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Can We Halt the Race for Atomic Arms?

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My purpose is to ask if there is a role that men of science may play in proposing an affirmative answer to the question: Can we halt the race for atomic arms?

Day by day in the Congress of the United States we are alerted to this question. It colors the debate on the size of our military establishment. It increases as our agricultural storehouses fill and overflow. It influences the volume of our foreign aid. It throws into sharp controversy the relative value of guided missiles and jet aircraft. It builds a nuclear navy and equips an atomic army. We know all about Nike batteries; we watch ground-to-air, air-to-ground, and air-to-air encounters. But we find no peace.

And yet, through all our thinking runs the belief that the true significance and greater ultimate effect of atomic energy for the human race will come not from its destructive capabilities but from its contributions to the betterment of man's lot upon this earth. The weapons of mass destruction are impressive but so would be the fruits of peace. The difficulty has been that the power to destroy comes before and grows faster than the power to build.

The conviction is growing that disarmament, in the sense in which it was proposed and may have been possible from 1945 to 1948, has now become impossible. There was once a day when a rigid system of inspection could have prevented the growth of dangerous stockpiles of fissionable materials for military use, but in the last decade the sizes of stockpiles held by the principal atomic powers have presumably grown so large that substantial amounts could be secreted before any inspection system begins and would be adequate for a devastating attack if one of the powers so chose. But wholly apart from this question of secreting materials before initiating inspection, it might be recognized that even if this did not occur and a rigid inspection system and control of materials were imposed, then still, in the event of war, the facilities that have grown up for peacetime uses of atomic energy are of such productive capacity that it would not be long after the outbreak of war until adequate materials would have been produced for full-scale atomic devastation.

Moreover, we should not restrict ourselves merely to consideration of hazards implicit in wars of annihilation with atomic weapons. In technology applied to military ends, novelty is ever a prime goal. Thus there is the probability that a war between major powers would lead to types of destruction of a nature and scope not yet conceived, much less demonstrated.

Modern war makes certain for all participants their near annihilation and makes military conquest utterly illogical and absurd. The great powers of today thus find themselves in a sort of uneasy stalemate. Each is concerned with maintaining heavy retaliatory forces to insure that the other dare not risk the gamble of military conquest but, in turn, dares not risk it on his own except as a result of monstrous blunder.

Although much time will pass before we work our way out of our current military stalemate, certainly it is a hazardous stalemate that no one likes, and it may have merit only if we use the time it provides to take advantage of the evident value of peaceful collaboration on projects of common concern. Says the editor of the *Bulletin of Atomic Scientists,* "Atomic deadlock can have positive value only if man uses the breathing spell it provides to develop a permanent foundation for peace without terror."

On the one hand, we may strive to use this period for creating mutual respect for, and consent to use, the machinery of an expanded and strengthened United Nations to mediate international disputes and to diminish tensions that arise from international rivalries. On the other hand, we may move toward direct collaboration on technical projects, which the high level of modern technology makes unusually productive and beneficial to all concerned.

Obstacles to Joint Developments

Here I would like to mention several projects that seem especially appropriate for joint developments in world laboratories. But before doing so, let us look at some road blocks in this path.

Restrictions on free travel and free exchange of information have become increasingly irksome in recent years. These restrictions have fallen heavily on many scientists, on people in the arts, on businessmen, sometimes on religious leaders or other people whose interests and pursuits are not confined by national borders. The justification of these restrictions is the implicit argument that somehow they increase the national security and well-being of the nation that applies them. But today with the rapid approach of the time when any country that launches atomic warfare can create untold damage at will, we should examine whether we can remove many of our restrictions on free travel and exchange of information. We should encourage, by whatever means we can, the spirit of international cooperation and openness that will minimize the chances of a misunderstanding —an accidental spark that would lead to disaster.

