CANADIAN RESEARCH AND DEVELOPMENT IN A CHANGING WORLD

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Scientific and engineering progress during the last thirty years has greatly affected our lives. These changes continue at an ever increasing rate. Socially, economically, politically, scientifically and technologically, even ten years from now the world will be different. It is timely to ask if we are adequately and suitably prepared for the changes that are coming. In part this is a question for the social scientists. In this symposium we need to consider only that part of it which affects natural science and engineering.

During the past thirty years manufacturing has become a major factor in Canadian economy. Circumstances of the war and of post-war industrial disorganization in Europe made possible a rapid expansion of our manufacturing industry, but the continuing prosperity of this industry depends on markets. Prospective customers should not be expected to buy our products unless they are cheaper, better or of more advanced design. These are qualities which come from research and development. Obviously, we cannot hope to be very successful in competing for markets, either at home or abroad, with those foreign producers on whom we depend for the development of the product we want to sell. This concern lies behind the question of the adequacy of our preparedness for research and development in a changing world. It is understandable, of course, if the management of a few of the Canadian subsidiaries of large foreign companies do not feel that there is cause for concern, but it is not only from their point of view that we should consider this question.

Of the recent scientific and technical developments that have great consequence the first that comes to mind is nuclear energy. It has altered the character of warfare, changed the balance of power among nations, and dominated international relations. It has made available to us enormous resources of
energy for peaceful purposes which will be of great economic importance.

Those of us who have been close to nuclear energy development have looked upon it with a more restricted view and have been less conscious of the far-reaching political and economic consequences than we have been of the technical problems associated with it. We soon found that Canadian industry was not well prepared to undertake some of the research and development needed for atomic energy purposes. It was the policy of the Federal Government, reflected in the efforts of Atomic Energy of Canada Limited, to encourage Canadian industry to participate as fully as possible in this great new development. One of the means by which AECL attempted to do this was through research and development contracts in industry.

It was not always easy. Canadian companies that were accustomed to refer their development problems to parent companies in the United States were scarcely prepared to deal with AECL's problems. Sometimes they lacked even a clear conception of the nature and method of research and development. Often it was felt that it would have been cheaper and faster for AECL to do the development itself.

It is far from my purpose to suggest that it might have been otherwise. The possible markets for Canadian nuclear industry were not then expanding so rapidly that these companies could foresee in the near future continuing employment for research and development facilities specializing in the nuclear field. Nevertheless, it was clear that in certain areas of engineering research and development Canadian industry was very weak. I hasten to add that some Canadian companies have very competent and productive research and development departments. The Northern Electric Company is a noteworthy example.

In atomic energy development Canada has had the advantage of an early start. The opportunities for foreign trade are great, but in this industry, where the technical progress is rapid, research and development is necessary to compete with obsolescence, and therefore to compete successfully in trade abroad. I speak here of nuclear energy because it is the technology with which I am most familiar. Surely what I have just said is true of other industries also in which the technology is rapidly changing and where we have aspirations in world trade.

For the scientists and the engineers the change that most affects their work is the great increase in the complexity and in the quantity of scientific and technical knowledge. The problems thus created will increase. The technical libraries will strive to store more and more information in small space by
use of microfilm and other means, and will face a growing problem of indexing and cross reference and of providing for the quick recall of the information from storage. Engineers will not find the comprehensive data on the properties of many new materials for their needs in a single handbook and two or three catalogues. Electrical methods may help greatly in recovering data in both the library and the design office, but the demands on human memory are bound to increase.

Man has invented electromagnetic memory to supplement human memory, and thereby he has increased enormously the capability of storing technical data and verbal descriptions. However, the ability to apply science and technology requires more than tabulation of the properties of materials. It needs also understanding of physical process, understanding that makes it possible to use the numerical data, applying it to new problems to reach useful conclusions. To some extent that kind of understanding can be given to an electrical computer so that it can use the data under prescribed conditions to reach the right conclusions, in other words, to "think". The computing device is rather stupid because it takes considerable effort in writing a programme to teach it how to think about a very limited class of problems. On the other hand, when it has learned the lesson, it can think very much faster than the human mind, and that is its great advantage.

