

INTERNATIONAL COOPERATION

By Edward Teller

Born in Hungary in 1908, educated in Germany at Munich and Leipzig, Dr. Edward Teller has held posts in many of the world's most distinguished universities and research institutes. A citizen of the United States since 1941, he played a key role (with Manhattan Project colleagues) in the development of America's nuclear capabilities and has been consulted on atomic energy matters by most of our Presidents since World War II. Since 1953, he has been with the University of California as professor of physics and as director of the Lawrence Radiation Laboratory.

Professor Teller has been the recipient of honorary degrees from Yale, Fordham, George Washington and St. Louis universities (among others), in addition to awards for distinguished service in science, including the Joseph Priestly Memorial Award (1957), the Albert Einstein Award (1959), and the Enrico Fermi Award (1962).

Most recently, Professor Teller has been active in the development of the Sherwood Project (the controlled thermonuclear program) and in the development of Project Plowshare (involving the peaceful uses of nuclear explosives), as well as in astrophysics and molecular physics. He is the author of numerous volumes, including The Reluctant Revolutionary (1964) and The Miracle of Freedom (1972).

Professor Teller delivered this extemporaneous speech at Hillsdale College as part of the Center for Constructive Alternatives seminar on "Energy."

I would like to talk about the general problems of international cooperation on energy as well as on other subjects. I start, however, with energy and I don't want to make it comprehensive. I would like to use nuclear energy as one of the examples where international cooperation has been important and obviously will remain important.

The first point that comes to mind is the strong recommendation of President Carter. In enumerating the various sources of energy he said that nuclear energy should be used if it is absolutely necessary. But he also said that it should have the lowest priority. And furthermore, he suggested that while we may use nuclear



energy we should rule out reprocessing. Now that needs a little explanation.

In a nuclear reactor you cause the fission of some appropriate materials. The one material that is most generally used today is an isotope of uranium, uranium 235, which is present in normal uranium only in an abundance of .7%. If you use nothing but uranium 235 or not much more than that, then uranium as an economic energy source probably will be exhausted in half a century or sooner. And therefore, energy from nuclear sources will essentially not be much more useful than energy from oil.

On the other hand, as uranium 235 is being used up, another substance is produced, plutonium; and that is produced from the abundant isotope of uranium. Plutonium in turn can give energy. In this way instead of .7% of the uranium, in the end all of it can be used. This is

im•pri•mis (im-pri-mis) adv. In the first place. Middle English, from Latin in primis, among the first (things).

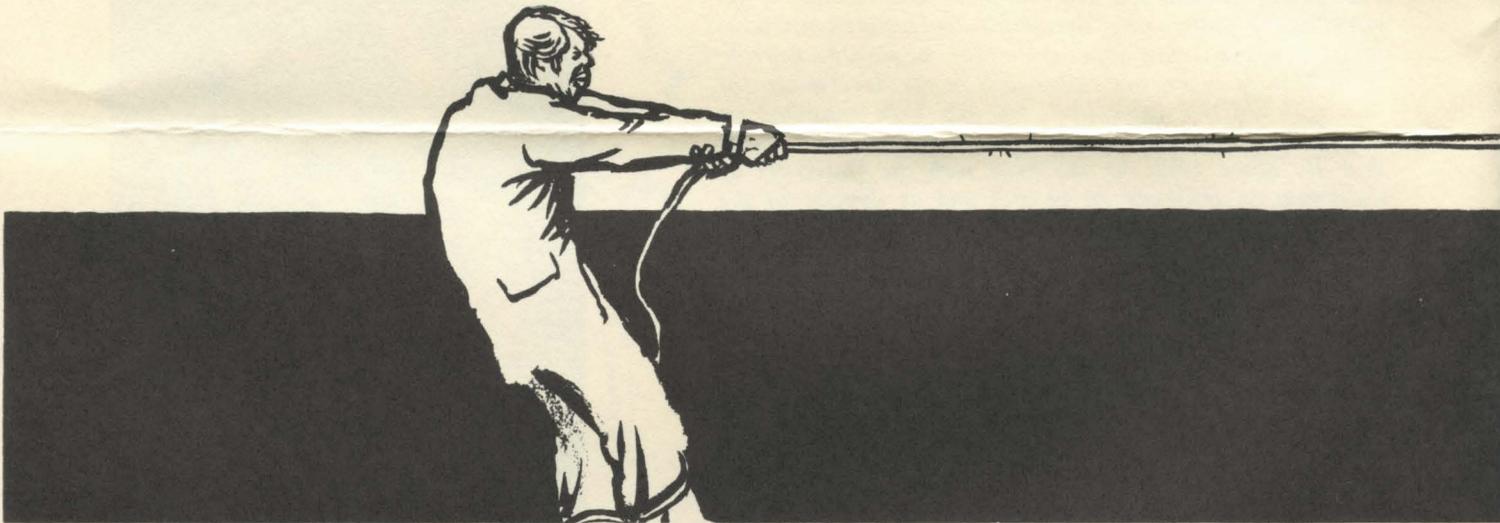
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the idea of the breeder. Something like the breeder will be necessary to make nuclear energy really useful. Now please, I said something like the breeder. I do not insist on the present form of the breeder. And I will have to specify that much more carefully because the decision has to do with energy and it has to do with international cooperation on energy.

