Nuclear Technology and Beyond : The Challenges

by Dr. R. Chidambaram

Mr. Ajit Nimbalkar, Ms. Pratima Doshi, Mr. Arun Bongirwar, Mr. Bharat Doshi, Mr. Prabhakaran, Mr. Chawathe and other distinguished people in the audience.

It is a great privilege and an honour to be invited to give this Lalit Doshi Memorial Lecture and as you heard from Mr. Nimbalkar - many of you knew him personally - he was an ideal bureaucrat. That is why I am very happy that I have been invited to give this lecture.

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Lalit Doshi
1942-1994

- Joined the IAS in 1966
- Specialised in Economics, Management of PSU's
- Headed MIDC & SICOM
- Secretary, Dept. of Housing, Industrial Finance & Planning
- Secretary (Industries), Energy & Labour Department, Govt. of Maharashtra
- Brilliant, Humane, Affable and Admired

I read the biographical papers which were provided by the Trustees; his interest was in economics and management of PSUs, he had headed MIDC and SICOM and held many other portfolios. In Science we go for peer evaluation and I think he was peer-evaluated by the community of administrators and, apart from being brilliant and humane and affable, he was obviously admired for what he did and what he achieved.

I chose this topic of "Nuclear Technology and Beyond: The Challenges", because what I want to say today is that India needs a range of technologies before it can become a 'developed' country in the fullest sense of the term. We need nuclear technology, at the same time we need technologies related to rural development and in between a whole host of other technologies.

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Components of Development

I visited two places recently:
International Atomic Energy Agency, Vienna
Conference on Innovative Technologies for Nuclear Fuel Cycles and Nuclear Power.
HESCO, Uttaranchal : Initiative of Dr. Anil Joshi
Innovative design of Gharats (Water Mills) and Products made by Rural Women
Nuclear-wise, we are no longer a 'developing' country; Rural-wise, we are very much a 'developing' country

I visited two places recently, in September this year. There was a meeting of the International Atomic Energy Agency in Vienna and there we were discussing about innovative technologies for reactors and nuclear fuel cycles; this is because when one talks about nuclear technology, it is not just the reactor, there is a front end and then there is the back end of the nuclear fuel cycle. So you have to make the fuel apart from designing the reactor, building and operating it, and there is the back end of the fuel cycle when we cut open the spent fuel, take out the plutonium, which is a very valuable fuel, and there is also the question of waste management. And here was a seminar which talked about the kind of innovations which are needed to make nuclear more competitive, to make it more safe, more proliferation-resistant and also in the context of how to maximally use the fuel resources that we have, Uranium and Thorium, to get the maximum power out of it. This requires what you call closing the nuclear fuel cycle, taking out the plutonium from the spent fuel and then using it to build more reactors. Then it requires closing the fuel cycle with Thorium, and Thorium, as you know, gets converted to Uranium 233, which is also a very valuable fuel. So if you want to use the resources that we have to the maximum extent, then you have to close the fuel cycle. Without Thorium, the Uranium that we have – along with the plutonium produced from it - will be something like half of our coal reserves. But if we are able to effectively use our Thorium and go into the Thorium-Uranium 233 cycle, then our nuclear fuel resources are three to five times of our coal reserves. But, of course, it will require a great deal of research and development. At the other end, last week I was in Uttaranchal and I visited a place near Dehradun, some of the rural communities there. It is the initiative of a scientist Dr. Anil Joshi and there down the mountain come the streams and the question is how to use that kinetic energy. It has been going on for a long time, they call it Gharats. They have used that energy to grind flour. But what Dr. Joshi had done was to innovate it to simultaneously produce power which is really a micro hydel plant and also use that energy to operate a lathe. So he had put all of these together. In a neighboring village he had empowered women and they were producing a variety of processed foods and other kinds of improved arts and crafts. Whether it is nuclear reactor or whether it is rural technology, it has to be developed on an evolutionary basis. If you introduce a revolutionary design, it becomes more difficult for the people to fabricate and operate it. But if you can improve an existing design and make the people do things which they are capable of doing, but assure the quality, do value addition and then also teach them how to market it and that is what Dr. Joshi had done. So, in a sense, these two represent the range of India's requirements.

If you look at India from a nuclear point of view, the world community does not consider us as a developing country. My friend Mr. Hans Blix used to say you are an "advanced developing" country or a "nuclear-developed" country, but if you look at rural India, which is two-thirds of India, then surely we are a developing country. A great deal more has to be done before we become a developed country.

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To Become a 'Developed' Country!

