Some Requirements for Effective R&D*

An essential feature of progress in our times is the harnessing of technology for improving the quality of life of the people. Because changes are taking place at a highly accelerating rate and with increasing sophistication, in many cases prior experience or tradition can be totally irrelevant or even dangerously misleading. This means that in order to arrive at conclusions that are consistent with

1. The deep rooted sentiments of those who have to make the work flow/obtain results and that
2. The organizational set up must be in conformity with the natural realities that have to be dealt with.

We must arrive at the requirements to satisfy the above criteria for which it is necessary to appreciate

- the evaluation and structure of scientific knowledge
- the role of a central research organization
- the relationship to research to the professionals and industry

and then only can we arrive at a definition of strategy ie policy. This approach may appear to be over-complicated! But has over-simplification ever provided an answer to complex problems? The baby is thrown out with the bath water, no problems therefore exist. If it were to easy, as some make it out to be why is it that we find it so difficult to obtain out of our "well thought out plans" results that do provide satisfaction. Can it not be said that we are usually confronted by a series of crises of implementation? And it has to be admitted that there are so many failures that it can hardly be said they are exceptions in general pattern of success!

Scientific knowledge has evolved over the years through the accumulation of individual observations made to solve immediate problems eg navigation, at sea or in the desert, lead to the beginnings of astronomy, the requirements of dwellings/stores/places of worship lead to mechanics, the necessity for a proper definition of land holdings helped generate plane geometry… The movement in all cases was from the particular (problem) to generating general statements (theories or laws). Having arrived at a theory or law it was then possible to apply it to a wide variety of undefined situations and not reinvent the proverbial wheel again and again. How to systematize prior experience is, therefore, a necessity for progress. Systematization amounts to

- Classification of observed phenomena (facts)
- The establishment of their mutual relationships leading to
- Increasingly general statements ie better theories or laws.

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* By Masood Hasan – Sept 1982

There are four agencies that advance scientific knowledge

- The professions and industries
- The universities
- Scientific/learned societies and
- Central research organizations

There are several sectors in which knowledge, over the years, has conveniently broken itself into: including amongst others energy, transport, structures, communications, materials, earth sciences, agriculture, sociological and medical. Hence R&D should reflect this reality. In a way this amounts submission to evolved natural experience. Any policy and organization built on this conceptual foundation will indeed have the best chance of being effective.

Organized research has progressed over the years in the last century in what is called the developed world, in the various forms:

1 Pure/Fundamental/Basic
2 Applied
3 Developmental

Basic research is concerned with original investigation and is primarily for advancement of knowledge. Applied research is similar to basic, but it is directed towards a practical purpose because of a current need. It is through technological transfer to produce, economically, prototypes or processes through an innovative approach that is characteristic of the developmental role. The basis lies in the spirit of enquiry which in turn is based on the empirical method which is a reality that we must recognize.
At the outset it may be mentioned that the time horizons involved, usually beyond the tenure of those who make the critical decisions, need careful consideration otherwise incorrect conclusions may be arrived at because of the difficulty in establishing a relationship between resources expended and benefits to be obtained.

Certainly, the Japanese could not have quantified in advance that insisting on much more mathematics, amongst others, in their school education would help produce shop floor workers who are superior than their counterparts in the UK and USA. Japanese operatives ie ground floor workers are able to "stand up and give technical presentations of their work and in the extent to which they were able to cope with high levels of automation and other sophisticated production methods". But how much less productive they would have been otherwise, no wiseacres could have predicted. Yet there are those on account of lack of faith in the scientific/empirical method keep asking for "cast iron" safeguards before the event!

We move from the special to the general in a better understanding or in improving our methods where the physical transactions take place ie at the cutting edge of work and as a result of a lot of observations we build up hypotheses, theories or even laws. However, in the field of education we move from the general to the particular. The particular amounts

to proving that the laws put forward by the teacher are correct, through examples. If divergencies are found, which a law cannot explain then we go through the loop again (if necessary again and again) to frame more general statements which can encompass unexplained phenomena more satisfactorily.

In the process of such happenings considering the several sectors of knowledge which are being "looked into" by thousands, in several countries we find that "pure" disciplines in themselves cannot explain many things. To study---as an example---the effect of industrial wastes on the environment, biology is not enough many times. Most surely there has to be plenty of multi-disciplinary effort, we need biophysical ecology which means at least three disciplines at the same time. The mechanisms to ensure this approach is effectively used have to be worked out very carefully.

