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An address to the Canadian Club of Toronto by the Chairman of the Defence Research Board, Dr. O.M. Solandt, March 7, 1955.

When the history of this century comes to be written I am sure that it will then be clear that we are living in the midst of one of the greatest periods of transition in human history. Our times will be outstanding not for the great political and social upheavals that they have seen but because during this era man has begun to understand and to use the vast store of energy that is locked up in the nuclei of atoms.

We are living in the early days of what will certainly be known as the Age of Nuclear Energy. It is always difficult to see in perspective and to understand the significance of great events in which you are yourself immersed. Nonetheless I think that it is particularly important for us to try to comprehend the significance of the developments in nuclear science that are taking place and try to control and direct their use. Should we fail in this task there seems to be a fair chance that the history of our era will never be written.

The story of the Age of Nuclear Energy begins far back in the history of fundamental reserach in nuclear physics. The pace of discovery in this field began to quicken around the turn of the century. A small band of brilliant research workers began to see that the trails they were following were leading toward important destinations. Some of the most important contributions to research during this period were made in Canada at McGill University by Lord Rutherford and his colleagues. In 1904 Lord Rutherford said:

> "There was reason to believe that an enormous store of latent energy was resident in the atoms of radioactive elements --- energy which was derived from the internal energy of the atoms.... If it were ever possible to control at will the rate of disintegration of the radio-elements, an enormous amount of energy could be obtained from a small quantity of matter."

In the same year Frederick Soddy, a colleague of Lord Rutherford's wrote:

> "In only two days radium gives out more energy, weight for weight, than the most powerful explosive known liberates during its explosion. If the

> energy liberated in a thousand years could be released instantaneously, a single milligramme of radium would equal in its effect a ton of any known explosive."

It is clear from these quotations that, even at that early date, the ultimate results of their researches were apparent to this group of pioneers. For the next forty years a small number of research workers scattered throughout the world, but still mainly in Europe, pursued this fascinating trail of knowledge into new and uncharted country. It is important to notice that the rapid progress that they made was due very largely to the complete freedom with which they interchanged the results of their discoveries. Had military secrecy interfered with the free interchange of research knowledge in nuclear physics thirty or forty years ago it is reasonably certain that we would not yet be faced with the problems of how to get along in a world dominated by the existence of thermo-nuclear weapons; nor would we be able to contemplate the early advent of nuclear power for peaceful purposes--but that is a separate story in itself.

By about 1940 scientific knowledge throughout the world had accumulated to a point where the more enthusiastic exponents of nuclear energy felt that it would be possible to produce either a slow and controlled liberation of energy by nuclear fission for power production or an explosive liberation for military purposes. I will not attempt to go into the history of the wartime development of nuclear energy. Under the impetus of war tremendous resources were made available to the scientists, mainly in the United States, and the rate of progress exceeded anything that the world had ever seen before. The first atomic reactor, the primitive ancestor of the great power stations of the future, began to operate in Chicago in December 1942. The first atomic bomb, an equally primitive progenitor of the thermonuclear weapons of today was exploded near Albuquerque, New Mexico in July 1945.

It is interesting to recall that Canada continued to play an active part in this dramatic progress. A joint British, French and Canadian research unit was set up in Montreal in 1942 in laboratories operated by the National Research Council. The outstandingly successful atomic reactor at Chalk River was designed in these laboratories.

During this war-time period and for some years after the war the work directed toward controlled nuclear reactions for power production and that aimed at producing weapons of destruction was pursued under the same auspices and often in the same laboratories. In recent years the two streams of research and development activity have begun to emerge as distinct programmes leading in divergent directions. The main purpose of my talk today is to try to outline to you what is likely to lie along these two paths and the nature of the dilemma that their very existence presents to mankind.