- My definition of a 'Developed' India: "When the Quality of Life in Rural India becomes comparable to that in the non-urban areas of already developed countries".
- National Development and National Security are two sides of the same coin.
- To become a 'Developed' Country, we have to be not only economically developed but also scientifically advanced and militarily strong.
- What are the 'Measures of Development'? In my opinion: 'Per Capita Electricity Consumption' and 'Female Literacy'

Each one of us has perhaps a different definition of a developed India. My definition is when the quality of life in rural India becomes comparable to the quality of life in non-urban areas of already developed countries. That is the point of time when I will consider India as a developed country. But then it has to take place in an environment of security. No country can develop if it is always afraid of its security. That is why I say that national development and national security are two sides of the same coin. That means, to become a developed country, we have to be not only economically developed but also scientifically advanced and militarily strong. Basically economic development, but it has to be backed by science and technology (S&T) and no technology is static. Technology continuously evolves and, if you have to keep pace with the already developed countries, you must have a very strong scientific community and at the back of it you must have a country which is militarily strong. Many years back I have said that the measures of development for a country like India are two: per capita electricity consumption and female literacy. If you read the Human Development Index list the United Nation brings out, they use three parameters, per capita GNP, life expectancy at birth and adult literacy. I prefer female literacy, because in every region of India, every state of India, female literacy is lower than male literacy, and the difference between them is more the lower the average literacy. I am using it as a measure of development, I am not saying that only the females in India should be educated; I am saying as a measure of development, female literacy is an excellent parameter. If you look at infant mortality plotted against female literacy or plot birth rate against female literacy, you will find strong correlations. India cannot become a developed country until it becomes nearly hundred percent literate and until there is no gender discrimination. But coming back to the first thing, per capita electricity consumption, it is very obvious that per capita GNP and per capita electricity consumption are monotonically related; the more electricity you produce, the more goods you produce, the more services you can provide and naturally you get more wealthy. It is not so obvious that life expectancy in a country like India is also related to per capita electricity consumption. You introduce any kind of electricity producing system, part will go to the industry, part will go to urban consumption, but a part will also go to small towns and villages which will produce better drinking water, better sewage facilities, better primary health care and all these have an effect on health parameters, particularly on the ultimate health parameter, viz. Life expectancy at birth.

If you analyse the data carefully, it is clear that the per capita electricity consumption in India must go up by maybe eight to ten times before India can become a fully "developed" country. Now if you look at the fact that coal is not going to last us forever and there is the question of greenhouse gas emissions, there is already the first symptom of global warming though we are not the people who are causing it; the difficulty in building big hydro-electric projects, because inevitably you displace people; and you realise that non-conventional sources, very important for India, like the solar, the wind and bio-mass, but they are not going to give you big packets of energy. You then realise that if you want to increase substantially the electricity consumption per capita in India, and we are talking about a nearly one order of magnitude increase, nuclear energy has got to play a very important part. Now we have to take our own decisions on this. This is what I was telling the people in Vienna, your perspective on nuclear energy could be very different because your quality of life is already very high and additional energy consumption is not going to make any substantial change in this quality of life and people in developed countries are now beginning to understand the importance of conservation. But the attitude to nuclear energy could be very different, public acceptance problems could be very different when you are desperately trying to improve the quality of life of the people. That's why I want to quote here the famous statement by Homi Bhabha and you have to listen to this carefully. "There is no power as costly as 'no-power'". That is, if you don't have power, you go for alternate sources. You set up your own costly captive plants. If you have a very uncertain power situation, that can be very dangerous for development.

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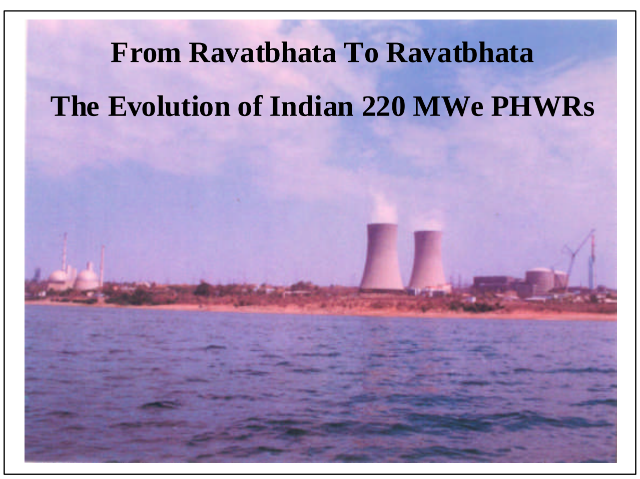

In the nuclear field, we have progressed very well, thanks to the foresight of our founder Homi Bhabha and the pioneers who worked with him. That is why I say we have progressed greatly from Ravatbhata to Ravatbhata. The main kind of reactor we have built so far is, what are called heavy water reactors, pressurised heavy water reactors (PHWRs). The first ones we built with Canadian collaboration and that is why they are called 'CANDU' CAN for Canada, 'D' for Deuterium, because heavy water is used as the moderator and the coolant, 'U' of course for Uranium because natural uranium is the fuel. These reactors, which you see on the left, were built with Canadian collaboration. Because we did the Pokhran test in 1974, the Canadians walked out from a half-built reactor. It took time for us to get our Indian industry to build every thing there, whatever had to be done. But now we are self-reliant, hundred percent of what we need for our nuclear reactors is now built by Indian industry not just by the Department of Atomic Energy. We have got leading industries and also a number of smaller ones which supply all the components that we need. The Indian industry in the last ten / twenty years has progressed tremendously. So the kind of products that we get, the kind of services that we get is extremely good and that is why you find that the capacity factors of nuclear power plants have gone up very very substantially. That is why I say this kind of reactor, two units of which were dedicated to the nation a couple of years back by the Prime Minister, are among the most modern ones in the world. The more impressive part of the reactor for looks, is not the reactor but the cooling tower; the reactor is relatively small. Looking at the kind of technical advances that we have made there, the International Atomic Energy Agency often calls it not CANDU but INDU - 'D' for Deuterium, 'U' for uranium but CAN replaced by IN! This is because for twenty-five years we have had no contact with the Canadians and all the developments which have taken place have been by the Indian scientists and engineers.

