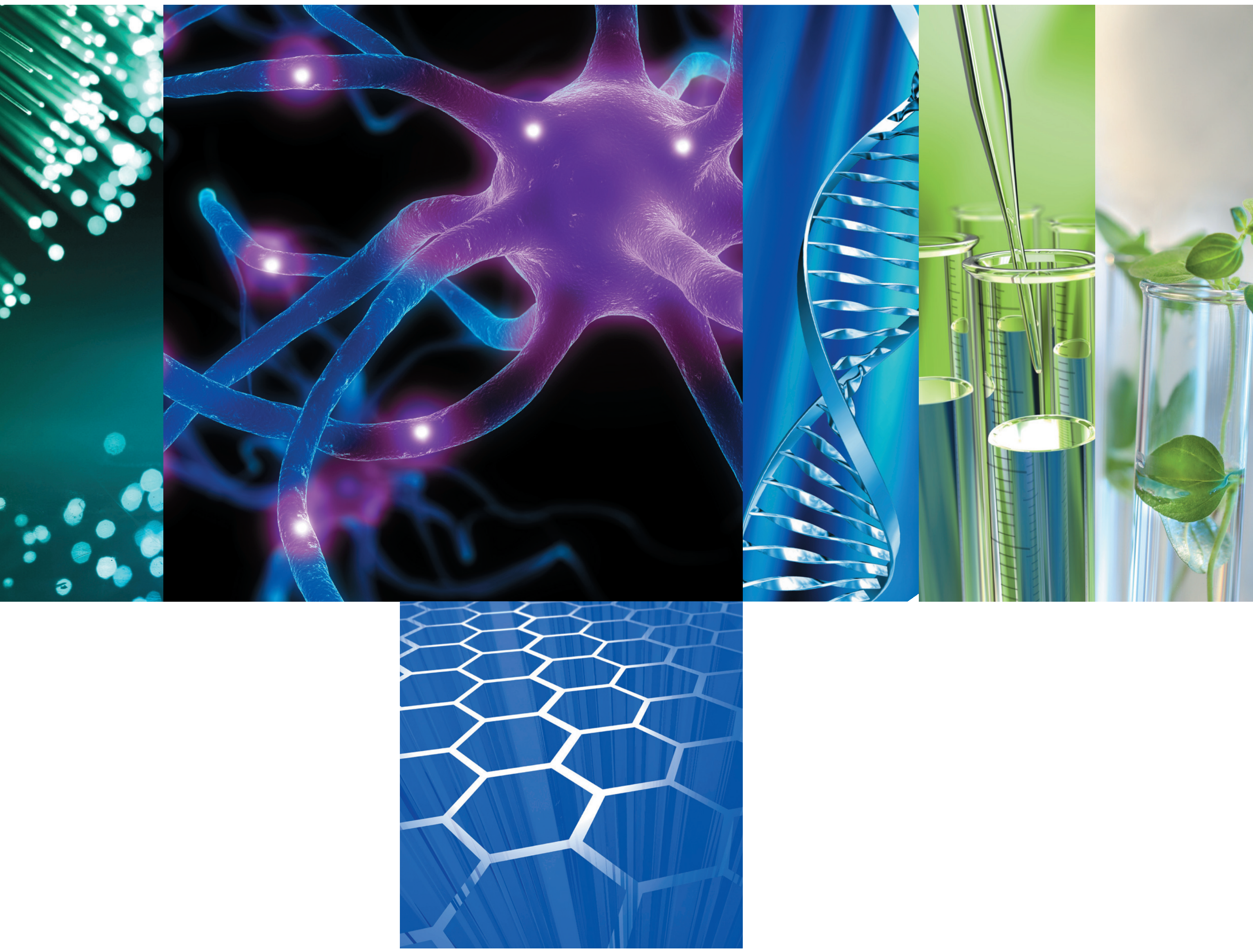
SCIENTIFIC ADVISORY COUNCIL TO THE PRIME MINISTER



BI-ANNUAL REPORT

2011

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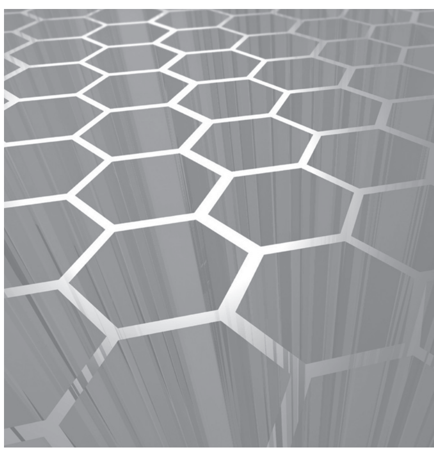


सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF SCIENCE & TECHNOLOGY
NEW MEHRAULI ROAD, NEW DELHI-110 016

Contents

Preface

The Scientific Advisory Council to the Prime Minister (SAC to PM) was reconstituted in December, 2009. The first term of SAC to PM between January 2005 and January 2009 saw several of its recommendations being implemented by the Government. Some of these included passing of the Science & Engineering Research Board (SERB) Act (2008) through the Parliament and the subsequent constitution of the SERB in June, 2010. Some of the other important happenings are the initiation of Department of Health Research and formation of Earth Commission and the Ministry of Earth Sciences, initiation of a new Institution for Animal Biotechnology and five new Indian Institutes for Science Education & Research in addition to new Indian Institutes of Technology.

The reconstituted SAC to PM had its first meeting in December 2009 and has since met 13 times till March, 2011. The Council had an initial meeting with the Hon'ble Prime Minister wherein it reviewed the successes achieved and the challenges that the S&T sector faces today. The Council apart from the expertise available within itself has made use of experts in different fields from academic and industry sectors to discuss specific issues thoroughly and arrive at proper recommendations.

This Bi-annual report provides a summary of the various important issues discussed and the recommendations made by the Council during the last 11 months of the first term of SAC to PM and around 15 months of present term of SAC to PM. It is encouraging that many of the Council's recommendations are being actively acted upon by the Government. In this process, new institutions of science and technology have been created and new initiatives being supported.

The Council set itself the task of preparing a road map for Indian S&T and presented a Vision Document entitled "India as a global leader in Science" to the Hon'ble Prime Minister on 18th September, 2010. The document has been widely circulated. This roadmap has paved way for the Council to think beyond the present. The Council has recently recommended certain essential steps to improve the higher education scenario in the country and has discussed them in detail with the Hon'ble Minister of HRD. The checklist to improve Higher Education Sector is a part of this Report. Several other issues pertaining to higher education have been discussed by the Council. A synergy is being built between the Ministry of HRD and S&T. The Ministry of HRD has since set up an S&T advisory committee to advise the ministry on issues of importance.

The Council deliberated on a new S&T based structure for forensics in the country and prepared a background paper in consultation with Director, Centre for DNA Fingerprinting and Diagnostics, Hyderabad. The document has been passed on to the Home Secretary for further discussion and a new structure is likely to come up to take care of the crucial national needs in this sector.

Based on the advice of SAC to PM and an inter-agency meeting, the Government has revised emoluments of Research Fellows in Science and Engineering. On specific issues such as Data Intensive Scientific Discovery and High Performance Computing, the Council had the advice of experts in organizing brainstorming workshops/discussion meetings for arriving at recommendations. Thus, a national workshop on Data Intensive Scientific Discovery has made important recommendations for action in this important area. The Council has suggested setting up of regional Centers in High Performance Computing.

The Council is now planning to build models of support that may create a proper innovative ecosystem in the country which may lead to young people taking teaching, research, and other innovative pursuits.

The Council has deliberated on issues related to selective improvisation of 10 to 20 Institutions to ensure there place in top 100 Institutions/Universities in the world. This would be a good programme for the Year of Science declared by the Prime Minister. It also suggests that a few Departments of Chemistry be provided adequate support for improving facilities during the International Year of Chemistry (2011). There are several other issues which the SAC to PM is concerned with related to solar energy, issues related to social sectors and education in rural areas. The Council is planning to review the major national programmes and recommend one or two important areas to be taken up as national missions for the next 5-10 years.

The Council is thankful to Shri Kapil Sibal, the earlier Minister of Science & Technology and Earth Sciences for his unstinted support and to Shri Prithviraj Chavan, Minister of State (IC) for S&T and ES for his encouragement.

The Council is most thankful to Hon'ble Prime Minister for his support in giving effect to the recommendations of the Council. With the continuing support of the Prime Minister, we hope to succeed in bringing about significant improvement in the science & technology scenario of the country.

C.N.R. Rao
Chairman

Executive Summary

Scientific Advisory Council to the Prime Minister (SAC to PM) has been actively engaged in developing a vision and road map for India emerging a global leader in science. The Council prepared and presented a vision document entitled **"India as a Global leader in Science"** to the Hon'ble Prime Minister on 18th September 2010. In his foreword for the vision document, the Hon'ble Prime Minister has said, **"The document brings out clearly that for India to become a knowledge-based society and to be a world leader in science, we would need to redouble our national efforts to promote scientific temper, strengthen S & T infrastructure, expand our educational base, establish centers of excellence, foster a culture of innovation and channelize greater investments in research and development".**

The vision presented by the SAC to PM has now been accepted and several actions recommended by the Council in realising the goals have been initiated. (Annexure-I)

SAC to PM has championed for the establishment of a new mechanism of funding basic research in the country. The Council had recommended earlier the establishment of National Science and Engineering Research Board (NSERB) as a body similar to the National Science Foundation (NSF) of the United States of America. The SERB has now been established through an act of parliament and its constitution notified in June 2010 (Annexure-II). The Board held its first meeting on 21st March 2011 and the Advisory Council to the Board constituted by the Government will meet on 6th May 2011. The Board is expected to start functioning in its rented premises shortly. The SERB is hoped to embark upon the development of new paths and help in the de-bureaucratization of science funding mechanisms.

SAC to PM has made some important inputs to the development of policies and legislations pertaining to the higher education sector. The Ministry of Human Resource Development has proposed a "National Council for Higher Education and Research (NCHER)". SAC to PM discussed the proposed bill extensively and made some important recommendations to MHRD through one of the members of the Council. Several modifications suggested by the SAC to PM have been incorporated by the Ministry of Human Resource Development in the NCHER Bill.

SAC to PM accords high priority for the development of well planned strategy and road map for addressing the challenge of large expansions in the enrolment of youth into higher education without loss of quality and excellence in educational systems. SAC to PM has identified essential steps for planning the progress of higher education sector of the country. The Council has engaged also in fruitful dialogue with the Hon'ble Minister of Human Resource Development and made some specific recommendations, which have been well received by MHRD. The formation of an Advisory Council to the HRM and preparation of a vision for education form some of the important recommendations of the Council. (Annexure-III)

SAC to PM had made an important recommendation to the MHRD for rejuvenating research in the university sector in the country. The constitution of an Empowered Committee to identify and support research in the university departments was proposed by the SAC to PM. Such a committee has been constituted and it meets regularly. Based on the recommendations of the SAC to PM, MHRD and UGC have supported research in more than 450 university departments recognized by Special Assistance Programme with a fund of Rs.180 crores. A special provision has also been made for supporting Departments not yet recognized under Special Assistance Programme and a financial support to the tune of Rs 45 crores has been extended to such Departments. Based on recommendations of the empowered committee, 2800 BSR doctoral fellowships and 280 Dr D.S. Kothari post doctoral fellowships have been supported. Networking centres/ summer–winter schools and Faculty Recharge Schemes have been mounted. There is already evidence of impact for the all the programmes suggested by the SAC to PM for rejuvenating research in the university sector. (Annexure-IV)

SAC to PM has attached high significance to the development of special training and motivational programmes for teachers in high schools, colleges and universities. The Chairman has initiated dialogues and discussions with the Hon'ble Minister of Human Resource Development. It has been decided that the Ministries of Human Resource Development and Science and Technology will jointly develop suitable programmes with the advice of SAC to PM and integrate the new schemes into the 12th plan programme of the country.

SAC to PM has addressed a felt need of the country for strengthening R&D inputs into Forensic Science by establishing institutional mechanism for linking main stream scientists in the knowledge domain with the scientific staff of Central Forensic Science Laboratories (CFSLs). On the basis of several suggestions made by SAC to PM, the Home Ministry initiated an internal review process for CFSLs. At the invitation of SAC to PM, Dr Gowrishankar, Director CDFD has prepared a concept note on institutional mechanisms for forging linkages between main stream scientists and the scientific staff of CSFLs under the Home Ministry. The concept note has been sent to Home Secretary on behalf of the SAC to PM by the Secretary DST in January 2011 (Annexure-V). Further discussions in forging alliances between the Ministry of Home Affairs and Ministry of Science and Technology as conceived in the concept note are ongoing.

SAC to PM has foreseen the emerging opportunity for the country in the use of science as a diplomatic tool in development of Nation's External Affair relationships. The Department of Science and Technology was assigned the task of preparing a concept note. The note thus prepared was discussed by the Council which recommended strongly that the proposed alliance between the Ministry of External Affairs and Ministry of Science and Technology should be further followed up as proposed in the concept note. (Annexure-VI)

SAC to PM had proposed an intervention in the area of research and development on Aeronautics, especially taking into consideration of high growth rates in civil aviation industry in the country. A National Aeronautics Board was proposed (Annexure-VII). A Committee has now been constituted under the chairmanship of Dr Madhavan Nair formerly Chairman Space Commission and current Chairman of Research Council of National Aerospace Laboratory Bangalore for further developing the programme.

SAC to PM has been making several and important recommendations with respect to enhancement of fellowships and attraction of Indian Diaspora for research in the country. In order to attract talented youth for doctoral programmes and careers with research, SAC to PM considered it important to enhance the value of doctoral fellowships in harmonious manner across the country. Based on the recommendations of the SAC to PM, the doctoral fellowships have been enhanced from Rs 12000/- plus HRA per month to Rs 16000/- plus HRA per month with effect from 1st April 2010. This has been welcomed with appreciation by student community. (Annexure-VIII)

Parameters for the JC Bose Fellowships and Ramanujan Fellowships have been improved taking into account of general revisions in pay scales after the sixth pay commission report was accepted. **J.C. Bose Fellowship** has been increased to Rs.25,000/- per month with annual contingency grant upto Rs.10 lakhs. SAC to PM has recommended that the term of the Ramanujan fellow should be for a period of five years at a monthly remuneration fixed by DST from time to time. The Ramanujan Fellow in addition to the salary should also be paid house rent allowance (HRA) taking Rs 75000/- as the basic pay. The annual contingency grant provided to these Fellows has been enhanced to Rs.10.00 lakh per year. The recommendations of SAC to PM are under process by the Department of Science and Technology.

SAC to PM has been making many important recommendations concerning the promotion of research and development in medical and bio-medical areas. The Council played an important part in the establishment of new Department of Health Education and Research (DHR). The Council has been advocating for interagency programmes of research involving DHR, DBT and DST. Following a brainstorming meeting involving more than 150 experts, a series of initiatives under interagency programmes was identified and presented to the SAC to PM. The Council strongly recommended the short & mid term initiatives along with setting up of Inter-agency task force for long term planning. (Annexure-IX)

SAC to PM has discussed at length the importance of agricultural research and identified several needed interventions for reinvigorating R&D in the area of agricultural sciences (Annexure-X). The Council members have decided to take up this issue regarding enhancement of investment in agriculture with the Hon'ble Prime Minister in the presence of Hon'ble Minister for Agriculture.

SAC to PM has identified the importance of solar energy research for the country. Dr P Rama Rao, formerly Secretary - Department of Science and Technology was requested to prepare a concept note on the nature of solar energy research to be promoted in the country (Annexure-XI). The report of Dr Rama Rao was discussed at length by the Council and specific recommendations have been made. The solar power systems; whether solar PV or solar thermal, require substantial capital investment in terms of land and other infrastructure. The Council also noted that solar energy generation has attracted unprecedented number of private players. After detailed deliberations, the Council made the following recommendations.

(i) Ensure that necessary land and infrastructure for connection to distribution systems for photovoltaic generated power are provided by the State governments on priority.
(ii) Ensure that State governments put in place appropriate policies keeping in view the large scale entry of private developers.
(iii) Ensure that research and development in solar energy is promoted with vigour, adequate funding and efficient management.
(iv) To set up a few units of solar thermal power generation in the country in collaboration with overseas institutions with established track record.

SAC to PM has made a strong recommendation for the initiation of Diamond Jubilee India Chair (DJIC) to commemorate 60th year of India's declaration as a Republic. The Department of Science and Technology has been developing the scheme and seeking necessary approvals of the Government as a national scheme.

SAC to PM has evaluated the need for mission mode programmes in some areas of national interest. This includes a) a national programme on data intensive discovery; and b) PETA and Exa scale computing.

Data Intensive computation in R&D supported by high computational power is becoming necessary. The Council advised a discussion meeting on this topic among a group of experts and scientists. Such a discussion meeting, coordinated by Professor Spenta Wadia and Professor Narashima was held during 2-11 February, 2011 in Bangalore (Annexure-XII). Major recommendations emanating from the expert group meeting are:

1. Access to a shared Super-computational infrastructure is necessary.
2. A National platform for Inter-disciplinary and inter-institutional collaboration on multi-disciplinary scientific problems using large data needs to be created.
3. Growth of local/ regional networks wherever possible so as to provide high speed last mile connectivity which was identified as severe lacunae in the existing infrastructure should be encouraged.
4. Innovative financial models for academia industry interaction needs to be developed and positioned.
5. A mechanism is necessary for negotiation and acquiring of licensed software on national basis so that it can be shared within the scientific community.
6. National projects like National Archives of data which can be shared on the network needs to be encouraged.
7. Capacity building and human resource development in this area.