But this is not the end! We find that lateral movement is frequently required between the various main sectors of knowledge. Observe the utilization of electronics in medicine, for say steadying the heartbeats through a pacemaker, neurobiology cannot be far away.

Hence the organization of research must allow for the necessary inputs by devising a proper system which also permits the free movement of information. After all administration **does** express itself through the types of organizations it devises. A proper structure can permit movement in the right direction. Just as law and order does not in itself generate development but it is an essential backdrop. Hence we must agree there is a basic requirement for having these essential hygiene factors to provide the threshold to productive achievement.

The development of knowledge successively at each stage provides questions to be answered by the next and in the process one goes deeper and deeper into the more specialized aspects of what one is investigating. For example, in the manufacture of sugar, attempts are made to reduce the time between cutting cane in the field and processing it in the factory, because delays cause enzymatic action which converts crystallizable sugars into the non-crystallizable type. It may be added that only the crystallizable type can be recovered as a solid. Plenty of highly specialized work has been done to understand the biochemical microbiological changes that take place. After various types of processing such as extraction, clarification and bleaching the sugary syrup is concentrated and then seeded to encourage crystal growth. When studies are made to understand the crystallization process through an examination of the physico-chemical process are common to several other operations and a lot can be learnt from other branches of knowledge concerned with crystallization.

We must be careful to ensure that in our effort to specialize in a particular area, that we do not lose sight as to how the particular area fits into the larger picture. The view must not be obscured. Otherwise after obtaining the highest efficiencies in obtaining the maximum amount of crystallizable sugars dissolved in the extracted juice, to find that we lose out on account of an inefficient crystallization process. This happens many a time when the more generalized form of expertise required for investigations is forced to adopt

the same means as in the case of the more specialized. The administrative structure must permit the right things to be done.

In the more specialized case, the more dependent we ar on the natural environment both for the problem as well as data acquisition so as to build up a systematic body of knowledge. In the more generalized case we become more self-oriented and depend much more on manipulating data generated **within** the system for development. The flow of work moves in this case from immediate clinical on to the microbiological and thence on the chemical engineering in a kind of smooth continuum. Such continua will be found to exist in all the major sectors of knowledge development. We should recognize this recognize their reality and then reflect it in our methods of getting work done.

The proof of the success or otherwise of any approach or plan lies in results achieved. Look at the early Muslims who were the forerunners of the scientific method ie of making observations and then arriving at conclusions---but that was more than the centuries ago. Did they obtain results? Observations of phenomena were made and patterns were established leading to hypotheses, theories and even laws. Progress followed in ophthalmology; in understanding reflection and refraction; in introducing the pendulum to determine time; in setting up hospitals; in determining the effect of the mind on the health of the body; in originating chemistry; in developing the laws of falling bodies in mechanics; in producing tables of specific gravities; in giving trigonometry its modern form; in ship building; in developing commercial methods; in introducing the Indian system of arithmetic; in astronomy developing catalogues and ascertaining the earth's size, the length of the year, and publishing correct tables of the sun and moon along with verification of the accuracy of the equinoxes; in developing algebra (hisab al jabr wal muqabla) from the germ left by Diophantus, the world algorithm derives from a famous mathematician of Khawarizm.... It would appear somewhere down the line the empirical method has been given an unceremonious burial by Muslims! Hence when we talk of organized research it would be better to now learn from the more recent past ie from the developed world of their approach.

In the seventeenth century a start was made to set up scientific societies eg in the UK the Royal Society was founded in 1663. As scientific knowledge progressed more societies came up and they advanced theoretical understanding of chemistry, of physics, of biology.. both at the increasingly specialized level, as well as at the more general level which cuts laterally across the various sectors off knowledge. This creates problems similar to the coordinative problems between different departments of an organization, with one comment; that in the development of scientific knowledge the language can get most involved. This means if those involved cannot express themselves properly they must be trained to do so. This deficiency can be made good. Systems on the civil side of the governmental process are quite innocent of the requirements of the type of training to make up personal deficiencies. Elementary personnel administration admonishes us accordingly.

By the nineteenth century with the accelerating rate of scientific development the Universities came into the picture. Increasing compartmentalization of knowledge

continued (in fact continues to this day). Just imagine we can be loaded with more than two dozen types of psychology or two dozen types of economics... The University's function is to find the underlying unity in this diversity. This had led to the creation of multidisciplines---consider bio-petrochemical engineering in which a number of disciplines attempt to understand better the processes of synthesizing proteins from petroleum fractions. Or cancer research involving epidemiology, experimental pathology, biochemistry, chemistry, radiobiology, virology, genetics and molecular biology.

