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SCIENCE AND DEFENCE

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Science is a comparatively recent thing in man's history, and newer still is its cultivation on an organised scale and its large scale application in peace and war. As everyone now knows, science is an immensely powerful thing. It has profoundly altered man's material environment and it has even altered his pattern of thinking and his sense of values. It has deeply affected the way we look at the world and its problems. It has given new meaning to old problems—including the problem of living and life itself—and it has raised a host of new ones. In all civilised countries, science (—but not always, and not necessarily, scientists—) enjoys tremendous prestige, and people have great hope and faith in its power of doing good, and there is also the fear that this power may not be wisely used. And, all this has taken place in the amazingly short period of about three centuries.

In 1710, more than two decades after the publication of Newton's Principia, Steele wrote in the '**Tatler**' "They (Virtuosi, i.e. scientists) seem to be in a confederacy against men of polite genius, noble thought and diffusive learning; and choose into their assemblies such as have no pretense to wisdom, but want of wit; or to natural knowledge but ignorance of everything else. I have made observations in this matter so long that when I meet a young fellow that is a humble admirer of science, but more dull than the rest of the company I conclude him to be a F.R.S." The Royal Society was called the "Grand Champion of Errors". About the Society's publication, a critic, early in the eighteenth century, referring to a paper entitled "Child Born without a Brain", submitted by Sloane, President of the Society, said "Had it (—the child without brain—) lived long enough, it would have been an excellent publisher of the Philosophical Transactions". Such criticism of science and scientists has now long been a thing of the past. In fact, if anything, the pendulum sometimes tends to swing rather too much on the other side. To quote Sir Henry Tizard, "the time is near when, as Huxley warned us over sixty years ago, science, like Tarpeia, may be crushed with the weight of rewards bestowed on her. Let us then beware, when all men speak well of us, and be critical of ourselves. Let us ask whether we are claiming too much in some directions, and doing too little in others; let us consider in fact whether the great forces of science, on the proper exercise of which all social progress depends, are in balance."

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Science and things military have always influenced each other sometimes more and sometimes less, sometimes more the one way and sometimes more the other way. Lewis Mumford in 'Technics and Civilisation' asks: "How far shall one go back in demonstrating the fact that war has been perhaps the chief propagator of the

* Inaugural address to the First Annual Session (1952) of High Explosive Factory Technology Association at Kirkee.

machine ?" In ancient times there was the poison-arrow, there was the armed chariot "with the scythes that revolved with its movement, mowing down the foot-soldiers". Long before the Christian era burning petroleum and Greek fire were effectively used in sea warfare. There were high-powered mechanical devices, catapults and ballistas, hurling stones and javelins to several hundred yards. The swords of Damascus were noted for their effectiveness in battle: It is very likely that the steel for these swords came from India.

These ancient achievements, however notable though they were, owed much more to craftsmanship than to science. After the period of the 'dark age' in Europe when little effective science was done, we come to Roger Bacon. He, in the thirteen century announced to the western world, possibly it was his own independent discovery, the composition of gun powder in the form of the Cryptogram "SED TAMEN SALISPETRE LURU VOPO VIR CAN UTRIET SALPHURIS", which (when deciphered) means, to make gund-powder mix 7 parts of saltpetre 5 of young hazelwood (charcoal) and 5 of sulphur. (The Service gun-powder has approximately the composition: saltpetre 75 per cent., sulphur 15 per cent., and charcoal 10 per cent.).

The works of Leonardo Da Vinci and Galileo played a great part in improving artillery and the art of fortification. The use of fire-arms made the tactics of offence and defence much more deadly than before, and building of roads, canals and bridges became a necessary part of military operations. This led to a new type of professional man—the military engineer. It was not until the eighteenth century that we have civil engineers as distinct from military engineers: Originally all engineers were military engineers. Arms factories began to rise, one of the earliest being founded by Gustavus Adulphus in Sweden, in the seventeenth century.

