and you close your mind, you close your eyes to things that you saw. Why? Because stating that something is amiss is not consistent with the political dimension of the IAEA. And this is a particular problem of international organizations such as the IAEA. After all, they're a product of their membership. And if they overstep certain bounds, countries will withdraw. There are steps beyond which an international institution such as the International Atomic Energy Agency can't go. But it's hard for us on the outside to judge. The agency puts forward a report every year assessing safeguards. The summary, typically, says everything is fine. There has been some congressional testimony that came out, I think, in 1982–1983, and suggested that everything wasn't fine. There were anomalies in the assessment, and the reviews weren't as scrupulous as they ought to have been.

Filings from plant operators around the world in some cases came very, very late, months later than was appropriate. Questions were raised, and the IAEA says they followed up to their satisfaction. But it's hard for an outsider to really judge. There's no oversight of the agency by an independent body. All I have is several pieces of congressional testimony raising these questions. The most damning testimony was this testimony by inspector Roger Richter, but there was also later testimony — I think roughly in 1983 — which raised some serious questions about the agency. The agency is not disposed to sharing information because it's given to it in confidence. So without the scrutiny of an independent body, it's hard to judge how scrupulous the agency really is.

Q. I think it's interesting, historically, how the agency got into the safeguard business and its relevance to the whole notion of third-party efforts that monitor compliance with arms control agreements. As I understand it, the safeguards function of the IAEA really was a continuation or an extension of the kinds of safeguards arrangements which the U.S. had in place on a bilateral basis before the setup of the IAEA. And the United States was in a position to introduce those safeguards because it was really the sole party providing the services, tit for tat, to the nations that really had a great interest in gaining access to the technologies and the know-how that the United States was prepared to provide. These states simply accepted this infringement of their national sovereignty in return for assistance. Essentially, when the IAEA was set up it assumed the same kind of responsibility, and a great bargain was struck. I think most of the countries looked at the IAEA primarily as a source of information about nuclear power — the peaceful uses of nuclear power — and were prepared again to accept certain safeguard measures as the necessary cost for getting access to this information. The Agency developed a momentum of its own. But it clearly was not the intention of most of the parties to the IAEA at the time it was created that it would have as a principal function a safeguards activity. Now, things have changed over time. But I think that this historical background is important in understanding the extent to which the IAEA really can, in fact, continue to develop safeguards. I mean it has a very, very small budget. I think the budget now is around 13 million dollars a year or so. It's ironic that the United States, in particular, should promote nonproliferation objectives and yet not provide more funding for the safeguards mission of the IAEA. All of the problems that you noted are definitely true. On the other hand, until we've had more support for this essential agency, I think it unrealistic to expect it to have a greater impact.

A. There's another question that ought to be raised in terms of international scrutiny of atomic energy from a safety or strategic risks point of view. An example is the United States' experience with the Nuclear Regulatory Commission in scrutinizing our own nuclear industry. You know it's not been perfect. In fact, a number of questions have been raised about the effectiveness and the honesty of the NRC. There may be some former NRC people here. But I'm making the statement not only on the basis of my readings but on some personal experiences I had at UCLA concerning a research reactor on the campus. Issues were raised about its safety. Suggestions were made to improve the safety. Yet, one of the principal obstacles was the Nuclear Regulatory Commission in conjunction with the University.

Q. They did not want to make the changes?

A. That is correct, they did not want to make the changes. Among the issues were the following: highly enriched uranium (HEU) at the reactor was stored in a cabinet. We suggested greater safeguards be provided for HEU. Second, the reactor was releasing radioactive material from its stack. The prevailing plume was directed toward an air conditioning vent in the adjacent building. We suggested that a modest step be taken; that a fan be installed and that the velocity of the fan be increased and the stack be raised several tens of feet. This would be a modest cost. The NRC refused to endorse it. Evacuation of the building was another issue. The reactor building was not earthquake proof. The NRC fought the remedies tooth and nail. And if you can't address such issues in the United States, where we have the Congress and the courts, how can you address it in an international environment? I can put forward, as I did in a book, various idealistic scenarios on how things should run. But management of these scenarios in practice is another matter. I'm dubious that you would really have an enforceable international safety regime or a regime that could address in a very scrupulous manner some of the other strategic challenges that I put forward.

