Priorities in science and technology for development: Need for major restructuring

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The paper presents and analyses the considerable distortions in our national S&T priorities as reflected in atomic energy, space and defence R&D being allocated around 65% of the Central Government R&D budget (which itself is 65% of total national S&T budget) and the serious neglect of R&D in health, biodiversity meteorology, non-conventional energy and ocean S&T and resources. It also analyses the weak institutional structures in the latter set of sectors for both their internal management and for promoting and utilizing the results of S&T performed by them, and proposes institutional reform of the S&T agencies concerned to overcome those weaknesses. A similar analysis is undertaken of the serious situation in regard to research in the university system. It proposes a new mechanism for consciously setting national R&D priorities involving the Planning Commission and the Scientific Advisory Committee to the Cabinet. The paper also calls for not only the total outlay on S&T to be increased from the present 0.9% of GDP to at least 1.5% by the end of the Tenth Plan, but for much of that increase to be allocated to the 'neglected' areas/sectors.

Our present development predicament

The country is facing grim scenarios in many basic areas in the coming decade unless major corrective measures are taken urgently. The Green Revolution, it is now clear, is exhausting itself. Yields of rice and wheat, except the revolutionary new hybrid rice, even in the nation's principal granary, the Punjab, are falling. The recent drought in some western and central states is not an isolated development, but part of a major water crisis which the World Watch Institute has described as 'India Heading for Hydrological Poverty'[1]. The energy scenario is grim. The rates at which consumption of petrol, diesel and LPG are being allowed to grow and the failure of domestic crude oil production to grow in the last decade and even today, will present us with a huge crude oil and natural gas bill by as soon as 2010. Coal production is also static and no major plans and programmes have been announced by the government to not only restore its earlier growth rates, but increase them further. As M. S. Swaminathan[2] has observed, large areas of our country have already been ecologically devastated. Some 300 million persons constituting the poorest segments of our society suffer from poverty-induced hunger. Every third child born is underweight, i.e. has a body weight of less than 2.8 kg, due to acute maternal under-nutrition. The situation regarding primary and secondary education is no less grim.

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How can we design a Strategy and Action Plan for making India a knowledge superpower on such an appalling foundation in terms of the key raw material needed, viz. a healthy and educated population? As Mashelkar (Director General, CSIR)[3] has put it, 'Never before in the history of mankind has a country with a democratic dispensation, had to feed so many poor and teach so many illiterates and also *simultaneously* compete with the most advanced nations for a place in the Sun'.

Tackling these daunting challenges will call for a multi-faceted strategy, but S&T is likely to play a major role in it. However, how can S&T play that role, when the annual budget on R&D relating to health, communicable disease control, nutrition and family welfare all put together is only around Rs 350 crore[4] and we are spending Rs 2500 crore on defence R&D and Rs 800 crore on atomic energy R&D[5]? When the annual budget for R&D in meteorology, an area of such crucial importance to our agriculture, water resources and natural disaster prediction is only about Rs 130 crores[6], the budget for the Botanical and Zoological Surveys which are the linchpins of the inventorization, utilization and conservation of our biodiversity[7], is only Rs 15 crore each.

The Annual Session of the Science Congress in Pune in January 2000 organized by Mashelkar stands out as a stunning and unique achievement in bringing thousands of students and youth to the Congress and its mammoth exhibition, to assembling a national and international galaxy of scientists, including two Nobel Prize winners and several Fellows of the Royal Society to give lectures at various sessions of the Congress. The Prime Minister gave an exhilarating Inaugural Address[8]. A particularly important point made by the PM in his address was his government's commitment to increase the financial outlays to be made on S&T in the last two years of the Ninth Plan, and even more so in the Tenth Plan. Specifically, that the ratio of the S&T Budget to GDP would be raised from its present about 0.7 to 1% by the end of the Ninth Plan in 2001–02 and to 2% by the end of the Tenth Plan. But when the Union Budget for 2000–01 was presented by the Finance Minister to Parliament barely two months later, the actual financial outlays made for S&T did not reflect the Prime Minister's commitment. The increase in the Plan outlays of even the major S&T Agencies – S&T, atomic energy, space, ocean development, biotechnology and CSIR – was a mere 7% over the 1999–2000 outlays. It must be recalled in this connection that in the Rajiv Gandhi era (1985–86 to 1989–90) *despite a high growth rate of GDP*, the annual R&D : GDP ratio was in the range of 0.9 to 0.98% after which it progressively and rapidly declined during P. V. Narasimha Rao's Prime Ministership to 0.66% in 1996–97 (ref. 9). What is more, while in the 1974–1979 Fifth Plan, the financial outlays of the Departments of Atomic Energy and Space combined came to around Rs 300 crore (18% of the total), those of ICAR and CSIR came to the same absolute and relative levels. But in the Ninth Plan (1997–2002) while the former doubled even proportionately to around 35%, the latter had fallen to around 22%.