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NPCIL

- a. Among PHWR's around the world, Kakrapar unit had the highest capacity factor of 98.4% in 2002.
  b. Average capacity factors of Indian PHWR's 1% more than LWR's of USA in 2002.
  (CANDU Owners' Group, Jan/Feb 2003)
- Eight reactors under construction, to add 3960 Mwe to present 2720 Mwe. Also 500 Mwe PFBR to start soon. Target for 2020: 20,000 Mwe.
- Gestation periods coming down, good internal resource generation

Look at the performance of the Nuclear Power Corporation of India (NPCIL) and this is symptomatic of the state of Indian science and technology and of Indian industry. Whether it is the automotive sector – Dr. Pawan Goenka I saw somewhere, he and his colleagues make Scorpio, Dr. Sumantran with the Indica design - or nuclear power plant, this is indicative of India's development.

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Nuclear Technology Foresight

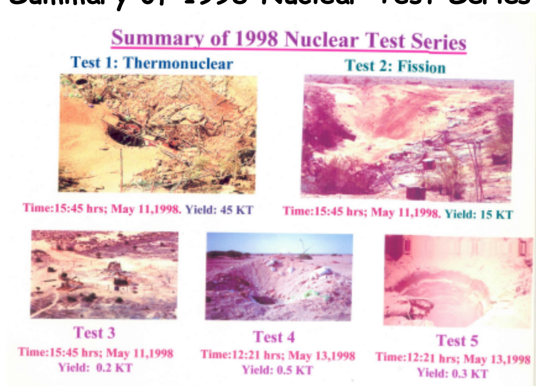
- Three-stage Nuclear Power Programme
- Credible Minimum Nuclear Deterrent
- Spin-offs in Agriculture, Medicine and Industry
- Development of Major Facilities for Research

That is why we have a very strong support from the Government for the nuclear power programme; eight reactors are under simultaneous construction and work on the Prototype Fast Breeder Reactor (PFBR) is going to start soon, the gestation periods are coming down continuously.

Of course there is the other side to it, nuclear is electricity, but nuclear is also weapons.

Slide Seven

Summary of 1998 Nuclear Test Series



These are the five nuclear tests that we did in May 1998; you are familiar with this. We tested a whole range of advanced nuclear weapon designs. All the scientific objectives of these tests were fully achieved. Everybody realizes that this has been done on the basis of self-reliance.

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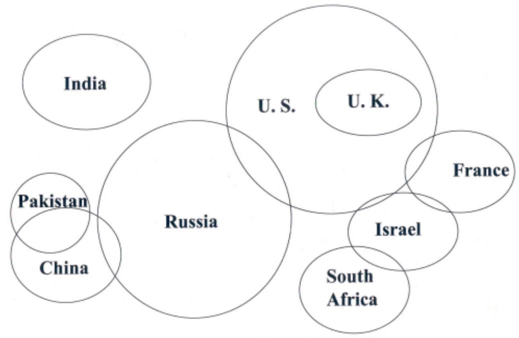
Historical Sharing of Nuclear Weapons Knowledge
(from Paine & Mckenzie, 1998)



Historical sharing of Nuclear Weapons knowledge (from Paine & Mckenzie, 1998)

I have adapted a figure from an article by Paine & Mckenzie. Of course they were talking in the context of the United States' Nuclear Weapons stewardship programme, following the cessation of the nuclear tests. But in that article, they have shown what is called a Venn diagram. If you are still teaching mathematics to your children or more likely grand children, you will know that this is from set theory. If two sets share something, they intersect. What he is talking about is sharing of nuclear weapons knowledge. Intersection between Russia and the United States has nothing to do with spying, both of them are bringing down the number of nuclear weapons they have, from a higher astronomical figure to a somewhat lower astronomical figure! The Russians have a lot of high enriched Uranium and Plutonium to dispose off. The Americans are buying and the Russians are handing over without remelting the pits. Because melting this nuclear component is almost as expensive as making it in the first place. Not worth it! And anyway both of them know all about nuclear weapon design. Not that we don't know it! So they are handing the pits, as they call them, as they are. And that is what the intersection is about. Transfer of knowledge is indicated also between U.S. and France, Israel and South Africa, Russia to China in the early days, China to Pakistan and as you see there India stands alone. So they concede that, in the field of nuclear weapons development, India's program was based totally on self-reliance.

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Rural Development – Related Technologies

We had two meetings in the PSA's Office on rural technologies. There are two Approaches.

- Collect all information on successful dissemination of technology in rural areas. NIRD, Hyderabad has prepared a Directory of rural technologies (in four volumes). CAPART has also prepared directories of such technologies. There are also directories of CSIR and ICAR developed technologies.
- Find the problems in the field at taluka/district level and identify technology solutions. The two approaches must converge.

