DIRECTED BASIC RESEARCH

by

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Abstract

In its execution, and in the requirement of no other deliverables than knowledge generation, 'directed basic research' is no different from conventional (self-directed) basic research. The selected areas are determined in a national perspective. 'Directed Basic Research' may be in an area where the knowledge generation would benefit Indian Society in the long term, or it may be in an area where the results of the research would benefit Indian Industry or our strategic interests in the long term.

India can become a global innovation leader provided we have 'technology foresight' to make the right technology choices, provided we introduce 'coherent synergy' (a phrase I coined a few years back in this context) in our science and technology – related activities and provided we establish an effective 'innovation ecosystem'. We must also selectively promote some technology areas through 'directed basic research'.

Sustainable economic development in the future requires strong and increased funding of basic research. While directed basic research should be encouraged, self-directed basic research should also receive substantially increased support.

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"Technology is Power"

The modern futurologist Alvin Toffler has said many years back: "Yesterday Violence was Power, Today Wealth is Power and Tomorrow Knowledge will be Power". What is the common thread in all this – Technology! So I paraphrase Toffler to say: "Technology is Power". And this is true today more than at any time in history, and this will continue to be so in the future. Technology domination is sought both by companies and by countries, in fields as diverse as human genomics and strategic weapon systems, through the instruments of Intellectual Property Rights (IPR) and Technology Control Regimes (TCR). So, in areas, which are commercially profitable or strategically important, technologies will continue to be denied to India. And India must counter this by becoming self-reliant. I have been saying for many years now that 'self-reliance' should no longer be interpreted as self-sufficiency but as 'immunity against technology denial'.

In today's world, self-reliance also does not mean avoidance of international scientific and technological cooperation. In fact, the latter is a must and today's India must take and must give in equal measure in international cooperation. That is India must go for international cooperation on an 'equal partner' basis and must also participate in international 'mega-science' projects. In the nuclear field, for example, India needs the world in the short term, but there is no doubt that the world will need India in the long term[1].

Technology Foresight

Technology Foresight involves forecasting of possible futures, taking into account existent as well as emerging technologies, with the objective of achieving the maximum economic, social and security benefits. Technology foresight analysis has to be in a national perspective. If you ask questions in this context, the answer may sometimes be different from India and from, say, the United States of America. Examples are fast breeder reactors and rural food processing. It is important for India to reprocess the spent fuel and close the nuclear fuel cycle, because we have limited uranium reserves and the world's largest thorium reserves. U.S.A., with easy access to world's relatively cheap uranium, may put away the spent fuel as 'waste' for decades. But we must remember that plutonium, with its half-life of 24,000 years, is not running away anywhere. In fact, the later you reprocess, the easier it is because other shorter-lived radioactivities would have died down significantly.

Critical Technologies for India

Technology Foresight analysis helps in the selection of critical technologies for development at any point of time. So what are the critical technologies for India today? India is a large country and its technology requirements also correspondingly span a wide range from nuclear to rural. It has to continue to develop strategic technologies – nuclear, space and defence-related. Technologies related to energy security, food and nutritional security, health and water security, environmental security, advanced manufacturing and processing, advanced materials, etc. are all-important for us. So are the so-called "knowledge-based' technologies (Information Technology, particularly hardware; Nanotechnology, particularly nanoelectronics; Biotechnology; and convergence of these technologies like nano-biotechnology for drug delivery). Among all these, I place rural development-related technologies also at high priority.

Nuclear Technology Foresight

The three-stage nuclear power programme is the fulcrum of our efforts in nuclear technology. We are now one of the leaders in the world in Pressurized Heavy Reactor Water (PHWR) technology. We have self-reliance in the entire fuel cycle in this technology. This is the first stage. The second stage involves reprocessing the spent fuel from the PHWRs and using the resultant Plutonium in Fast Breeder Reactors (FBR). A test reactor has operated successfully for more than two decades and the first 500 MWe Prototype Fast Breeder Reactor is under construction in Kalpakkam. By closing the fuel cycle with Plutonium, we can extract 50 times more power from our limited resources of Uranium. For using our vast reserves of thorium, we would then enter the third stage of our nuclear programme. Thorium-232, used as blanket in the fast reactors, gets converted to Uranium-233, which is an excellent nuclear fuel. By going into the Thorium-Uranium-233 cycle which, of course, would require an enormous amount of Research and Development, we can effectively produce 600 times more power starting from a given resource of Uranium. That is why it is so important for India to close the nuclear fuel cycle with thorium. Any emerging international cooperation in the nuclear field would lead to additionalities to our own vigorously pursued three-stage programme. The other components of our nuclear technology foresight are spin-offs in agriculture, medicine and industry and the development of major facilities for Advanced Research. Over the years, the Department of Atomic Energy (DAE) has developed unique and comprehensive capabilities for building facilities like the Research Reactors, the Superconducting Cyclotron, the Synchrotron Sources and the Superconducting Steady State Tokamak. All this has been possible because the DAE has carried out not only applied research and technology development but has also encouraged what can now be recognized as 'directed basic research' in related areas.