An excellent comprehensive analysis of the many complex issues of S&T priority setting has been undertaken by Chandrasekhar[10]. Here I will only give a few examples of major S&T programmes where critical issues of priorities and choices occur.

Communicable diseases and public health

We bemoan the state of health of our citizens, particularly in regard to the toll that communicable diseases like malaria, cholera, hepatitis, measles, etc. take, year after year. We have also been concerned that our population growth rate is not falling as rapidly as it needs to – a grim reality confirmed by the recent All-India census. Yet, we have not modernized our vaccine production plants at Kasauli, Coonoor or Chennai. They remain 'departmental production units' with technologies, infrastructure and skills almost as the British left them. As for the tragic case of the Haffkine Institute, Mumbai, the less said the better. And yet we pour hundreds of crore of rupees into operational immunizations programmes based on inputs from such antiquated production and virtually non-existent R&D structures. Why? Because we have made hardly any financial investments in them, and organizationally and managerially reformed them.

What can and must be done is illustrated by the achievement of a Hyderabad-based company, Shanta Biotech (SB). Working with the Centre for Cellular and Molecular Biology, Hyderabad (CSIR) and the Osmania University, SB has successfully developed and is commercially marketing a biotech-based Hepatitis B vaccine. What is more, that has been achieved in a total time span of five years. The total investment on R&D, pilot plant and commercial plant was only Rs 170 million, of which Rs 85 million was provided by the Technology Development Board of DST. Till SB entered the market, Hepatitis B vaccine was practically monopolized by the transnational corporation Smith Kline and Beecham (SKB). SKB was selling the vaccine at Rs 780 per dose. But as soon as SB entered the market in 1997 selling its vaccine at a retail price of Rs 520 per dose, SKB dropped its price to Rs 350. However, when SB was able to drop its bulk (institutional) price to Rs 70 per dose, in two years SKB was forced to practically drop out of the market due to its inability to compete. The pay-off to the nation has been enormous. What is more, a couple of years ago, the US transnational company Pfizer approached SB to source the vaccine from it for sale internationally and jointly with SB here. SB agreed to do so but under a separate brand name and with full control of the arrangement. SB itself sells at home and outside under its own brand name SHANVAC. SB is now undertaking R&D on a whole slew of new biotechnology products, including other vaccines all of which are being internationally patented.

These examples only show what can be done. However, if a comprehensive multi-institutional plan was drawn up at the national level by DBT and ICMR and adequately funded, we could have effective state-of-the-art vaccines for practically *all* our communicable diseases in 10 years What is more, we can also become *the* vaccine supplier to international agencies like WHO and UNICEF and to the whole Third World. The recent offer of another of our pharma companies, CIPLA Laboratories, of a revolutionary anti-AIDS 'cocktail' of drugs to South Africa at prices much less than those of multinationals, shows that this opportunity is a distinct reality.

Superconducting thermonuclear fusion reactor

There is little knowledge outside a small segment of the scientific community – the physics sub-community – that in 1995, the Department of Atomic Energy was able to get the Atomic Energy Commission, the Planning Commission and the Cabinet to approve a huge Rs 200 crore project to set-up a Superconducting Thermonuclear Fusion Reactor at the Institute of Plasma Research (IPR) at Gandhinagar. The IPR was originally one of the research institutions of DST. However, to enable the highly capital-intensive fusion reactor to be set-up without distorting the financial outlay profile of DST, IPR was shifted to the Department of Atomic Energy in 1993. When the Fusion Reactor Project was proposed as part of the Ninth Plan, no one in the Planning Commission raised any questions as to why a poor country like ours was proposing to invest such huge monies in an area on which billions of dollars had been invested by USA, Europe and the former Soviet Union over the last 30 years, without any success? A paper[11] by the Vice-President of Systems and S&T at the Sandia National Laboratory of the US Department of Energy, with long years of experience in fusion research presents some major technical advances in fusion research and then concludes, 'but none of these experiments is expected to provide a commercial source of electric power'.