Also need to downsize technology for rural development (7-9 October 2003, International Conference, RRL Bhubaneshwar)

Now we go to the other side – Rural Development Related Technologies. In my office (Principal Scientific Adviser) in Delhi, we have had a couple of meetings. There are basically two approaches. There is a National Institute of Rural Development in Hyderabad, they have made a directory of four hundred rural development related technologies and it is coming in four volumes. I have been suggesting to them, if they can bring it down to may be twenty or a couple of dozens, which have been successful on the ground, and this is what they are now trying to do. CAPART (Council for Advancement of People's Action & Rural Technology) has also prepared similar directories. There are also directories of technologies developed by CSIR (Council of Scientific and Industrial Research) and by ICAR (Indian Council of Agricultural Research). One way to look at it is, these technologies are now available. Is it possible to apply them in other places in India? If somebody is able to go and work in the rural areas, find out what are their technology needs, what are the possible technology solutions and then select out of the existing technologies, those which are applicable for these areas; the S&T institutions can then help in further adapting the technologies to the local situation. And very often there are differences. What you need in Rajasthan may be different from what you need in Uttaranchal. And what should be done is to bring these two approaches together. You also need to down-size technology. This has been done very well in milk and in leather. Very often we talk about economy of scale, higher the size, the lower the cost of the product. But the positive side, the other side of it is, for India, that our raw material is distributed.

Even if it is talk about leather, we take dead animals, it happens all over the place, and here the question is how to downsize technology. On the one hand you lose economy of scale and on other hand you take advantage of the fact that the raw material is distributed. That is why we are organizing a conference on downsizing technology for the rural development.

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Rural Technology Dissemination

Successful NGO's – MSSRF, (Village Knowledge Centres) BAIF, TERI, CDA, HESCO…,
Govt.Agencies – KVIC, CAPART,……
Administration – District Level
Industry - e-Choupals (ITC) etc.,
CII group on Rural Development
The challenge is to establish synergy among these efforts, which are often fragmented, and to nucleate new initiatives.
RuTAGs – Rural Technology Action Groups being conceptualised by my office for this purpose

Take simple things like rice milling, for instance Buehler India makes equipment for milling ten tons per hour, TIFAC (Technology Information, Forecasting & Assessment Council), with which I am associated, asked them can you make equipment for two tons per hour, which is more suitable - not yet for the smallest fellow - but still for a reasonable size industry in small towns and villages. And they have done it. We should downsize such equipment even further. And another thing is that a number of NGOs have been very successful in India. We have BAIF (Bharatiya Agro Industries Federation) in Urulikanchan, near Pune. Very impressive. Inaugurated by Mahatma Gandhi in 1946 and then it was Shri Manibhai Desai who built it up. In animal husbandry they have done some extraordinarily good work and TIFAC has helped them through Indian Institute of Immunology in developing embryo transfer techniques in order to propagate faster the high breed cattle. M. S. Swaminathan Research Foundation in Chennai and so many others, HESCO (Himalayan Environmental Studies & Conservation Organisation) I talked to you about in Uttaranchal and so on. Question is, we need more of these. We must do something to nucleate more of these S&T-inclined non-governmental organisations, who seem to be familiar with what is needed in rural areas and then are able to take technology there. Of course, there are government agencies, KVIC (Khadi & Village Industries Commission), CAPART, we had meetings with all these people and then companies are beginning to do more and more to provide rural technology support. The e-Chaupals of ITC seem to be a very good idea. There are also village knowledge centers. I saw some in Pondicherry set up by the Swaminathan Foundation. What they talk about is giving them locale specific, demand-driven information. We also have a project with Swaminathan Foundation on how to improve the livelihood of people living near coastal nuclear power stations. Because he is interested in coastal systems research. Preserve the ecology of the coastal region and how to balance it with improving the livelihood of people who are living there. For example, Kudankulam Power Station. We have a project there. There is a fishermen community with whom they are working. What they are looking at is not the weather map that you see on our TV every day. But they want to know if I go out fishing today, will I come back safely day-after-tomorrow. So what will be the height of the waves for the next twenty-four to forty-eight hours and this kind of information is now available through National Remote Sensing Satellites. There is a whole institute on Ocean Information services in Hyderabad operated by the Department of Ocean Development and there are some data from buoys, there is global ocean data now very easily accessible. So that is what we should be doing and this is now expanding. Shri Prabhakaran was telling me about the tele-education Satellite of the Department of Space. And all this requires, of course, establishing synergy, synergy among efforts which could be fragmented and we should also nucleate new initiatives. A lot of resources in India are not fully utilized. People who have retired, for example. I think, for the next ten years after retirement they have got a lot of energy, skills and ideas which you can make use of. Similarly there are retired technical people from the armed forces settled in rural areas and so on. Very often I found that when I go to our project sites, nuclear project sites, in somewhat remote areas, the resources of women – the wives of scientists and technologists - are not fully utilised, there are teachers, lawyers and doctors and engineers among them and unlike in big towns, Bombay or Delhi, these are people whose resources we could make use of and that is why we are now thinking, whether we could nucleate rural technology action groups (RuTAGs). They could act as an interface. Many organisations are doing excellent rural development work but may be they lack some technology inputs. There are resources in India which we can make use of for providing this.

Slide Eleven

Academia - Industry Interaction : The Issues

Several meetings in P.S.A.'s Office last year

- The Mindset Problem – of Scientists and Industry Leaders! This is changing in the present liberalized trade environment
- Different Mechanisms – Mature Industries and New Industries: Technology upgradation and completely New Product/Process development require different approaches.
- Role of Industry in guiding academic activities in the direction of industry interests – HRD, R&D Prioritisation, choice of areas of international cooperation, etc.