Universities in UK are supported in two ways. The first is from their general funds and the second from outside bodies such as the University Grants Committee (who makes block allocations) and to a small extent by industry, to develop intellectual initiative. True this is becoming difficult in view of increasing costs and increasing difficulty for anyone to keep up with progress in their field. But it is also true that the wider ones awareness of the effective the research effort. Hence the necessity of a well stocked, particularly journals-wise, library. As also the opportunity to meet with ones peers frequently within the country and less frequently abroad.

In Pakistan, the necessity of bringing the Universities into the mainstream of activities concerning developing development of scientific knowledge requires more thought. What methods can help? What new organizational expedients are required to be experimented with? This needs discussion.

The three agencies involved are the government, industry (public and private) and the University. Some understanding of the proportioning of resources in basic, in applied and in development research would be necessary. And when we talk of development, it will become ever so much more meaningful to talk of a **development and acquisition** policy. Otherwise with no commitment of acquire the results of developmental work, compartmentalization of effort will be intensified which is a bad thing. Hence it makes make more sense to talk of a research, development and acquisition policy wherever possible. Projecting well ahead it will be necessary to understand the coming implications of the quality and quantity of the output of the educational policy's planning and more importantly its execution. Let us never forget that science is the main factor in national superiority. An educational system that cannot convey a general understanding of science condemns us to continuing ignorance of forces that are changing our future. After all what is the main characteristic of the scientific method? It is docile submission to natural experience.

In the UK with the development of scientific knowledge over the years, in1918 a committee was set up to report on the machinery of government. This committee concluded, in relation to research, that there were two types

- research supervised by administrative departments
- research for general use

The former dealt with problems directly affecting the business of the departments---operational research. The latter the responsibility of organizations such as the Medical

Research Committee and the then constituted Department of Scientific & Industrial Research (DSIR), which were concerned with advancement of knowledge.

Obviously the former would be concerned with the short term and the latter the long term aspects. The short term would be concerned with the immediate practical. Because science does not recognize an international boundary, leave alone a departmental barrier it is the more general research organization (not responsible for implementation) that would further knowledge without having to look up to an administrative department for orders/guidance. This would indicate the requirements of separate Ministry independent of departmental pressures. It is of historical interest to note that the British Medical Research Committee which was to have put under the new ministry of Health (1919), was not. As a result Parliament and the UK were not deprived of a permanent source of informed opinion on a number of matters that cropped up, such as atomic fall out, safety of new vaccines, which was as unbiased as could be expected to any man-made system. Over fifty year later the "Committee of Enquiry into the Organization of Civil Science" endorsed his separation which resulted in the setting up of autonomous Research Councils. In 1962 Sir Burke Trend in considering the organization of civil science supported from public funds took into consideration the fact that while certain departments had their own research establishments (for the more specialized work) that the DSIR had no Ministry hence the specialized work had to be set up by industry and DSIR encouraged it in the form of funding etc. The scope was obviously too broad and DSIR in course of time got overloaded. The Trend Committee's recommendations was to dissolve the DSIR to

- firstly, set up an authority to assume responsibility for research arising out of the specialist industrial experiences and
- secondly, a Science Research Council to be formed to promote unspecialized research in the Universities.

However, one authority, over the years would suffer the same fate if only on account of too broad a remit. This points to a break-up of R&D on a sectoral knowledge basis. The above is of interest to us in Pakistan because our scientific establishments have mirrored those in the early days of the UK.

Professions and Industry

At the provincial level a beginning will have to be made and ways and means found to encourage and motivate industry to go in for R&D. But we must recognize the following

1. Why should industry be motivated to go in for R&D---no matter how well it is academically articulated---if the economic advantages do not promise to outweigh the costs of R&D?
2. For R&D to be really beneficial requires dissemination of the results so as to assist in an acquisition policy. What is to be done in a competitive milieu?

While it is true some exchange of views/information does take place in the Seminars/Meetings organized by organizations such as the Institute of Engineers Pakistan (IE,P) or the Pakistan Institute of Chemical Engineers (PIChE) and several others. All these professional bodies (organized on a national basis) require financial support to permit more productive effort. Too much time is spent in working out the mundane mechanics of organizational day to day living.

Since there is a continuum between research commencing with the

- pure/fundamental/basic and then
- applied thence
- developmental

leading on to full scale production, it is necessary to find ways and means to reduce the resistance between the interfaces. The pure scientist, the industrialist, the engineer, the bureaucrat are **ALL** citizens of this country and there is no reason why a practicable lines of action cannot be formulated based on an appreciation of reality.