Now why is the President opposed to reprocessing? The reason is, as probably most of you know, that plutonium, if separated from uranium, can be useful not only in nuclear reactors, but also in nuclear explosives. The President does not like to see more and more

uranium. Any shortage will hit them first. These people, when they hear that we don't want to permit reprocessing and more nuclear energy, suspect that we only want to have more money for it, that we are out-"arabing" the Arabs. We have lost a good deal of friendship in France, Germany, in Brazil, in Iran.

I claim that the only way really to stop proliferation is through politics, through diplomacy, through friendship and cooperation. We may stop reprocessing, but these countries that need nuclear fuels more desperately than we do will not be deterred, and they will reprocess. All we are doing is losing leadership, losing



countries getting hold of nuclear explosives, and I think that most people agree with him.

However, I claim that the policy that he has proposed does not work. And by trying to do it the way he is doing, he does much more damage than good. Let me give a few reasons.

1. Nuclear explosives can be made in other ways. Uranium 235 can be used itself when separated from the other uranium; the methods of how to separate these isotopes are not easy, but they are developed and are known by now the world over. Almost any country can get hold of it. For instance, the South Africans apparently have plans to make nuclear explosives, not with the help of plutonium, but with the help of isotope separation.

2. There are throughout the world approximately 100 small experimental reactors. These are sufficient to produce plutonium, and reprocessing plants connected with such small plants would be very difficult to control.

Therefore, what the President proposed is not sufficient to do what he wants to do. Furthermore, it has a harmful effect. We in the United States happen to have quite a bit of uranium. Most countries that need energy as badly as we do, or more badly than we do, don't have

influence, losing control.

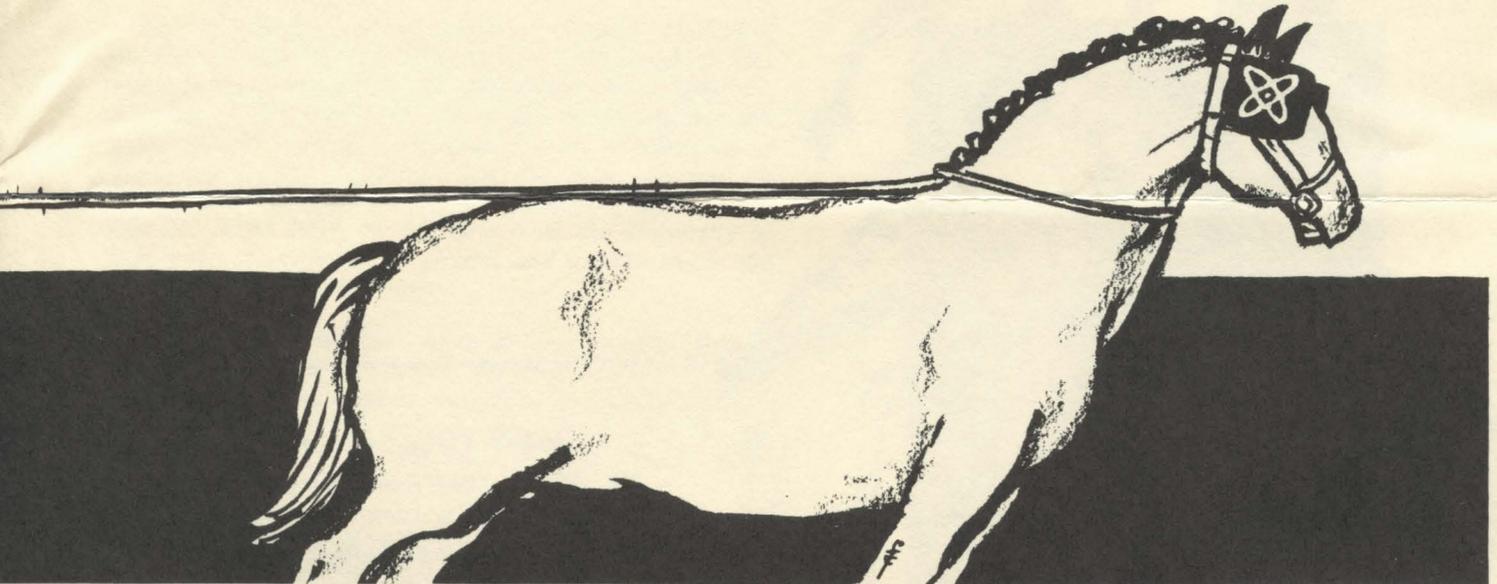
Furthermore, the energy problem is bad enough in the United States. It is worse in Western Europe and Japan. But it is really horrible in the Third World. These people have to eat, and the population of the world, which is now 4 billion, is going to be 7 billion by the year 2000. So far there has been no mass starvation because of the green revolution: new kinds of rice developed in the Rockefeller Institute in the Philippines, new forms of cereals developed by a similar institute in Mexico City. There are now around the world a dozen of these institutes. And this gives more, very badly needed food. But it turns out that the new methods are no good unless much energy is used. The new methods need irrigation, and that means pumps. It needs nitrogen based fertilizers, and these are made out of oil or gas or coal—out of energy. No energy, no grain revolution results in mass starvation. Millions of people will starve to death. People will become desperate. This is the stuff of which wars are made.