SAC to PM discussed the recommendations of the expert group meeting and Dr Khakhar has been directed to prepare and submit a proposal for gaining access to the CRL facility of TATA group of companies. DST has been advised to negotiate with TATA group for providing access for a group of researchers in data discovery mode to the CRL facility on payment basis.

PETA and EXA scale computing facility is considered necessary for the country. A concept note for launching a National Mission on developing Exascale supercomputing capability has been now prepared by C-DAC (Annexure-XIII). SAC to PM discussed the note and recommended strongly that the proposal should be submitted through the administrative ministry to the planning commission for inclusion into the 12th plan programme of India. A draft proposal on peta–scale computing is already submitted to D/o Information Technology for support.

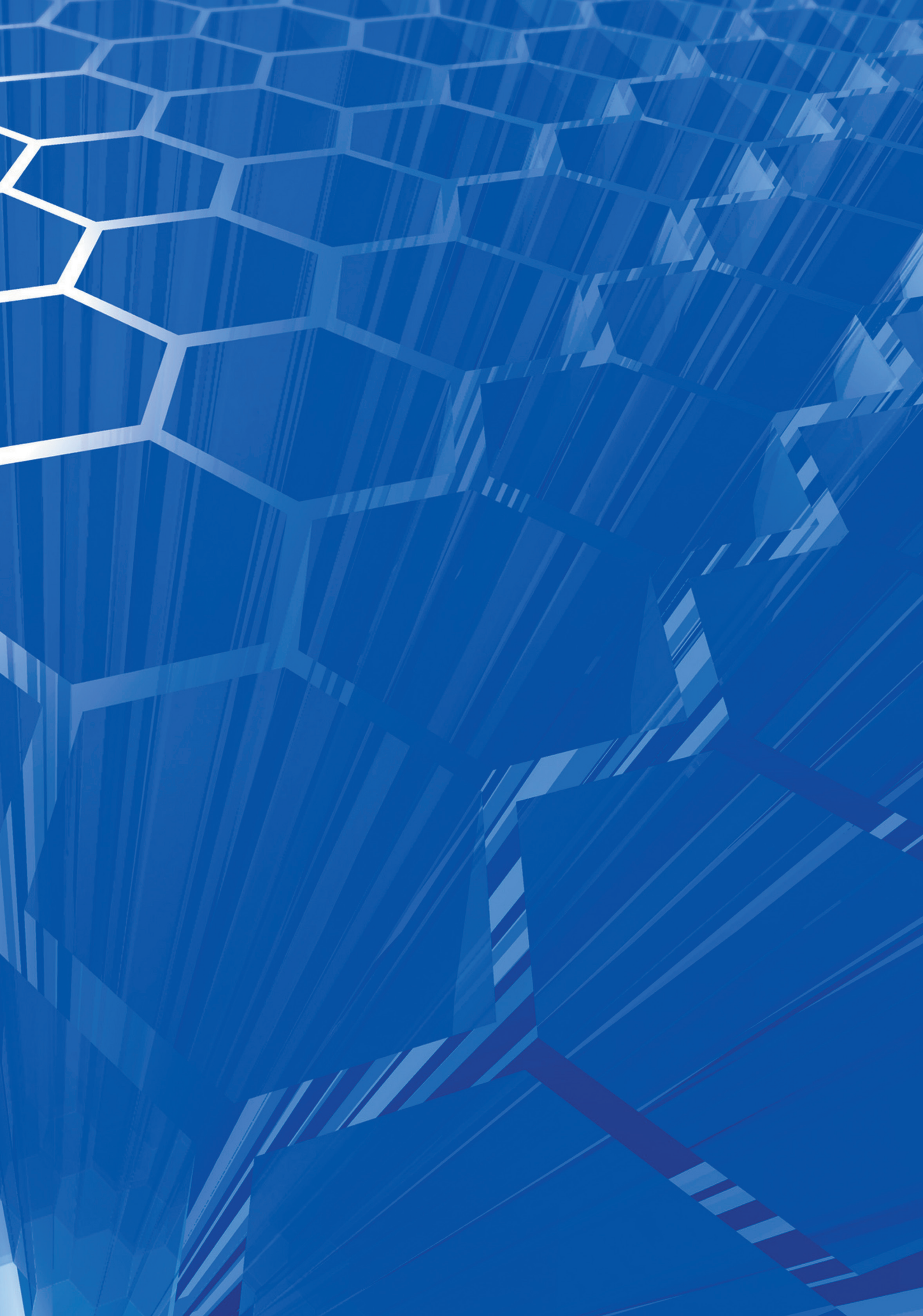
SAC to PM, in one of its meeting with the Honble Prime Minister had emphasized the value of possible sensitization of the Chief Ministers of various state Governments to the national perspectives on science and technology and the need for support to Research and Development. The Hon'ble Prime Minister had agreed to convene a NDC meeting on S&T. In order to prepare the background paper, the items to be included in the agenda for this meeting were discussed in details and possible agenda for discussions has been proposed to Office of the Hon'ble Prime Minister. (Annexure-XIV)

One of the members of the **SAC to PM** briefed the Council about the need for national bio-security system and a policy. The Council recommended that Dr. Bhan and some members of the Council may meet the Cabinet Secretary and apprise him of the current scenario related to bio-security. The Council requested Secretary DBT to coordinate this discussion on behalf of SAC to PM.

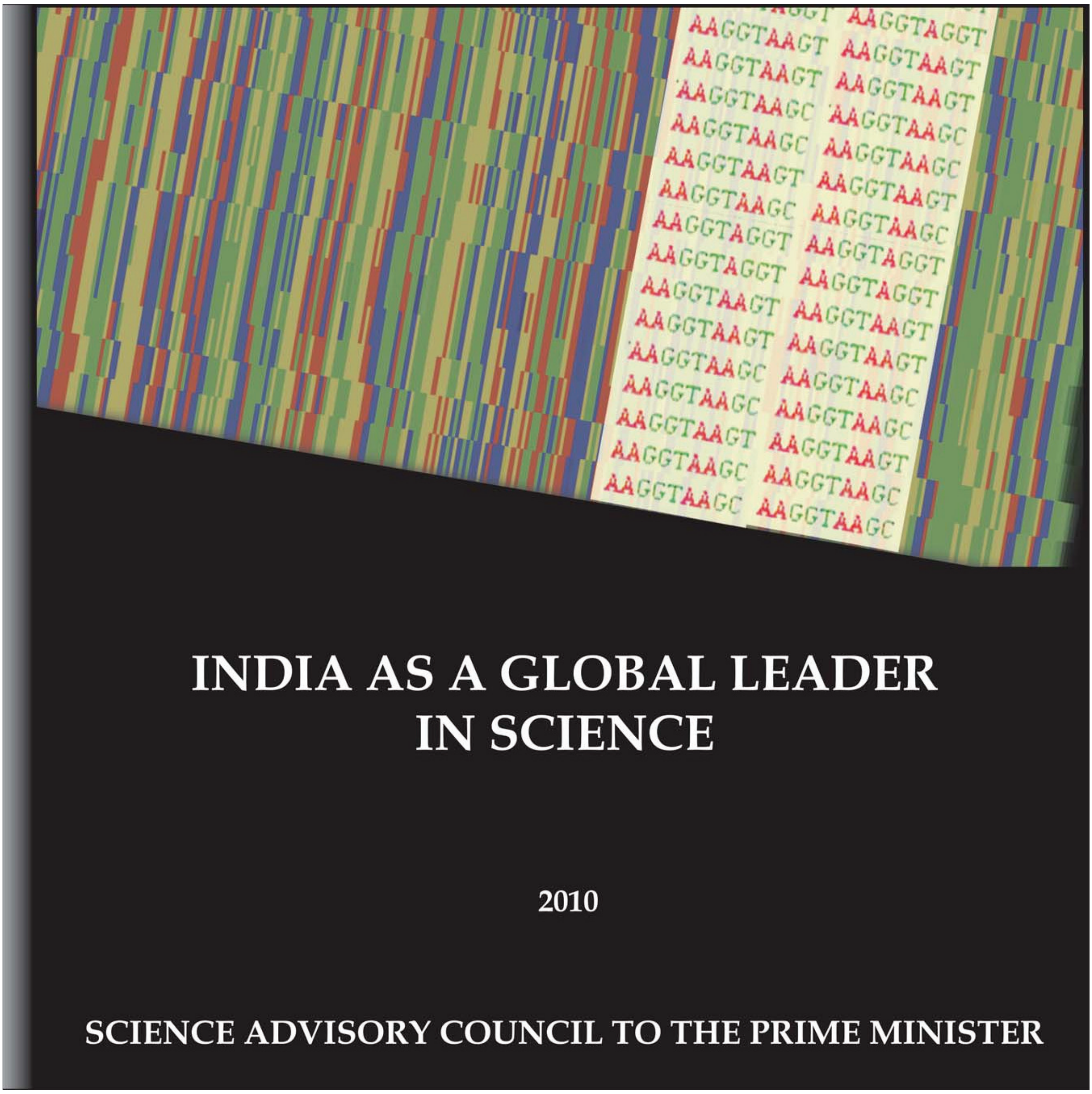
SAC to PM has advised the establishment of a joint foundation between the Ministry of Science and Technology and the Ministry of Rural Development. After several discussion meetings with the Ministry of Rural Development and consultation meetings with stake holders, the Department of Science and Technology has constituted a Council for Science and Technology for Rural Industries (CSTRI). Under CSTRI, two units, one in IIT Madras at Chennai and the other at NEIST at Jorhat have been supported to develop pilot programmes of value to rural development.

On the whole, SAC PM had made several important recommendations during the years 2008-11. It is gratifying that several of the recommendations made by the Council have been accepted and implemented while actions on some of the recommendations are ongoing.

Annexures



Annexure I


INDIA AS A GLOBAL LEADER
IN SCIENCE
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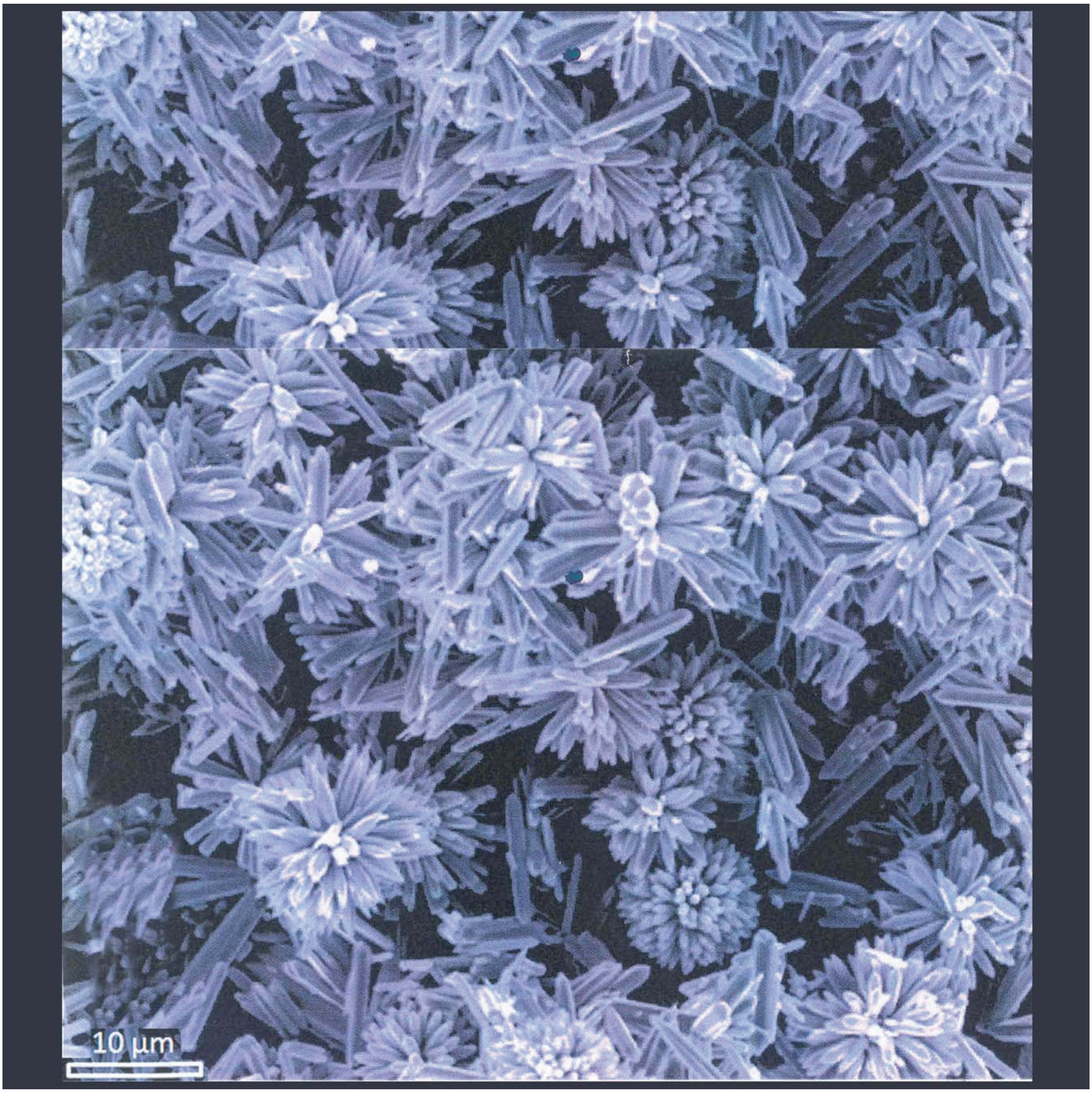
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INDIA AS A GLOBAL LEADER IN SCIENCE

2010

SCIENCE ADVISORY COUNCIL TO THE PRIME MINISTER

Department of Science & Technology,
New Mehrauli Road, New Delhi - 110016.

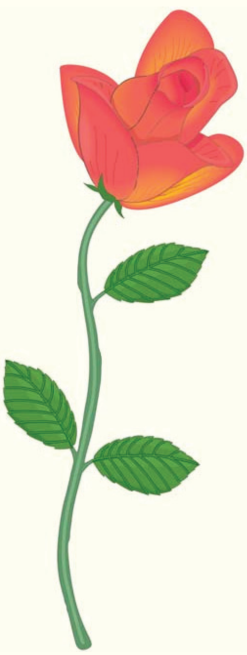
A VISION FOR INDIA

In the next two decades, India is likely to become an economically prosperous nation and move significantly towards being a far more inclusive society, with the bulk of its population gaining access to facilities for education and health care and living a life with hope and security. To realize such a vision, it is essential that science is at the heart of the strategy that the next stage of national development demands. In what follows, we present a vision for the growth of Indian science that can help the strategy succeed, and a road map for India to emerge simultaneously as a global leader in science.

प्रधान मंत्री

Prime Minister

FOREWORD



I am delighted that the Science Advisory Council to Prime Minister under the chairmanship of Prof. C.N.R. Rao has prepared this valuable document, "India as a Global Leader in Science" which makes a realistic assessment of the opportunities that lie ahead and the challenges that we face in developing strong capabilities and acquiring global leadership in the area of science.

The document brings out clearly that for India to become a knowledge-based society and to be a world leader in science, we would need to re-double our national efforts to promote scientific temper, strengthen S & T infrastructure, expand our educational base, establish centers of excellence, foster a culture of innovation and channelize greater investments in research and development. We need to create a robust enabling environment for harnessing the creative energies of our youth, which can make a visible impact in improving the quality of life of our people.

I do hope that the ideas contained in this vision document will inspire our scientific community , entrepreneurs, administrators, policy makers and civil society to search for solutions that would help build an inclusive, economically and socially vibrant, creative and an enterprising India, and to pursue excellence in science and technology for global good.

New Delhi
26 August, 2010

(Manmohan Singh)

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INDIA'S PLACE IN THE WORLD OF SCIENCE TODAY

As we near the end of the first decade of this new century, there is a growing perception around the world about the emergence of India as one of the potential global leaders in Science. (In this report, the word science is used as a generic term that includes mathematics, engineering, technology, medicine, agriculture and other related subjects.) The US National Academy of Sciences (NAS) published an influential report in 2005 titled ***Rising above the gathering storm***. The storm referred to in this report is concerned with the emergence of other global leaders such as China and India in science, and the challenges that such a development would pose to the position of the US in the world of science (Box 1). Interestingly, the US President has spoken about young people in China and India working round the clock hungry for knowledge, and how jobs in Buffalo may be lost to Bangalore and Beijing.

We should resist the temptation to get carried away by the NAS report, since India is yet to become a major force in global science. The creation of new scientific and technological knowledge is largely concentrated in three areas of the world: the US, Western Europe and the North-east Asian hub (Japan, South Korea, China and Taiwan), with a few peaks in Russia and Australia (Graphic 1). India unfortunately presents no comparable peaks.

2 *India as a global leader in science*

Box 1

The gathering storm?

Excerpts from the US National Academy of Sciences report *Rising Above the Gathering Storm*:❷

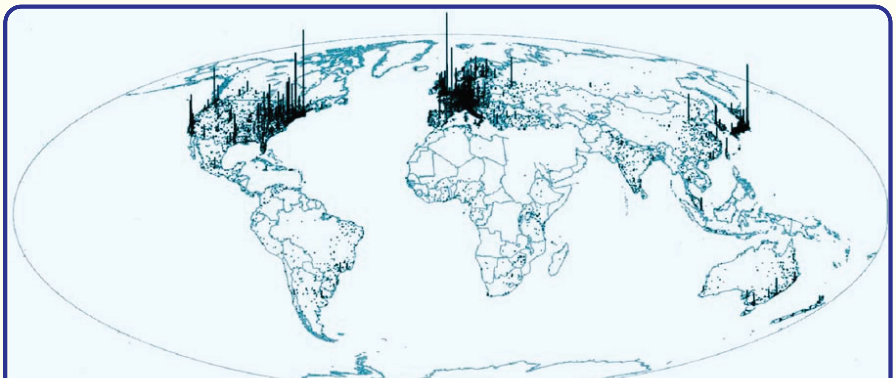
Economic studies conducted even before the information-technology revolution have shown that as much as 85% of measured growth in US income per capita was due to technological change.