Q. Your theory, in particular, on the way problems arise on the policymakers' agenda explains a great deal.

A. It's something I recently applied to try to understand why things occur. It's a simplified model of public policy. But it helps explain certain things. I can speak from another perspective — as a policy entrepreneur, trying to place matters on the agenda, that is, the matter of military attacks on reactors. I raised this issue in the late 1970s, published a paper at Princeton University, and later published a book in 1980 before the Israeli attack on the Iraqi reactor. And I tried to get government attention.

I think a remark a year and a half ago summed up the problem. A State Department official told me, "Dr. Ramberg, there's no career advancement associated with your issue." This is the problem of the policy entrepreneur; trying to get the issue on an agenda. I don't know people who really have taken military attacks seriously. What I've proposed is a convention — a treaty prohibiting attacks. There're legitimate reasons to attack reactors if you believe the reactor is going to be used to manufacture nuclear weapons. If you're an Israeli looking at the Iraqi plant, an alternative would be to subject the plant to scrupulous international safeguards. Failure to adopt the safeguards would make the plant a legitimate target.

Q. Would such a convention prevent attacks?

A. What you try to do through international law is establish a norm. It's the weakest remedy. Then you pursue other remedies, potential remedies. Examples are locating the plants underground, locating the plants in distant locations away from populated areas, or perhaps not locating plants in war-prone regions at all. For example, the Israelis for some years conceived of having a nuclear power plant along the proposed Dead Sea canal. Now is it reasonable, given the problems Israel confronts, to have a nuclear power reactor at all? This is a question that an Israeli official took up with me. He argued that no Arab air force has ever penetrated Israeli air space so there was no danger. First of all, that wasn't true. Further, he didn't consider what rockets can do. The Soviets, for example, provided the Syrians with SS-21s.

Q. There's another way of arguing this. I don't necessarily believe it, but nonetheless, if the Israelis had nuclear power reactors, it might make them more prudent in their international relations, on the one hand, and more anxious to achieve some kind of settlement of political questions, on the other hand.

A. In fact, I do address the possibility that reactors could serve as potential weapons or threats by an adversary. That is, if you have a reactor and your adversary can target your reactor, it affords your adversary with quasi-radiological weapons, not a nuclear weapon. It could be a deterrent. And I apply the scenario, for example, to the European theater. There's a great deal of concern about the reliability of the American nuclear deterrent. So you could put forth a scenario where you provide the Germans with the capability to target Soviet reactors. But this raises a slew of sensitive political issues. Still, if deterrence works, and if the Soviets are sensitive to this particular problem, this option would have provided Germany with a radiological deterrent.

Still, the Soviets might not be impressed. Chernobyl proved that you could evacuate large populations relatively quickly and that the loss of life, at least immediate loss of life, would be relatively small. However, the lessons of Chernobyl have to be taken gingerly. After all, the roof blew off of the reactor. It took place in the evening. There was a high inversion. Had the release occurred at the base of the reactor, had there been a low inversion, and had there been a drizzle, a slight drizzle, early fatalities as a result of the Chernobyl accident might have been considerably greater, assuming there was a large population nearby.

Q. You made an interesting suggestion about the relationship between Chernobyl and the armed attacks issue. You hinted at a similar connection with nuclear terrorism. Do you want to flesh that out a little bit? Do you conceive that these are substantially the same issues, or do they have different parameters?

A. I think these issues have somewhat different parameters. The question with regard to nuclear terrorism, or let's say sabotage of reactors, is how far are terrorists willing to go? The history of terrorism over the past 100 years or so suggests that terrorists have not been willing to take large numbers of lives. In recent years, very recent years, terrorists have been willing to take larger number of lives. For example, you have the destruction of the Indian airliner off the coast of Ireland by Sikh terrorists. Several hundred people lost their lives. You've had indiscriminate attacks in Beirut killing and injuring hundreds. But these were not catastrophic losses of life, and there're a variety of ways you can take catastrophic losses of life, if one wants to poison city water and so on.