Rural Technology Delivery

In spite of a great deal of rural development-related technology efforts, their impact, particularly in the non-farm sector, has not been very significant. A variety of initiatives are now on to correct this deficiency. One of them is Rural Technology Action Group (RuTAG) started by my Office. The RuTAG initiative is based on the realization that active scientists are not the best people for grassroots technological intervention. This is because they are busy in their own areas of research and development. However, if some voluntary organization or a government agency has recognized a problem in a rural area and implemented a technological solution up to a point, the higher-level R&D institutions and Universities can carry it further. Here is where my Office can help to create the required synergy.

We have made beginnings in Uttaranchal and Tamilnadu and are making a start in the N.E. region. Some of the projects taken up at Uttranchal are upgradation of water mills by HESCO through assistance of IIT, Delhi, improved packaging and food processing technology through the help of CFTRI Mysore, water recharge characteristics study through BARC using the isotope hydrology technique, low-cost solar drier through a design developed by BARC, etc. In Tamilnadu, projects have been taken up in the areas of natural dyes (conversion from liquid to powder), improved and energy-efficient manufacturing process for ayurvedic medicines, etc. Institutions such as IIT, Madras, CLRI, Anna University, NIOT are providing technology as well as R&D support. The Rutag Centres for these regions are located in ONGC Dehradun, IIT Madras and IIT Guwahati.

Much of rural technology delivery can take place on the basis of known science, what Gerhard Sonnert[2] calls Baconian Science. However we also need what he calls "Jeffersonian Science" – securing a social need through new knowledge – for rural development.

Academia-Industry Interaction

Reverting to hi-tech industry, we have success stories in atomic energy, space, etc. – the outcomes of successful interactions between academia and industry (for convenience, I am using the term 'academia' to include both the University system and the national laboratory system) . However, the driving force for these interactions came from mission-oriented agencies. Can we have a similarly strong academia–industry interaction when the driving force has to come from the industry? I think that the mindset problem in scientists and industry leaders, which has prevented this from happening in significant measure in the past , is changing in the current liberalized environment. Technology transfer from abroad is becoming more and more difficult because foreign companies can set up shop here and are, therefore, less willing to share technologies. Secondly, Indian companies are becoming more and more globally competitive. I have been told by many industrialists that, even in joint ventures, the foreign companies are trying to buy out the Indian partners! The good news for the Indian scientists is that Indian industry will, therefore, in the future go more and more to Indian R&D for new technology development. If industry begins to interact actively with academia, it can also play a greater role in guiding academic activities in the direction of industry interests, be it human resource development, R&D prioritization, or the choice of areas of international co-operation.

At the end of several academia–industry interaction meetings in 2002 in my Office, we came up with a series of recommendations.

One of them is the following. Very often people with degrees in engineering don't go in for research and technology development, even though they may have a talent for it, but opt for jobs in IT, management, or just go abroad. Now, if the industry were to send some fresh employees (from among those they recruit during placement interviews in academic institutions) - the most talented among them - to do research with professors whom the industry respects and in institutions that they respect, and pay them company salaries, then there would be greater scope for industry-oriented research. The student should be no different from any other student of the professor and his or her work should not be limited to problem solving for the company which is too restrictive. Although the employee-student might not be addressing the company's problems consciously, subconsciously the company's products would manifest in his (or her) thoughts and actions in all professional interactions. Over a period of 4–5 years, he or she could evolve into someone very useful for the company's product or process development. Dr. J.J. Irani, who was actively involved with us in developing this model of interaction, told me recently that this is beginning to happen in the Tata companies and also some others. SMEs (Small- and Medium-Enterprises) have to be dealt with differently. Large enterprises generally have their own R&D centres, but SMEs do not have the resources for trying out a new idea or a new process. Thus, the concept of 'incubation centres' is very important for SMEs. Correspondingly, there must be flexibility in the rules of the academia to encourage interaction with industry, and this is also beginning to happen. It should also be possible to select areas of 'directed basic research' to address the needs of the industry.

The Automotive Sector

Arising from the discussions during the academia-industry interaction meetings I referred to earlier, a core group for R&D in the automotive sector, appropriately called CAR, was formed by my office in April, 2003. Though it is called CAR, this Group deals with all vehicles from two-wheelers to heavy vehicles. CAR is mandated to identifying frontier technologies, so as to promote development of vibrant, world-class automotive systems, sub-systems and parts industries. The group has drawn up a technology road-map for the Indian automotive sector and its recommended programme includes advanced materials and manufacturing, alternate propulsion and automotive infotronics. Projects in these areas are funded for *pre-competitive applied research* jointly by the Department of Heavy Industries, the Department of Science & Technology and my Office. There are also opportunities for selecting areas of 'directed basic research' in the automotive sector. This initiative has had significant success. Following the same model, my Office has set up an R&D Advisory Group for the machine tool industry and is planning to set up one for the electronic hardware industry.