R. Chidambaram (Chairman, Atomic Energy Commission) during whose tenure the fusion reactor was approved justifies the decision as follows[12]: '... we cannot invest billions of dollars (in fusion energy development) like the developed countries are doing in the International Thermonuclear Experimental Reactor (ITER) project, but nevertheless *we should be in the game*' (emphasis added).

R. Chidambaram does not give any rationale as to why a poor country like ours 'should be in the game', in one of the most expensive and uncertain areas of energy research, even for the developed countries. This is despite he himself admitting that, 'it is difficult to predict when it (fusion power) will become a practical reality'.

But the real S&T policy issue is not only one of technology and techno-economic assessment. The issue of whether as a nation we should or should not be in 'the fusion game' is not something that the Department of Atomic Energy *alone* can decide. The issue must be debated and analysed in the S&T community both inside and outside the government and in Parliament and the media. It must then be considered by the Scientific Advisory Committee to the Cabinet (SACC), with the help of expert panels and consultants, if needed. Then independent advice must be given to the Cabinet by the SACC unlike the present scenario where the Cabinet gets only a 'captive' view from the Department of Atomic Energy, *the project-proposing agency*. While making this assessment the SACC should also consider the comparative potential of other futuristic energy sources, e.g. coal bed methane or gas hydrates, both of which natural resources we have in abundance. *The issue should be choice of energy technologies rather than merely pursuing the nuclear programme.*

The 500 MW prototype fast breeder reactor

The same kind of considerations apply to the 500 MW prototype fast breeder nuclear reactor project of the DAE. This massive project is currently 'assessed' by the DAE itself to involve a whopping financial outlay of Rs 3000 crore; starting in 2002–03 it will be completed in eight years[12]. It is to be based on scaling-up by over 30 times the small 15 MW Fast Breeder Test Reactor (FBTR) set-up at the Indira Gandhi Centre for Advanced Scientific Research (IGCAR), Kalpakkam near Chennai. The FBTR was set-up based on government-to-government technology transfer and financing agreements with France signed as far back as 1972, except for the plutonium carbide fuel which was developed indigenously. It took around 14 years, 1972 to 1986, for the FBTR to attain some degree of operational stability compared to a project completion period of five years which was projected by DAE and approved by the government in 1972. Although approved at an outlay of Rs 45 crore, it consumed Rs 60 crore by the time it was 'completed'. Against such a track record we can imagine what is likely to happen to the much larger prototype reactor. Moreover, no other country in the world, except Japan, is proceeding with fast reactors, because of the serious technical problems involved in their construction and operation. As for the *economics* of such reactors, no country even talks about it because it is just not known with any degree of certainty. If we set-up such reactors we would also need to set-up concomitantly fuel fabrication plants upstream and fuel re-processing plants for plutonium separation in separate downstream plants, which will call for further huge investments.

In 1996, V. S. Arunachalam, former Scientific Adviser to the Defence Minister, for a whole decade (1982–1992) and originally a metallurgist from BARC undertook a detailed techno-economic analysis of fast breeder reactors using worldwide data. He came to the conclusion that such reactors would not be techno-economically viable in India until 2060 (ref. 13)! John Holdren, one of the leading energy (particularly nuclear energy) experts in the USA, and a member of US President Clinton's Committee of Advisors on S&T (PCAST), in a detailed testimony on nuclear energy before the US Congress in July 2000 has brought out in detail the serious, technical, safety and environmental problems of fast breeder reactors, including the aspect of the large amounts of plutonium produced from the reprocessing of fast reactor fuel[14].

Against such a background is this an area in which we should be making further investments at all, let alone investing such a huge amount of money? Is the blanket of secrecy which covers all projects of the Department of Atomic Energy – even entirely civilian ones like the PFBR – preventing a thorough public S&T

debate on such major projects before huge investment decisions are taken?