I am not claiming that nuclear energy is *the* solution. There were talks here in the U.S., I understand, about getting more oil, about real incentives. We could get more oil; we could save more energy; we could use more coal; and there are further methods. But all of these

methods take time and unless we act with a lot of diligence very soon, there will be trouble. You may think there won't be because this year we happened to have a good harvest in most parts of the world. But if weather changes a little, crops will not be as good. The number of people is increasing rapidly, particularly in the underdeveloped countries. In the U.S. and in Europe the population increase per year is one percent, or less. In the underdeveloped countries it is 3 percent and that means a doubling of the population in 25 years in those parts of the world. Therefore food is a highly critical issue.

233). This approach uses slow neutrons, and here we can predict how much it will cost and we know it can be done. Unfortunately, this is not what we have been trying to do in our country. The people furthest ahead in this particular respect are the Canadians.

I want to finish this discussion about fission with one last remark. We had an attempt at a breeder using fast neutrons. And I might tell you a little story here so as not to be too serious. A short time ago, a few of us testified to a Senate committee about the breeder using fast neutrons. When the testimony was nearly over one of the Senators said, "May I ask a few questions? All five of



So what does one do about nuclear energy? One breeds. Breeding means converting the abundant uranium 235 into useable plutonium. The President has forbidden it. We need it or something like it.

The present program involving "fast breeders" has a very considerable difficulty. You probably have heard of the fact that in fission reactions neutrons play a role. In each fission, neutrons get loose and they produce more fissions. This is called a neutron chain reaction. There are two kinds of such neutron chains, a well known kind and a new kind where we have less experience. The known kind is one where neutrons are slow, though not very slow. They move with the velocity of sound, which is not terribly fast. This technology is known, but for breeding of plutonium it is no good. There you need fast neutrons which move with 1/10 of the velocity of light. It is a velocity approximately a million times greater than that of slow neutrons. This is difficult to accomplish. For the future when this method is worked out completely nobody can tell how expensive it will be. It may be economically not really useful.

Fortunately, there is another approach. Instead of using uranium, we could use thorium, an element a little lighter than uranium. This can be transformed not into plutonium, but into a certain kind of uranium (uranium

you here, you are experts, aren't you?" We nodded in unison. "All of you did have an opinion on the fast breeder a year ago." Again, we agreed. "Has any one of you changed your opinion in the last year?" "No, we haven't changed our opinion, we didn't agree, none has changed his opinion." "Then what difference did the President's opposition have?" I was rash enough to answer, "I can tell you very briefly but it won't be very polite." Somebody yelled, "The Emperor has no clothes." Immediately afterwards, I was sorry I said that. You have all read the story *The Emperor's New Clothes*. Do you remember how the story ended? The father of the little boy shushed him and the procession went on, clothes or no clothes. I think the procession should stop, though not altogether. We in this country happened to choose a clumsy kind of a fast reactor, which is known as the Clinch River Breeder. The French apparently have done much better with their "Phoenix" reactor. I am advocating that we should continue a little work on the fast breeder, but in cooperation with others, for instance with the French.