❷ Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China, India, or dozens of other nations whose economies are growing.

❷ [We] are worried about the future prosperity of the United States.... Great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost – and the difficulty of recovering a lead once lost . . .

The recommendations of the NAS Committee focused on four issues: K-12 education, research, higher education and economic policy.

From a recent survey (*Nature* 2004)[1] of impact-making scientific publications, we are 22 in global ranking – below China, South Korea and Poland. Indeed India's *relative* position in the world of science has declined in the last twenty years. We produce more science than before, but several more ambitious countries like China and S. Korea have outpaced us. The fraction of GDP that is spent on R&D has remained stagnant in India for two decades now (Graphic 2), whereas the more dynamic Asian countries have surpassed us in this period.

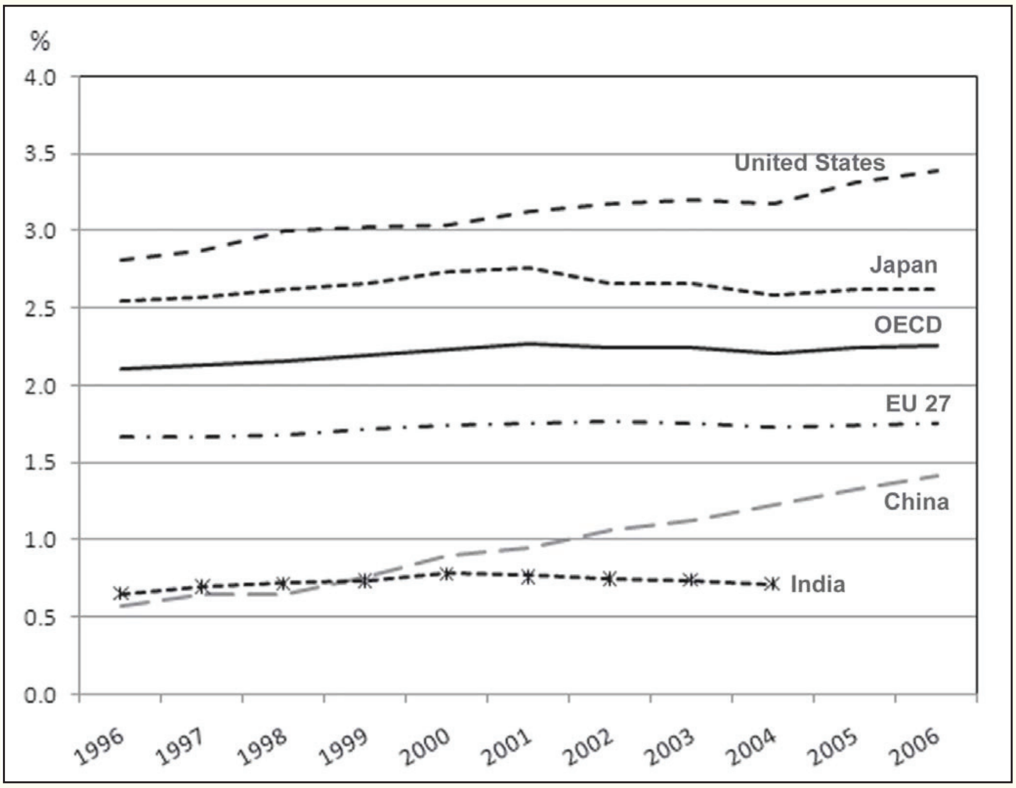

Global distribution of number of papers produced

Graphic 1: The Geography of World Science[2]

Two-thirds of the national R&D expenditure in India comes from the central government, and a quarter from industry. In contrast, it is almost the other way in S. Korea: about 30% of its R & D budget (about 3 ½ % of GNP), comes from the Korean government – which spends about the same on R & D as the Indian government does – but all the rest of it comes from industry. Indian industry is spending more on R & D now than before in absolute terms, but less relative to GNP (0.38% of GNP in 85-86, 0.2% currently). Except in sectors like pharmaceuticals and drugs, our industry does not appear to be making major investments in or demands on Indian science.

Yet, there are good reasons why India's presence in the world of science cannot be ignored.

Graphic 2: Gross domestic expenditure on R & D by area, 1996 - 2006 as a percentage of GDP[3]



OUR VAST BUT UNREALIZED POTENTIAL

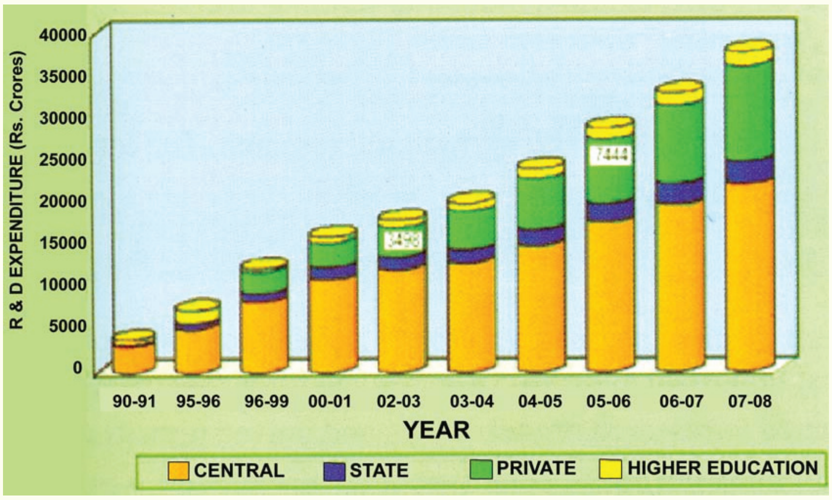
The untapped scientific and technical knowledge available to India for the taking is the economic equivalent of the untapped continent that was available to the US 150 years ago.

Milton Friedman, 1955 Report to the Union Finance Minister

India's Strengths

India's resources and strengths in science are considerable, but the potential is still far from realization. The rapid economic growth of the last fifteen years makes it feasible for the country to invest a great deal more in science than it could earlier. Contribution to Research & Development (R & D) from private sources is on the increase even though it still remains relatively small (Graphic 3). We believe, therefore, that the present time is a special one in the history of India's science as it offers an unusual opportunity to move towards a new and higher level than the one that we have become used to for decades.

At the school-leaving level there is great enthusiasm for science. A national science survey[4] has found that the most popular subject among tenth standard students is mathematics (with a vote of 35%). In the international Olympiads, Indian students have been in the same class as USA, South Korea, China and Japan in terms of medals won in mathematics[5]; in biology, they rank above the US. However, as these bright young minds begin choosing their careers they prefer other options, chiefly because they see science as offering fewer opportunities.



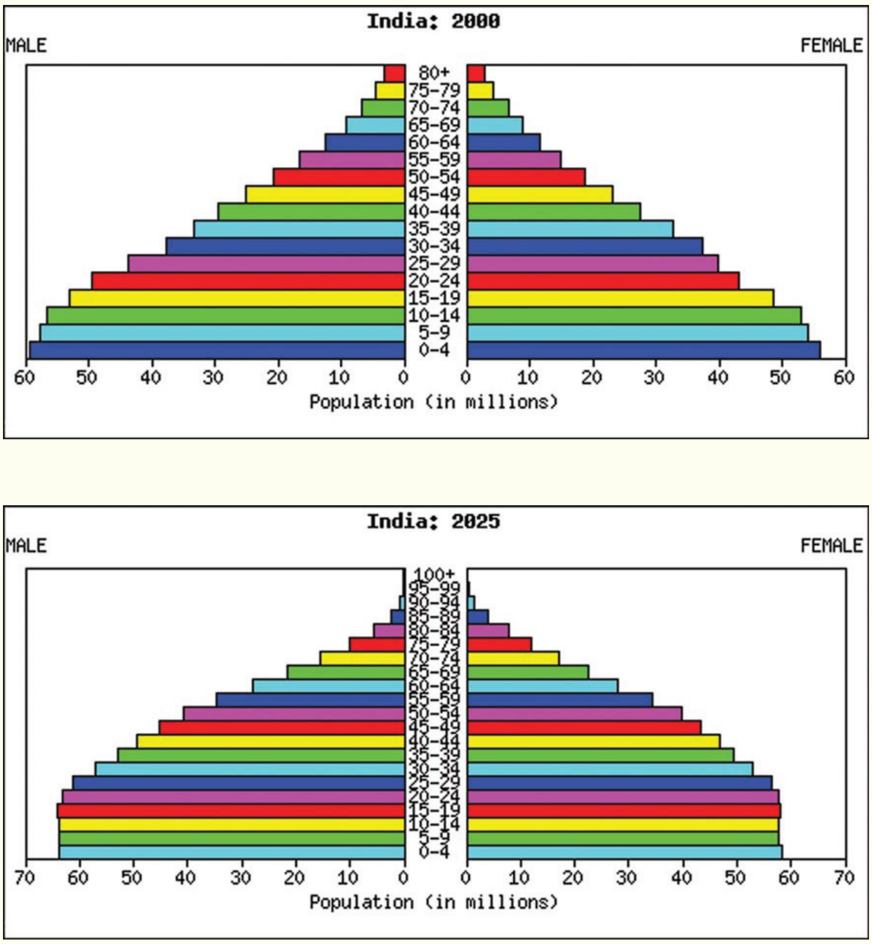
Graphic 3: Growth in Indian science budget

R&D expenditure[5]

India has several natural advantages as well. A major one is the youthfulness of India's population (Graphic 4), -which currently has a median age of 25 years. The number of Indians in the university-going age group (between the ages of 17 to 21) is currently about 9 crores (90 million), and will be 10 crores or more in 2025: the demographics will still be dominated by youth (Graphic 4). Only 13% are enrolled in higher education today. There is therefore vast scope for expansion.

India's strengths in original research in basic science have been substantial. The science, done in India, has often led to striking new technologies, but these technologies have generally been developed elsewhere in the world. We believe that this is a consequence of the overall weakness of the innovation ecosystem in India, as we shall discuss later in this report.

Graphic 4: Age-wise population distribution[6]



8 *India as a global leader in science*

Indian basic science has spawned new technologies - but not in India

There is a fairly widespread perception that basic science done in India is not relevant for technology. The history of Indian science shows that this perception is not true. As elsewhere in the world, applications sometimes follow discovery decades later. Here are three examples

Millimetre waves and J C Bose

In 1895, Jagadish Chandra Bose used what are today known as microwaves to ignite gunpowder and ring a bell at some distance – without the aid of any mechanical or electrical contact[7]. This demonstration, carried out with electro-magnetic radiation of 5-25 mm wavelength in Kolkata, showed for the first time that communication signals could be sent through electromagnetic waves (over distances of upto a mile at the time), *without the use of wires*. In further demonstrations at the Royal Institution in London in 1897, Bose used waveguides, horn antennas, dielectric lenses and polarisers, and was the first in the world to use a semiconductor crystal (galena) as a detector of radio waves. In the years following, attention was focused on long distance transmission which demanded using much longer electromagnetic waves, but in the middle of the 20th century microwaves became very relevant, for greater resolution rendered them central to such important applications as radar. It is the sort of microwave radiation that Bose demonstrated in Kolkata more than a hundred years ago that today drives the almost ubiquitous mobile phone, which has ushered in a communication revolution in India among both rich and poor. Other striking applications of millimetre waves are satellite communications and remote sensing. Data on the earth's atmosphere (e.g. humidity) are obtained by satellites sensing microwave radiation in the 1-30 mm wavelength range. Millimetre wave radars are used in short range applications on automobiles and at airports. Why did all these applications emerge in the West, not in India?

Raman scanners

C. V. Raman won the Nobel Prize in 1930 for the optical effect known after his name. Using condensed sunlight (the most intense source of illumination available to him at the time), Raman discovered a new kind of radiation, in which the scattered light had a different frequency from that of the illumination. Scattering changed the colours, so to speak. And the scatterers could be gases, vapours, liquids, crystals and amorphous solids. It turns out that the change in spectrum provides a unique identity tag to any type of molecule: i.e. gives it a 'finger-print'. Raman foresaw early that his discovery could have many applications. But it is only some 70 years after its discovery that Raman spectroscopy is beginning to directly affect the common man's life. This has become possible because of several other recent developments in technology: small, inexpensive and powerful lasers, fast digital image processing techniques developed for the space and communication industries, and surface-enhanced spectroscopy – all these have now combined to create a new 'Raman technology'. 'Raman scanners' using this technology have just reached the market place. With a hand-held device weighing less than 250g it is now possible to scan a surface non-intrusively and in real time to detect, to less than one part in a billion, traces of a wide variety of molecules – from pathogens and drugs to explosive chemicals. This technology appears set to grow vigorously in the next decade in a wide variety of fields – from health care to security to many others besides. So, the question is how and when do we build the ability to traverse the journey from the Raman Effect to the Raman scanner in our own country?

Mathematics and technology

The work of mathematical genius Ramanujan is a striking example of how basic research in such abstract branches of mathematics as number theory can have, many decades later, unexpected consequences and applications in new areas such as modern cryptography, population dynamics and theoretical physics. There are other examples (e.g. control theory, mobile communications) where basic research in mathematics done in splendid isolation has turned out to be crucial in some new technology. With the explosion of data and the advances in genomics, it is now widely agreed that newer areas of mathematics, in theoretical computer science, statistical analysis, information theory etc., need to be developed, as more scientific discoveries begin to be made through exploration of the vast quantities of data that modern technology provides us with. The paths of knowledge application and knowledge creation have clearly to combine to make rapid strides in development.

Many such examples can be given from other fields. What all of them show is that the journey from idea to product is complex, and demands science and technology developed in a variety of other fields for quite different applications, and a variety of expertise all the way from science to manufacture, financing and market knowledge. As we argue elsewhere, it demands a whole new ecosystem that encourages innovation.

THE NEW WAVE

Considering that India's potential in science and technology is immense, we believe that a policy of vigorous pursuit of science in the country can lead to rapid growth – of the kind that occurred in our GDP following the economic reforms of 1991.

The 1991 reforms have just now begun to touch the Indian science system. The revision of salaries by the Government of India in 2008 has been a significant step forward. The new Indian Institutes of Technology (IITs) established in recent years, the new system of Indian Institutes of Science Education and Research (IISERs), new universities being established in the country, new milestones in national mega-projects, the outstanding performance of a small number of state universities and the considerable growth in private wealth (in some cases arising out of the innovative initiatives taken by Indian industrialists and businessmen), all these are changing the scientific scenario in India dramatically. These strides should presage a new wave of investment and growth in Indian science – the only one of such magnitude after the early initiatives taken by the government led by Jawaharlal Nehru, in the late 40s and the 50s.

SCIENCE AT THE CORE OF NATIONAL DEVELOPMENT

What science should we do?

Curiosity and quest for understanding have driven human beings to discover many wonderful things. As we have already seen, it is virtually impossible to exactly predict how today's basic research will eventually improve our quality of life or to guess the new technologies or markets that may emerge. There is little doubt however, that such improvements and industries will eventually arise. The results of basic research are prerequisites for many future technological advances and societal benefits.

At the heart of the initiatives proposed here is the need to promote the pursuit of basic science in the country. Without the anchor of the strong foundation that basic research can provide, and the new ideas that can lead to future technologies that could be generated in the laboratories of the country, the vision of this document cannot be achieved. Tomorrow's technology often depends on today's basic science as exemplified earlier.

Innovative solutions will have to be encouraged, by establishing the whole ecosystem that is necessary for ideas that germinate in research centres to reach the market place. Indeed some of the work in the basic sciences should be driven by programs that the nation will have to undertake to tackle the major problems that the nation, and indeed the whole world, face (Box 2).

Advances in basic science will not by themselves make India a global knowledge power. It will be essential to identify the real causes behind our lack of progress in attaining food security, energy independence, efficient water management, tackling climate change, providing universal health care and a variety of other areas, some of which are global in nature (Box 2). From this point of view, it would be essential to incorporate a strong scientific component in education in socially important areas such as agriculture, medicine and veterinary science. We briefly indicate the kind of challenges faced by us in three areas, water, energy and food.

Box 2

Pressing problems of India

- Equity and social justice
- Universal access to education
- Energy independence
- Health-care for all
- Efficient water management
- Food security
- Mitigating effects of possible climate change
- Strengthening the innovation ecosystem
- Skill development for better employment opportunities
- National security, internal and external

The pressing problems that we face need complex, interdisciplinary solutions. None of them is easily solved, but there is no way that we will ever solve these problems without the proper use of science.

Water, Energy, Food

Among the foremost of these is water - in particular drinking water. Because of the vagaries of the monsoon, the nature of the hydrological cycle and the physiographical and geological attributes of the country the only replenishable water availability is finite and subject to unpredictable variability. Scientific analysis suggests that India's current water usage is already close to annual availability, and that this could lead to serious shortfalls over the next two decades. Furthermore, the physical and ecological integrity of India's water resource system is seriously jeopardized by rapid industrial and population growth. The time has come for India to formulate a coherent unifying policy that combines scientific knowledge with the need to ensure equitable sharing of a vital resource among all sections of society.

What are the principles that may govern such a water policy? In the first place, it must be realized that atmospheric water, surface water, soil water and ground water constitute a single interconnected resource. Management of such an interconnected resource is best achieved with drainage basins and ground water basins as the basic units. Resource integrity has to be preserved for future generations. It is time to realize that water use privilege cannot be granted to any person or institution in perpetuity. It is no longer possible for us to take water for granted as an abundant renewable resource. Yet, water is humankind's birthright - after all, the minimum that the state should provide every citizen is safe drinking water.