We have success stories in Atomic Energy, Space, Chemical Industry, etc.; What can we learn from them? Also, from our failures!
In the case of Atomic Energy, the drive for the interaction came from DAE, the Industry took no risk! The push must now come from Industry

Now you go to the other side, academia-industry interaction. Here I use the word 'academia' in a broad sense for convenience to include universities, national laboratories and other institutes, excluding, however, the in-house R&D centres of industry. Eighty percent of all our R&D expenditure in India is provided by the government. Many countries, Japan, South Korea, to some extent even the Unites States, most of the money comes from Industry. Private Industry by and large does not take up speculative long-range R&D projects. Naturally, they look at it from their own perspective, that is why nuclear R&D has come down in the United States. In fact, I have been telling them that the nuclear heritage is likely to be preserved in Asia, India and China, which have very strong and growing nuclear programmes. You are only fighting for preservation, I am fighting for growth. Knowledge management in these two cases has to be done with different perspectives. Coming back to academia-industry interaction, things are changing now. So far there has been this mind-set problems. The Industry has always said scientists are working on areas which is not of their interest. And scientists have been telling them that you are producing shoddy goods using second rate-imported technology. Why would you need R&D in any case. But things are now changing. In this liberalised environment one finds that technology transfer to India is going to come down. It is coming down. In joint ventures, the foreign guys are buying out the Indian partners. Of course we will have to access technology abroad. I am not saying you should go reclusive. But technology transfer has always been difficult in strategic areas, for strategic reasons.

It is going to get equally difficult in commercial areas as Indian products become more and more competitive, manufactured products in the international market. You must use different mechanisms for different industries. Matured industries and new industries. Suppose you are making a product for the first time, you are designing a drug molecule for the first time and I must say the Pharma industry is doing very well, relatively speaking, compared to, say, IT in the context of research. Biotechnology and Pharma industries have gone for R&D much more aggressively. Because they are looking for their own molecules and products. New molecules for treating various kinds of diseases. Mature industries must have a different approach; it is not as though we are not producing steel or fertilizers or sugar or whatever or many other kinds of machinery. But you want to make better products. We want to make them more cost efficient, more energy efficient. This requires technology upgradation and this has to be viewed somewhat differently. In fact, the interlocutor from the industry side was Dr. J. J. Irani from Tata Sons. Of course we talked to a lot of industrialists, a lot of academia people; Dr. Irani understands both the R&D side and the industry side. He says that in the case of mature industries the scientists have to go to the plant and look at the problems in the plant environment. To develop a molecule we can do it in the lab but if you want to improve the quality of steel or heavy water, make it more energy efficient for example, somebody has to work under the plant environment. Of course, if the industry begins to participate and begins to fund more substantially in R&D, it will have a greater role to play in guiding academic activities in the direction of the industry's interest. In human resource development, prioritisation of the R&D or if you go for international collaboration, then industry can have greater say in choosing the areas of cooperation. You have had success stories of academia-industry interaction. Take my own familiar field of atomic energy, very strong interaction between academia and industry. When I say the nuclear power plant is built indigenously in India, it is done by Indian industry. Based on research and development carried out by the Bhabha Atomic Research Centre and other Centres. But the driving force for this has been the Department of Atomic Energy. The industry has not taken any risk. When you give them a development project it goes by the cost plus twelve percent. So they have not taken any risk. Now the time has come that the motivating force, the driving force has to be the industry.

Slide Twelve

Academia – Industry Interaction : The Action Points

- Industry should send some of the fresh employees for research in institutions and with professors, for whom they have respect. This suggestion has elicited encouraging response from industry leaders.
- Academia expertise should be utilized by Industry for technology assessment, upgradation and absorption; to ensure acquired technology is suitable for indigenous raw materials, indigenously fabricated equipment.
- Incubation Centres for SME's. (Small and Medium Enterprises)
- Flexibility in rules of Academia to encourage interaction with industry. IIT's, IISc, etc. are willing to play a more pro-active role