Thermal electric power generation, transmission and distribution

A glaring anomaly in the S&T priorities for the electrical power sector is that while the Ninth Plan outlay on R&D and demonstration/prototype plants for atomic power is around Rs 300 crore and the installed nuclear electricity capacity is only around 2800 MW, the R&D and demo/prototype outlay on *conventional* thermal power, which is our mainstay and where our installed capacity is around 75,000 MW, is negligible. As far as generation is concerned, it is dominated by the Rs 90 crore BHEL spends annually on R&D in its corporate R&D centre and the design and development it undertakes in its various plants. The R&D budget of NTPC, our largest generating company with an installed capacity of around 20,000 MW is small, while that of the State Electricity Boards (SEBs) is almost zero. To address the numerous technological problems of improving our transmission and distribution system, we have only one relatively small R&D institution, the Central Power Research Institute. And yet when a major programme to put up a 100 MW Integrated Gasification Combined Cycle Thermal Power Plant as a joint effort of NTPC, BHEL and the CSIR at a total cost of Rs 600 crore without any budgetary support from government is formulated, it takes years in the approval process. Such combined cycle power plants, which are being actively worked on in the industrialized countries would increase the efficiency of electricity generation from the 35–36% of the best-run, current technology, coal-fired power plants to 40–42%, leading to a 10% reduction in the cost of generation and huge improvement in environmental impact[15].

As for transmission and distribution, numerous technological tasks for improvement of system performance, stability, safety, etc. have been identified and documented in detail[16]. But there is just no funding available either to the Department of Power or to our national transmission company, the Power Grid Corporation of India Ltd (PGCIL). All that exists is a few crores of rupees per year to the SEBs for small R&D 'schemes' through the Central Board of Irrigation and Power.

Therefore there is urgent need for:

(a) A specific plan outlay for a major government-funded R&D programme by BHEL (*none* exists today as part of the policy of withdrawing *all* budgetary support to profit-making public enterprises like BHEL).
(b) Setting up with Plan funds of a major R&D and Engineering Design Centre by PGCIL.
(c) Plan funds in the Department of Power for major prototype/demonstration projects such as the HVDC link of BHEL, Department of Heavy Industry and the erstwhile Department of Electronics (now Ministry of IT) to prove new products, systems and techniques under actual field conditions.
(d) A reappraisal and revamping of CPRI perhaps to concentrate on R&D in power *distribution*. Inventories of major technological tasks in the distribution area have been prepared[17] and these can constitute the R&D agenda for a 'new' CPRI.

Non-conventional/renewable energy sources

Our country has a large and dispersed rural population and abundant solar, biomass and wind energy resources. Recognizing this potential, a Department of Non-Conventional Energy Sources (DNES) and a Commission of Additional Sources of Energy were set-up as far back as 1982. DNES was to undertake R&D, demonstration and promotion of large-scale operational deployment of non-conventional or renewable energy sources. However, actual exploitation/operationalization as of today is only 1340 MW of wind power, 1358 MW of mini hydel power and 292 MW of bagasse co-generation and biomass power. In comparison, Denmark has targeted 50% of its total grid capacity to be derived from wind power by 2030 (up from 15% at present), while Germany is adding around 4500–5000 MW of wind power capacity to its grid *annually*. Five years ago we had the third largest installed wind power generating capacity (after USA and Germany), but now Denmark and Spain have overtaken us and Germany has gone far ahead. As for small hydro power, China has 20,000 MW installed.

Detailed wind profiles across the whole country painstakingly built up through extensive and sustained field measurements have shown that our wind power potential is as much as 45,000 MW, of small hydro power, 15,000 MW, and of biomass power, including bagasse-based co-generation alone 19,500 MW. Moreover, all three are much cheaper than current SEB prices of electricity.

Then there is solar thermal energy for both domestic and industrial use, where techno-commercially viable technologies are available – installation of 1 million domestic solar water heaters would save 500 MW of electrical grid capacity. And finally we have solar photovoltaic (SPV, solar electricity) energy systems. This renewable energy source has, in the last 3–4 years, become much more competitive with grid electricity not only in remote rural areas but for powering VSATs and cellular radio base stations and repeaters in urban areas. They are also competeting with fossil-fuel generators in urban areas due to the need now for such generators to comply with more stringent air quality and noise pollution standards, which leads to increasing costs of such generators by as much as 50% compared to earlier years. These developments are reflected in the following two examples: (i) One of our SPV manufacturers, Rajasthan Electronics and Instruments Ltd (REIL), Jaipur has been able to sell some 6500 SPV domestic lighting systems in the desert districts of Jodhpur, Jaisalmer and Barmer during 2000–01, with a subsidy component *which is approx. 50% of what it was as recently as 1998–99* – something which would have been unthinkable in 1998–99 (ref. 18); (ii) The ONGC is undertaking a major programme of induction of SPV and solar thermal water-heating systems involving payback periods (SPV) of only five years due to a combination of increased hydrocarbon costs and lower solar energy costs[19]. So, solar energy costs are decreasing rapidly.