Formulating a rational water policy for the whole of the country is an enormously complex task. Nevertheless it is essential that effort be made that combines public education at all levels with the best scientific evidence and wide consultation with all stakeholders. The only way forward is to set up a water management system that is for the common benefit of the people and combines scientific analysis with considerations of social justice[8].

Energy shortage is a chronic and serious problem in many parts of the country. Uncertainties in the availability and pricing of oil resources, increasingly serious concerns with climate change, difficult ecological and human displacement problems with large dams, and a host of other similar considerations have made it essential for us to take a more integrated view of energy, in order to be able to secure it for our future. Our most abundant domestically accessible source of energy remains coal, but its use poses serious problems associated with emissions. Here, science and technology should be able to offer practical solutions, provided appropriate research and development programmes are pursued.

Energy at present is the core mandate of six Ministries: Power, Petroleum and Natural Gas, Coal, New and Renewable Energy, Environment and Forests, and the Department of Atomic Energy. A proper policy is clearly necessary for us to develop an appropriate energy economy that creates an optimal mix of energy sources capable of meeting the steeply increasing demands in the country. We have to become more involved in research in areas such as solar energy and hydrogen energy to fully benefit from the advances being made elsewhere, and to add to them from our own efforts. Even as we write this document, major new developments are being reported in these areas, and we should be pursuing relevant R&D with vigour and purpose.

If we consider the science of combustion and the need to enhance the efficiency of automotive or aero-engines, or for that matter the use of new fuels (such as bio-fuels) across the energy sector, so much can be meaningfully attempted and accomplished with the combined knowledge available in the different ministries. Much more has also to be done to develop more knowledgeable human resources in the energy sector.

Food security is associated with problems of water and energy resources that we have indicated above. Here again, science can play a major role, as it already did in the (first) green revolution. A second green revolution is now needed. In spite of all the controversies surrounding genetically modified foods, the science of genetics is bound to play a major role in these advances - as indeed it has done in the past.

In all these problems concerning the essentials of life - water, food, energy etc. - further progress will depend on the best use the country can make of evidence-based science, but its effectiveness will also depend on establishing new mechanisms of consultation, mutual education and dialogue among different disciplines as amongst various stake holders. Devising such mechanisms is essential if science is to be harnessed for the next phase of national development.

Science outside the science departments

Promoting the use of science and technology in various socio-economic sectors, outside the departments of science is of prime importance. With this objective, S & T Advisory Committees (STACs) in the socio-economic ministries were proposed to be set up during the Seventh Plan period. As a result, over the last two decades, 25 STACs and an Inter-sectoral S & T Advisory Committee with Secretary, DST as

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Chairman have been established. The performance of most of the STACs does not present an edifying picture. It is understood that about half the STACs have not met even once during the last few years. It is not clear if any major programmes or projects have been taken to a stage where their impact has been felt in the economic growth of the concerned sector. However a few STACs that had distinguished scientists as Chairmen have yielded better results.

No coordination to achieve well-defined objectives from the use of S&T in a given economic sector appears to have been attempted.

Currently the science and technology components receive less than 1%, and in several ministries less than 0.5%, of the ministry's total allocation. The rate of increase of allocation to S & T is significantly lower than that of the total allocation to the ministries. Given the authority of the ministries, there is considerable room to derive support from industry, in the public as well as in the private sector, if collaborative projects can be thoughtfully crafted. Such measures can attract more investment in S & T from industry.

The scientific advisory system in the socio-economic ministries need to be restructured, in particular also to exploit the potential S&T strengths residing in national laboratories in several areas of considerable economic relevance.

A new mechanism must be evolved by the Prime Minister and the Cabinet to ensure that the STACs function smoothly and effectively, and that science plays its role in national development across different sectors.

INDIA AS A GLOBAL LEADER: THE WAY FORWARD

INDIA AS A GLOBAL LEADER: THE WAY FORWARD

Making India a global leader in science

In order to begin to contribute significantly to world science and to make an impact on it, India's contribution to global scientific literature would have to rise to something like 10% (from the present 2% or so) – that is a major increase in ten years. Similarly our ownership of intellectual assets would also have to show an increase – from a little more than 1900 filed by Indians and sealed in 2007 to about 20000 patents sealed per year by 2020.

A mere increase in the number of publications or of patents, however striking, will not by itself make a great impact on India's position as a global leader. What is needed in addition is that, first, the science that is generated is of high quality, and second, it also helps in tackling the numerous problems of Indian society and state, and indeed of mankind as a whole, as already discussed. We must be able to afford the opportunity for all Indians to lead a life of dignity. These include such essentials as food security, water resources, energy independence, health care for all, a clean environment, universal access to education.

The country should get to be known for its excellence in science; in terms of metrics, the number of Indian publications among the top 1% of the most cited in the world would have to be higher than 5%. Some of our educational institutions should be amongst the top 50 in the world. Indian science products would have to be seen on the highways and sea lanes, in the skies, at home and everywhere in the global market place. India's natural advantage in knowledge-based industries must be fully exploited to generate novel solutions for old as well as new problems. To accomplish all this, pursuit of excellence has to become a way of life and only this can make us leaders in science, technology and innovation.

How can we begin to move towards achieving these goals? Given the young India advantage, one major instrument should be stronger science education at all levels, from elementary schools to post-graduate institutes, including a system of vocational training that can produce excellent technicians. At the early levels of education, the key to excellence in the education system is the teacher – as indeed it has always been in history and as our ancestors recognized all along (Box 3).

In technical education, a national or an international council could be appointed to restructure the present system and monitor its progress.

We will have to give considerable attention to provide massive continuing education programmes for teachers. Summer and winter schools (month or two long), retraining something like 50000 teachers each year over the next 5 years, are essential. We need to give teachers a position of honour in society – one from which teachers themselves encourage an open, creative questioning attitude. This involves permitting schools to adopt a wide variety of systems to suit the diversity of India's population, while at the same time ensuring quality – defined in a broad sense rather than as the mere ability to secure high marks in scholastic tests. The administration of the education system would have to take on a totally different character, drawing on all appropriate sources of funding and other support for establishing more schools. At the same time, given the inequities that have unfortunately been inherent in Indian society for far too long, a vast system of financial support to those in need or those who cannot afford appropriate education for economic reasons although they have the ability, will have to be created. The same private sector that has set up or promoted schools must be persuaded to support a vast system of new pan-Indian networks of assistance to the Indian young.

Similarly, in higher education, the vast expansion the country needs (Box 4) can only be achieved by public-private partnerships. We must recall that major investments in science education in the late 19^{th} and the first half of the 20^{th} century, were the result of private initiative. We should do everything to revive that spirit, including large tax benefits to private

Box 3

How to run the best schools in the world

The best school systems are not to be found in the countries which have done a great deal of research on education systems, nor in the ones who pay teachers the highest salaries, according to a report by McKinsey[9] The best-performing systems (as measured by the mean score in mathematics on an international assessment) are apparently in Finland, South Korea and Japan. What is common about them is that they have found ways to attract the best teachers to the profession. In South Korea, primary school teachers come from the top 5% of the graduating class in the 4-year undergraduate programmes undertaken in 12 selected universities. No more than the required number of teachers is taken every year. In countries like South Korea, Finland and Singapore the teaching profession is competitive, difficult to get into, and prestigious. Teachers undergo special training programmes every year. Failing pupils get attention, through separate programmes designed specifically for them.

No educational system can be better than the teachers it manages to get. This simple principle seems to be common to all the high-performing countries. In India, where teaching is unfortunately no longer a respected calling, we need to experiment with new methods of getting the best teachers into the profession and recognizing them for the profound national and societal value of teaching – and forming – new generations of citizens. The school system has to support all parts of the distribution – the high- and low-achieving tails and the mid-level groups. This needs a diversity in the system, but a method of preparing and rewarding the right teachers at each level remains the key ingredient of a successful system.

Space, communications and computer technologies should be fully exploited to provide best possible teaching across the country. The knowledge TV channels now running should be improved. Whatever else we may do, we should not forget that a main aim of our educational efforts should be to inculcate scientific temper amongst children and, indeed, all our citizens.

partners. It is equally important to take a major initiative in technical education, with special support for technology universities that can bridge the gaps between science and enterprise. Science must become an integral part of education in agriculture, medicine, pharmaceuticals, veterinary medicine etc., and in particular also in technology.

Box 4

How many scientists do we need?

In 2006-7, the total university enrollment in S&T (including medicine and agriculture) was 36.6 lakhs. The out-turn in 2003 was 6.1 lakhs, of which 82.6% took the first degree, 16.3% post-graduate degrees, and only 1.1% obtained a PhD. India graduated 8420 PhDs in science in the year 2005-06[10].

In the age group 17-21 years, the number enrolled in higher education in 2006-7 was about 1.1 crore, i.e. approximately 13%. Of these, S&T account for about a third – say 4 to 5 %. In 2025, the 17-21 year group will number around 9.8 crores. If we should plan for about twice the present ratio and require that 25% of them should be enrolled in higher education, we will have to cater to about 2.5 crore – nearly 2½ times the present number. This means a student body in S&T of nearly a crore, against the present number of about 37 lakhs. These are probably conservative estimates.

At higher educational levels, the numbers would have to increase a great deal more if India has to be competitive. In 2005-06, India produced about 1000 PhDs in engineering and technology, whereas the US and China were already producing about eight times as many in 2004-05. We should plan for a huge increase by 2030; even ten times would barely match China's current output. This shows the enormous magnitude of the problem. In areas such as computer science, the situation is serious, with only 25 or so Ph.Ds being produced per year in India.

During 2004-06, India produced one research scientist for every 7100 people; China 1 in 1080, S. Korea 1 in 240, Sweden 1 in 163.

Another way of looking at the problem is to plan for world-class education in all of S&T for 20% of the university-age Indians – i.e. to about 2 crores in 2025; If 10% of these went on to post-graduate work to embark on research (Masters + PhD – say over 4 years) we would have 20 lakhs – of which about 5 lakhs will graduate each year, say a tenth of these with a PhD (50000 approximately). At current ratios, about 35000 will be in natural science, and 5000 will be in engineering and technology.

No matter how we look at the numbers, if India has ambitions of becoming a leading global force in science, a massive increase in S&T education will be necessary – both in quality and quantity. We should expect the number of scientists to increase at least at the following rates by 2025:

Graduate scientists: 15 lakhs per year

Post-graduate scientists: 3 lakhs per year

PhDs: 30,000 per year

The large S & T manpower in India will not only support our national efforts but will also be able to assist the aging world elsewhere, making India a leading knowledge provider through its human resources.

It would indeed be advisable for a group of wise persons to examine the education scenario and manpower requirements of 2025.

It is not a question of numbers alone. We need to pick the best talent for science. This should be possible with the large untapped talent especially in rural India. Every effort should be made to attract young people in schools and colleges to science by taking various types of initiatives including setting up a large number of fully funded residential schools and colleges in India's interior. We should also use the talent of Indians settled elsewhere for various national endeavours and provide suitable opportunities for talented persons from other countries to work here. We should strive to make a scientific environment in India that is so attractive that many Indian scientists now working abroad will want to return and join in the exciting project of building a new India.

As much of the rest of the world grays into a predominantly older demographic profile India will only show a middle-aged bulge even in 2050, and will continue to possess a considerable human advantage.

Another advantage that India has is that it is today the most cost-effective source of internationally accepted R&D in the world. Roughly speaking, India spends only ½ % of what the world does on science, but produces 2-2½ % of global scientific literature (Table1).

Table1: Some S&T indicators for Select Countries[11]

Country	Total no. of publications (2006), (change over 1997)	High-impact publications % (change)	GDP, $ T(2003)	Investment R&D, %GPD	Investment R&D, $B	$ M/ publication	PhDs E&T per year
USA	451 028 (+18%)	63% (-4%)	10.9	2.68%	292.0	0.65	8000
UK	~122 000	12.8% (+25%)	1.79	1.89%	33.8	0.28	
China	78 671 (+358%)	0.99% (+125%)	1.42	1.31%	18.6	0.24	9000
South Korea	(+290%)	0.78% (+178%)	0.61	2.64%	16.1	0.60	
India	26 963 (+60%)	0.54% (+69%)	0.60	0.77%	4.6	0.17	700

INDIA AS A GLOBAL LEADER: THE WAY FORWARD

Our total production of world R&D is small, but its cost-effectiveness is unsurpassed. Furthermore, public sector science in India, wherever it has been successful, confirms this advantage. For example, in comparison with that of the other major space powers, India has been described as running its 'prolific programme' on a 'shoestring budget' as *Aviation Week and Space Technology* has commented.

Although India is not yet a major source of innovation in the world, many Indian scientists (often working abroad) have shown that the innovative spirit is widespread among Indians. In a recent poll taken by Zogby International in the US 28% of 3000 respondents voted that the next Bill Gates will come from India: only the US (at 29%) had a better chance[12]. What India lacks is not the innovative spirit, but an effective innovation eco-system.

A framework for higher education

There have been numerous studies of the Indian higher education system, and several proposals have been and continue to be made to improve its performance. Successive Prime Ministers (beginning with Pandit Jawaharlal Nehru) have often remarked on the bureaucracy and political interference that characterize the system. As the problem has persisted in spite of all this attention, some radical ideas have to be considered. The following proposals are made, in the light of the Government's intention of establishing several world-class universities. As the present system is by common consent inimical to the success of such a project, a new framework has to be devised. Here are some criteria that would define a new framework.

- Seek dynamic leadership at the top and provide "real" autonomy with minimal bureaucracy.
- Get the best faculty and establish the best facilities
- Establish a proper faculty promotion policy.
- Keep out political interference
- Welcome private investment and support from private wealth.
- Assemble a diverse student body balancing excellence and inclusion.
- Combine undergraduate teaching and world-class research

- Balance educational efforts in science, technology, humanities
- Inculcate national pride amongst pupils
- Build campuses with character and suitable traditions.
- Keep student numbers manageable
- Offer integrated 4+1 year BS/BA + MS/MA programmes with a flexible package of courses
- Match supply and demand

The innovation eco-system

In a world of rapidly-advancing and ever-changing technology, innovation is a key driver of science, technology and – indeed – of economic advance. Innovation is not just about patents and new products, though these are important outcomes of innovation. It is equally about new ideas, services, and even business models. Social networking sites like the Facebook are examples of new services based on technology, while Google represents an innovative business model (where the user does not pay for service).

India has been active in innovation of certain kinds. Its IT industry created a new and disruptive business model through its on-site plus off-shore structure, which resulted in unprecedented growth and success. The Tata Nano represents a combination of innovative design and engineering, while nano in a different sphere – shampoo and other sachets – has created a new business model serving what has been called the "bottom of the pyramid". This has been emulated in such vital areas as health. Grass-roots innovation thrives, as documented by the National Innovation Foundation. However, much of our innovation has been incremental and has focused on "jugaad", best characterized as improvisation rather than true or radical innovation. Inventions, break-throughs and large value-addition are rare.

The potential for innovation is extremely high since diversity and adversity, both crucial to innovation, are characteristic features of the Indian scene. The first permits, even encourages, out-of-box thinking, while the latter throws up day-to-day problems that can be overcome only by creative solutions. Our investments in higher education and R&D facilities should provide the wherewithal to facilitate innovation. In recognition of India's capabilities, a large number of MNCs have set up R&D centres in India. Yet India has not become a leader in innovation. (It is worrisome that 9 out of the top 10 entities receiving Indian patents are of foreign origin) What seems to be lacking is the overall eco-system that can translate the undoubted Indian potential into reality. The main elements of such an eco-system would include the following:

Venture funding: While there is now funding available for commercial scaling-up of successful proof-of-concepts or pilots, there is yet a problem with regard to seed or "angel" funding that is willing to take risks on ideas. At this stage, failure rates are necessarily high and in many countries such funding is often provided directly or indirectly by government (Israel is a striking example). However, in the case of government involvement, there must be high failure-tolerance: conventional auditing, that tries to fix accountability for unsuccessful investments, will not do, as some failures are an integral part of innovation. A separate, large fund (of the order of Rs. 1000 crore/year) must be set up and administered autonomously– possibly through a public-private Board, or as a not-for-profit company that invests in innovative start-up ventures.

Tax incentives: Given high failure rates, there must be some tax write-off and other incentives to encourage angel investing, linked to the crucial element of mentoring.

Greater funding for new ideas and innovation in government-funded R&D organizations, academic institutions and universities, and a willingness to risk failure: Such funding could be separately provided (as extra-budgetary grants) through the fund mentioned earlier.

Less bureaucratic controls in government-funded R&D organizations: This is a big impediment to free thinking, experimentation and innovation.

Encouragement: Through both sabbatical leave and other schemes and appropriate funding, scientists and technologists should be encouraged to realize and monetize their ideas through commercial ventures.

Changes in education curricula to encourage creative thinking and innovation (as opposed to rote learning): Since a great deal of innovation takes place through cross-fertilization of ideas, we need to encourage trans-disciplinary centres and give freedom to students to take various combinations of courses (as against the present strait-jacketing).

A fund (either as part of the one suggested earlier or separately) to promote social innovations: Ideas or ventures that may not be commercially profitable but have high social returns will have to be supported.

Encouraging tie-ups between academia, R&D laboratories and commercial ventures: This, as proven elsewhere in the world, is an excellent combination for promoting innovation and taking it to market quickly.

Strengthening the intellectual property laws and their enforcement: While there are strong arguments for putting certain kinds of developments in the public sphere, there is also need to enforce IP laws, so as to encourage investments in and development of new products and processes.