So what is the attraction of nuclear terrorism? The attractiveness may lie in the name nuclear. It seems to create a certain specter in the mind's eye. And we have seen attempts at sabotage of plants. Most people who looked at this suggest that these attempts have not been particularly serious — but as we speculate into the future, things may be different. Terrorists might not be satisfied with what analysts in the field call current "theater." After all, terrorism has a political purpose. And, as a result of terrorist acts in recent years, hijackings and so on, the theater quality of what they're trying to do, the message that they're trying to convey, has declined to some extent. It's old hat. I don't really buy this argument. But this is an argument made by terrorist specialists. Some suggest that since terrorist acts have been relatively benign, they may be willing to take the next step. They might try to engage in some catastrophic episodes. And nuclear facilities might afford an attractive target. Other analysts counter that this will not help their political cause — that terrorists have a message to convey. Yet others contend that if terrorists become so angry, so frustrated, they will become irrational. This was a message from the recent Nuclear Control Institute Symposium on Nuclear Terrorism. Now this is speculation. We can spin any scenario we want and it has some degree of plausibility.

Probability is another matter. But my point is that an ounce of prevention really is worth a pound of cure, and there're certain remedial measures which could be undertaken. For example, I appeared in a hearing before the Nuclear Regulatory Commission, the Advisory Committee on Reactor Safeguards, with several colleagues. We suggested that some steps should be taken to deal with truck bombs. We've seen them in the Middle East. We suggested that zigzag concrete barriers be placed in the entry ways to facilities. The response was that if we do that, the terrorists will use another mode to attack a facility. Bill Potter and I, accompanied by some students at UCLA, recently took a trip down to San Onofre. We discussed the protection of the plant against terrorist acts and the issue of truck bombs came up. Facility security people advised us that they placed a zigzag concrete barrier down the access roadway at the time of the Olympics. These barriers were removed after the Olympics because it was too costly for trucks to zigzag up the hill. Still, two operators recognized that facility zigzag barriers are a remedy. Now, as to the argument that you could use other modes by which to attack a plant, you could, of course, hire a helicopter or load a light plane or even a commercial plane with explosives.

Our counter to the argument was that you do what you can do. I mean we've seen truck bombs. We pointed out to the people at the Nuclear Regulatory Commission that just a few blocks away the White House is protected with concrete barriers, and so is the State Department. The consequences of a detonation, aside from the immediate loss of life, would not be in any way catastrophic in terms of contamination resulting from the destruction of the State Department, but it could have serious consequences at a nuclear reactor. The Advisory Committee on Reactor Safeguards was not willing to buy our argument. We also brought to their attention literature that they published on the vulnerability of nuclear facilities to terrorist acts. To our astonishment, one can go to the Nuclear Regulatory Commission library and find guides to blow up plants.

I think there are many things in government which *are* stamped "secret" which should be in the public domain. But clearly there are other things which *should* be stamped "secret" which are in the public domain — and among the things that are not stamped "secret" are these documents. Included is a booklet describing the amount of explosives required to break down walls. It includes how many times you have to swing a sledgehammer in order to break down barriers. It includes steps one can use to circumvent security barriers. We asked the NRC advisory committee why the documents are in the public domain. They said reactor operators have a need to know. We agreed, but at the same time argued that, in this case, the public doesn't. In addition to those reports, the NRC publishes a board game that you play with the roll of the dice. And we have a picture of people at Sandia playing the board game. You can get the board game from the NRC, and its purpose is to show various ways by which people can break into nuclear power plants. Well, it's fine for the folks at Sandia, but to have this in the public domain is another matter. Nonetheless, the people at the advisory committee weren't willing to suggest to the NRC that these documents be removed from the public document room. I don't know what more I can say.

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