Let us first consider the path that leads to the ultimate horror of total nuclear war. The world

first had a glimpse of what lay along this path whem atomic bombs were dropped on Hiroshima and Nagasaki in 1945. At that time many people felt that the atomic bombs used there were the ultimate weapon and that the very existence of such powerful means of destruction made the thought of a possible future war untenable. However, most experts who were familiar with the scale of destruction achieved by other weapons did not completely support this view. The atomic weapons used at Hiroshima and Nagasaki had a destructive force approximately equal to the explosion of 20,000 tons of TNT. They were therefore called 20 kiloton and later "nominal" atomic bombs. The one dropped at Hiroshima devastated about four square miles of solidly built up city and killed possibly as many as 80,000 people. However, a single raid with incendiary and high explosive bombs on Tokyo destroyed nearly 16 square miles and killed at least 84,000 people. There were several raids in Europe which were almost equally destructive. Therefore although the nominal atomic bomb of 1945 did make possible huge destruction in seconds instead of hours and through the use of one instead of a few hundred aircraft it did not as at first used introduce a new scale of destruction. However, it was obvious that should nominal atomic bombs become sufficiently cheap and abundant to be used in large numbers they would drastically alter the nature of any future war.

Unfortunately since 1945 the application of new scientific knowledge to weapon design has proceeded rapidly and effectively, both in the United States and in Russia, and in 1954 we learned for the first time of the existence of thermonuclear weapons which really did produce destruction on a scale hitherto undreamed of. Had this research instead led to the conclusion that natural laws limited the size of atomic weapons to those that were used in Hiroshima and Nagasaki mankind would still have been faced with a very difficult problem. However, the scientific discoveries that underlie the thermonuclear weapons demonstrated in 1954 open possibilities for the unlimited increase of the destructive power of weapons and consequently face mankind with the ultimate possibility of self destruction.

The US Atomic Energy Commission in a press release about two weeks ago gave further information concerning the effects of thermonuclear weapons. It was revealed that some of the weapons exploded in the Pacific had released energy equivalent to many millions of tons of TNT. An approximate idea of the scale of such an explosion can be grasped from the fact that a bomb of 10-megatons yield would destroy or damage beyond repair all ordinary Canadian houses and other light buildings within a radius of about 10 miles. The AEC announcement also emphasized the fact that bombs of this kind produce huge amounts of radioactive fission products which fall out over a vast area which may cover many thousands of square miles. As a specific example of the lethal effects of this fall out they state that in one of their Bikini trials the radioactivity was sufficiently intense at 160 miles downwind from the explosion to have threatened the lives of about one-half of the persons in the area who failed to take protective measures.

I will not attempt to go into the other details that were included in this AEC report. I am sure that

most of you read it at the time of its release. With the information that has been given in this release it is a matter of simple arithmetic to calculate very approximately the number of such weapons that would be required to wipe out most of mankind. There are obviously many uncertainties in such a calculation but it is alarming to find that whatever reasonable assumptions are made the result is to conclude that the number of weapons required is not beyond the conceivable limits of production or the known availability of raw materials.

Man is making almost equally spectacular progress in perfecting methods for the delivery of these terrible weapons. The United States Air Force have announced that they are beginning to produce the B-52, a huge bomber capable of flying at very high altitudes and close to the speed of sound and of dropping these huge weapons anywhere in the world. Last May the U.S.S.R. demonstrated for the first time the prototype of a very similar aircraft.

During the last war the Germans demonstrated the possibility of delivering substantial quantities of high explosive by guided missiles. The German bombardment of London with the V-2 was unsuccessful because of the small explosive power of the warhead carried. Had the V-2 carried even a nominal atomic bomb as a warhead London would have been destroyed. The V-2 carried a ton of high explosive over a range of 200 miles at speeds exceeding 3,000 miles an hour.

Most scientists and engineers are convinced that there are no theoretical reasons why this weapon cannot be scaled up to produce the so-called 'inter-continental ballistic missile' capable of carrying a thermonuclear warhead to any part of the world with quite acceptable accuracy. But there are some very formidable practical difficulties to be overcome before such a possibility becomes reality and even the most enthusiastic weapon designers are very reluctant to name the exact dates at which these difficulties will be overcome. However we cannot take too much comfort from the existence of these difficulties since the very advent of the thermonuclear warhead has brought the possibility of inter-continental missiles perceptibly closer by tremendously reducing the requirement for accuracy.