The use of gun-powder and the development of fire-arms not only democratised warfare—"It made all men equally tall"—but it also provided an effective incentive for the study of the laws of motion. Aristotle had discussed the motion of a projectile. He held the view that a body when projected continues to travel in a straight line till it reaches the highest point in its trajectory, and then it falls down vertically. Accordingly, the path of a projectile consists of two straight lines meeting at the highest point attained by the body during its flight. Views such as these, which are based on speculative arguments and not on experiment, could hardly be seriously entertained when firearms came into use. The study of the Laws of Motion of falling and projected bodies became the central problem in European natural science of the seventeenth century, and as we all know, Galileo formulated the Laws of Motion which later were put in more systematic form by Newton.

Thus, science and warfare have always profoundly influenced each other. This has grown with the growth of science itself and now modern warfare is completely dependent on applied science (—war has been described as applied science—) and methods of precision mass manufacture which originated in the last few decades. The time-gap between laboratory results and their application to defence has been continually diminishing, and in certain fields (radar is a striking example) the laboratory can be regarded as almost a frontline of offence and defence. Notice also that in World War II two things happened which did not happen in earlier wars. Firstly, "World War II was the first war in human history to be affected decisively by weapons unknown at the outbreak of hostilities. This is probably the most significant military fact of our decade: that upon the current evolution of the instrumentalities of war, the strategy and tactics of warfare must now be conditioned. In World War II this new situation demanded a closer linkage among military men, scientists and industrialists than had ever before been required, primarily because the new weapons whose evolution determines the course of war are dominantly the products of science, as is natural in an essentially scientific and technological age." Secondly, it was in World War II that for the first time deaths in the fighting services caused by epidemics and septic wounds were less than actual deaths in battle. In all previous wars the number killed in battle was much less than the number who died of disease and septic wounds. In the last war, more than 80 per cent. of the wounded returned to normal health. This was due to great advances in medical science—the single greatest thing being the discovery of penicillin.

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The ever increasing importance of science in relation to military preparedness is reflected in the high percentage of defence budgets spent on research and development in technologically advanced countries. In U.K., for instance, something like 10 per cent. of the defence expenditure is on research and development, and about 5,000 scientists are engaged in this field. Again, the increase in the range of action of a weapon, its striking power, the accuracy with which it can engage a target and the speed (that is, portability; mobility) with which it can be brought to bear on the target; these all imply increased technical refinement and complexity and lead to higher costs of production and still higher costs—in money and manpower—in maintenance and repair. In U.K. for instance, the cost per man in the armed forces is now over £1,000 a year. It is roughly two to three times higher in the U.S.A. In our case, the figure is about one-third, possibly less, of U.K.

In some of the countries the military expenditure has almost reached astronomical figures. The U.S.A.'s expenditure is about 60 billion dollars (roughly Rs. 30,000 crores) a year. The world expenditure on armament may be put down at about 150 billion dollars a year; which is equivalent to about 70 dollars per man per year; and all this—so it is hoped—to ensure that another Hiroshima does not happen, or at any rate does not happen too soon. As the U.S. Senator McMahon observed the other day this huge expenditure has faced even the U.S.A. with the Hobsonian choice of either military security at the expense of economic solvency or high level social economy at the expense of military security.

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In any country the standard and efficiency of weapons and equipment of its fighting services is, in the ultimate analysis, largely, if not entirely, determined by the technological and industrial potential of the country. Any marked disparity between them is neither possible, nor, if artificially sustained, can it survive for long. Again in a technologically backward country the cry for the latest weapons is, relatively speaking, often more than ordinarily loud. The reason is obvious. There is not enough appreciation of what is possible and what is not, what is difficult and what is easy, and what is necessary and what is not. These are, in practice, anywhere and always, very hard things to assess, and much more so in technically less advanced countries. Work such as this requires scientific men of outstanding ability, daring and character working in the closest touch with the service.