Costs apart, due to forward-looking policies, we have over the last 15 years built up a considerable industrial base for the manufacture of equipment and systems involved in all these renewable energy sources. However, total investment on our R&D, in all these areas combined is today running at only around Rs 15 crore. Compare this with the PFBR! It is not surprising, therefore, that even a former Chairman of our Atomic Energy Commission, who some years ago was sceptical about the contribution renewable energy could make to our energy picture has, more recently, come to support it[20].

However, low R&D budgets have prevented the design, engineering, testing and evaluation, and then commercial manufacture of wind turbines optimized to Indian wind regimes, and therefore of lower capital cost and higher efficiency and availability than the present systems which are all based on foreign technology. To move in that direction, a Centre for Wind Energy Technology (C-WET) has been set-up in Tamil Nadu, but it needs urgent funding. Much larger demonstration projects are needed for non-bagasse-based biomass combustion plants for which also additional funding is needed. We also need to put up a demo plant to produce electricity from biomass *gassification*. Biomass power projects of 6 MW capacity are being implemented at a cost of only Rs 24 crore and generate power at 20% lower cost than new coal-based plants coming up at a capital cost of Rs 5 crore/MW.

However, the main problems inhibiting more rapid expansion of renewable energy systems which are gird-connected are policy and institutional in character, largely connected with the functioning of the SEBs. For stand-alone solar thermal systems – whether for domestic water heating or hot water and low pressure steam for industry (thus saving furnace oil or grid electricity), there is need for a policy of mandatory use by law as in countries like Israel, Cyprus and Malta.

Unfortunately, successive governments during the 90s which have shown such alacrity to solve similar policy or institutional problems of the Department of Atomic Energy, have been lukewarm at best in regard to renewable energy. There could perhaps be no clearer reflection of this than the fact that the Renewable Energy Policy which, among a number of other provisions, targets that 6% of the total installed capacity of grid electricity would be based on renewable energy by 2012 compared to the present almost 2% (i.e. 12,000 MW compared to 2000 MW has been pending with the government for over six months now.

Ocean S&T

Satish Dhawan, the builder of our space programme, commented that the long-term goal of the programme was 'for India to have a presence in space'. He did not say so explicitly, but it was clear he meant this 'presence' to be in geopolitical, military and commercial terms. But what about that other great frontier – the oceans? Should a country with a 7000 km coastline, two sets of island territories, an acute dependence on offshore oil and gas not have a 'presence in the oceans' also? And as in the case of space, would the latter also not call for a major S&T capability and capacity in the oceans? But what is the reality? Eighteen years after it was set-up in 1982, the Department of Ocean Development remains a small one with a limited set of programmes, and an annual budget of Rs 100 crore. If one adds the budgets of the three defence R&D laboratories – the Naval Physical Oceanographic Laboratory, Cochin, the Naval S&T Laboratory, Vizag and the Naval Materials Research Laboratory, Mumbai (Rs 80 crore), the National Institute of Oceanography, Goa (CSIR) with a budget of Rs 20 crore to the few crore per year that the Navy spends (mostly on warship design), the Rs 5 crore of Engineers India Ltd and all the shipyards on Design and Engineering and even the Rs 50 crore, the ONGC spends on offshore Geoscientific and Engineering Research, the nation as a whole is currently spending a measly Rs 300 crore a year on ocean S&T. These efforts badly need coordination and integration in terms of policy, plans and programmes, and expansion and upgradation in terms of number of S&T personnel and S&T facilities. In capital-intensive areas like ocean, S&T, funds for such plans and programmes cannot (with the exception of ONGC which made a profit of Rs 5000 crore in 2000–01) come from the companies, no more than the R&D funds for the first 500 MW CANDU nuclear reactor now underway are coming from the profits of its 'user', the Nuclear Power Corporation; they have to come from the Union Budget. As for laboratories, the funding source is obvious. But what is needed is not only a step up in the total S&T outlay in this area. We need at least four things to be done urgently *and concurrently*: formulation by the Central Government of a *national policy* for and in the oceans, a *national vision 2020* for the oceans, *coordination and integration* of the work of all the above organizations in terms of policy, plans and programmes *and steeply increased funding right from now.*