A special package for a Small Business Initiative that will promote the establishment of and provide support for small R &D intensive firms.

India needs innovation to tackle the diverse problems confronting it, including the one for converting our knowledge-assets to economic growth and strength. Fortunately the country has great potential to be truly innovative. Demography, democracy and diversity give us a unique advantage. If we can create the right ambience through an appropriate eco-system, we can reap the benefits of these advantages.

Finally, the investment in science that began some sixty years ago has left the country with a broad infrastructure going all the way from a few excellent academic institutions to fine research laboratories and effective technology delivery systems. This infrastructure has many weaknesses, but with the growing economic strength of the country a rapid build up has become feasible.

Investment in science

Science budgets of the Government have been steadily increasing, although as a fraction of GNP they have remained more or less stagnant in the last ten years (See Graphic 2).

The State Governments do not invest much money on science either. Only in some special sectors such as pharma have significant budgets been set apart for R&D

by industry. India is still a small player in high technology exports (Box 5), and the new wave in science that we advocate here would not be sustainable unless the demands made by not only the science sector itself but also by industry and commerce for scientist-personnel show significant increase. In recent years the nature of exports from India has been changing, and high-tech products are beginning to show a rise although the total still remains small. But there is promise that this can increase a great deal more. For example the Indian automobile industry surpassed the performance of China last year; the main force that drove this development was the higher skill levels of the Indian industrial work force[13]. Indian satellites continue to be 25-30% less expensive than those launched from western nations. With appropriate incentives for innovation and high technology exports, Indian industry will be well set to grow in internationally competitive sectors.

Box5

High-tech exports

The European Union's definition of high technology includes nine sectors: aerospace, computers and office machines, electronics and telecommunications, pharmacy, scientific instruments, selected electrical machinery, selected chemicals, selected non-electrical machinery and armaments. Over the period 1995 to 2006 India's high tech trade increased more than four fold (from US $ 1.0 B to 4.5 B), but over the same period Brazil's went up by 8 times and China's 25 times (to about US $ 300 B).

High-tech trade accounted for only 0.49% of India's GNP in 2006, and for 0.23% of global high-tech trade. India's imports of high tech goods increased form $ 2.6 B in 1995 to $ 23 B in 2006 – still only 1.2% of global imports. These figures are disproportionately low (the lowest in the BRIC countries), and explain the generally low demand for science in Indian industry: we are still largely a low-tech trading nation[14].

In such cases, government schemes must provide the full funding where necessary (for example in energy research and development, with specific goals over a 5-10 year period). Formulation of economic policies that reward competitive knowledge-intensive industries should receive high priority.

To make sustainable growth in science possible, it is necessary that it is perceived as a national goal, cutting across the various ministries of the Government of India, the public and private sector industry, educational institutions, national research laboratories and the growing private initiatives in R&D. This will need to be signalled through a variety of actions. First of all, the investment of the Union Government in science must begin to show a significant increase as a percentage of GNP, rising to at least 2.5% by 2020. States should also invest more in science as well as higher education and support their own universities adequately.

A special economic package must be put together for the promotion of high-tech industry in India and its exports (just as in the IT sector). Educational and research institutions in the country would have to go more global and make special schemes for exchange of scientists at various levels with selected partner nations or institutions across the globe. In particular, we suggest a major initiative that makes international collaboration both ways easier. It is necessary to devise special schemes for post-doctoral fellows and other professionals, both Indian and foreign, that make it attractive to work here. It should be noted that post-doctoral fellows have been largely responsible for the greater productivity in top class science in the advanced nations of the world; in India, a recent initiative makes post-doctoral fellowships more attractive, but a great deal more needs to be done. A scheme that will make it possible for increasing numbers of young foreign scientific workers to conduct collaborative research with Indian colleagues in our own laboratories can be a major step forward in enhancing the quality of communication and cooperation between the scientific communities of India and other countries of the world.

Can NSERB be an engine of change?

The recently established National Science and Engineering Research Board (NSERB), which is the Indian counterpart of the U.S. National Science Foundation, can act as an engine driving some of the changes. The Board should constantly monitor the state of health of Indian science, and take action on its own initiative to promote the growth of science and to realize the vision that this document sets out. It will be necessary to see that all serious scientists in India get adequate support for their professional work. It is also necessary that NSERB takes the initiative in putting together mega-projects or mounting grand challenges that will bring together scientists and their institutions from across the country, and perhaps the rest of the world, in achieving these objectives. One mechanism that might be particularly useful is to set apart funding for projects executed by teams of scientists cutting across disciplines and institutions, assembled together by enterprising scientists in the country. NSERB could also create new types of fellowships and professorships to support and encourage outstanding scientists of all age groups.

THE INDIVIDUAL AND THE INSTITUTION

The growth of modern science and technology in India owes a great deal to visionary individuals who went on to build great institutions. Beginning with the Indian Association for the Cultivation of Science set up in 1876 by a well-known physician of Calcutta, Dr. Mahendra Lal Sircar, the Indian Institute of Science established in 1909 by the vision of the great industrialist Jamsetji Tata, and the Banaras Hindu University in 1916 by Pt. Madan Mohan Malaviya, private initiative played a key role in reviving Indian science at a time when the national scene looked extremely bleak. Sir M.Visvesvaraya was the greatest national champion of modern Indian industry in the first half of the 20th century. Many of these pioneers encouraged public-private partnerships, of which the most striking example was the Indian Institute of Science, which came up by a three-party agreement between the House of Tatas, the Maharaja of Mysore and the British government. The Tata Institute of Fundamental Research has had similar origins, and was the result of the shared vision of H. J. Bhabha and J. R. D. Tata. There are numerous less well-known examples in the form of professional colleges built by successful local professionals or princes. In 1942, Indian private enterprise came forward to fund the Board of Scientific and Industrial Research when the British Indian government cut budgets because of the War [15].

Has this private passion for the growth of Indian science waned in the last sixty years? Since the economic reforms of 1991, private wealth in India has soared, but it is generally conspicuous by its absence on Indian campuses barring professional undergraduate courses. Indian business is now more entrepreneurial than ever. It has built the most competitive automotive and software businesses in the world, created the largest telecommunication market in the world, and a vigorous pharmaceutical industry. It also has the world's largest petroleum refinery. An Indian-born businessman has brought into being the largest steel-making entity in the world. The public sector has remarkable examples as well: one of the most cost-effective space programmes, and a science base that is the source of world-level R&D for most major multinational companies. The spectacular growth of private engineering and medical colleges, the former producing more than 10 times the graduates that government institutions do, indicate the potential of private enterprise in education.

Is post-reform private wealth allergic to major investments and initiatives in education? Does the present educational system, dominated by the Government since 1947, discourage bold new individual initiatives through over-regulation? Are there sufficient domestic incentives for such public-spirited initiatives? Is the United States doing better in inviting Indian wealth to *their* campuses than we are able to do ourselves here in India? These are important issues that need to be debated. We need to understand why private wealth has turned away from supporting excellence in higher education.

A WAY TO GET GOOD ADVICE

Many problems today, typified by climate change, genetically modified foods and water resources management, to mention only a few, touch the daily lives of all Indians directly. The problems raised here are complex. They have widespread social and economic impact, and often become subjects of intense political debate. While science must continue to seek advances on the basis of its own internal drives and judgements, a serious problem will remain in communicating the conclusions of science, simply and accurately, to the public at large. This requires a special effort. On controversial scientific issues (for example, genetically modified foods and climate change), the Government should make a serious effort to get the most unbiased and accurate advice possible by calling on the academies of science to present accurate accounts of the state of the art. It is worth considering whether this objective could be better achieved through a council such as the Science Advisory Council to the Prime Minister or by the constitution of a National S&T Council (NSTC), on the lines of the US National Research Council. NSTC would comprise all the major academies of science, engineering, agriculture and medicine, heads of science agencies and eminent scientists in their individual capacity. Such a council will be assigned the responsibility for major scientific assessments by commissioning reports through well-defined contracts and for advising the government on relative priorities in S&T and associated investments.

32 *India as a global leader in science*

LIBERATING SCIENCE FROM BUREAUCRACY

Prime Minister Manmohan Singh stated in the recent science congress session that it is high time that we liberate science from bureaucracy. How true! Practice of science in India has been severely hampered by oppressive bureaucratic practices and inflexible administrative and financial controls. One of the necessary conditions for progress in science is the elimination or minimization of bureaucracy. This is required in the central government and even more so in the state governments.

In addition to eliminating bureaucracy, it is important that we restructure many of our organizations and institutions so that they are able to create the right atmosphere to pursue research and higher education more effectively. Restructuring is specially essential in the state university system and its educational institutions, where there is need for much better methods of appointing vice-chancellors, greater autonomy, major changes in the examination system, procedures for admission, recruitment and promotion of faculty, research administration and, in fact, a total transformation of the academic environment. We suggest that the Government appoint a Science Administrative Reforms Commission, comprising largely of scientists, to propose a new administrative system for universities, national laboratories and the science departments and agencies.

When asked about how to build a great institution, James Conant of Harvard University said the following: ***"Get the best minds and leave them alone"***. There is a lesson for all of us in this statement.

EPILOGUE

What has been projected here has to be accomplished within a short period, if India has to truly find a place in the sun; we cannot afford to lose time. The nation is demanding accelerated, inclusive growth and world class governance. Indian science is today in a position to help in this endeavour. India has to become a leader in the scientific world, and a knowledge provider for the world. For this to happen, it is essential that science gets an important position in our way of thinking. Pursuit of excellence and elimination of mediocrity should become guiding principles in all our endeavours. Policy makers, administrators, and politicians as well as the general public have to view science as an essential agent of transformation. There is much to be done by individual scientists, scientific institutions, academies, universities and the society at large. One hopes that the entire nation will rise to the occasion.

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"The key to national prosperity, apart from the spirit of the people, lies in the modern age, in the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital. But technology can only grow out of the study of science and its applications.

The dominating feature of the contemporary world is the intense cultivation of science on a large scale, and its application to meet a country's requirements. It is this, which, for the first time in man's history, has given to the common man in countries advanced in science, a standard of living and social and cultural amenities, which were once confined to a very small privileged minority of the population. Science has led to the growth and diffusion of culture to an extent never possible before. It has not only radically altered man's material environment, but, what is of still deeper significance, it has provided new tools of thought and has extended man's mental horizon. It has thus influenced even the basic values of life, and given to civilization a new vitality and a new dynamism".

From the Scientific Policy Resolution (1958)

Annexure II

रजिस्ट्री सं० डी० एल०-33004/99 REGD. NO. D. L.-33004/99

भारत का राजपत्र
The Gazette of India

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विज्ञान और प्रौद्योगिकी मंत्रालय

(विज्ञान और प्रौद्योगिकी विभाग)

अधिसूचना

नई दिल्ली, 11 जून, 2010

का.आ. 1402(अ).—केन्द्रीय सरकार, विज्ञान और इंजीनियरी अनुसंधान बोर्ड अधिनियम, 2008 (2009 का 9) की धारा 3 की उप-धारा (1) और उप-धारा (3) द्वारा प्रदत्त शक्तियों का प्रयोग करते हुए, विज्ञान और इंजीनियरी अनुसंधान बोर्ड का गठन करती है, जो निम्नलिखित सदस्यों से मिलकर बनेगा, अर्थात् :—

(1) सचिव, विज्ञान और प्रौद्योगिकी विभाग, भारत सरकार —अध्यक्ष (पदेन)

(2) सदस्य सचिव, योजना आयोग —सदस्य (पदेन)

(3) सचिव, जैव प्रौद्योगिकी विभाग, भारत सरकार —सदस्य (पदेन)

(4) सचिव, वैज्ञानिक और औद्योगिक अनुसंधान विभाग, भारत सरकार —सदस्य (पदेन)

(5) सचिव, पृथ्वी विज्ञान मंत्रालय, भारत सरकार —सदस्य (पदेन)

(6) सचिव, व्यय विभाग, वित्त मंत्रालय, भारत सरकार या उनके प्रतिनिधि —सदस्य (पदेन)

(7) सचिव, स्वास्थ्य अनुसंधान विभाग, भारत सरकार —सदस्य (पदेन)

(8) प्रोफेसर दिवांग विपिन खक्खर, निदेशक, भारतीय प्रौद्योगिकी संस्थान, पोवई, मुंबई-400076 —सदस्य

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[फा. सं. एसआर/एस 9/जेड-09/2010]

डॉ. बी. हरि गोपाल, वैज्ञानिक-'जी'

MINISTRY OF SCIENCE AND TECHNOLOGY

(Department of Science and Technology)

NOTIFICATION

New Delhi, the 11th June, 2010

S.O. 1402(E).—In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Science and Engineering Research Board Act, 2008 (9 of 2009), the Central Government hereby constitutes the Science and Engineering Research Board consisting of the following members, namely :—

(1) Secretary to the Government of India in the Department of Science and Technology —Chairperson (ex-officio)

(2) Member-Secretary, Planning Commission —Member (ex-officio)

(3) Secretary to the Government of India in the Department of Biotechnology —Member (ex-officio)

(4) Secretary to the Government of India in the Department of Scientific and Industrial Research —Member (ex-officio)

(5) Secretary to the Government of India in the Ministry of Earth Sciences —Member (ex-officio)

(6) Secretary to the Government of India in the Department of Expenditure, Ministry of Finance or his nominee —Member (ex-officio)

(7) Secretary to the Government of India in the Department of Health Research —Member (ex-officio)

(8) Professor Devang Vipin Khakhar, Director, Indian Institute of Technology, Powai, Mumbai - 400 076 —Member

(9) Professor (Ms.) B.K. Thelma, Department of Genetics, University of Delhi, South Campus, Benito Juarez Road, New Delhi-110021 —Member

(10) Professor Manindra Agrawal, Department of Computer Science and Engineering, Indian Institute of Technology, Kanpur-208016 —Member

(11) Professor BN Goswami, Director, Indian Institute of Tropical Meteorology, Pune - 411008 —Member

(12) Professor (Ms.) Sujatha Ramadorai, School of Mathematics, Tata Institute of Fundamental Research, Mumbai - 400 005 —Member

(13) Professor M.R.S. Rao, President, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore - 560064 —Member

(14) Dr. Anil Kakodkar, Department of Atomic Energy Homi Bhabha Fellow, Bhabha Atomic Research Centre, Central Building Complex, 7th Floor, Trombay, Mumbai - 400 085. —Member

(15) Prof. K Srinath Reddy, President, Public Health Foundation of India, PHD House, 4/2 Siri Fort Road, August Kranti Marg, New Delhi - 110 016. —Member

(16) Dr. C.V. Natraj, 120, Adarsh Vista, Basavanagara, Bangalore - 560 037 —Member

(17) Professor Bina Agarwal, Director, Institute of Economic Growth, University of Delhi, Delhi - 110 007 —Member

[F. No. SR/S9/Z-09/2010]

Dr. B. HARI GOPAL, Scientist-'G'

Annexure III

Essential Steps for Progress in Higher Education: A Check-list

The higher education sector in India is facing serious problems and challenges which include the big rush of young people to go for higher education, declining quality and indifferent performance of institutions, serious problems related to administration of the education sector and increasing global competition. These problems will probably get even more severe in the near future when an explosive increase in the number of young students aspiring for higher education is likely to occur. In spite of the variety of problems, India is also a land of opportunities with certain advantages, young India being a specially noteworthy feature. In view of the crucial importance of the higher education sector for the overall development of the country, we found it imperative to highlight the most essential aspects which need immediate attention in our effort to improve the status and quality of higher education and to ensure that the steps taken are the right ones. In preparing this short check-list, we have subjected the numerous important issues to distillation, and it is possible that some of the items of concern to some colleagues have not received due importance.

1. With several million additional students likely to come up for higher education in the next two to three decades, it is necessary to make a serious manpower planning effort so that young people get directed to different areas of study, instead of all of them going for standard university courses in science, engineering and other subjects. How do we ensure that there is a wide variety of course packages and flexible curricula? How are we going to handle the surge of young students? How do we ensure that undergraduate education is relevant to employment, well-rounded and at the same time sufficient for taking up higher studies? There is manpower mismatch in many countries with too many professionals in some of the subjects, with employment opportunities getting fewer. It is not unlikely that there will soon be excessive production of Ph.Ds in some of the countries. At the same time, there could be shortage of people in some sectors. A group needs to be appointed by MHRD to prepare a vision document which foresees the problems 20 years hence.

2. It is widely recognized that quality up-gradation requires the greatest attention if India has to become a global leader in science and technology, and other creative endeavours. Today, there is not a single educational institution in India which is equal to the best institutions in the advanced countries. It is important that in the next 10-15 years, several of our educational institutions are in the top 100 in the world. Much effort is needed if India has to emerge as a major contributor of higher quality research. As a step forward, around ten higher educational institutions could be provided all the support required to enable them compete with the best of institutions in the advanced countries. This would be a good programme to initiate in the year of science (2011-12) declared by the Prime Minister recently.

3. It has been said that we have an examination system but not an education system. Examinations have got increasing importance in the last few years. One is not talking about the final annual examinations alone. Entrance examinations have become a menace. IIT entrance examinations have the reputation of being difficult and purposeful, but they have also had a negative effect on young minds. Young people suffer so much to succeed in these entrance examinations, and in the process lose excitement in education itself. Those who do succeed would have got exhausted and are not able to perform as well as young people with fresh minds.

Even after getting a good degree, students have to take ever so many entrance examinations to go for higher studies. For example, one hears of a proposal to have a qualifying or accreditation examination for medical graduates and postgraduates. When will young people stop taking exams and do something worthwhile? It is important to relook at the entire examination system including the system of final examinations, entrance examinations, qualifying examinations, selection examinations, and so on. For entrance examinations related to admission to higher education institutions, there should be only one national examination which should be able to assess the eligibility of the candidates. Note that US institutions take young people from India based on one GRE examination.