Effective weapons systems for use against the high flying subsonic bomber already exist, and equally effective means of dealing with the supersonic bomber are beginning to come into being. The evolution of an effective defence against inter-continental ballistic missiles poses some very difficult problems which are not yet completely solved. However history suggests that provided we avoid the disaster of an all-out atomic war an effective defence will ultimately be found. Nevertheless we must recognize that the existence of thermonuclear weapons and the possibility of inter-continental ballistic missiles has given the offensive in war tremendous superiority over the defensive. We are in fact faced with the scientific possibility of reaching some time in the future a state in which there exist offensive weapons of power and number adequate to destroy our whole civilization with no adequate means of defending against them. From the purely scientific

point of view this suggests a very grim outlook. However from a broader point of view there do seem to be some rays of hope because if we in the free world use our scientific and technical resources intelligently we can at least keep abreast of and possibly ahead of any competitors. In this scientific race we must strive to keep our offensive and defensive developments in step but if this cannot be done we must be sure that our offensive capabilities are at all times adequate to deter an aggressor from attacking. Should we ever lag significantly behind him in either offensive or defensive capabilities we run the risk of tempting him to embark on World War III. Therefore the peace and possibly the survival of the world depends upon the speed with which the scientists and engineers of the free world can devise and perfect successive offensive and defensive weapons systems.

I would like here to digress for a moment from the main theme of my talk to put in a word for civil defence. The announcement by the US Atomic Energy Commission two weeks ago of the fall out effects from large thermo-nuclear weapons may well have induced some people to feel that civil defence is of no value. This is far from being the case. Careful consideration of the data shows that the existence of these large weapons not only justifies the continuation of all our present civil defence measures but will make possible important new roles for civil defence. For instance it is quite obvious that a large proportion of the people who are likely to be injured by fall out can be saved from death or injury by suitable guidance and instruction after the explosion has taken place. I will not attempt to go into the details of such measures, but merely wish to assure you that from the point of view of the scientist the advent of the thermo-nuclear bomb has made civil defence more rather than less important.

Let us end our reconnaissance of the trail along which the military applications of atomic energy are leading us at this point and on this note of qualified optimism return to pursue the other and more inviting path to the peaceful applications of nuclear energy.

It is obviously impossible to enumerate the benefits to mankind that have already been and will in the future be found along this alternative pathway of peaceful discovery. You are all familiar with the advances that have been made in medical research through the use of radioactive isotopes produced almost as a by-product of military programmes. A good deal less is generally known of the growing importance of the use of radioactive isotopes in industry. However, I wanted today to emphasize particularly the importance of atomic power to our civilization.

One of the most distinctive features of our modern western civilization is the lavish use of low-cost power. The high material standard of living that we enjoy is ultimately dependent upon the supply of power. May I express here in parenthesis doubts of my own which have nothing to do with the main stream of my argument. The fundamental basis of most of our political and economic actions in the western world is the assumption that an increase in material comfort and a lightening of

the load of labour leads to increasing happiness. I personally have some nagging doubts concerning the fundamental truth of this principle. It would be quite out of place to attempt to debate its truth here. All I want to do now is to point out that it is the basis for many of our actions and that we as Canadians are every day acting as if we believed it to be true.

If therefore we agree that increasing material welfare and leisure lead to increasing peace and happiness for us it follows that if we are to have peace in the world we must help everyone else to have the same lavish material standard of living that we ourselves enjoy. If we are to go on providing even the existing standard for an increasing number of Canadians and at the same time help other nations of the world to achieve our standard of living we must have steadily increasing quantities of energy available and this energy must be available at existing real costs.