One step we can take in this direction is to remove our present restrictions on transmission of nonsecret scientific information among nations. The United States has helped to foster such restrictions, but

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their contribution to our security is open to question. We know that such measures foster fear and suspicion rather than cooperation and understanding. They decrease the rate of gain of knowledge, which is at the maximum only when free communication exists. Physical truths cannot be protected by such policies. They are everywhere the same—equally measurable in any laboratory.

Exchange of Teachers and Students

We can break down barriers in communications still further by encouraging an expansion in our present system of exchange of teachers and students among nations. Most of our American universities do not have visiting professors from other lands on their faculties but would be happy to have them. Many of our own scientists go abroad to study and teach in foreign institutions. They come back with new ideas, a fresher outlook on their own problems which cannot help but be of benefit to science as a whole. An increase in opportunities for exchange of faculty and students between our great institutions of learning would be an important integrating factor in our pursuit of knowledge. We have plenty of disintegrating influences; we need men and women who are concerned with mutual problems and prepared to dedicate themselves to their solution.

The importance of the international meetings cannot be overemphasized. Information exchanged among participants will hasten the day when science will understand the secrets of the nucleus and of fundamental particles and will move man another step forward in his understanding of the universe about him.

World Passports

A further measure we might well undertake now to promote a spirit of international cooperation would be the establishment of a world passport, which would be granted annually to a select list of nominees from all over the world. Such a passport would permit its holder to travel freely in lands of all member nations. A list of nominees for this honor would be prepared by a committee of participating nations, and the honor would be conferred only on those who received a unanimous vote of approval from all member nations. The list might include, for example, Nobel prize winners, outstanding artists, leaders in religion, in government, in science, in education, and in business. It could become a highly coveted award all over the world—a suitable mark of distinction for our public servants in every walk of life. Above all, it could promote a degree of mutual trust and understanding that might, in the end, help to halt the race for atomic arms and forestall a war that nobody wants.

A world in which restrictions on communication and on the travel of individuals has been minimized is one in which the combined intellectual and technical powers of many nations can be brought to bear in unison on common problems. We are aware of many problems that can be and should be attacked by an international effort. Even under the imperfect conditions of international communication that exist today, significant projects are under way, and important beginnings have been made on others.

International Cooperation in Science

There is the superb example of regional cooperation illustrated by CERN, set up by the European Organization for Nuclear Research. Here men of many nations gather together for a joint assault on the experimental and theoretical problems of nuclear physics. There is likewise the inspiring scope of the International Geophysical Year. When it opens, a great network of observatories will embrace the entire earth. Chains of weather stations strung out on three meridian lines from the arctic to the antarctic will chart the circulation of the atmosphere during the intense period of activity spanned by the International Geophysical Year. All of the modern instruments of meteorology and geophysics will be mobilized in a global accumulation of data, which should provide the basis for years of analysis, speculation, and debate. The final reduction to conclusive findings will mark a new step in man's understanding of his global home.

There is the World Health Organization, which through its many laboratories and agencies is waging successful war against the diseases of mankind and is promoting in the less fortunate areas of the world new understanding of medical care for infants, for the aged, and for the handicapped.

In the Atoms for Peace Program, there are more than 25 bilateral agreements between the United States and countries less advanced in nuclear technology.

There is a multitude of activities supported by UNESCO: its educational training centers, its support of travel for scientific and cultural reasons, its contribution to the European Organization for Nuclear Research mentioned in a foregoing paragraph, the creation of the International Computation Center at Rome, the conferences in arid-zone research, and the many less noticed activities of the Field Science Cooperation offices. The UNESCO 1954 participation in the U.N. Technical Assistance Programs amounted to 56 projects in 36 countries.

These are but some of the most evident international cooperative efforts that are bringing the benefits of modern science and technology to peoples around the world.

Goals for World-Wide Effort

I have reviewed briefly both the positive and the negative steps toward increased collaboration among scientists of different nations, as they have developed in recent years. Now let us glance at a few fields in which joint efforts may prove especially beneficial.