4. Administration of the education system requires a serious overhaul. There is urgent need for restructuring institutions and reforming administration. The indifferent manner with which educational institutions are being handled may destroy even the system that we have. What is unfortunate is that educational and research institutions are administered by people with IAS or similar administrative backgrounds, many without any real interest in education. Even technical education is administered routinely by administrators trained in bureaucratic practices. Unless this situation is changed, it will be difficult to improve the quality of educational institutions. Even more serious is the direct intervention of governments in administering institutions, particularly those run by the States. For example, governments choose vice-chancellors of universities. Universities are overloaded with work related to the conduct of examinations. Some of them are too large because of the affiliated colleges. There should be guidelines as to the maximum number of students in educational institutions.

   State governments should be persuaded to support higher education with greater care as well as investment. Administrative autonomy, dedicated budget for R&D, recruitment and promotion of faculty are some of the other issues that require attention.

5. Considering that there are already many colleges of engineering, management and so on, how do we plan for educational institutions in the future? How many university type institutions should/can be there in the country? It would seem counter-productive to allow uncontrolled increase in the number of government-supported colleges and universities without careful consideration of manpower requirements.

   Should we not differentiate curricula for general-purpose basic degrees from degrees with subject specialization? How, where and for what purpose should the central government establish the so-called quality institutions or central universities?

   How do we ensure acceptable quality of most of our higher educational institutions? What would be the best way(s) of rating institutions? Is it not necessary to separate affiliating and unitary universities? Would it not be useful to establish tertiary education authorities both at central and state levels? How do we keep abreast of "futuristic practices" in education?

   What should be the criteria and procedures for appointment of Chairmen of Governing bodies of institutions, Directors of national institutes and VCs of Central Universities etc.?

6. It is well established that education is effective only when teachers get the prominence and recognition. A country which has succeeded in making the teaching profession an important one in society is Finland. If India wants to succeed in education, it should give greater importance to the teaching profession and accord due respect to teachers. This would involve providing good emoluments and amenities as well as continuing education opportunities to

teachers. Teaching profession should be sought after by young people. High-quality continuing education and training programmes for teachers at all levels should be provided on a massive scale.

7. We need the best talent for many of our efforts in the country. It is likely that some of the most talented young people are in rural India. In order to tap this talent and provide opportunities to young children in rural India, we must increase the number of fully supported residential schools up to higher secondary level in rural India. Best of these students should get opportunities to pursue higher studies in the best of our institutions.

8. The examination system as well as the reward system seems to have destroyed creativity in young people. We need highly creative and innovative people to take up challenges in science and other subjects and also to tackle problems related to national and global needs. It is therefore essential to see that everything we do in the education sector promotes creativity. It is noteworthy that many of the advanced countries (e.g., U.K.) are making serious efforts to promote creativity and innovation amongst the youth.

9. We need to create an atmosphere where there are barrier-free connectivities amongst educational institutions within the country as well as internationally, to promote fruitful collaboration and cooperation, quality upgradation and synergy in performance.

10. We should seriously consider a possible scenario wherein the young India advantage enables India to emerge as the provider of trained manpower for the entire world in the next 20-30 years. This could be a worthwhile national objective.

It is possible that planners, policy makers, administrators and the general public may react to this check-list by saying that one is already aware of these issues and that there are agencies and committees looking at them. What is required is a serious application of mind to these and related issues, to ensure that major transformations are brought about in the country that would create a healthier higher education scenario. It is only when we bring in such a transformation in the higher education that we can hope to meaningfully compete with neighbouring countries such as South Korea, Singapore and China.

In order to prepare ourselves to face many of the problems and challenges in the higher education sector, it is important that an action-oriented document on higher education is prepared as early as possible. The document should be able to provide a roadmap for the higher education sector. It is hoped that the Ministry of Human Resources Development will soon set up a task force to prepare such a document. ***It is desirable that the document becomes available in the next 12 months. What may also be necessary is for MHRD to declare higher education as a national mission for the next decade and designate capable individuals to be in-charge of each important item listed above to oversee that changes for the better occur without much delay.***

Annexure IV

Rejuvenating Research in Universities Activities of the Empowered Committee for Basic Scientific Research (BSR) in Indian Universities

Preamble

The previous SAC-PM had recommended to the MHRD to look into harnessing the Universities to produce, through a quantum jump, quality Ph.D's throughout India. The Committee constituted by the MHRD, consisting of Professor M.M. Sharma (Chairman), Professor G. Mehta, Professor P. Rama Rao, Professor Kota Harinarayan, Professor S.P. Thyagarajan, made many recommendations which were accepted in toto by the MHRD and the Committee was converted into an Empowered Committee (EC) and entrusted the implementation to the UGC, associating the Chairman of the UGC. The key assignment was to trigger excitement in the University System to carry out research vigorously. The EC meets frequently and has, so far, held Forty meetings.

Infrastructural Development Grant

The Universities have a serious lacuna in terms of power supply, water supply, safety measures, fume cupboards, bench tops, flooring, etc. All the Departments which are recognized under the Special Assistance Programme (SAP) of the UGC have been supported and this covers nearly 450 Departments and a total sum of about Rs. 180 crores. A number of non-SAP Departments, based on a rigorous appraisal, have been supported with a total grant of Rs. 42 crores. The members of the EC make personal visits to selected Departments for on-spot study of the utilization of grants.

BSR Doctoral Fellowships (DF)

There has been a remarkable progress and over 4800 DF were sanctioned and as of now nearly 2800 are in position and some Departments, on the basis of the past performance, have 15 DF per year. There is a great enthusiasm through this endeavour.

Dr. D.S. Kothari Post-Doctoral Fellowship (DSK-PDF)

In order to give a proper fillip to the research programme, this innovative scheme, completely outsourced, for the first time, through PUNE Univ., with Professor S. Gadre as the coordinator, with on-line applications, and a rigorous review system, has been implemented with great success. The decision is given within 6 to 8 weeks and so far nearly 400 PDF were sanctioned and nearly 240 are in position. The value of PDF is higher than the usual GOI PDF's.

Networking Centers / Summer-Winter Schools

Nine Departments, covering different disciplines, have been covered and about Rs. 40 crores has been sanctioned. All Departments are acquitting themselves well.

Faculty Recharge

This crucial activity faced several serious difficulties in implementation, first with INSA and then in J.N.U. After a lot of follow-up and appointment of Professor R.P. Gandhi as coordinator and Professor (Mrs.) S. Nangia as Associate Coordinator and help of JNU, it has been now possible to launch this important activity. An innovative procedure will be followed with rigorous refereeing and powerful selection committees and interviews to select highly accomplished persons. A proper MOU will be signed with the recipient Universities.

Support for Colleges

In order that proper B.Sc./ M.Sc. students come for research it was considered prudent to support colleges which have been identified as " Potential For Excellence" (CPE) and Autonomous Colleges (AC) through Infrastructure Grant to improve their laboratories. About 1500 Science Departments of nearly 190 CPE have been supported. In addition nearly 600 Science Departments of 77 colleges have also been supported. In all about Rs. 120 Crores have been spent on this activity. 210 AC's have been supported with a total grant of about Rs. 55 Crores. 610 NACC accredited colleges have also been supported with a total grant of Rs. 61 Crores. Thus the spread has been enormous and these will surely show results in coming years, as it has created a lot of enthusiasm.

Concluding Remarks

EC has worked systematically and met frequently to provide support to Universities. However, there is considerable weakness in the system of Universities to absorb grants and utilize in time. There is also lacuna in sending utilization certificates on time. Last year at the meeting of the UGC/MHRD with VC's, State Ministers, Secretaries, it was emphasized to give consideration, in a vigorous way, to the activities of the EC. On 24th / 25th March, 2011, Prof. P. Rama Rao, brought out the importance of the Faculty Recharge and this seems to have been well received.

The Chairman, EC, would like to thank members of the Committee, the Chairman, UGC, Prof. P. Prakash, Addl. Secretary, UGC and his staff for their total commitment to these activities. The SAC-PM deserves our grateful thanks for ushering this much wanted activity. We also thank the MHRD, GOI, must sincerely, for providing generous grants for activities of the EC.

M M SHARMA

Annexure V

Concept Note On Improving Forensic Science Activities In India

I. Preface: This concept note has been prepared at the request of the Scientific Advisory Council to the Prime Minister (SAC-PM) following a presentation to it by Dr J Gowrishankar, Director, CDFD on 22 November, 2010.

II. Introduction: The inadequacy, both qualitative and quantitative, of forensic science activities at present being undertaken in the country, and its consequent negative impact on the criminal justice delivery system, has engaged the attention of various constitutional and Govt. agencies in the last few years, including SAC-PM itself. At present, forensic science is under the ambit of the law enforcement agencies of the States and the Centre, and the problems and difficulties of such an arrangement include the following:

- **Cultural:** The rigid command structure in law enforcement agencies is often at odds with the non-hierarchical and disruptive ("irreverent") cultural ethos normally expected for scientific activities.
- **Technical:** The heads of law enforcement agencies are from the IPS or IAS, often with little knowledge of science.
- **Potential conflicts of interest:** Ideally, forensic investigations must be undertaken by an agency which is independent of the police and the prosecution, so that they are seen to be impartial.

Therefore, a view that is gaining increasing acceptance is for forensic science activities in the country to be managed or overseen by the Ministry of Science and Technology, of course with close operational linkages maintained with the law enforcement agencies that come under the Ministry of Home Affairs. It is noteworthy in this context that the National Academy of Sciences of the USA, in its 2009 report that was commissioned by the federal legislature, has also made similar strong recommendations for transfer of all forensic science laboratories in the USA from the administrative control of law enforcement bodies to that of an independent science agency.

The Concept Note below discusses three issues in this context, namely, (i) what are the alternative administrative structures that can be considered for implementing the new arrangement (of science agency oversight and/or control of forensic science); (ii) what are the alternative mechanisms that can be considered for effective delivery of forensic science services in support of the criminal justice system; and (iii) what is the road-map and time-frame for implementation of the above.

III. Alternative administrative structures: Three alternative administrative arrangements can be envisaged by which forensic science activities are overseen by the S&T Ministry.

The first is to continue with the existing system but to put in place an alliance mechanism between MHA and MST, perhaps by creation of an oversight body that is co-chaired by Secretaries from the two Ministries, that would closely monitor and direct the forensic science activities in the country.

The second is to bring all the existing, and in future expanded, activities of forensic science under the ambit of one of the existing agencies of the S&T Ministry, which could be DST, CSIR, or DBT.

The third alternative would be for creation of a new Department of Forensic Science (DFS) to be headed by a scientist/technologist. In one variant of this third alternative, the DFS would be under the MHA, whereas in the other variant it would be under the MST.

In the cases of the second alternative as well as both variants of the third alternative, once again there would be the need to establish alliance mechanisms between MHA and MST, to enable co-ordination to ensure that the investigative agencies are **obligated** to send the cases for forensic investigations rather than doing so at their **discretion**, as is the current practice.

Of the various alternatives above, the first would appear to be just an incremental improvement that may be insufficient to take care of the criticisms of the existing system. Additionally, given the scale of the required operations (discussed below), one could reasonably support the suggestion for creation of a new DFS; and locating the latter in the MST would have the advantage of more effective co-ordination of its activities with those of the other science agencies of MST such as the DST, DBT, and CSIR.

IV. Alternative service delivery mechanisms: Irrespective of the structure by and through which forensic science activities shall be administered, three alternative mechanisms for undertaking the expanded services can be envisaged, which are not mutually exclusive.

The first mechanism is through forensic science laboratories and autonomous institutions/public sector enterprises, both existing and newly created, of the Central and State Governments. In the expanded scale of operations (see below), this would require the establishment of a cadre of over a thousand forensic scientists. Furthermore, the general experience has been that it is quite difficult to sustain standards, quality, enthusiasm/motivation, and academic rigor and independence in the provision of high-technology services (which is what forensic science activities represent), when such service activities are divorced from other academic pursuits such as research and technology, in a Government organization.

The second approach is for forensic science activities to be undertaken in existing academic and /or research institutions. Several successful examples exist in other countries where forensic investigations are performed by faculty in University departments, such as in the Dept. of Forensic Medicine at the University of Copenhagen, Denmark; the Institute of Forensic Medicine at University of Berne, Switzerland; and the Dept. of Forensic and Investigative Genetics at the University of North Texas Health Science Center, USA. Of these, the Institute in Berne is of interest in that it is highly multidisciplinary, encompassing Departments for Forensic Medicine, Forensic Chemistry and Toxicology, Physics/Ballistics, Forensic Imaging etc. In all of the examples above, the faculty engage themselves both in academic work including teaching and research, as well as in forensic investigations, and the academic affiliation has ensured the independence of their service activities. In this country as well, the CDFD, Hyderabad would represent a successful example of an institution whose faculty undertake both research and forensic service activities, where the two activities support one another and each in turn is enriched by the other.

The major advantage in this second approach, apart from providing the academic rigor and independence for the service activities, is that a large cadre of permanent Government officials does not have to be created. One possibility, therefore, would be to announce a Request for Proposals (RFP) after sensitizing the academic community through a write-up in a journal such as Current Science, and then to have an expert Committee short-list and identify Departments/ investigators with the required competence and motivation to provide these services in a decentralized manner (after a suitable training and orientation programme). It must be noted that the RFP in this case would be for provision of services and not for research (which by definition has uncertainty in attainment of its goals), and therefore is more likely to succeed provided proper care is taken in the selection and monitoring of groups/individuals.

The third approach for forensic service delivery is through public-private partnerships (PPP), for which again successful examples exist in several other countries. The PPP model would have the following features:

- The public partner (Government agency) would provide the required funds to the private partner(s) who would undertake the forensic activities.
- The private partner(s) would create the infrastructure and hire the personnel as needed for the purpose.
- An alternative model would be for the public partner to create and own the infrastructure, and for the private partner only to hire the personnel who will deliver the services by operating the infrastructure so provided by the public partner (ie., an operations-contract).
- Quality issues and confidentiality issues would be governed by the conditions imposed by the public partner.
- In crime investigation cases, it is expected that the public agency would send coded samples to the private partner's laboratory for forensic analysis following established procedures for maintenance of chain of custody. The laboratory would then analyse the samples and communicate the data back to the agency. Sample decoding, data analysis and their interpretation would be done by the public agency which would submit the report to the courts and also defend the same during examination/cross-examination.

As mentioned above, these three different approaches for forensic investigations are not mutually exclusive, and hence could be combined to varying degree in the overall strategy.

V. **Roadmap of and timeframe for implementation:** In the discussion below, the example of DNA profiling alone is considered since this would in any case represent the major component of forensic investigations in criminal cases today, and furthermore it is also illustrative of all the other disciplines of forensic science. It is estimated that approximately 100,000 cases per year can potentially benefit from DNA analysis in India, to undertake which there is need for around 1000 DNA examiners (the international average being 70-100 cases undertaken/DNA examiner/year). (A DNA examiner is a technical officer, and around 8-10 of them can function in a laboratory under the supervision of one faculty member/scientist). At present, there are < 10 forensic laboratories with DNA analysis facilities, with < 20 examiners in total and < 500 cases being done per year. Hence, the need is for an approximate 100-fold increase in the scale of operations.

The timeframe for achieving this would be around 5 to 10 years if all three mechanisms of service delivery are made operational, or longer if the model of public forensic science laboratories alone is employed. Over this time-frame, it is expected that the service activities would be rolled out and expanded fairly uniformly across all the geographic territories, making use of the provision that establishment of "Union agencies and institutions for scientific or technical assistance in the investigation or detection of crime" is included in the Union list of the Seventh

Schedule of the Constitution. Since law and order is a State subject, all State Govts. would also need to be taken on board so that Government Orders are issued in the respective states making it obligatory on the part of crime investigation personnel to send forensic samples to the concerned laboratories. The RFP model (approach 2 in Section IV) would be particularly suitable for the scaling up of activities across all the States in a time-bound manner.

The complete administrative structure of the DFS may also be expected to be established over a period of around 5 years. To begin with, its operations could perhaps be initiated through a Board that is established in an existing Department of MST (much like how DBT was set up from the erstwhile NBTB in the 1980s). It must also be emphasized that the DFS would engage in co-ordination of all activities related to forensic science including service delivery, liaison with MHA, training (of technical officers, crime investigation officials, police, judiciary), research, reagent manufacture and supplies (since these are at present imported and very expensive), establishment and enforcement of quality standards etc.

VI Summary of recommendations:

1. Establishment of a Board, later to be converted to a Department of Forensic Science in the Ministry of Science & Technology to administer all activities associated with forensic investigations in the criminal justice system.
2. Establishment of an alliance mechanism between the Ministries of Home Affairs, Law, and Science & Technology for co-ordination between forensic science and the other activities necessary for efficient delivery of criminal justice.
3. 100-fold expansion of forensic investigation services including through RFP and PPP models.
4. Timeframe of 5 to 10 years for implementation.

Annexure VI

Role of Science Diplomacy in External Relations of India

Introduction

The Science Advisory Council to the Prime Minister has recently developed the Indian Vision for the emergence of India as a global leader in science. The Indian vision for science has provided a road map for India becoming a leader in the scientific world and become a knowledge provider for the world. There is an aspiration in the country. Our youth population and talent base offer unique advantages in global knowledge economy.

The Scientific Advisory Council to the Prime Minister foresees the possibility and strategic advantages of building science as a diplomatic tool in forging international alliances and partnerships. This background note has been prepared for institutionalizing the internal alliances between the Ministry of External Affairs and The Ministry of Science and Technology of the Government of India.