We shall use computers in our science and engineering more and more in the future, but it is well to remember that we must ourselves understand the solution of a problem before we can instruct the machine how to solve it. The master of this powerful slave must still be a human mind with greater knowledge and understanding. The computing device is most valuable for the class of problems of frequent repetition, but the thinking that leads to important new development is not repetition but a venture in a new direction and it requires human intelligence. Thus computing devices cannot remove the need of engineers in the future for broader training in basic science.

As technology has become more complex with passing years university engineering courses have become longer and more difficult. Still, the formal training of most engineers is much shorter than that of research scientists and medical practitioners. For the research and development activities in which engineers will become increasingly involved, training leading to the Bachelor's degree is scarcely sufficient. Further training in basic science is needed. Moreover the engineer who would succeed in research and development must learn the method of research. This he can most readily do in the same way as the fundamental research scientist; that is by doing research in the university under the supervision of a professor experienced in research.
Another important change that has become evident in nuclear industry is the trend of replacing manual control of equipment and of process by automatic control. Automatic control is preferred to manual control for a nuclear reactor because it can operate to protect the equipment if components fail much more quickly than a man can realize the situation and act. The automatic devices also can maintain a constant vigilance without distraction. They have been developed to a very high degree of reliability. Where the elements of the control system are duplicated or triplicated, defective components can be removed without interruption of the plant's operation, and they can be overhauled thoroughly during the daytime shift.

Modern computing equipment is beginning to replace visually indicating instruments for the control of complicated processes, providing a record of many variables which is quickly recovered later when required. This trend towards the replacement of highly trained personnel by automatic control combined with computing devices may increase rapidly in many industries.

An important affect of this change is a difference in the training requirements for the personnel involved in plant operation. As the engineer turns his attention more to research and development and new enterprises, he will entrust some of his former duties to technicians. There will be increasing demand for personnel with a technical training that prepares them to do the routine tasks of plant operation without necessarily having the understanding of process and the background science and the analytical abilities that are expected of the engineer. Canada will need more schools like Ryerson that give training similar to that which in England leads to a Higher National Certificate in various branches of technology.

The wider spreading of technical training for industrial employment will be limited by the native abilities of those who are to receive it. Accordingly, there will be need for tools and process control equipment that can be entrusted to less clever people. Thus engineers will be giving greater attention to the design and development of process apparatus and its instrumentation and control, and to the instruction of technicians in the use of these devices.

Great changes are taking place in the scientist's methods of working. Half a century ago he worked alone on a problem or supervised a number of students each of whom worked on separate problems. Now equipment is becoming more and more complex and costly, and in some cases a fairly large staff is required to operate it. Certain kinds of research, therefore, can only be carried out in a few specialized research centres. An undesirable consequence is that it draws some of the best scientists away
from the universities where their leadership and their teaching could inspire younger men. This can be mitigated by frequent exchange of personnel between the universities and the central research organizations.

Because many fields of science are so related to other science and technology a team of different specialists is required to carry out many investigations. It is often advantageous to bring together the knowledge of engineers, metallurgists, physicists, chemists, biologists, meteorologists and other specialists in various combinations according to the subject. This kind of collaboration can be particularly valuable in the universities and be especially rewarding in the little explored boundary areas between the older disciplines. The collaboration of the engineering departments with the basic science departments should be particularly valuable for both.

The teamwork of engineers and fundamental physicists and other scientists on a huge scale is to be seen in the American space research programmes. The mutual stimulation and inspiration of scientists and engineers is contributing greatly to the advance of fundamental science and leading to great technological developments.

The prestige incentive should not be despised. It matters very little what a man does while he is on the moon if the achievement of getting him there serves as an easily recognizable goal, advances scientific knowledge, and leads to engineering developments that may have far-reaching commercial and economic importance. Canada does not have a great space research programme, yet the success of the Alouette rocket was an encouragement to the staff of the Defence Research Board that will lead to other achievements.