But we can get competent men for defence research only if the Universities produced competent men. And again the quality and quantity of the work of research workers is conditioned by the general climate and tradition of scientific enquiry that exists in the country.* Man is the first weapon, says the book on the 'conduct of war', and it is equally true in science that man is the first instrument. The primary concern should, therefore, be to ensure that the Standard of teaching and research in the Universities is adequately raised so that the science-men who come out of them will have the ability and competence to undertake defence research effectively. Everything should be done to assist in the creation of an atmosphere which will make it possible for scientific men to devote themselves with zeal and single-mindedness to their scientific pursuits.

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How is a scientific establishment to be organised so that the men there will devote themselves completely, entirely and fruitfully to the pursuit of scientific research ? This is a problem difficult as well as delicate. It is beset with difficulties even in scientifically advanced countries. Firstly, the establishment should be manned by able and devoted men. Secondly, the conditions should be such as will allow them to grow in their full scientific stature and not dampen and dry up their enthusiasm and abilities. Thirdly, the problems to be worked at the establishment should be selected with the utmost care. This is extremely important. Do not have too many problems, but concentrate, and concentrate, on a small number selected judiciously. This lesson of 'successful concentration' is one that the scientists have and can still usefully learn by association with the Services. In selecting problems take account of the usefulness of the problems, the resources available for investigation, and the speed with which they can be solved.

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*In this connection the following remarks of Polanyi are of some interest ; (Scientific Monthly, Vol. 60, 1945).

"Those who have visited the parts of the world where scientific life is just beginning, know the back-breaking struggle that the lack of scientific tradition imposes on the pioneers. Here research work stagnates for lack of stimulus, there it runs wild in the absence of any proper directive influence. Unsound reputations grow like mushrooms : based on nothing but commonplace achievements, or even on mere empty boasts. Politics and business play havoc with appointments and the granting of subsidies for research. However rich the fund of local genius may be, such environments will fail to bring it to fruition."

The organisation of research is incidentally made much more difficult than organisation in other fields of work. It is difficult to explain precisely to non-technical authorities concerned, what the programme will accomplish. Funds for research programmes have to be assigned largely on faith. Condon has said, "It is characteristic of most fundamental research that several years are required for the completion of any work of importance and that the end result may be difficult to evaluate by anyone except specialists. What, for example, is the cash value of Einstein's discovery of the relation $E=mc_2$? No doubt it is an astronomically large value now. But what was its worth at the time of its formulation? and who was qualified to make the evaluation? The point simply is this: pure knowledge cannot be evaluated in cold cash, and pure knowledge is independent of such evaluations. Unfortunately, appreciation of this fact is not as widespread as it should be, which suggests the story of two partners who had long operated a chemical manufacturing business. They finally decided to employ a research chemist. Along about 11 A.M. of the first day of his employment, one partner said to the other, "Shall we go and see whether that research chap has discovered anything?" "No" replied his partner, "It is a little too soon. Let's wait until after lunch"

Generally speaking the object of defence research and development is two-fold: (i) it is to enable the armed forces to make the best operational use of their existing weapons and equipment, and (ii) to continually seek new weapons (including serious modifications to existing weapons so as to gain a lead over possible enemy countries). The first object is largely met by operational research, whereas the second requires a background of high level scientific knowledge and industrial productivity. Operational research is the application of scientific method to the study and analysis of operational effectiveness of weapons, and this has been a conspicuous feature of the last war. Probably no other field of research or development has provided a larger yield than this in relation to the effort expended on it. The assessment of the operational effectiveness of weapons (weapon efficiency and weapon economics) has now become one of the most important, if not the most, field of defence research. Often it is a matter of the highest complexity to decide whether a proposed weapon 'A' is superior to an existing weapon 'B', and if so is this superiority sufficiently large to make the replacement worthwhile. It has to be realised that this assessment of weapon efficiency must take account of the tactical use of the weapon and the level of training of the troops in its use and so on. A less accurate weapon or a less sophisticated one may, depending on the tactical situation, give better battle-value than a more accurate or complex weapon. There is no such thing as the absolute superiority or efficiency of a weapon: it is always in relation to tactics, the nature of the terrain, the ability and resourcefulness of our fighting men and of the enemy. This, therefore, can only be done by the scientists in the closest association with the fighting services. Assessment of weapon effectiveness demands an intimate knowledge of its performance and experience in its operational use. Such a knowledge is essential if we are to utilise existing weapons to their maximum advantage, and effect such improvements as may be required to meet local requirements, and also to help us in purchasing weapons best suited to our needs.