If they want to improve their product, then they have to seek out R & D partners. We came to some action points. The first suggestion I made seems to be picking up. It was not as though there is no interaction between academia & industry now. People do sponsor candidates for specialised courses. Industrialists have been associated with even IITs. Shri Rahul Bajaj is the Chairman of Board of Governors in IIT, Bombay at the moment. But what we are now talking about - of course scientific research is a different issue - is engineering research. Young people who are extremely talented in engineering research and technology development are not going to those fields. They are going in for management and until recently for software or may be even abroad. So one of the suggestions we made was suppose a fraction of the employees who are hired by industry during placement interviews, whom they consider very talented. Suppose they send them for research, give them company jobs, company salaries, but let them go and do research. I am not talking of problem solving that will put the young fellow in a straitjacket. But let him or her be like any other student, let it be in a broad area of interest to the company, but let it be with a professor for whom the company has respect, then what will happen is during the four/five years he is working in the company, he is sub-consciously thinking of the company's products. When he goes to an international conference, when he meets foreign professors, he will get information, which is important for the company. And our industry should realise that information access is very free in the academic community. A professor talks to another professor from abroad, he will tell him what he is working on, for which company, why he is doing what he is doing. But the moment a company scientist or a technologist tries to ask the same question, the doors begin to close. And the doors get closed totally when proprietary product or process development takes place. So the Indian industry will gain a great deal by having their young people in R&D laboratories, who will, hopefully, later on join the company. And, of course, academia expertise should be utilised by the industry for assessment and upgradation. Even when they import technology, I have heard cases where the import has been made, but the equipment is unsuitable for Indian raw material. It is so obvious to a scientist that he could have told it in the first place that this kind of technology, this kind of equipment will not work with Indian raw material. Small and medium enterprises have to be dealt with in a slightly different way. I understand that Shri Lalit Doshi was also interested in small and medium enterprises. Big companies have an R&D Centre or at least have imbibed the culture of research and development to some extent, though, in my opinion, not adequately. But small & medium enterprises even if they have a good idea, they don't know where to go and try it out, a new kind of process, a new product, a new kind of raw material; incubation centres, in institutes or departments, where such related work is going on would be valuable so that they can also interact with specialist scientists and use advanced equipment and facilities. So these are all the decisions we came to in the series of meetings that we had. And, of course, correspondingly there has to be a change of attitude in the academia as far as interaction with industry is concerned. In the leading institutions, professors must be allowed to work with industry, not with reluctant approval but with pro-active push and hopefully things are changing.

Slide Thirteen

Automotive Industry – Database and beyond

Suggestion made by Mr. Rahul Bajaj in one of the Academia-Industry interaction meetings in the P.S.A.'s Office last year to create a user-friendly database of Scientists/Professors willing to and capable of interacting with Industry. Concept Expanded to include Frontier Technologies. Core Group on Automotive R&D (CAR) constituted – with leading academia scientists, industry technologists and representatives of SIAM and ACMA - to prepare roadmap for cooperative R&D programme to support Indian automotive industry. Six Expert panels created in specific technology areas.

TIFAC is the secretariat for this effort

I would like to give the automotive industry as an example, because this is an industry, which has grown quite a bit in recent years. In one of the meetings Shri

Bajaj said that: "even if we want to interact with academia, we don't know whom to interact with. Can you make a database of professors and scientists willing to and capable of interacting with the industry?" This has snowballed very nicely. In the sense that I have two co-chairmen of the group, one is professor of Indian Institute of Science and one is an NRI who was till recently the President of International Society of Automotive Engineers. And then we have got all these people. I mentioned Dr. Pawan Goenka, a very active member, who is chairing one of the panels. Because the group said that not only should you have the database of people but you should also identify the technologies, which are important for the Automotive Industry in the future. Tomorrow's car, one person was saying, is forty-percent computer on wheels. So many embedded systems carrying out well-defined functions. In fact, the Automotive Industry we picked up as a starter because this is one industry, like IT software, which is beginning to challenge the world industry. Mr. Shahed said that today, in the Automotive Industry, either you play on the global stage or you will have no stage to play on. This is getting more and more true of many, many industries as India develops. Six per cent growth rate is passe now. P.M. wants eight percent. Indian industry thinks it is possible. Shri C. K. Prahalad says ten to twelve percent is possible, provided you get your act together. If China can do it, why we can't do it. You know, any physical phenomenon - capacity factors of nuclear power plants or anything else – the improvement at the start is fast and then it saturates off. Four minute-mile, it was achieved, but beyond that it gets tougher and tougher. We are in the starting stage and that is why very high growth rates are possible in the initial stages. We can grow at ten percent but America cannot grow at ten percent. There is no place for them to grow. Their growth has got saturated.

Slide Fourteen

Genetic Algorithms and Technology Development

GA's are ideal optimization tools to search for the global minimum or maximum of functions spanning large multidimensional and non-linear spaces.

This technique can be used to search for optimum technology-related solutions to national problems. Enhancing Academia-Industry Interaction, role of RuTAG, etc

Here is where I think I should tell you about genetic algorithms. The interface between physics and biology is becoming more and more important. When we talk about biophysics, that is use of physical techniques in biology. Now we talk of biological physics. That's treating biological systems as complex physical systems. People working in soft condensed matter are working now on complex biological systems. Here is where it is also nice to observe how nature operates and copy from that. Neural networks all of you have heard of. It is one method of optimizing. Finding optimized solutions. Genetic algorithm is something which is now catching on. It is again an optimisation tool. You have a problem. Each one of the possible solutions, you consider as an individual. And you treat an individual like a linear chromosome. Put it all in the soup and you are now trying to see which is the chromosome, which is the best optimised solution for you. Some of them are so wildly off you throw them out. Part of one solution is good and part of another is good. So you can have a crossover. You can mutate a solution. This is how, in an iterative process, you can find out what is the best solution to a problem. I was in the Centre for European Nuclear Research (CERN) in Geneva where they are building what is called the Large Hydron Collider, the world's biggest accelerator. This is an accelerator located 100 metres below the ground, 26-kilometers in circumference. The particles go round and round. They are accelerated by high voltages, bent by magnetic fields. The particles are allowed to collide once in a while and when a collision occurs, energy disappears and new particles are produced. This is how high energy physics experiments are done. This is how they look for new particles and they are looking for the Hicks Boson now. So as the bending magnet design should not only bend the particle the way you want but, for example you can put in factors like it should be easily fabricatable. And this kind of thing you can do using the genetic algorithm. You are not looking for an exact mathematical solution. This is an optimisation problem. I think the same thing should be used for technology-related solutions to social problems. Very often a funding agency or an administrative body is requested for bureaucratic approval. The answers given are yes or no. Not good enough for India anymore! Somebody is asking for something, probably has some good idea in his mind, the aim of all us together must be to find how to do that; if this is not the way to do, find out which is the best way to do that. Help him along. This is where I have a feeling whether you are looking for rural technology solutions or you are looking for academia and industry interaction, this is one thing one can look at.

