UCRL-JC-135608
PREPRINT

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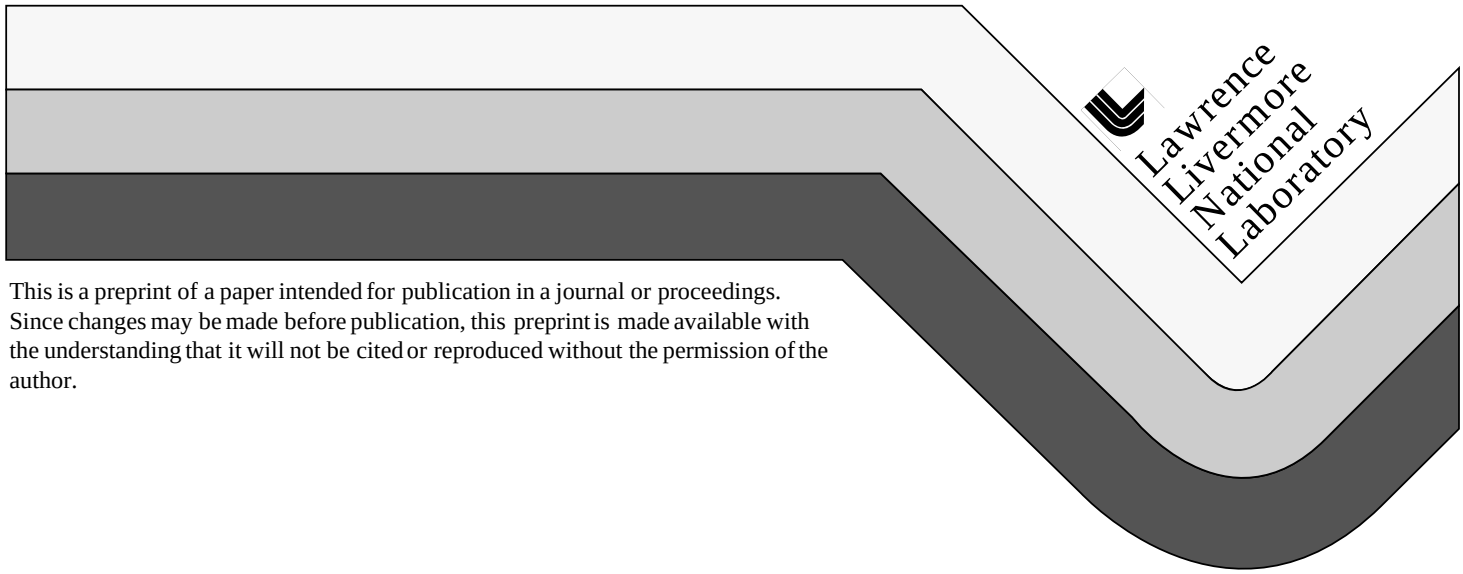
This paper was prepared for submittal to the
Second International Symposium on the "History of Atomic Projects–The 1950s: Sociopolitical, Environmental and Engineering Lessons Learned" (HISAP '99)
Laxenburg, Austria
October 4-8, 1999

September 6, 1999



THREE PROBLEMS: NUCLEAR ENERGY, NATIONAL DEFENSE and INTERNATIONAL COOPERATION

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A little more than half a century into the Nuclear Age, we cannot look back on a peaceful period, but we can say that the second (nuclear) half of the century has seen much less violence than the first half with its two violent wars. Also the second half of the century has seen the fortunate ending of the Cold War. But as to the future, we are left with three great questions.

1) How can the world be provided with ample energy?

2) How can we avoid the potentially devastating sudden applications of new destructive technologies? And finally,

3) How can we preserve the development of the world's new potentialities without producing a continuation of violent conflicts?