The Defence Science Laboratory, at present accommodated in the N.P.L. Building, Delhi, is intended to be the central place for such studies. It is somewhat on the lines of the Army Operational Research Group, Byfleet, U.K., but, of course, in our case on an inter-service basis. In this sense we shall have some advantage over the UK set-up, where the operational research work for the different Services is not as closely joined together as it should or can be.

Apart from operational research, scientists are required also to assist the Services in other ways. All these may perhaps be summarised as below :—

(a) **Purchase of weapons:** The help of scientists is required to assess the operational effectiveness of the different weapons so that within our purchasing resources the most effective weapons are purchased.

(b) **Optimum use of existing weapons:** This is the most important subject in which the contribution of the operational research scientist is well recognised. In relation to the effort put in this study yields very often the largest dividends.

(c) **Modification to existing weapons to suit them to local conditions:** (e.g. tropicalisation: super-refraction in the case of radar).

(d) **Development and design work:** With a view to produce in India existing (conventional) weapons which at present are imported. This is becoming most important in view of the difficulties in importing weapons now from abroad.

(c) **Research and also development and design:** With a view to produce in India new weapons in general of the World War II class.

(f) **Research and study to keep in contact with advanced weapons work in foreign countries.**

(g) **Research with a view to develop radically new weapons:** (This stage is not likely to arise in the country for the next few years).

(h) **To suggest improvements in inspection techniques and procedures.**

The scientists bridge the gap between the tactical and the technical.

I spoke earlier of the extreme importance of providing a proper environment and conditions of work and service, if scientists (who are generally shy and sensitive creatures, interested in the work rather than in themselves) are to be enabled to give their utmost and their best to the pursuit of science.

President Truman in his address to the Centennial Celebration of the American Association for the Advancement of Science in September 1948, says: "If we are to maintain the leadership in science, that is essential to national strength, we must vigorously press ahead in research. There is one simple axiom on which this thought is based. The secrets of nature are not our monopoly......

.................Pure research is arduous demanding and difficult. It requires unusual intellectual powers. It requires extensive and specialised training. It requires intense concentration, possible only when all the faculties of the scientist are brought to bear on a problem, with no disturbances or distinctions. The Government has, I believe, two obligations in connection with this research if we are to obtain the results we hope for. First, it must provide truly adequate funds and facilities. Second, it must provide the working atmosphere in which research programme is possible."

Perhaps, the single most important thing that can be done with regard to the proper organization of research and development is the institution of a scientific service. A beginning has been made by instituting a **Defence Science Service** which will include all civilian scientists engaged in research, development or teaching employed in any of the three Services or in the Ministry of Defence. This Service will come into operation shortly. "An Indian Defence Scientific Service is needed to set the seal on intentions for Inter-Service action in research and development; it is needed as a machinery for determining satisfactory conditions of service for defence scientists; it is needed to give esprit de corps to those taking up this new vocation in India; and its formation can be of the greatest value in attracting interest amongst scientists in Defence Science careers. I regard the institution of an Indian Defence Science Service as a foundation stone in the construction of Indian Defence science" (Report to Ministry of Defence by Dr. Keyston).