Biodiversity: The BSI and the ZSI

In today's world there is no need to emphasize the importance of rational assessment, utilization, management and conservation of a nation's biological resources and its biodiversity, especially for a country like ours with enormously rich biodiversity. Yet two scientific agencies which are key to this task – the Botanical Survey of India (BSI) and the Zoological Survey of India (ZSI) – are languishing in a corner of the Ministry of Environment and Forests. Both agencies were set-up by the British early last century. They are therefore old organizations. In addition, in government terms they are 'subordinate offices' of the Ministry. Consequently, they have antiquated organizational and management structures with great rigidities in regard to personnel and procurement policies and practices, financial rules, and overall operational autonomy. Moreover, their budgets are running at appallingly low levels of around Rs 15 crores each (2000–01). They are crying out for total reform and modernization, but neither successive Scientific Advisory Committees to the Cabinet, Planning Commissions or Administrative Ministries (even when the Ministry was the DST till 1981) have paid any attention to them. And yet there is much rhetoric about herbal drugs and other herbal products and how China's exports are 20 times ours, none of which would be possible on any scale without massive modernization and relatively steeply increased funding of these two organizations.

The universities

A crucial problem in S&T policy-making which has dogged us since the 50s has been the declining standards of teaching and research in our universities.

The situation has become so serious that some leading scientists have even proposed that 'we must cease building new laboratories for ten years and reinvest in university research'[21]. This is probably an extreme view. But there is little doubt that *the* major problem in attracting and retaining able faculty in the universities, motivating faculty and research students, and improving the quality of both teaching and research, is lack of funding.

A report by DST[22] on funding of research by agencies such as DST, Department of Atomic Energy, Defence R&D Organization and the UGC, of universities, IITs and national laboratories, reveals the following: The total level of such funding by all such external agencies as recently as 1997–98 was only Rs 220 crore or just 3% of the national S&T 'budget'. Even of this amount, grants to universities and deemed universities were only 54% and to autonomous institutions under Central Government Ministries/Departments (e.g. TIFR, PRL), only 26%. When seen in relation to the budgets of the major S&T agencies the share going to universities is trivial, e.g. DRDO's Rs 15 crore in relation to its 1997–98 budget of Rs 2500 crore. Of the above-mentioned 54%, some 90% went to only around 25–35 universities and their affiliated colleges (depending on the S&T sector involved) in 1997–98 out of the 235 universities in the country. This shows the very high concentration of even the limited extramural R&D funds the university sector receives. Many of the university departments which, from the late 60s up to the late 80s, were recognized by the UGC as 'centres of excellence' and funded by the UGC at relatively higher levels than others, are today not continuing to receive such funding. No wonder the universities are in a pathetic state. Indeed, but for the Rs 40 crore that the Science and Engineering Research Council (SERC), DST disburses and the Rs 45 crore the CSIR disburses by way of fellowships for research students and grants to the universities in the project mode, university research would have totally collapsed.

In USA, Germany and France the bulk of university funding for advanced teaching and research has been provided by the so-called 'mission-oriented agencies', i.e. space, atomic energy and defence with the National Science Foundation in USA only providing some 20% of the total funding. This is because these mission-oriented agencies have large budgets, and are extremely dependent both on the student turned-out and the basic knowledge generated by university research for achieving their mission objectives.

It is therefore necessary and urgent that our mission-oriented agencies do the same. Existing mechanisms for the purpose such as the extra-mural funding programme of the DRDO and the more specialized 'windows' of the Aeronautics R&D Board and the Naval Research Board as also the Inter University Centres of the Department of Atomic Energy and the Board of Research on Nuclear Science (BRNS) are good initiatives, but far from enough in terms of character, scope and levels of funding. So is the funding by the Technology Information Forecasting Council Aid Assessment Council (TIFAC) of currently around Rs 100 crore/year. But the departments of non-conventional energy, ocean development, environment and forests must also develop university research and advanced teaching support programmes, as the Department of Biotechnology has been doing for many years now. The Ministry of

Petroleum and Natural Gas must also do likewise, e.g. using the substantial quantum of funds already available with the Oil Industry Development Board as must its giant public sector companies, ONGC, IOC and GAIL. If such measures are taken, it should be entirely possible for all these agencies to be putting 5% of their total annual S&T budgets into the university system by the last year of the Tenth Plan (2006–07). But these funds must be clearly earmarked under a separate head in the budgets of the agencies and effective dedicated divisions set-up in each agency to administer them. The impact on the university scene will be dramatic – and of course, long overdue.