As a prime example of a project that involves a subject that clearly has no relevance to national boundaries, we may think of climate control or world-wide weather modification. Recent advances in meteorology suggest that efforts in this direction may produce useful results sometime in the future. Yet evidently the control of amounts of precipitation, directions of winds, and like matters, are not properly planned by a single national power or even by two or three in regional collaboration. For instance, I believe that much of the weather of the United States is made along the coast of Alaska, in the Gulf of Mexico, or out in the Pacific, and my country has little or no control of the sea areas involved. Any regional effects on climate will have, perhaps, attenuated effects on climatic conditions in most distant areas. Moreover, such information as we now have strongly implies that the most effective weather control requires coordinated efforts over vast areas of the earth's surface, and the broader the cooperation, the greater might be the results.

Another example on a large scale that inevitably crosses national boundaries is the project to send a rocket into outer space. Purely from a geographic viewpoint, efforts to send missiles and ultimately passengers to the moon and the nearby planets are of world-wide interest. Although the intensely nationalist feelings characterizing international relations on our planet at the present time suggest that we may even see, as a result of interplanetary travel, an extension of the competitive colonialism that the last century saw for the backward areas of this planet, the prospect of seeing different sections of Mars staked out by different national governments of this earth seems on the face of it ludicrous. Are we trying to play God and develop a new planet in our own image and likeness? A much more rational and probably more productive basis for the exploration and development of other worlds would be under an organization that properly reflects the common interests of all the peoples of this earth in such development. The man in the moon belongs to the children of every country, is a part of their dream-world, and, if it is reached by space ship, might better remain the property of all.

Returning now, however, from the fanciful and the future to the more immediate problems of initial efforts to get a space ship away from the earth, we recognize hazards of a rather severe sort that may arise as a result of the erroneous function of a space missile intended for the moon but, instead, through defective mechanism or planning, lands on the territory of another nation. If such a nation were at that time in an advanced state of tension in anticipation of a possible attack, this simple error might touch off the spark of world conflict.

This brings me to the competitive race to develop an intercontinental ballistic missile. We in the American Congress have already learned that it would be a drain on all of our budgets if this race should set a pattern in the whole field of space conquest. The U.S.S.R. and this country are working at high speed toward the attainment of an intercontinental ballistic missile, called by many "the ultimate weapon." Yet if the missile were to be attained almost simultaneously and prove to be as accurate as now forecast, if indeed it could carry atomic warheads with a striking power of several kilotons and place them within the area of a small circle, then no city in the world would be safe, no jet interceptor could police the skies, and no highway could promise egress from the affected area. In that day, the people of the earth would banish the weapon, as poison gas was outlawed in World War II, but only after the expenditure of fantastic sums of money, materials, and scientific skills.

Might it not be better to examine the chance to use space conquest as another project for an international laboratory? If we will never use this weapon once we achieve it, might it not be set aside as one segment of world-wide competition that could be surrendered to the effort to halt the race for a full arsenal of atomic arms in every land? Or must everyone carry his own six-shooter constantly strapped to his belt?

A third area might be research on the problem of controlling thermonuclear reactions in such a way that they would produce useful power. Many of my readers know far better than I the great amount of energy that may be released in the fusion of the lightest elements to form helium. The great abundance of heavy hydrogen, or deuterium—the great quantities of this valuable isotope that are contained in the world's oceans—leads to a staggering picture of energy available to lift the yoke of labor from men's shoulders throughout all the world. It has been estimated that the amount of heavy hydrogen in the oceans is sufficient to meet world power needs at 1000 times the present rate of consumption and for the next million years.

There seems to me to be no other field of technology today in which there is more evident need for pooling all the imagination and ingenuity that the world's scientists can bring together. The riches for mankind that must flow from the solution of these problems are without parallel. The history of science dramatizes again and again that problems of special difficulty are most usually solved by the cross-fertilization of ideas from diverse sources. The effort of any one country to develop controlled thermonuclear reactors in a unilateral manner under the secrecy required by an attitude of competitive nationalism must certainly have the effect of retarding the progress of such a country in this vital field.