In this connection it may be mentioned that in the United Kingdom all scientists employed by the Government whether in civil departments or in Service establishments belong to a unified Science Civil Service. It would be useful to summarise here some of the salient features of the Scientific Civil Service as these would be applicable mutatis mutandis, to our Defence Science Services.

The service, in its present form was instituted in 1945, with the object of providing for scientists working for the Government such conditions of service as to attract men of high calibre, and to enable them to play their full role in the national development. The three essential conditions of a strong and healthy Scientific Service, as laid down in Comd. Paper 6679 (1945) are:

(1) Better conditions of service for scientists, and, in particular, conditions under which their own experimental research will be both facilitated and stimulated,

(2) Improvement of their status and remuneration, and

(3) Centralised recruitment.

The scientific scales are divided into two main classes: (1) Scientific Officers, and (2) Experimental Officers.

Recruitment is done centrally through the Civil Service Commission, who are assisted in this work by an Additional Commissioner (Dr. C. P. Snow), with a special responsibility for recruitment of scientific and experimental officers. There has also been set up an Inter-Departmental Scientific Panel to maintain uniform standards for promotions and special advancements in the Scientific Service, and improve administrative liaison between departments, and also the well-being and efficiency of the Government Scientific Service. These proposals of the (U.K.) Government were generally based on the recommendations of the Barlow Committee on Scientific Man-power. Some of the recommendations of the latter Committee are noted below :—

(1) The outstanding man should be able to reach the Principal Scientific Officer's grade in the early thirties.

(2) **There should be the closest contact between research and development.**

(3) The tendency of Government Scientific Branches to isolation from the rest of the scientific world must be eliminated. Possible methods of doing this are: (a) Extra-mural research contacts to help that end. Heads of Scientific Departments should try constantly to improve contacts with both University authorities and students. (b) Temporary interchanges of staff with the Universities should be arranged. (c) The introduction of a scheme on the lines of a sabbatical year is desirable. (d) Scientific staff should be given special leave to enable them to attend scientific meetings and conferences. (e) Exchange of staff with industry would be valuable, if the difficulties can be overcome. (f) Direct contact between Government Scientific Branches particularly in matters of administration is needed. (g) Transfers of scientific staff from one Department to another are desirable. (h) Research scientists should, wherever practicable, remain associated with projects which they themselves have started. (i) Research Establishments ought, so far as possible, to be located within easy reach of a University or intellectual centre and in close proximity to other establishments working on kindred problems. Direct contact at all levels between the staff of different establishments should be made easy. (j) Secrecy restrictions appear to be excessive and should be relaxed. (k) Fuller use of the members of Advisory Councils should help to secure professional recognition of the work of Government scientists. A wider extension of the admission by Universities of theses for higher degrees on secret subjects would be valuable. (l) Lectures by eminent scientists and "Colloquia" should be encouraged, and adequate lecture-rooms, libraries and workshop facilities should be provided.

(4) Heads of laboratory Units should be given more freedom in regard to the procurement of equipment.

Mention may also be made of the proposal to establish a place some thing like a University college—for the study of the basic principles of armament. Here civilian scientists from the Universities and other research institutions would be most welcome as 'visiting scientists to familiarise themselves with aspects of defence science of interest to them. Such contacts will, of course, be most useful to the defence scientists ; these will keep the defence scientists in the closest touch with the main currents of Indian scientific thought and research.

Scientists whether working on defence problems or in other fields, fundamental or applied, constitute but one fraternity—therein lies their strength and the real secret of rapid progress in science. And wherever they work their hearts are always bent on peace and peaceful applications of science. They realise all too well that war is a sin and if some of them work on defence, it is only, perhaps, that if there is a greater sin than war, it is losing it.

Be that as it may, we all share the hope that before it is too late man will give concrete shape to the truth that War is utter folly and futility. And it is certain that in practical life man can only realise this, if based on the secure and enduring foundation of scientific knowledge, about himself and of his environment.