Looking at the development of the world for the next fifty years and assuming that there will be no major wars to interfere with our expansion it is clear that the very nature of our civilization would be substantially altered should there be any curtailment of our rapidly expanding use of power, whether due to a failure of supplies of fuel or to rising power costs. At present the world depends mainly upon wood and the so-called fossil fuels, coal, oil, and gas for its energy supply. Water power supplies less than one per cent of man's energy requirements and other sources such as windmills, solar furnaces, etc. supply even smaller quantities. There have in the past been many exhaustive studies of the resources of fossil fuels. These studies have sometimes disagreed widely concerning the extent and availability of usable reserves of the fossil fuels. However, all of them have agreed that the end of our readily available resources is already in sight and that some time during this century the cost of recovering these fuels will begin to rise so seriously as to limit their use. It is very important to try to view this problem in historical perspective since it is easy to be diverted from the main problem by arguments over the exact date at which one or other of the fuels will begin to be uneconomic. From the long-term point of view exact dates are unimportant. All that matters is that some time within the foreseeable future the rate at which our economic machine requires energy to keep it going will exceed the rate at which we can expand the recovery of fossil fuels. If this is accepted, then it is obvious that we must begin now to think about other possible sources of energy capable of supplying our steadily increasing needs. Scientists and engineers have already explored the path toward the development of nuclear power sufficiently to be certain that along this trail lies one certain solution to our problem. There is I think no doubt whatever that the means of utilizing nuclear energy in vast quantities and at costs well within the range of present energy costs will be perfected in ample time to take over from our dwindling resources of fossil fuels. Here again there is disagreement among the experts concerning the details but I think no fundamental disagreement in broad principle. There are certainly enough fossil fuels available in the world

to go on expanding our energy dependent economy for say another twenty-five years or even more and it is perfectly certain that within that time nuclear energy will be economically available.

Even if nuclear energy should in the future be entirely dependent on uranium as a fuel there is already enough uranium known to be available in the world to supply many times the energy that has been derived from fossil fuels. However, it seems very likely that science will find ways of using a wide variety of other fuels for nuclear furnaces and so it is unlikely that the development of our civilization along present lines will be limited by the availability of cheap energy for industrial and domestic purposes.

In attempting to imagine how the present world scene will look in historical perspective there is a temptation to suggest that divine providence found it necessary to allow man to discover the secrets of nuclear energy at this time in order to ensure the continued development of our material civilization. Unfortunately this discovery necessarily carries with it the possibility of the destruction of our civilization. Man is therefore faced with a dilemma of a magnitude which he never faced before. The whole history of civilization is a history of wars. Man has never solved the problem of living without fighting. In the past these wars have wiped out individuals, families, tribes, and even small nations, but the destructive power of the weapons available was never sufficient to destroy the race. We have now reached a stage in history where we can foresee the possibility of having weapons available in the world in numbers capable of destroying our civilization and of rendering large parts of even the whole of the world uninhabitable by man. This means that our attitude toward war must be fundamentally changed if we are to ensure survival.

At present we in the free world are working on the assumption that the Russians wish to dominate the world and that they will seek to dominate it by force should an opportunity offer. We have built up and are maintaining our armed strength, not with the idea of attacking Russia, or even to ensure victory should war be forced upon us but because of our firm conviction that the best way to avoid the disaster of another world war is to be so strong as to deter any aggressor from starting a war. It is a pity that we have to devote such a large part of our energies to defence but it is obvious that this is a state vastly to be preferred to war. It is of vital importance that the ordinary citizen should not feel that by cheerfully paying his taxes and allowing a large part of them to be spend on defence he is doing everything that he can to ensure world peace. All that defence expenditure can do is to prevent the disaster of war while other forces in the world work toward a more lasting solution of the problems of living together. It is now obvious that we must seek some form of world organization that will make war impossible. This is not an easy task and will not be accomplished quickly. However, there is no reason to give up hope. History shows that man is gradually solving the problems of living together in larger and larger groups. NATO has been more successful than any

previous association of nations in solving the problems of joint defence. But although there are grounds for hope there are no grounds for complacency. Even while we are beginning to see the first fruits of nuclear power for peaceful uses stocks of thermonuclear armaments are building up and world tensions are not diminishing. We must hasten to solve our ancient problems of living together if we are to survive. We are now at last faced with the desperate alternative of one world or none.

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