Context

It is widely known that technological changes play critical roles in the growth of per-capita incomes of most countries. The Indian science system is learning to connect knowledge to wealth generation. Several major companies of the world are establishing Research and Development base in India.

The recently enunciated Science vision of India has made a strong case for strengthening and investing further into research and development. Demographic dividend of India is seen as an important advantage of the country by many developed countries in building alliances through science.

Although India has developed a good base for science and technology, there is a need to improve the quality of our scientific institutional base. India's position in scientific outputs as well as innovation index could be vastly improved through strategic international scientific collaboration. India is establishing a large number of new universities, Indian Institutes of Technology (IITs) and Indian Institutes of Science Education and Research (IISERs). If Indian institutions were to emerge as global leaders in some branches of science in shorter time span, international S&T cooperation would be essential.

Science as a Connecting Bridge between Nations

Science is global. Performing scientists are truly global citizens. Therefore, Indian science sector could play a major role in developing strategic alliances with developed countries in Europe and Americas. There is a matching enthusiasm in the developed economies for forging mutually gainful alliances with India.

Advantage India

India offers advantages in the development of affordable innovations. The bulk drug industry, vaccine production, Nano car and many more developments in India are attracting global attention for development of technologies and creation of extremely affordable innovations. India's strength in space and atomic energy is widely recognized. Many developing countries look up to India for developing their own technological base. Many advanced countries with well developed science and technology system have started to value the ability of the country in cost optimization of high technology products.

Indian Science Sector for Enabling Partnerships with Developing Countries

India has enjoyed a robust economic growth during the last decade. Public investments into Research and Development are increasing. There is now a potential for the country to make investments to building strategic alliances with select countries through the tools of science and technology. It may be gainful proposition to invest asymmetrically into some developing countries both resources and S&T outputs with long term advantages. "Giving may be gaining" in some select international partnerships where giving through science may amount to long term investment.

Synergy through Indian Science Sector with Strategic partners

It is now becoming possible for India to invest into equal and reciprocal partnerships with some countries by virtue of advantages of Indian science and technology sector. When India is in a position to invest, we should be able to negotiate terms and conditions of sharing of intellectual properties generated out of joint research and development. Such investments would add to the national prestige on the one hand and contribute to the global competitiveness of technology base of the country on the other. Symmetrical partnerships with co-investments and reciprocity principle into science sector with some developed economies would be of high value.

Technology Acquisition for Accelerated Growth

Technology acquisition through international partnerships is an area. There is an emerging opportunity to build partnerships with well developed innovation ecosystems in the world to rapidly develop our own innovation ecosystem. Technology acquisition fund coupled with an ecosystem to rapidly develop cost optimized solutions through global partnerships would provide for India a unique leadership space.

Science Diplomacy

There is now a possibility to leverage science and technology as a tool in diplomacy and building strategic alliances and partnerships with both developing and developed economies. The Indian science sector could play a vital role in science diplomacy. Technology diplomacy, Technology Synergy and Technology Acquisition could form three pillars of Indian strategy for developing science diplomacy as a tool in strengthening of our external relations.

Many countries in Africa and other regions of the developing world value the Indian science and technology sector. They seek India to play the soft leadership role among the developing economies in several areas of science and technology. India has adopted the Small and Medium Enterprise sector as the growth engine. The Indian model suits the developing countries with widely distributed raw material base. Technologies for decentralized production offer advantages of low capital investments for every job created. This also follows from the Gandhian model of decentralized production and consumption.

If India could play a traceable role in strengthening of R&D institutions in many parts of the developing world, leadership position through technology diplomacy would be a natural consequence. India could share technologies for forewarning of natural disasters like cyclone, Tsunami, flood etc, it would earn for the country significant goodwill and support from developing countries. Strategic technology partnerships with developing countries are valuable tools in technology diplomacy.

Enlarging the engagement of Indian science and Technology sector with select countries under technology synergy model could provide mutual advantages to India and our partnering countries in both scientific developments and socio economic benefits. Indian strength flowing from talent base and youth population provides a strong dividend for technology synergy with developed economies.

Recommended Actions

Some important lead actions to leverage the potentials of Science, Technology and Innovation sector of the country in building science diplomacy could be considered. They are

General

- There are only science counsellors only in four countries. For India's global presence and impact through science sector, we would need at least additional 20 science counsellors in carefully selected countries and regions.
- We would need a special advisory mechanism for developing strategic relationships based on mutual benefit.
- An institutional mechanism is needed for undertaking due diligence of our technology partners based on science diplomacy policy.
- Establishment of an Alliance Office between Ministry of External Affairs (MEA) and Ministry of Science & Technology.

Technology Diplomacy

- Establishment of a long term fellowship scheme for citizens of the developing world to undertake doctoral and post doctoral research in the institutions in India to be administered nationally with a provision for 100 fellowships a year.
- Creation of Technology fund of Rs 4500 crores for developing countries for promotion of technology partnerships to build over a period of five years through synergy between MEA and Ministry of Science and Technology.
- Special package for developing countries for strengthening of their own R&D institutions through sharing of technology and experience in select areas of mutual interest.
- Assistance to least developed countries in developing science-led development policy by creating 60 positions under Technology up gradation fund to be implemented through collaboration between MEA and Ministry of Science and Technology.

Technology Synergy

- Establishment of an institutional mechanism for undertaking scientific assessment of opportunities for technology synergy partner countries.

- Establishment of bilateral fund based on the principle of reciprocity and co-investment of matching funds and equitable sharing of intellectual properties.
- Establishment of a suitable advisory, oversight and monitoring mechanisms.
- Selection of projects of national importance in areas like water, climate change, environment, energy, food and health security related challenges.

Technology Acquisition

- Establishment of a technology observatory in the country to map specific technologies of national interest.
- Creation of technology acquisition fund under Public-Private Partnership complete with an efficient management system.
- Leveraging strength in areas of core competence of India in areas like aeronautics (with>75% growth), biotechnology (>35% growth), auto components, telecommunication and other high growth sectors based on high technology areas.
- Constitution of special National Advisory Council for acquisition of high technologies to develop a policy framework.

Way Forward

Science offers a handy and soft tool for building diplomatic relationships with strategic allies in the modern world. The Indian science sector has reached a stage of development in which it could play a more effective and critical role for India's Foreign policy makers. This note defines the context and enlists some specific recommendations for the Government of India to consider. An institutionalized alliance between the Ministry of External Affairs and the Ministry of Science and Technology is the next best way forward.


Bisleri

Annexure VII

The Future of Indian Aeronautics

The SAC to PM had deliberated extensively on the Civil Aviation sector which had attracted attention due to an extraordinary boom in that sector over the last few years. According to the DGCA, a total of about 415 aircraft were likely to be introduced into service during 2007-12 and projections for the next 20 years indicate that India may need about a thousand medium sized aircrafts for Civil Aviation sector. Thus it was imperative for the SAC to PM to look into this sector in a meaningful and coordinated way. Apart from this, in terms of number of aircraft the Indian Air Force is the fourth largest in the world (behind only US, Russia and China) which does not operate its own fighter designs. Considering the R&D along with Design and Manufacturing component the Council constituted a Sub-Committee with Professor Kota Harinarayana; Dr Kiran Karnik; Dr Rishi Krishnan; Dr V Sumantran; Professor Roddam Narasimha; Dr C.G. Krishnadas Nair and Dr T.S. Prahlad as its members.

The Sub-Committee had few meetings and its recommendations were presented to the Council in one of its meeting held in 2007. In the report of the sub-committee the importance of air power was widely acknowledged so also the civil transport which is vital for the communications network and transport of men and material across country. The importance of the affordable civil aviation in the large stretches of India, particularly the North-Eastern Region; the Leh - Ladakh area; the islands of Andamann & Nicobar and Lakshdweep etc. are now well established and it plays a key role in national integration – economically, culturally and politically. In fact the report states "The state of aeronautical technology in any country is often an indicator of the state of technology in general in the country." This is due to significant spin-offs that have emerged from the aviation sector in the past and also likely in the future. Moreover it has been pointed out by the sub-committee that research in this sector is multi-disciplinary and involves interconnected scientific and technological pursuits. It borrows from and also advances many branches of engineering, including mechanical, structural, aerodynamic, electronics, electrical, chemical, thermal, material and other fields.

As argued above, the sub-committee also pointed that aviation and aerospace span a wide range of modern technologies that are of critical importance to our country. Moreover these technologies are hi-tech and require matching hi-tech inputs from the manufacturing industries, aerospace products and parts involve the highest number of hi-tech input industries. Additionally, advances in several materials technologies are driven by the aerospace industry's quest for lower weight and emissions. The recent growth of the Indian civil aviation industry is driven by the growth of the economy, deregulation of the industry, the aggressive plans of low-cost carriers, and the large investments being made or proposed to be made in civil aviation infrastructure. And hence the sub-committee had suggested that the Indian industries initiate design and manufacturing part of aircraft components in the country, something similar to ACMA, since this would give rise to hi-tech manufacturing capability in the country.

The sub-committee wanted India to play a major role since Indian organizations have some outstanding talented designers and technologists with tradition of team work and project management skills that are crucial for success in these ventures. The country however lacks the marketing skills of hi-tech aeronautical products in International arena. But keeping in view the huge market size of aeronautics products globally and the fact that Indian manufacturing sector has risen to the global hi-tech standards, the sub-committee has suggested that the Indian manufacturers work in tandem with International players and also that the Government should encourage private industry to enter in a big way and actively promote public-private partnerships. However a boom in aeronautical design services for foreign manufacturers may well develop in the near future, as experience with outsourcing builds up through such companies as Honeywell and the Indian software majors. The industry, if properly orchestrated can create large employment opportunities not only in the semi-skilled sector but also in high-growth design and manufacturing industry in the civil aerospace sector. From an economic standpoint, this industry would be able to deliver value addition to the economy, high technology employment, new technological capabilities with possible spillover benefits, and also enable us to attract foreign direct investment (FDI).

The sub-committee further suggests that the argument for the support of Semiconductor industry by the Government is also appropriate for the Civil Aviation sector. It recommended that the Government should constitute a National Aeronautics Commission to look into the issue and come up with a National Strategy for R&D in this area along with manufacturing of the aircrafts. It should also, in parallel, build a concerted effort involving policy support, national initiatives, research capacity-building, human resource development, and marketing efforts that will be essential if India is to succeed in building a strong position in the aerospace domain. The sub-committee had proposed an Aeronautics Mission for the country for the next 20 years or so with its main objective being bringing in a unified and focused approach for aeronautical development in the country involving all the stakeholders.

The report of the sub-committee concluded that the Aeronautics Mission under the umbrella of a National Aeronautics Commission can lead India to become a key player in global aeronautical developmental activities. This will facilitate in elevating the technological and economic strength of the country, and creating a vibrant national aeronautical enterprise that will both enhance national security and create national wealth.

The Government had recently acted upon this report and has set up National Civil Aviation Development Programme (NCADP) – High Powered Committee under Chairmanship of Dr Madhavan Nair with DG-CSIR as Co-Chairman and Cabinet Secretary, Secretary – M/o Civil Aviation, Scientific Adviser to Raksha Mantri, Director – NAL, Shri Damodaran, Dr Sumantran, Shri Firodia and Professor Narasimha as members. The Committee would suggest the plan of action for the Government on Civil Aviation projects. The Council felt that this was a step in the right direction.

सत्यमेव जयते

PROFESSOR C.N.R RAO
CHAIRMAN

GOVERNMENT OF INDIA

SCIENTIFIC ADVISORY COUNCIL
TO THE
PRIME MINISTER

SAC-PM/02/08-410
JANUARY 21, 2008

FAX: 011 23086857/23019545

Dr. Manmohan Singh
Hon'ble Prime Minister of India
South Block
NEW DELHI 110 001

Dear Dr. Manmohan Singhji,

Re: Aeronautics in India

During the last year, this Council has closely examined the future of aeronautics in India, first through a sub-committee consisting of several experts from within SAC-PM as well as outside, and then through various discussions within SAC-PM itself. There is widespread agreement on giving greater attention to civil aeronautics, which falls outside the scope of the Ministry of Defence and of the Ministry of Civil Aviation, but would gain considerably by coordinated national policies that make the best use of the strengths available in the different ministries. We distinguish here aviation, which is concerned with flying as an operation, from aeronautics, which is the science and technology of design and manufacture of aircraft.

After considering various options, and taking into account suggestions which came from a meeting with the National Security Advisor, Mr. M.K. Narayanan, SAC-PM has a draft report which proposes a National Aeronautics Commission reporting to the Raksha Mantri. There have been however some differences of view about the structure of such a Commission, its chairmanship and its functions. I write this letter to seek your advice and guidance, in broad terms, on how vigorously we should pursue a vision in aeronautics that will at one and the same time enhance the security of the nation and create wealth. We feel that a coordinated effort which includes both civil and military aeronautics, and both public and private sectors, is now essential if India has to gain the

Contd...

benefits of the facilities and talents that it undoubtedly possesses. While the SAC-PM would prefer setting up of an Aeronautics Commission with you as the Chairman, it is possible that you may feel that you do not have the time needed to guide it. In such a case, SAC-PM would suggest that such a commission be headed by a technocrat, and have adequate powers to guide the important area.

I would be grateful for your views and advice on the matter before we proceed further.

With best wishes and personal regards,

Yours sincerely,

(C.N.R. Rao)
National Research Professor
&
Linus Pauling Research Professor

सत्यमेव जयते

PROFESSOR C.N.R RAO
CHAIRMAN

GOVERNMENT OF INDIA

SCIENTIFIC ADVISORY COUNCIL
TO THE
PRIME MINISTER

SAC-PM/04/08-454
August 11, 2008

FAX: 011 23316745

Mr. Kapil Sibal
Hon'ble Minister for Science & Technology
Government of India
Anusandhan Bhavan
2, Rafi Marg
NEW DELHI 110 001

Dear Sibalji,

If you remember in our last meeting with the Prime Minister, it was decided that we should have an Aeronautics Advisory Board or Commission to ensure a good future for the aeronautical industry in India. To establish such a Board or Commission, it is necessary to have cooperation from both the civilian and military sectors. You were kind enough to offer to take the necessary steps to see that such a structure is established. I am just writing this to recollect this decision so that we may have such a structure in the next few weeks.

With best wishes and personal regards,

Yours sincerely,

(C.N.R. Rao)
National Research Professor
&
Linus Pauling Research Professor

Address for Correspondence: Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur P.O., Bangalore-560064. India
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Annexure VIII

A.20020/11/97-IFD
Government of India
Ministry of Science & Technology
Department of Science & Technology

Technology Bhavan,
New Mehrauli Road,
New Delhi 110016

Dated the 31st March, 2010

OFFICE MEMORANDUM

Subject : Revision of emoluments and revised guidelines on other service conditions for research personnel employed in R&D programmes of the Central Government Departments / Agencies.

In supersession of this Department's O.M. of even number dated 06.08.2007 on the above subject, the matter has been further considered by the Government and the following are the approved revised emoluments and guidelines on service conditions. This O.M. is applicable to the research personnel working on R&D programmes funded by the Central Government Departments / Agencies.

i) Junior Research Fellow (JRF)/ Senior Research Fellow (SRF)

Sl. No	Designation & Qualification	Revised Emoluments per month for first 2 years	Emoluments per month after 2 years / SRF
1.	Junior Research Fellow (JRF) leading to PhD Post Graduate (PG) Degree in Basic Sciences and NET qualified OR Graduate Degree in Professional Courses and GATE or equivalent qualification	Rs 16000/-	Rs 18000/-
2.	Junior Research Fellow (JRF) leading to PhD Post Graduate (PG) Degree in Basic Sciences who have NET qualified for Lectureship	Rs 12000/-	Rs 14000/-
3.	Junior Research Fellow (JRF) leading to PhD Post Graduate Degree in Professional Courses	Rs 18000/-	Rs 20000/-

The local institution should review the performance of the fellow after two years through an appropriate review Committee constituted by the Head of the Institution. The fellowship in the slab after 2 years of research experience may be provided after successful assessment by this review Committee.

The earlier "Guidelines for selection of non-NET qualified JRF/SRF" issued vide DST Office Memorandum No.12(1)/76-GRS dated 30th July, 1990 stands withdrawn.

In programmes where there is a need to engage research personnel at a level higher than JRF/SRF and such need has been accepted by the funding agency, the remuneration for such personnel may be fixed as indicated below.

ii) Research Associates (RA)

Research associates may be fixed at a consolidated amount at one of the 3 pay levels given below, depending upon the qualifications and experience. The Institute / Organisation concerned may decide the level in which a particular associate should be placed based on the experience. The Essential Qualification (EQ) for RA is as follows:

EQ: Doctorate (PhD/MD/MS/MDS) or equivalent degree or having 3 years of research, teaching and design and development experience after MVSc/ MPharm/ ME/ MTech will be eligible for award as RA.

Sl. No	Category	Revised Emoluments per month
1.	Research Associate I (RA-I)	Rs 22000/-
2.	Research Associate II (RA-II)	Rs 23000/-
3.	Research Associate III (RA-III)	Rs 24000/-

The stipend of research fellow/associate is exempt from the payment of income tax under 10(16) of IT Act, 1961.

Service Conditions:

1. **DA and CCA:** JRFs, SRFs and Research Associates will not be entitled to these allowances.

2. **House Rent Allowance (HRA):** All research fellows may be provided hostel accommodation wherever available and those residing in accommodation provided by the Institute will not be eligible for drawing HRA. Wherever provision of hostel accommodation is not possible, HRA may be allowed to all the above categories viz., JRF, SRF and RA as per Central Government norms applicable in the city/ location where they are working. The fellowship amount may be taken as basic for calculating the HRA.

3. **Medical Benefits:** The research fellows and research associates (JRF/ SRF/ RA) will be entitled for medical allowance as applicable in the implementing institution.