But there are also a number of measures that the universities have to take. The most crucial one is to 'loosen up' and modernize their recruitment, procurement, construction and other management practices. There must be drastic modernization of curricula and the undertaking of a huge Human Resource Development (not the narrow traditional 'training') Programme of faculty at all levels, with the emphasis obsessively on *quality*. There should be a much tighter set of norms and standards in regard to the quality of research done, papers published and Ph D and M Phil theses/dissertations accepted. If the S&T funding agencies are to steeply and quickly step up their extramural funding into the universities as argued and called for above, can the universities make effective use of such increased level of funding? The whole process of research project proposal preparation, internal 'clearance' in the university, despatch to the funding agency, etc. will all have to be streamlined, professionalized and speeded up several fold. In today's world, the universities which wish to be progressive and professional in their securing of research funds will only be those who set-up 'R&D grants, contract consultancy and intellectual property departments/centres' as nodal in-house institutional forms to not just 'receive', but go out and aggressively 'acquire' basic research grants from the extramural funding agencies, applied and developmental research contracts from government departments and public and private industry, offer technical consultancy and training services to industry and provide Intellectual Property Protection services to their faculty. This being said, a major facilitation that DST and CSIR as the multi-sectoral S&T agencies could provide to these more progressive universities is to fund them for five years, on both capital and recurring accounts to set-up such departments/centres/offices. The monies involved would be small and the multipliers would be large.

All this is not going to be done in a day. What I foresee happening in practice is that the 25–35 universities (and their associated/affiliated colleges) which were indicated earlier as currently receiving around 90% of the university-directed extramural funding from the mission-oriented agencies, will be able to respond to the new opportunity, modernize themselves further and so be the dominant beneficiaries of the additional extramural funding. Then there will be a second category of perhaps around 100 universities who will be able to respond only partially, while the remaining 100 will just not respond. However, this would not be a pattern unique to us. It has been the pattern in USA for over 40 years now. The goal should be first to bring those 25–35 universities as close to at least IITs, if not to 'good' university standards in developed countries, and then over the coming decade, increase that number to 70–80 with the centres of excellence tempered by relevance to national needs for problem-specific knowledge being brought back in a big and an explicit way.

Institutional reform of some critical S&T agencies

The re-orientation of S&T priorities illustratively dealt with in the previous sections of this paper is important. But for the whole S&T system to be more effective there is need for simultaneous action to be taken on institutional reform and removal of institutional anomalies. An illustrative set of these is now dealt with.

Medical research: Largely for historical reasons, the R&D laboratories of the Ministry of Health are irrationally split – 21 under the Indian Council of Medical Research (ICMR) and 11 under the Director General of Health Services. The moving of these 11 also under ICMR (as C. Subramaniam did for ICAR 35 years ago) is a glaring anomaly needing immediate correction. The DG, ICMR must be made a Secretary to the government with full administration, financial and personnel related powers as DG, ICAR has had since 1975.

Meteorology: A similar institutional restructuring and step up in level of funding is needed for the India Meteorological Department (IMD). Today, IMD is an 'Attached Office' of the Department of S&T, despite having 8500 scientists and technicians spread all over the country. There is urgent need to make IMD an *independent* 'Department of Meteorology (DOM)' in the Ministry of S&T and Ocean Development, to make the DG, IMD, Secretary of the DOM and upgrade the presently weak apex body, the Council for Atmospheric and Meteorological Sciences, into a Meteorological Commission. Equally important, is the integration into the new DOM of the National Centre for Medium Range Weather Forecasting (NCMRWF) which was created separately under DST in 1987 for purely idiosyncratic reasons and the fallacious argument that IMD personnel could not even operate, let alone use effectively for weather modelling, the Cray XMP-14 Supercomputer that was bought from USA under the Rajiv Gandhi–Ronald Reagan entente. The new DOM, should, like all other major scientific departments be exempted from the purview of UPSC, DGS&D and CPWD because of its highly specialized technical goals and character.

Ocean S&T and resources: We have seen earlier that the DOD is only one of the smaller agencies with responsibilities for S&T in the oceans. There are many other players involved. This is reflected in its charter indicating that it will be responsible for areas/aspects of the oceans 'not allocated to any other ministry/ departments'. Today there is hardly any interaction, let alone coordination and cooperation between the DOD, ONGC and the Department of Fisheries, Ministry of Environment or the naval DRDO laboratories. And yet there is need for the nation to have a coherent policy, programmes and S&T infrastructure to deal with ocean S&T and resources. However the other agencies with operations in the oceans are major ones like the Navy and ONGC. There is need, therefore, for an Ocean S&T and Resources Board/Commission composed of the Secretaries of the concerned ministries/agencies, e.g. Fisheries, Environment, Chairman, ONGC, the Vice/Deputy Chief of Naval Staff, DG, CSIR and DG, ICAR chaired by the Principal Scientific Adviser to the Government and secretarially serviced by the DOD with the Secretary, DOD as Member-Secretary.