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PURPOSE OF TECHNOLOGY DEVELOPMENT

- Creating National Wealth
- Improving Quality of Life – particularly in rural areas
- Enhancing National Security – including Food and Nutritional Security, Energy Security, Health Security, Water Security etc

We must be clear in our mind why do we want to develop technology. You want to create national wealth, you want to improve the quality of life, particularly in rural areas, and you want to enhance national security. National Security you can define, not just as military security, but as food and nutritional security, health security, environmental security and so on. For this you must choose the right critical technologies.

Slide Seventeen

Technology Foresight

- The choice of technologies for development requires technology foresight – forecasting plus assessment based on social, economic and security issues, on national resources and on infra-structural strengths. The answers to some questions may be different for India and for developed countries, e.g., on the desirability of fast breeder reactors and rural food processing

That is, you ask the question, at this point of time, where would you put your major emphasis in technology development and this requires technology foresight. Examining all existant and emerging technologies and deciding what technologies are important for us and sometimes, the answers you get from here may be similar to the answers you get from, say the United States. But sometimes the answers could be different. Fast Breeder Reactors! We say emphatically yes. The Americans say not now. For us with limited resources of Uranium and world's largest resources of Thorium it is very important, very quickly to take the plutonium out, put it into Fast Breeder Reactors, that is reactors which produce more fuel than they consume. Use Thorium as blankets there, convert Thorium to Uranium 233 and go over into the Thorium-Uranium 233 cycle. The United States has access to the world's Uranium and right now Uranium prices in the world are running cheap. Why would they bother about reprocessing and making more costly plutonium? Though fuel is not a big factor in the total energy cost, they say we don't reprocess now and we put away the spent fuel as waste. But remember, that spent fuel is not running away anywhere. Plutonium has a half-life of 24000 years. The later you reprocess, the easier it is to reprocess because the other radioactivities would have died down. So when you ask questions on whether Fast Breeder Reactors are important, whether reprocessing of spent fuel is important, you get one answer in India and get another answer in U.S.A. Rural food processing! Why would they bother about rural food processing. But when I went to Uttaranchal, I saw women making some absolutely fancy - I have not seen rhododendron juice, apparently it is a very healthy drink - being made there. Question now is how to ensure the quality of the product, make it of international quality and give them marketing outlets.

All this will require technology foresight and technology foresight requires a national perspective. We must have a global vision and a national perspective. The choice of critical technologies has to be backed by Research & Development.

Slide Seventeen

What Kind of R&D is Important?

Globally Competitive Basic Research
(Without too much concern about impact on Indian Technology)
AND
Research and Development which feeds into Indian Technology

If you ask the question what kind of R&D is important, I would say: globally competitive basic research. Basic research is a cultural necessity. You don't ask a Ramanujan or a Raman why he is working on, what he is working on. Any civilised country must allow its highest intellects to work on fundamental problems of their choice. But everything else must relate to Indian technology, must relate to the critical technologies which you have selected for development and to the needs of industry.

Now there are two expressions, which I have been using and let me talk about them a little.

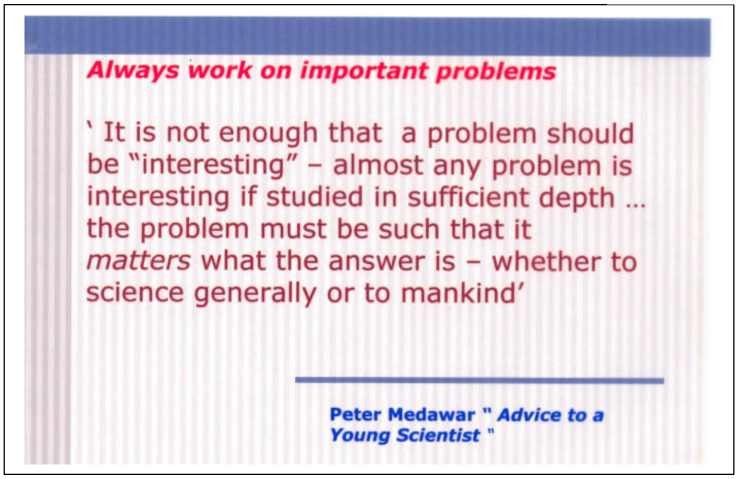
Slide Eighteen

Velocity of Research & Development / Self-Reliance

- I defined many years back a term called 'the Velocity of R&D'. This is a relative velocity and is continuously improving. When we reach the levels prevalent in developed countries, India would see spectacular growth rates.
- Self Reliance: Immunity against technology denial. And we seek international collaboration on equal partner basis. We should participate in mega science projects – whether they are in high-energy physics, genomics or information technology