The development of nuclear reactors appears to provide a most interesting new initiative to make energy available to every one. The reality of this promise is at least indicated by progress in France where electricity now is 80% "nuclear." Unfortunately, fear of radioactivity and fear of weapons proliferation has turned public opinion in many parts of the world against nuclear energy. The fear of

radioactivity seems to be exaggerated, as indicated, for instance, in the recent international conference in Vienna on the consequences of Chernobyl. The conference concluded that most of the anticipated difficulties (cancer and congenital malformation) have been grossly exaggerated. In my opinion, both the worry about radioactivity and the worry about massive military use of reactor products can be solved. There remain further real difficulties connected with expense and the availability of expertise that may be needed to handle nuclear reactors that may be absent in many parts of the world. I believe that all these problems can be solved. The three major accidents, Windscale in England in 1957, Three-Mile Island in Pennsylvania in 1979, and Chernobyl in Russia in 1986, could have been avoided by proper handling of reactors. The obvious answer seems to be more strict education of the reactor operators. In my opinion, however, human error, even major human error, cannot be sufficiently excluded. I, therefore, propose two obvious remedies.

One remedy is to locate reactors in appropriate areas several hundred feet underground surrounded by loose dry earth, so that even in the case of a major accident, no radioactivity will appear on the surface. Underground locations may be made possible by completely automatic regulation of reactor efficiency excluding fallible human interference. Obviously underground location and automation can go hand and hand. More explicitly, reactors should be constructed with a sufficiently large negative temperature coefficient so that an increase in temperature will decrease and eventually stop the output of the reactor. Such a reactor could then deliver energy on demand. One may use a coolant that will be heated by the reactor underground and deliver its energy near the surface for electrical energy production. More energy demand will be satisfied for an increased flow of the

coolant connected with the reactor running at a lower temperature. If the coolant is shut off, the reactor temperature will rise and the energy production will be shut down. Thus, there will be no requirement for operators to get to the reactor after it has started functioning. This practically eliminates operator error and also makes it unnecessary to involve highly educated operators in the first place. In this way, the reactor will become inaccessible after it has operated for a short time and so the misuse of the reactor products is practically excluded or at least greatly reduced.

A further major hazard arises from the need to exchange fuel from time to time and to transport the old radioactive products to a new location where it is allowed to decay. This is an obviously hazardous undertaking, particularly taking into account accidents during transportation. It is much simpler to leave reactor products where they are and let them decay after the reactor has been shut down. Such an ambitious plan should be discussed in connection with breeder reactors. Indeed, one should envisage a series of underground reactors; when the first member of the series has used its fuel, it is shut down by stopping its cooling mechanism. At that time, a neighboring reactor in the series could begin to function after having been activated by the neutrons of the preceding reactor. I like to envisage a plant consisting of several reactors which altogether can function for a number of decades and which subsequently will be allowed slowly to release radioactive energy over centuries and millennia. Such a program is certainly ambitious and many details will need to be worked out, but eventually, one may be led in this way to simple operations, low price, and continuing safety.

The second problem of national security arises for two reasons. One is increasing power of destructive weapons, the other is the possibility of sudden application of this power. In widespread discussions, the first of these problems has

been overemphasized. Of course, the explosive amounting to 20,000 tons of TNT equivalent which has destroyed Hiroshima, has been big (though in its effects perhaps not as big as the earlier massive multi-airplane raid on Tokyo). It is also true that nuclear explosives today are available and are designed to deliver a multiple of the Hiroshima output. But what really frightens people is that one can design weapons whose yield easily exceeds thousands of megatons. One should remember, however, that such weapons may become proportionately heavier, no longer quite easy to deliver and that a limit can be reached after which military usefulness ceases to increase. The biggest exploded weapon so far can indeed destroy an area of a thousand square miles and heat the air to a temperature where it will escape the gravitation of the earth. If one now increases the yield by another factor of a thousand, it turns out that (in the most easy way to deliver) there will not result much more destruction of the surface. Instead, practically the same amount of air will now be heated to an even higher temperature and will depart with a thirty times higher velocity. The limitation to the damage is due to the relatively shallow depths of the atmosphere which limits the sidewise propagation of destructive pressure. It is a remarkable fact that, in the Cold War, the United States and the Soviet Union have increased the number of their weapons, but after a certain limit, both sides refrained from further increase of the yield. This was not due to any international agreement but to the recognition that such an increase would be of little military use.