R&D management and productivity: No serious S&T policy analyst would argue that the levels and distribution of a nation's R&D funding are the *sole* determinants of the returns that the nation secures from R&D for its development and security. The quality of leadership of the scientists and engineers involved in the S&T policy-making/advisory levels and at the R&D performing levels, the work culture in S&T agencies and laboratories, the ability of scientists in R&D institutions to work in teams and task forces on both intra-institutional and inter-institutional bases (and their being formally trained to do so if they lack such abilities), *capability in the distinctive feature of R&D project/programme management* – as opposed to those applicable to industrial or infrastructure projects (again formally imparted to R&D scientists) policy and institutional linkages to ensure effective commercialization/utilization of R&D results in the society and economy are all crucially important. Indeed, the lack of many of these elements in our S&T system calls for urgent remedial action as a key component of our overall S&T policy. *However, there are threshold levels of funding in all S&T agencies below which the adoption of the best of such R&D management techniques cannot deliver results and it is my case that we are way below those thresholds in a number of key S&T agencies and the socio-economic sector.*

Need for new approach for preparing the 'S&T plan budget': The kind of approach discussed above for defining S&T priorities at the sectoral and major programme levels will have little chance of success unless the Planning Commission fundamentally overhauls its Plan Budget formulating process. Today, the so-called major S&T agencies – Atomic Energy, Space, DST, DBT, CSIR and Ocean Development – have their plan outlays determined by the S&T Division of the Planning Commission. ICAR's outlay is determined by the Agriculture Division of the Planning Commission; ICMR, by the Health and Family Welfare Division; C-DOT by the Communications and Transportation Division and C-DAC by the Ministry of IT, while IT is treated as an industry. The same applies at the Secretary-level meetings – they are bilateral between Secretary, Planning Commission and the concerned individual S&T department. As a result, *at no level in the Planning Commission is an integrated view of all sectors/agencies of the Central S&T plan budget taken*. Except when the National Committee on Science and Technology functioned under the Chairmanship of minister C. Subramaniam in the 1971–1974 period (the Fifth Plan 74–79) *has the Commission felt the need* or appreciated the importance of at least the Deputy Chairman and the Member (S&T) of the Commission looking at inter-programme, inter-sector and inter-agency priorities in both substantive and financial terms, *including undertaking trade-offs* before a *composite S&T plan budget* is sent to the Finance Minister for incorporation in the Annual Union Budgets. This exercise should be done with the involvement of the Principal Scientific Adviser to the Government of India and his Secretariat, so that the Planning Commission is provided with independent S&T analysis, assessments and advice in undertaking such an exercise.

Step-up of total S&T outlay in Tenth Plan: With the Tenth Plan now on the anvil, the time is most opportune to launch this new approach and methodology. But even doing so will be of little use unless the political leadership takes a decision to substantially increase the total S&T outlay from the present 0.9% of GDP to at least 1.5% of GDP in the last year of the Tenth Plan.

Such an increase is needed because government support for S&T has fallen by as much as 50% *in real terms* over the 90s (ref. 5). When compared with even Taiwan and South Korea let alone Israel and France, our engineering R&D pool is striking in terms of the ratio of public investments to output. With the average rate of growth of GDP over the Tenth Plan period now decided to be 8%, the increase of R&D to GDP ratio from 0.9 to 1.5% would mean that the approx. Rs 18,000 crores of outlay on S&T during 2000–01, would need to increase to Rs 46,000 crore in the last year of the Tenth Plan at current prices. A policy decision needs to be taken that a very substantial part of such increase would be allocated to S&T agencies *other* *than* Atomic Energy, Space and Defence, which have for many years now been allocated around 65% of the Central Government's S&T budget. This must be done because food, health, energy and ecological security are as important as military security. If this kind of step-up cum reorientation is not done, we will move into the 21st century with major areas of S&T of great importance to national development heavily, if not completely marginalized – a situation we just cannot afford.

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