Innovation Ecosystem

A strong and vibrant innovation ecosystem requires an education system, which nurtures creativity; an R&D culture and value system which supports both basic research and applied research & technology development; an industry culture which is keen to interact with academia; a bureaucracy which is supportive; a policy framework which encourages young people to enter into scientific careers; and an ability to scan scientific developments in the world and to use technology foresight to select critical technologies in a national perspective.

A part of the Innovation Ecosystem is courage to take risks on the part of the scientist and support of risk-taking by the S&T system. The greater the innovation, higher is the risk in converting it into a marketable product or process. Ross Armbrecht[3] has said that "the Advanced Technology Programme (ATP) of U.S.A. provides a unique source of early stage support of emerging technologies, those still at a stage in their evolution too risky for any but angel investors". India must initiate a similar programme. He also says that (S.) Korea, while increasing R&D expenditure, is focusing on areas of their strength, viz. telecommunications, electronics, computers and medi-optical equipment – on ten next-generation technologies in these areas. The buzz words in the context, I think, are *'risk-taking'* and *'focusing'*.

Patterns and Priorities in Indian R & D

An important factor which influences the pursuit of R&D in India is what I have called many years back as 'Velocity of R & D'. This is a relative velocity, and is a ratio of the time our peers abroad take to complete an R&D project in a frontier area of S&T and the time we take to complete a similar project. Though things have improved considerably over the last couple of decades, our velocity of R&D is still lower than that in a developed country. There are many reasons for this, including infrastructure weaknesses, communication inadequacies, bureaucratic delays, non-availability of industrial products from local sources, insufficient access to scientific literature, lack of adequate peer groups, inadequate synergy between the national laboratory system and the University system, etc. but the important fact is that things are improving in the country across-the-board. When the velocity of our R&D comes on par with that in the developed countries, India will see spectacular technology growth and we should all work towards that. I have classified[4] the types of R&D work done in India today into several categories. What I then considered important were: basic research; mission-oriented applied research and technology development; country-specific applied research; and industry-oriented research. Now I consider 'directed basic research' also as equally important.

My office took a meeting in December, 2002 with a 'group of scientists' (M.G.K. Menon, V.L. Chopra, R.A. Mashelkar, V.S. Ramamurthy, S.K. Sikka, R. Natarajan, T. Ramasami, R.C.

Mahajan) to discuss the issue of 'Measures of Progress'[5] of science and technology in India. The group observed that a mere count of publications does not capture correctly the progress of the S&T system of the country especially for the following:

- Mission-oriented agencies : DAE, DOS, DRDO;
- Industry-related applied research (for example, in CSIR);
- Country-specific applied research; and
- Application of science and technology for rural development and societal needs.

My office has, therefore, sponsored projects to develop the necessary measures in this context in these various areas.

Directed Basic Research

India is too big a country to absent itself from any field of Science and Technology. But how much it invests in any field at any point of time is a "matter of wisdom" (quoting Frederick Seitz[6]). Current 'exciting' areas of basic research are often, though not always, 'directed' by the interests of the industries in the developed countries or their strategic interests. Examples are high-temperature superconductivity a couple of decades back and Nano-technology now. We must also remember that what is "directed basic research" for the developed countries inevitably becomes a frontier area of 'basic research' for us, if we want to publish in front-line journals. We must be in these areas because usually they also involve excellent science and perhaps also help Indian technology in the longer term. What we should guard against is to prevent such research from becoming 'parasitic' research (excessive collaboration with developed countries, feeding exclusively into the latter's technology system; excessive value given to recognition and accolades from them), because it may distort our own national priorities.

Even Bell Labs has changed its paradigm for research in recent years. The Wall Street Journal of 21st August, 2006, says "Lucent Technologies Inc's Bell Labs, the birthplace of the transistor and the laser, has.... set more of its scientific stars to work on breakthrough technologies that could quickly turn into businesses. .....Steven Chu, who won a Nobel in Physics... says: 'working on applied things doesn't destroy a kernel of genius..it focuses the mind'." India should do this today in 'Nanotechnology', using technology foresight analysis to make the right technology choices in this exciting field. My own choices are Nanoelectronics and Nano-biotechnology for drug delivery.