I defined a term called velocity of research and development, many, many years back. Suppose there is frontier area of science or a frontier technology. There is nothing that we cannot do but we take a longer time doing it. The 'velocity of research and development' is a relative velocity. You divide the time our foreign competitor, our foreign counterpart in a developed country, takes to do the same thing and the time you take to do the same thing. It is like participating in the Olympics but waiting for one PT Usha trying to get or a Leander Paes to get one bronze medal once in a while. Suppose you push it forward, our velocity of research and development, and it is improving continuously over the last couple of decades. Because information access is much better, peer evaluation is much better, of course bureaucratic procedures must also get speeded up. If all this happens then India would see spectacular growth rates. When I talk about a national prospective I am not talking against international collaboration. International collaboration in science and technology is extremely important. Even in that Large Hydron Collider I was telling you about, the sextu-pole magnets and the deca-pole magnets, for focusing the beams - a thousand and more of them - they are being supplied by the Department of Atomic Energy. Similarly in trying to delineate the rice genome, the Indian Institute of Agricultural Research and Delhi University, now they are working together to delineate one of the dozen chromosomes which are there in rice. So whether it is high energy physics or information technology or genomics, India must be present. India is too large a country to absent itself from any field of science and technology. But how much you invest in any technology at any point of time is a matter of wisdom and careful analysis. We have to be careful and set our priorities right and that's where this technology foresight comes in.

Slide Nineteen



I like to quote the famous biologist Peter Medawar to my students from the marvelous book he has written on 'Advice to a Young Scientist'; may be it is good advice also to the old scientists or young anybody or old anybody! It is very simple, it says always work on important problems! He says that the problem you are working on should be important either to science or to society; anything you work on long enough becomes interesting but he says that is not good enough, you must also look for what is important.

Slide Twentv

Synergy

To make India into a 'developed' country would require efforts in many aspects of Science and Technology. Each of these efforts must have Synergy among the concerned parties. The interaction between academia and industry should increase. The National Laboratory System and the University System should work together in the area of human resource development. The Academia should synergise with the government to suggest policies, which improve the S&T environment in the country. And so on

And here is where I come to the last part of my talk and what India needs is what I call - it is a new phrase I have coined – 'Coherent Synergy' and I will explain to you what I mean by that. Suppose you take the science and technology part of development, it requires a number of efforts - human resource development, academia-industry interaction, which I talked about, prioritisation in research and development, policy of the government, areas of bilateral or multilateral cooperation, international cooperation. All these are the components of S&T efforts, each one of them requires synergy. Synergy in any effort gives you a momentum for growth and momentum is a vector and if you want to go fast in the kind of things we are now talking about, obviously all the vectors should point in the same direction. For example, there is no point in doing applied research and development in an area for which there is no demand in the Indian industry.

Slide Twenty-one

COHERENCE

Collectively there must be coherence among these efforts. The human resource development initiatives must match the choice of critical technologies, otherwise the trained manpower would tend to drift abroad. The R&D priorities in applied research must correspond to industry needs. We must be more pro-active in selecting areas for international S&T cooperation so that these areas relate to current national imperatives. And so on

And this where I say collectively there must be coherence. I forgot to tell you a little bit on the self-reliance. As I said we need international cooperation; self-reliance is no longer self-sufficiency. In the beginning when India became independent, you did anything for the first time in science and technology you felt happy. You built the Apsara reactor and felt happy, but today you have to be globally competitive. If Shri Anand Mahindra makes his Scorpio it has to be world-class and that is why I have been defining in recent years 'self reliance' as immunity against technology denial. If something is available to you from outside, which you want to put in a complex system, so that it is more efficient or cost-effective, why not. But if anything is denied to you, you must have the capability to do it yourself. International collaboration backed by self-reliance is what we need. The more self-reliant you become, more and more things will come to you automatically from outside. We are seeing it in the computer area. Take super computer development. The more we developed our capability in this area the denial to us decreased, the threshold for supply went on going up. The parallel processing super computer development efforts have been a very successful achievement in India, including by the Bhabha Atomic Research Centre.

Slide Twenty-two

The Need for Coherent Synergy

Synergy among concerned parties in every effort

Coherence collectively among all the efforts

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 coherence. Synergy in any effort, of course, has local coherence; but in 'Coherent Synergy', I am suggesting global coherence.

'Coherent Synergy' is a new phrase I have coined! Though I introduced it in the general context of our S&T system, equally valid for Technology Driven Industry, or for that matter, for any major national effort

So, let me come back to what I think is the solution to India's problems! 'Coherent Synergy'! Synergy among concerned parties in every effort and coherence collectively among all the efforts. Of course synergy itself has coherence, but that's local coherence, obviously the parties involved must work together coherently, but what I am talking about in this term 'coherent synergy' is global coherence. I have used the term in the general context of our S&T system, but I think it is also valid for any technology driven industry or for that matter for any major national effort.

As I said before, I am extremely happy to be here with you, we have had excellent bureaucrats in the Department of Atomic Energy with whom we have worked, many of them have gone on to occupy very high positions. Shri S. Rajgopal became Cabinet Secretary, then we had Shri T. N. Seshan, Shri N. Vittal and so many others with whom it had been a great pleasure for me to work with. And that's why, among other things, and of course after reading Shri Lalit Doshi's biography, I was extremely happy to come and be with you today. I wish all the best to his family and his daughter. Thank you