As many scientists have been saying repeatedly, science cannot flourish under secrecy. The essence of the scientific process is the exchange of ideas—the comparison of procedures and the development of new ideas and techniques in an active atmosphere of collaboration in which many people may contribute small parts of the solution to produce a whole far greater than the sum of the parts. No one can yet say that the immense problems associated with development of controlled thermonuclear power will be capable of solution. What we can say, certainly, is that if their solution is available to man, then it will be most readily available and perhaps only available in an atmosphere of vigorous collaboration built upon the genius of many people from many lands. It would seem that the enlightened self-interest of all technologically advanced nations would best be served by their contributing heavily to the creation of a joint world laboratory in which the solution of these problems is sought jointly by scientists from many nations.

Security through Free Communication

Some secrecy-minded individuals may object that the technology associated with each of these fields I have mentioned has possible military applications. This claim is perfectly true; however, it does not necessarily follow that the security of different nations will be furthered by developing these fields under the military security system that our competitive nationalism has imposed upon science in recent years. In fact, it may be just because of the possible military applications from these new technologies that we shall wish to develop them jointly with all principal powers participating in world laboratories created for the purpose. Perhaps we can learn an important lesson from our experiences in the development of atomic energy. The unilateral development of the field of nuclear technology has created the following dilemma. Assuming the universal desire of all peoples to achieve some sort of workable disarmament, we have, nevertheless, in the development of nuclear technology greatly accentuated both the need for, and the difficulty of, attaining disarmament. Whereas modern atomic weapons raise the destructive potential of war to a new level, the suitability of atomic weapons for concealment and surprise use has, at this advanced stage in the competition, made disarmament by mutual inspection very difficult, if not impossible.

This experience in the field of nuclear technology suggests that similar potentialities exist in as yet undeveloped technologies. Research into the killing diseases of man with the objective of eliminating these diseases may bring us, instead, new ideas on how we may visit death on opposing populations by new species of bacteria. Or we may find a new type of rust that will destroy the opponent's feed grains, or a virus that will kill his livestock. Successful travel in outer space will suggest new, more effective, and even less detectable means of attack on other nations. Unilateral success in the field of climate control will suggest important new schemes for military action against the unfriendly powers. Project Sherwood for the development of controlled thermonuclear reactors provides the greatest promise on the horizon today of immense, inexpensive energy sources. Yet in the event of success for this project, it takes no advanced military technician to realize that such energy sources would have great applications in the engines of war. Thus we are led to feel that in every area in which the scientific method has enabled the intelligence of man to gain new mastery over nature, we face the possibility of an added complication in future disarmament efforts.

It is to this problem that I have directed these words. If the great powers find themselves in an atomic stalemate today—and I think they do—it is a carry-over of patterns of "national security" which modern science has rendered obsolete. The military techniques that might emerge from the new areas of technology that I have discussed can make the stalemate no worse. Already it is at a level in which any major power can precipitate almost total destruction upon an adversary (and in return upon itself) if it should make so tragic an error in judgment. Yet there is the danger that if these new areas of technology are developed in secret, some nation, which at some future time may be led by reckless rulers, may feel that it has gained so great a lead in some field of science that it may dare to launch an attack for world conquest. Although this error in judgment will almost certainly be answered by mutual annihilation approaching totality, every effort must be bent while we still have the chance to prevent such dreadful miscalculations from occurring. Scientists, it seems to me, might suggest to the statesmen that modern technology could make the greatest contribution to the security of great powers if statesmen would move as far as possible from the secret competitive development of technologies under which we have largely operated in recent years. The scientists might urge, indeed, that the race for atomic arms could best be halted by having new fields of science developed jointly by all nations.

Responsibility for World Cooperation

The responsibility for carrying forward the proposals here made for cooperative studies of weather modification and for world laboratories of science must be placed with some international organization. A natural agency for this purpose is the United Nations. Such responsibility, such new avenues for accomplishing good, will strengthen and expand the capacity of the United Nations for reaching its goal of creating a world at peace.