In the meantime we should emphasize the more hopeful approach using thorium. Of that substance, there is enough to provide us with plenty of electricity. It will suffice for five or ten billion people; the world won't sustain many more than that. We could have all the

electricity we want from now until the next ice age if we use thorium. Of course we need other forms of energy. I repeat, the nuclear solution is not the only solution.

Another very popular solution is fusion energy, where energy is derived not by splitting atoms that are too heavy, but by putting together the lightest kind of atoms, essentially hydrogen atoms. Research on this has gone on for many years, and I happen to believe that we will succeed in demonstrating it. I think that by 1980, maybe even sooner, we will demonstrate its feasibility. But then it will cost \$3,000 per kilowatt hour. There is a little problem of bringing that cost down to 3¢, a problem for the engineers. I think they will have to be exceedingly good to accomplish it by the year 2000—and that is too late. Also it may turn out that in a good economic sense, it never can be accomplished.

Fortunately, in this particular field, we have good international cooperation. It is the one field in which we manage to cooperate with the Russians, under conditions where it seems the Russians are giving us full information. The cooperation could be and should be further improved.

Just a few days ago, I attended in Ft. Lauderdale an international conference, where we decided to write a paper recommending the proposal I am reporting to you. A very excellent Russian physicist, Basov, who won the Nobel Prize for work on lasers, participated and it so happened that he made at least one very valuable suggestion. The man who called the conference, a Turk by the name of Behram Kunsunoglu, suggested that we write a paper of 30 or 40 pages. Basov said, "Why not one page?" And I fully agree with him because we would never have gotten consensus on 30 pages. On one page there was more hope. In the end a paper of 2½ pages was produced, and everybody agreed. Basov agreed, with one reservation. He had to wire to Moscow for permission to sign it. I don't know whether he will get the permission or not.

I have talked enough about energy. I want to discuss other topics where international cooperation is absolutely essential. I am convinced that the big, historical process that is going on today is the spreading of the industrial revolution throughout the whole world. If we wonder whether the underdeveloped countries will ever catch up—they are. I researched the energy production for the third quarter of the century and in that period the per capita energy in the advanced countries doubled. But in the backward countries the energy consumption in the same period quadrupled. It is not true that the rich are getting richer and the poor poorer. People say this because, understandably, they are impatient. If there is not enough energy the poor countries will never catch up. And that is one of the strong reasons why we need more energy. I already told you that perhaps the most important use of this additional energy is to produce more food.

I have argued for nuclear energy. I am arguing for it in the advanced countries, in the United States, in Western Europe, in Japan. The underdeveloped countries would have difficulty in using nuclear energy. Such energy comes in very big packages. One reactor would supply in an underdeveloped country several million people, and their electric distribution network is practically non-existent. Those countries which already can easily distribute electricity can use nuclear energy most easily. By using such energy we would buy less oil, and in 10 years we could decrease the oil bought from the OPEC countries by 30%. Then the price would come down. Oil has the great advantage that it can be used in small units, in small machines, which is the form in which the developing countries want it and need it. They will have and should have nuclear reactors, though perhaps at a later date.

Let me return to the question of food. Probably even more can be done by methods similar to those that have been already used: producing better kinds of crops, more resistant to pests, and possessing many more advantages. There is one area which to my mind is exceedingly important and has been largely neglected. And that is to get food from the oceans. Today of all the food that is produced, 7% comes from the oceans. But of the proteins which are the most important and of which there is the greatest shortage in underdeveloped countries, even today 20% comes from the oceans. We are at present getting food from the oceans by stone age methods, by the methods of hunters or fishers. We don't grow the food; we don't cultivate the oceans. There are some hopeful beginnings, however. Salmon hatch in rivers, not in the oceans. They grow in the oceans; then they come back for hatching in the rivers. We are facilitating the process of hatching.

You have heard a good deal about the whales being all but exterminated. It is not quite true, but there are fewer whales. Do you know what that means? Fewer whales means more rill. They are tiny swimming beasts on which whales feed and on which the salmon can feed. There is today a surplus of salmon food in the oceans, and the yield of the salmon probably could be multiplied by 10, if not more.