We should thus select areas of 'directed basic research' in an Indian perspective. The approach could be from the side of societal interest. Examples are basic science behind Ayurveda (in which Dr. M.S. Valiathan is interested), heath-related macromolecular crystallography (in which Prof. M. Vijayan is interested), and megaprostheses implants for cancer-affected patients (in which scientists from TMC, IIT Bombay and NFTDC are interested). The approach could also be from the side of industry or of strategic interests. Examples are nanoelectronics, cyber security and automotive infotronics.

The culture gap that exists between the practitioners of basic research on the one hand and applied research and product development on the other (this gap also exists, though to a lesser extent, even in already developed countries) could be closed through 'directed basic research' and 'pre-competitive applied research' (see Figure 1). In its execution, and in the requirement of no other deliverables than knowledge generation, 'directed basic research' is no different from 'self-directed' basic research. So the University academics should be comfortable with this kind of research.

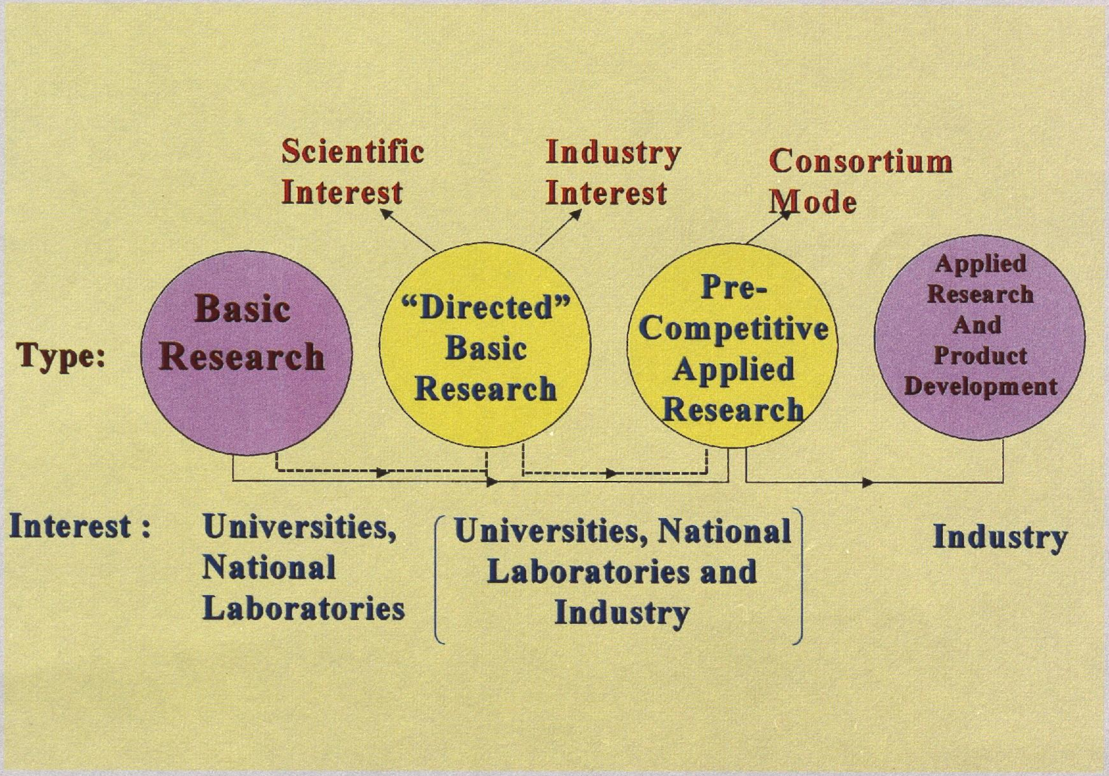

Figure 1. The Linkages among Needed Research and Development Efforts

The Need for Coherent Synergy

('Coherent Synergy' is a new phrase I have defined in the S&T context!)

The S&T System, to contribute maximally to national development, requires a variety of efforts – human resource development, R&D with prioritization, academia-industry interaction, international collaboration, etc.. Every such effort requires synergy among the concerned parties and every synergetic S&T effort gives a momentum for development. And momentum is a vector. All the vectors must point in the same direction for rapid development of the country. This requires space-time synchronization and phase relationship among the efforts. This is coherence. That is, synergy in every effort and coherence among all the efforts!

In R&D (Industrial) globalization, this implies coherence between the motivation of the transnational Corporates and national technology needs[7].

Conclusion

Sustainable economic development in the future requires strong and increased funding of basic research. While directed basic research should be encouraged, self-directed basic research should also receive substantially increased support. The study of the ultimate structure of matter or the origin of the universe, for example, are cultural necessities. You also don't ask a Raman or a Ramanujan why he is doing what he is doing!

India can become a global innovation leader provided we have 'technology foresight' to make the right technology choices, provided we introduce 'coherent synergy' in our science and technology – related activities and provided we establish an effective 'innovation ecosystem'. We must also selectively promote some technology areas through 'directed basic research'.

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