The demands of technology centre around the government and industry and it is of interest to note that it has been estimated that in the early 702 governments spending in R&D in the national effort in

- USA/UK/France/Sweden was more than 50%
- West Germany/Holland/Japan was 33-40%
- Greece/Spain was greater than 75%

It is vitally important not to forget that R&D requires not only scientists and technicians but managers apart from demand capital from government and industry) to stimulate and support it.

The national policy laid down by our President, when Dr. A. Salam returned to Pakistan after becoming a Nobel Laureate, inter alia stated.

1. Scientific, technological and engineering knowledge both basic and applied--- will be strengthened, acquisitioned and used for Pakistan's development at all levels. The resources of manpower and funding will accord with international norms. Pakistan's scientific and technological communities will not feel isolated from their international counterparts.
2. The decision-making process for development will have input from the local scientific and technological communities, at all levels and stages of discussion, advice and implementation.
3. Research & development effort will be located with universities, industry or government laboratories, wherever it can make the maximum impact on the country's development.

4. Science and technology policy will endeavour to make the nation as a whole conscious of scientific and technological advances pertaining to the country's development.

From the above it is possible to work backwards and construct the policy, from which the four principles can be derived, as being "To deliberately promote the growth and utilization of science and technology as a means towards achieving, through self-reliance, the socio-economic well-being and security of the country". The President also laid down, prioritywise the following areas that need to be attacked in this decade.

1. Agriculture (including water and allied resources)
2. Energy and Minerals exploitation\
3. Science-based industry
4. Population policies

Generally, it is accepted that our difficulties have been in the implementation of policies rather than in their enunciation. In any case, we must give full credit to the President for his forthright utterance as indicated above. The problem is how can the expressed intentions be converted into practical reality ie how can results be obtained?

All creative workers, the world over, are distrustful of authority. Yet some form of control is necessary because the tax payers money is what is being used. However, freedom for scientific enquiry means it is necessary to put in simple language the requirements of science. That the scientific method must be used to do so, is to tell the scientists/engineers: physician heal thyself! But it can be done, provided the proper type of training is imparted at proper times during the professional advancement of individuals.

Further, in order to encourage creativity at the cutting edge---ie the highly specialized and---the maximum amount of decentralization is required. Policy is expressed not through a definition of technical details but through the overall selection of investments in the various sectors of knowledge. There should be reasonable grounds for the attainment of results but the feasibility decision is an entirely scientific matter.

Two kinds of committees will b required the first

- to reconcile conflicting interests, hence representation of interested parties is required and
- secondly, an expert body to promote knowledge the criterion of membership being PERSONAL MERIT

While a member of the second committee can be a member of the first. But a member of the first would hardly know anything about the promotion of knowledge in a specialized field. What the implications of developing scientific knowledge are, the assessment of the feasibility of meeting a particular requirement through science or an objective appraisal

of adopting a particular course of action involving scientific consideration is only for those who have been scientifically trained to go into such professional matters.

Those who seek to integrate scientific knowledge into social activity must not only be at home in the language of science but also at home in a comprehension of the administrative process. Administrative arrangements for collaboration between adjoining sectors of knowledge and the common problems of technical management need a cross-walks approach and can be done by having the proper representation on a relevant committee. The correct prescription for bringing together the researcher's search for more knowledge and the developer's desire to transfer theory into practice is the key to the successful harnessing of technology. In the USA in 1965 an investigation was made by the Department of Defence to determine what clicked (or didn't) in the 1945-63 era to bring in cost effectiveness in a range of 20 systems examined by 13 teams with mixed government, industry and nonprofit corporation scientists. They concluded that advancing technology was much more in the area of minor improvements than in major scientific discoveries. This study concentrated on invention itself. Another study indicated that invention arose out of developing knowledge that had been generated 30 years or more ago including magnetic ferrites, the video tape, oral contraceptive pill, and the electron microscope. This certainly gives hope to an undeveloped country such as ours that properly organized R&D can help in achieving our national objectives.

Any approach to be successful to produce the proper climate of combination from the immediate results and medium/long term point of view will also require consideration be given to the sensitive human relationships along with the above. Ultimately the limiting factor is human. Hence whatever can be done to improve the effectiveness of existing establishments should take priority, though it may mean making some changes. And any change, even for the better never has unanimous acceptance.

In the final analysis, to use the oft worn cliché, it is the management of change that requires our serious attention. Technological developments are leaving us far behind because of our inability to glance at nature and make observations that will tickle our faculties of logic and reasoning. Va an-laisa lil insaani illa ma sa-aa!

/Some Requirements