One expects to find that the technically advanced nations are those which support applied research. It is worth noting, however, that these are also the nations that generously support fundamental research. Applied research does not thrive in countries where fundamental research is neglected. There is good reason for this. It is the fundamental scientists in their love for science that spread its teaching, that work to maintain high standards of education in science, both fundamental and applied; without their enthusiasm and efforts the training of new scientists and engineers would be second rate. Where fundamental science is not encouraged and supported, young students of active imagination turn their attention to other interests or go abroad.

The most basic of contemporary physical science is in the study of the fundamental particles of which everything in our
physical world is constructed. This study requires powerful particle accelerators, some of which cost many tens of millions of dollars. In this regard, Canadian physicists have been less favoured than their colleagues in other countries, even some less wealthy countries, and thus they have been denied the opportunity in Canada of participating in research on this frontier of physical science.

They have been, however, generously supported in another area of basic physical science, atomic energy, at a time when that science was advancing most rapidly, and they profited by it to bring great credit to physics in Canada. Their enthusiasm and inspiration was essential for the healthy growth of Canada's atomic energy programme which is becoming of ever increasing economic importance.

However, further understanding of the nature of the atom depends very much on our understanding of the nature of those fundamental particles, and our physicists are envious of their colleagues abroad with their big particle accelerators. It does not follow that because American or British physicists have a very costly research instrument of a certain kind we should import from abroad an instrument of identical design. On the other hand, if Canadian scientists and engineers should conceive and design a machine with important research capabilities that are different from those in other machines abroad, and if the machine would be produced, designed and manufactured in this country so that Canadian industry can benefit, and from the experience enhance its capability in industrial research generally, the proposal should be carefully considered.

The title of this symposium directs our attention to the respective roles of the government laboratories, the industrial laboratories, and the universities in scientific and industrial research. In industry it is natural to give greatest attention to applied research that may lead to new products, but industry must bear in mind that if it denies to its research staff the opportunity to pursue enquiry into fundamental science that lies behind their applied research problems, they will not hold a good research staff long. In the universities it is appropriate to direct research efforts along lines which are most useful for the training of young scientists in research method and system, and in this they will tend to favour fundamental research, but their usefulness in preparing scientists and engineers for industrial research will suffer if industrial research is neglected in university laboratories. Government research laboratories are required for research of national importance that lies outside the interest of particular industries, such as in defence and in the conservation of our resources, and for research of economical and industrial importance of long term significance.
They are also needed for fundamental research that requires equipment and supporting facilities that would be an unsuitably heavy burden for a single university, such as the reactors at Chalk River.

Rather than stressing the differences between the three groups, my purpose has been to emphasize what they have in common, particularly the importance to all three of close collaboration in their work.

Applied research in government research laboratories will not benefit industry in this country as well as it might unless it is directed and guided with an awareness of industry's problems. It is up to management and research directors to bring about the needed communion between industry and the national laboratories, but it will not be achieved by occasional meetings on the managerial level. It needs frequent contact between those who are actively engaged in research and development work. Exchanges of personnel on a yearly basis would benefit both industry and the government laboratories.

Similar comment may be made about the cooperation of industry and the universities. In visiting the university engineering departments, one is often struck by their isolation from industry. If industry would more frequently bring the university professors directly into the investigation of its problems, and at the same time take a greater interest in the research in the universities, both the universities and industry would profit greatly, and the training which engineers receive will become better directed towards their requirements in industry.

On the third side of the triangle, the justification for the support of fundamental research in government laboratories depends in part on the benefit it brings to scientific research in our universities. There is a need here for fuller participation of university professors and students in the planning, the organizing and the carrying out of fundamental science in the government laboratories. It is not sufficient for this purpose merely to allow visiting professors to attach themselves in the few summer months to research groups that have already progressed on projects which the visitors did not help to plan.

The question that was posed at the beginning of this paper was our preparedness in research and development in a changing world. At the root of the problem was the increasing complexity of science and technology. Although electrical means have been devised to store much information and to aid us in using it, there will be a need for more training for engineers and for technicians, and for greater participation of engineers in research. There will be increasing need for the collaboration of specialists in
different sciences, for the collaboration of scientists and engineers in single projects as well as in large programmes, and especially for much greater collaboration between different research departments in the universities, between different research organizations, and between government laboratories, industrial laboratories and the universities.