Unfortunately, the fact remains that the biggest weapons as they now stand are terribly destructive. One can go even further and remember that most horrible damage might be caused by biological weapons or even TNT delivered by rockets at ever increasing distances. For these reasons, it seems to me that the main danger in

the world does not lie in the size of the explosion but in the increased availability and flexibility of modern delivery systems.

In principle, the answer appears to be obvious. We need a defense against missiles. Actually in the last year, there has been an increasing recognition in the United States of the need for missile defense. It is most important to understand whether and how missile defense can be effective. The simple fact is that multiplying this defense is unlikely to suffice. Missile delivery is fast and flexible and decoys can be most frustrating. The most hopeful approach is to develop a defense which destroys the attacker at a very early stage after the missile has taken off. At that time, the missile moves slowly, and the need for acceleration makes it relatively easy to notice and locate the missile. The proposal of myself and quite a few of my colleagues is therefore to deploy a number of observation stations in satellites. These satellites should also carry defensive missiles which can be directed against the missiles of aggression in its early stage. The difficulty with this concept is that it will not defend any one country but will serve all countries by destroying dangerous objects even before we can know what is their target. To my mind, this circumstance is actually an advantage. It will make the defense of all countries relatively easy rather than to defend just one country. I, therefore, would suggest that we have a multi-national system whereby all missile launches which exceed some limits in their size and numbers will automatically be shot down by relatively small objects which collide with an aggressive missile or explode in its close neighborhood. I would like to encourage development of missiles for peaceful uses, and, therefore, I would provide the defensive set-up with an information system whereby the defensive units are instructed to withhold fire if missile launches have been properly announced together with their purpose and orbit. It is quite clear that

in this way, worldwide security could be provided more effectively for many nations rather than just for one country.

Looking back at my long association with nuclear weapons, I know most about three topics with which I was closely associated: One is the safety of nuclear reactors which I consider to be generally satisfactory but where I believe even further efforts toward greater safety can be justified. The second is my work on new forms of thermonuclear weapons where I contributed particularly to the hydrogen bomb. I believe that this remains an active issue possibly connected at the moment with smaller rather than with larger explosions. The third is the work on missile defense where I feel that more money is needed but new approaches are needed even more.

A last topic and possibly the most difficult one is what to do about improving international cooperation in an age of rapid technological development. The standard answer is to oppose the rapid technological development. I believe that this is the wrong answer. Its main disadvantage is that developments in secret are relatively easy, and so it will be very difficult to prevent development, particularly done in strictly controlled dictatorial countries. I would suggest that we look in the opposite direction. In the last decades, secrecy has received increasing emphasis. In the long run, I believe that will not work. Secrecy is not particularly compatible with a democratic government and is more easily enforced in a dictatorship. It is openness and cooperation that seems to me to show the promise of sound international relations. At this time, it does not appear practical to eliminate secrecy at a stroke. Furthermore, secrecy for the purpose of finding a reward for individual progress may even be worthy to continue. I would, therefore, like to see secrecy restricted to detailed temporary solutions of technical questions. General progress

and exchange of information should, in my opinion, be encouraged. Indeed, the magnificent development of missiles that can reach neighboring planets and that at some time might provide defense against incoming meteorites, such as have brought about a major examination of many species at the end of the Mesozoic Age, is certainly of international interest and should enjoy international development. It is remarkable that, at the present time, the possibility of a change in climate due to greenhouse gases is being discussed in terms of limiting the fuel that we permit to be burned. It turns out that other methods like sophisticated means to scatter a small percentage of sunlight can lead to planned changes of climate or to the prevention of changes which occurred in the numerous Ice Ages.

I want to conclude with a bit of advice. It is not easy, but it is necessary to be optimistic. Increase in our ability to influence the world around us will lead to disaster if we are afraid of it but may lead to happy results if attacked with a positive outlook including the ways in which we may find improved international cooperation.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.