The procedure for putting into effect ideas of this kind must fit the pattern of life in each land, and therefore what we will need first will be suggestions for possible courses of action. I hope they will be forthcoming. For my part, I intend to discuss the question with my colleagues in the U.S. Senate.

If we do succeed, no nation can then make the fatal error of assuming that it has an overwhelming technical lead over a possible adversary. The recent International Conference on the Peaceful Uses of Atomic Energy in Geneva illustrated how similar the achievements were in different nations, even though each had pursued its program of research and development in careful secrecy. Such similarity of development will no doubt be the case in the future on arms as well as on peaceful atoms.

My own experience at Geneva persuades me that many nations know a lot about the atom. When India's Homi J. Bhabha opened the "pie" of thermonuclear power, the blackbirds from four and twenty lands began to sing! What was secret at breakfast was table talk at lunch. Nations rushed to hold press conferences and attend activities. Is it not possible that there might be a similar pattern in weapons, and that no one nation holds all the cards?

Something new seems to be needed in this disarmament business. The nations make little headway in finding grounds for agreement on reducing the size of armies or destroying parts of atomic stockpiles. Very well; why not try to think constructively about disarmaments in potential weapons, in "ultimate weapons." The problems here are simpler because no one nation has so strong a vested interest in the new field that it will be contributing much more than valuable scientific help. It would be a new try at disarmament, this "disarming the future," and it would lack some of the defects of proposals for present disarmament.

This is not a suggestion that all nations pool their efforts in the field of present atomic technology, or a hint that the testing of atomic weapons be stopped by any of the great powers, and surely it is not a proposal that Oak Ridge, Hanford, Livermore, and Los Alamos be leveled to the ground. It springs rather from the feeling that the new technologies may displace the old, and that a war-weary world might achieve in time a form of disarmament by obsolescence.

If and when that day should dawn, each new technology would no longer be a source of dread power to be somehow kept from destroying us in the convulsion of global war. Rather, it would become what men of science have always intended—a means for opening up a new dimension in human life for defining a greater destiny for the forward course of the human spirit.

Note on Absolute Chronology of Human Evolution

Cesare Emiliani

Pleistocene temperature variations of equatorial, tropical, and temperate marine surface waters were recently investigated by means of oxygen isotopic analyses of pelagic Foraminifera from deep-sea cores (*1, 2*), using a method that was devised by Urey (*3, 4*) and developed by Epstein, Urey, and coworkers (*5, 6*). A time scale since the Günz glacial age was established on the basis of Washington radiocarbon dates of deep-sea cores by Rubin and Suess (*7, 8*), on ionium dates from other deep-sea cores by Urry (*9, 10*), and by comparison with the insolation curve for the 65°N latitude as recalculated by Brouwer and van Woerkom (*11*). This time scale is only a tentative one because it is impossible at present to date reliably the lower parts of the cores, but it is probably correct within about 20 percent.

Temperature Variations and Correlation with Continental Events

A generalized temperature graph for the Caribbean Sea has been published, based on the two stratigraphically longest cores that offer a good temperature record (*1*). The two cores were raised in the Caribbean Sea by Ewing, director of the Lamont Geological Observatory of Columbia University, and his associates; they were selected from among more than a thousand Atlantic and Caribbean cores and kindly sampled and made available by Ericson. The temperature graph is reproduced in Fig. 1. Temperature variations in higher latitudes were considerably greater (*2*), but the trend is apparently similar. Thus, the temperature graph of Fig. 1 is believed to have general stratigraphic value.

The classic alpine terminology is shown in the lowest division of Fig. 1. The absolute chronology in thousands of years before the present (B.P.) is shown in the second division. This chronology is considerably shorter than the chronologies usually suggested in the literature. If correlation between core stages and continental stratigraphy is correct (*1*), the Pleistocene time since beginning of

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