This is only one example of increasing the supply of fish. There are plenty of ways to increase food supply. But to whom will the fish belong? To whom does the ocean belong? Who will reap when we sow? Who will put out the effort to improve the fish supply when anybody can come along and catch what we have already brought about? If we want to do something with the oceans to produce more food or to get more food or to get more minerals from the ocean bottom, which is also possible, international agreements will be necessary. But we couldn't get these agreements. Perhaps we have been too ambitious. Perhaps we tried to spell out what should be done in detail, with not everybody then agreeing. One might more easily agree on fishing rights for each

country near its borders out to 200 miles. At any rate, international cooperation in exploiting the oceans is one of the things that is necessary and one of the really great hopes for feeding 7 billion people in the year 2000. And if there are worldwide efforts for family planning, then perhaps at somewhere around 7 billion or 10 billion the world population might level off. Sooner or later this has to happen.

There is one last example, and in a way the most exciting and potentially the most dangerous. I have been talking about doing something to the oceans, cultivating them, changing them, and exploiting them in a planned manner. What about the weather? We can't do anything about the weather; we can't even predict it. In actual fact weather predictions are slowly getting better. We are going to be able to predict weather for one day; we can almost do it now. For five days there is a little uncertainty. Perhaps for a month? Perhaps for a year? Perhaps for a decade? How would it be if I would tell you that we have calculated what the weather will be everywhere in 1985? Would you believe me? There is some hope because with satellites we can look down on the earth and see the big weather patterns, not as we used to see them from airplanes, which I would describe as "the bird's view." From the satellites we can see the weather as it would appear to the angels. We know the processes that influence weather. It is an enormous computational problem. But computers are getting faster. Perhaps we could compute weather faster than it happens.

There is one trouble. Weather is strongly influenced by instabilities. An instability is this: I take this pen and place it on its point. In which direction will it fall? You know that it always falls. An instability means that a very small difference at the starting point creates a huge difference a little later. This has a double consequence. We must find out the effect of instabilities in the atmosphere, the trigger effects. And if they are not terribly important, then we will be able to predict the weather for a long period. But if they are important, then they will limit the time in which weather can be predicted.

But in that case we have the possibility to influence the weather. If we ever can do so, this will have a tremendous effect. Whether the rain falls in the Pacific or comes on shore and falls in California makes the difference between a good year or a bad year. In India if the monsoon rain stays out in the ocean people in India starve. The shift of the rain pattern by a few hundred miles means the difference between abundance and extreme suffering.

But if we can influence weather there will be certainly another effect. We will have lost our last safe topic of conversation.

Can it be done? My guess is that it can. And I would like to mention one concrete possibility in whose discussion I was recently involved. The proposition is to

put up into orbit around the earth huge mirrors. We can accomplish this. Because we can make mirrors exceedingly thin, by using a hundred tons of materials we can make the mirrors of several square miles in area. We spin the mirrors to keep them nice and plain. There's no effective gravitation up there, and therefore we can operate with very light materials, if only they don't tear.

What can be done with such mirrors? We cannot focus them on small spots but we can increase solar radiation over an area of perhaps ten by ten miles, or thirty by thirty miles. There is one particular region on which I would like at sometime to direct sun light. As a result of the instability, which I don't have the time to describe now, cold arctic air flows south during the winter. Habitually in the Western Hemisphere this happens at particular locations over Alaska and the Aleutians. Then this cold air mixes with warm tropical air over the Pacific and is blown by the westerlies and brings rain to California.

Last winter the instability took a different path. Instead of the cold air traveling south near Alaska, it traveled south near Chicago and Buffalo, caused snow in Miami, blossoms in Anchorage, Alaska, and no rain in California.

The point where this instability forms is a point where the length of the day in winter time is only 6 hours. And during the 6 hours the sun is low on the horizon and there is little radiation. If mirrors were put up, we could increase over reasonably big areas, let us say 1,000 square miles, the temperature by quite a few degrees. And this may be enough to persuade the cold air to come south in one region rather than in another. This can make all the difference between one kind of winter and another.

On the other hand doing this may influence the climate all over the world. Therefore, we will have one more thing to fight about. And in that respect we don't have any shortage.

Does this mean that we should not influence the weather? I think we should. If we don't, others will. Understandably the Russians are very much interested in the subject, not to hurt us but to help themselves. This is a development which will come no matter what we do. But whether we will participate in it, whether we shall have a voice in it, depends on our diligence. Whether it will be used when the new possibilities arise for an agreed purpose, a compromise, where more good will be produced for most people and the little harmful side-effects accepted, or whether instead the new methods will be misused by someone for a small number, for the advantage of one country against another, depends on international cooperation.

From energy to food to weather it has become very clear indeed that all of us living on this planet are neighbors, and we'd better find ways to behave as good neighbors.



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