4. **Leave and other entitlement benefits:** The JRF/SRF are eligible only for casual leave while Research Associates are entitled to leave as per rules of the host institution. Participation of any of these categories (JRF/ SRF/ RA) in any scientific event/ workshops in India or abroad will be treated as "on duty". The travel entitlement for JRF/ SRF/ RA for participation in scientific events/ workshops in India will continue to be the same as earlier i.e. 2nd AC by rail. Maternity leave as per Govt. of India instructions issued from time to time would be available to female candidates in all categories.

5. **Bonus & Leave Travel Concession:** JRFs, SRFs and Research Associates will not be entitled to these allowances.

6. **Retirement Benefits:** JRFs, SRFs and Research Associates will not be entitled to these benefits.

7. **Publication/Patent:** The results of JRF/ SRF/ RA's research work may be published in standard refereed journals at the discretion of the Fellow or his Guide. It should be ensured by the fellow that the assistance provided by the funding agency of Government of India is acknowledged in all such publications.

8. **Encouragement for pursuing higher degree:** Students selected as JRF/ SRF may be encouraged to register for higher degrees and the tuition fees to undertake these studies may be reimbursed to the student from the contingency grant sanctioned under the project grant, if required.

9. **Obligations of JRF/ SRF/ RA:**
   a) He/She shall be governed by the disciplinary regulations of the host Institute where he/ she is working.
   b) The JRF/ SRF/ RA must send a detailed consolidated report of the research work done during the entire period of Fellowship on completion of the tenure/ resignation of the Fellowship at the earliest.

10. **Date of Effect:** The revision in emoluments come into effect from 1.4.2010 for all categories of JRF/ SRF and Research Associates.

11. Central Government Departments / Agencies are requested to ensure that the above guidelines are followed in regard to the remuneration and other benefits to the research personnel engaged in R&D projects funded by them. They are also requested to circulate these orders to their attached and subordinate offices and also to the autonomous institutes funded by them.

12. The above may be used as guidelines by CSIR, UGC etc.

(L INDUMATHY)
Director (Finance)

To
1. All Ministries / Departments of the Govt. of India.
2. All Heads of Divisions of DST

Annexure IX

Biomedical and Health Research

Health is a major driver of economic development and social contentment in any country. To achieve optimal health for its people, India has unique challenges due to its large population, demographic transition, vulnerability to out breaks and epidemics in an increasing globalized world, and the social and economic vulnerability of large sections of its people.

The health challenges relate to major, as yet not controlled infectious diseases, reemerging and emerging infectious diseases, as well as chronic diseases such as diabetes mellitus, heart diseases, cerebrovascular diseases specially stroke, cancer and health problems associated with growing aging population. Mortality in women and children is unacceptably high, and progress slow. Specific nutrient deficiencies that are widespread, add to the risk for poor health and early death. Why have we not come further, faster? While many of these are incredibly hard problems, the effort has been too small and the resources too few.

Biomedical and health research is an essential component of any effective health care system. Indian biomedical research system has served us well despite resource limitations, but given the enormity of the challenge ahead, major strengthening is an unavoidable imperative both in scale and quality. The Government of India, in a laudable initiative, and in full recognition of the emerging situation, has recently established the Department of Health Research (DHR) in the central Government. In recommending the move, the SAC to the honourable Prime Minister has visualized that the DHR shall, in addition to the Indian Council of Medical Research, engage the best of the medical college system, research institutes and universities to generate knowledge about major diseases and catalyze development of affordable preventive, diagnostic and curative health care technologies and products and find innovative ways to delivery of health care across the country with effective engagement of state systems and community.

The effort to build a new mission for biomedical and health research is critically compromised by lack of resources; financial, human, institutional framework and governance.

There is critical shortage of quality researchers in multiple areas of biomedical research. Different scientific disciplines relevant to biomedical research are not effectively linked, nor are the institutions that harbour talent of different types. There is insufficient opportunity for medical students and faculty to learn science and clinical translational research and little incentive to pursue a research career. Measures are therefore, required to be taken on a mission mode, rather than on incremental scale.

Long term initiatives:

1) An inter-agency Task Force convened by DHR be established to create a long term action plan for strengthening biomedical and health research in the country.

   It should address resource needs, education and training in research, incentives to attract medical people into research, career path and institutional reform, linkages across disciplines and institutions related to medicine, science, engineering and academia - industry partnerships.

Short and mid-term initiatives-:

1. Ten to fifteen best research oriented medical institutes in the country be upgraded as Institutes of excellence in biomedical and health research. These should have a separate Dean for research, a Research Advisory Council, and research governance through a Society or a Foundation separate from the governance of the hospitals with a dedicated research budget, core research manpower and centralized major equipment facility.

1 (a) These Centres of Excellence should forge links amongst scientific, medical, social, engineering disciplines and for health policy and implementation research with health economists within and across institutes.

2. At least one medical college in each State be strengthened in health research to serve as centre for transfer of technology to end users so as to contribute to an effective health care delivery system through local institutions and state health services. This platform will also serve as local hub of epidemiological/ public health research. State health systems have to be effective partners in public health research and implementation.

3. Inter-departmental mission of biomedical and health research, may be launched around the following medical priorities:
   i) Tuberculosis
   ii) Viral infections with potential for outbreaks
   iii) Diabetes, Cardiovascular and chronic neurological disorders
   iv) Maternal and child health
   v) Affordable health technology
   vi) Innovation in health care delivery
   vii) Diseases preventable through measures like vaccines, environmental interventions etc

4. It is important to create synergy among various science agencies/ departments – those mainly involved in basic science and or innovation on one hand (eg DST, DBT, CSIR/DSIR, DRDO) to those with major application on epidemiology, public health (eg ICMR). Thus the effort should be on establishing mechanisms to evaluate technologies for improving health care at individual & public health level ; fostering academia-Industry link: creating processes & cell to link developers with industry for translation of leads into products/processes and establishment of a rapid clearing house mechanism for evaluation of health research technologies including the commercial applications.

5. A strategy be evolved for science and health research education and training for medical faculty and students.

   Programmes such as MD-Ph.D, Masters in Science and integrated clinical translational oriented Ph.D programmes as well as mid- career specialized training to medical teachers must be established. This will require changes in existing rules of the Medical Council of India.

6. A career path for biomedical researchers is a priority on the lines of "INSPIRE" programme of DST.

7. Attracting medical and biomedical faculty to research requires flexibility in medical faculty career paths.

The faculty size of academic medical colleges that are centre of excellence in research should not be based on number of beds but on academic requirements. The proposed Task Force should create criteria for assigning Centre of Excellence status to a medical institution and norms for faculty size and working condition for faculty. Provision for dual appointments in biomedical and science establishments should be considered.

8. Fifty Chairs in biomedical research should be established.

9. Inter-institutional virtual centres of biomedical and health research must be encouraged with a view to link science, engineering, medicine, academia and industry. The Department of Biotechnology, Department of Science & Technology and Department of Health Research can all support such initiatives through clinical translational research network awards. Partnership with other science departments such as DRDO, DARE, DSIR, DOIT etc would be important in selected areas

Annexure X

Brief note on Dynamics of Change in Agricultural Research, presentation to made before the SAC to the PM on 22 May 2010 at IISc, Bengaluru

A meeting of the SAC to the PM is scheduled to be held at the IISc on 22 May 2010, wherein a presentation on Dynamics of Change in Agricultural Research is to be made by Dr S. Ayyappan, Secretary, DARE and DG, ICAR.

The presentation broadly deals with the national agricultural scenario, the position of Indian agriculture in the global context, how our agricultural research and education system has responded to the various agricultural challenges through technological interventions, our achievements and our ongoing research programmes for a scientific and sustainable growth of Indian agriculture. Established in 1929 as a registered society, the Indian Council of Agricultural Research is the apex body at the national level for planning, executing and coordinating agricultural research and education in the country. Under the aegis of the ICAR, a network 97 research and 54 education institutions with a combined strength of about 25,000 scientists has been developed in the country. These institutions constitute the major component of National Agricultural Research System. Certain programmes/schemes such as the All India coordinated Projects and Krishi Vigyan Kendras for are unique and highly successful models of technology generation and subsequent assessment and refinement respectively.

Today we are among the leading producers of wheat, rice, fruits, vegetables, milk, poultry and fish. Development of technologies for improving the soil - water efficiency especially the Conservation agriculture, high yielding crop varieties/hybrids, breeds with improved productivity, vaccines and diagnostics, diversification of agriculture etc. have significantly contributed towards these achievements. With continuous infusion of technologies the decades of 1970s and 80s the agriculture in India witnessed a very encouraging growth. The decades of 1990s brought about the concerns of natural resource degradation, drop in growth rate of total factor productivity and the stagnant farm incomes.

Responding to the changing needs of agriculture, over the years, the research approaches have also evolved from being commodity centric to more production to consumption and market oriented so as to make agriculture a strong component of national economy and an instrument of socio-economic change. The future of agriculture now depends on the level of application of advanced and frontier areas of science i.e biotechnologies, space science, information and communication technologies, in research. These are both, knowledge and capital intensive. The country would require state of the art agricultural research and educational institutions to generate appropriate technologies and to develop highly skilled and competent human resources. Enhanced public investments, suitable marketing mechanisms and infrastructure for farm produce are needed, sooner than later, to put Indian agriculture on a higher trajectory of growth.

Annexure XI

Jawaharlal Nehru National Solar Mission

A. General information pertaining to solar photovoltaic technology

Solar Photovoltaic (PV) technology is built-up over a number of stages. The crystalline silicon chain consists of the following stages :

(a) Polysilicon (feedstock)
(b) Ingot
(c) Wafer
(d) Cell
(e) Module
(f) Balance of system [comprises inverters to convert DC to AC, cabling and substructures, EPC (erection, procurement, commissioning and installation)]

Presented below are numbers about the utilization of solar PV technology at present.

A.1. Current installed capacity in India of grid connected renewable energy (RE) sources totals 15,543 MW (source : MNRE). The break-up of the total is given below :

Wind power : 10,890 MW; small hydro (up to 25 MW) : 2,520MW; cogeneration (bagasse): 1240 MW; biomass power : 820 MW; waste-to-energy : 67 MW; solar PV : 6MW.

This may be compared with the 2007 data from the NMCC (chaired by Dr. V. Krishnamurthy) 2008 report : The installed capacity of RE was 11,225 MW out of which solar PV accounted for 3 MW.

The point to note is that while the ramp up of RE capacity in the last two years is impressive, it is mostly accounted for by wind (70%) and small hydropower (16%) sources. The share of solar PV was nearly zero and has not changed in the last two years.

A.2. World production of grid connected SPV power

At the end of 2008, grid-tied PV installed capacity totalled approximately 13,000MW globally. It is estimated that the sector is growing at 30-40% implying a cumulative installed total by the end of 2009 of 17,000-18,000 MW. This is in line with current projections for the year.

A.3. Domestic solar manufacturing capacity

Unfortunately there is little publicly available data on domestic manufacturing capacity. However, here below is a set of figures which provide a broad picture (most of the manufactured products are for the export market!).

Company	Capacity
Tata BP Solar	Module capacity - 105 MW Solar cell - 128 MW
Moser Baer	Crystalline solar cell capacity - 40 MW plans to scale up to 240 MW. Crystalline module manufacturing – 40 MW in planning stages. Thin film - 200 MW line under installation with the first phase of the line recently commissioned.
Signet Solar	Proposed thin film applied materials plant of 300 MW. No production as yet.
Solar semiconductors	Module assembly capacity - 50 MW
Reliance Industries Limited	1GW proposed project vertically integrated from polysilicon to panels (not much appears to have happened).

Indian manufacturers either import wafers or cells as the input to their domestic manufacturing process (with the majority importing cells). Certain companies such as Lanco Group and Reliance Industries have discussed establishing polysilicon manufacturing capacity in India, but no such projects exist today.

Indigenous capacity for production of solar energy materials is practically nil.

A.4. How much silicon feedstock is needed for 1MW power? Will this quantity be available for 20GW of capacity by 2022 as projected by the solar mission?

Approximately 6-7 grams of polysilicon is required per 1 Watt of PV, so 1 MW would need 6,000-7,000 kg or 6-7 MT of polysilicon. The average polysilicon required has decreased from 10MT/MW in 2006 to 6.6 T/MW in 2009 and is forecasted to reach 6.3MT/MW by 2012. This is achieved by thinner slicing of wafers (now down to ~ 200μ) from ingots and less breakage of wafers/cells over the course of the manufacturing process. At the same time, global manufacturing capacity for polysilicon has increased significantly from 53,390MT in 2008 to forecasted 149,524MT in 2010 to 220,676MT by 2012. This would imply global wattage capacity based on polysilicon feedstock of 7-8GW in 2008 growing to 23GW by 2010 and 35GW by 2012.

When one compares this quantum of availability of polysilicon with annual global demand projected at 6.2GW by 2010 and 10GW by 2012, there should be ample polysilicon supply to meet industry needs. Thus polysilicon has entered the buyer's market! This demand is driven by 30% of global offtake by Germany, 10% of total each by Italy, Japan and United States and the remaining 40% by 10-11 other countries. India's growth as a major solar market **is not expected to constrain** the global supply chain in a way witnessed around 2005.

A.5. What is the likely cost of SPV for 1000MW output?

Solar PV is land-centric. 1 MW of solar PV crystalline silicon needs 3½ to 4 acres. And if it is amorphous thin film silicon, the land requirement for 1 MW could be higher at 5½ to 6 acres.

In order to install solar PV power generation at utility scales totalling 1000MW and installed in India by 2013, it is estimated that project capital totalling about Rs.40,000 Cr will be required. It is to be noted that, of the various stages in installing solar PV technology mentioned in the opening paragraph, the stage (f), namely balance of system, takes up 50% of the total plant cost.

A.6. Solar thermal power

Solar thermal power is often mentioned. The technologies for solar thermal power generation are either based on the concentrating trough principle or on the solar tower principle.

Current installed solar thermal power capacity globally totals approximately 670 MW, almost all of which is in Spain and in the United States. The largest concentrating trough units are in the Mojave Desert in the Southwest United States, each with 80 MW capacity and totaling 350 MW, which have been in operation since about 1990.

The largest power tower unit is in Seville, Spain with a capacity of 20 MW, which was completed recently in April 2009.

Solar thermal power plants are expected to be cost-competitive and therefore are regarded as extremely promising. R&D work is ongoing in Germany, Israel, Italy, Spain and the US. As a result, several new solar thermal power plants are expected to be completed soon. Once engineering challenges are successfully and fully met, solar thermal power plants are expected to witness unprecedented growth.

No solar thermal plants are currently under construction in India. Two 10 MW plants are in late stages of development in Rajasthan as part of RREC's (Rajasthan Renewable Energy Corporation) solar promotion scheme.

B. Proposals broadly spelt out in the JNN solar mission document

B.1. Targets

- Deployment of 20,000 MW of solar power by 2022 which is to be accomplished in 3 phases.

  Phase I 1000 MW by 2013
  Phase II 10000 MW by 2017
  Phase III 20000 MW by 2022 (dependent on learning from the first two phases)

- The mission document has additionally discussed promotion of the following:
  Solar thermal power (100 MW capacity demonstration project based on parabolic trough technology),
  Solar collectors (7 million sq. meters by 2013 going up to 20 million sq. meters by 2022) and
  Solar lighting systems (to cover about 10,000 villages and hamlets for which 90% subsidy is slated to be provided).

However, this note focuses on solar photovoltaic technology which is the only proven technology (over 40 years) in solar power generation. The effort is concentrated now on reducing cost of this technology, on enhancing performance and increasing its durability.

B.2. Observations

The main aim of the solar mission document is to create an enabling environment to promote predominantly private sector industrial investment in technology, manufacture and generation of electricity for lighting and heating purposes. Most of it is to be grid-connected and a relatively much smaller fraction is for distributed application.

Learning from the past experience of hurdles encountered by the developers, the mission document comes up with innovative new mechanisms to facilitate private enterprise making it good from their investment. The noteworthy innovation is to designate the NTPC (National Thermal Power Corporation) trading company NTPC Vidyut Vyapar Nigam Ltd. (NVVN) as the nodal agency for entering into a power purchase agreement (PPA) with the solar power developers to purchase power fed to 33KV-and-above grid in accordance with the tariff (determined for the year 2009-10 as Rs. 18.44/kWh) and PPA duration stipulated by Central Electricity Regulatory Commission (CERC).

The key driver of the programme is to impose a renewable energy purchase obligation (RPO) on the state and other utilities. The RPO may start with 0.25% of solar power (of the total power purchased by the utilities) to go up to 3% by 2022.

The overambitious target of 20,000 MW, seemingly arrived at by wishful thinking, is to be appreciated in light of the main goal of the mission which is to motivate private investment. The gigantic target is to act as a driving force for the prospective developers, whose numbers may thus increase, to enter into the expectedly expanding domestic market.

While the above is laudable, the success of the mission will depend on (a) speed of administrative approvals, in particular for land acquisition by the developers; (b) alignment of the States and the Centre (a remark made recently by the Prime Minister is noteworthy in this context: he said that everything cannot be or should not be driven by the Centre alone).

B.3. Research & development

The document recognizes that there is no significant solar energy R&D programme within the country. The Government proposes to launch a major R&D support initiative. The strategy comprises basic research for the development of innovative materials and processes as well as applied research for improvement of existing processes for enhanced performance and cost competitiveness of the systems and devices. For this purpose, the mission proposes the following:

(a) A high level Research Council
(b) A National Centre of Excellence and
(c) The Research Council in collaboration with the National Center of Excellence to harness the existing institutional capabilities.

The proposals with regard to human resource development are the following:

- Involving IITs and premier engineering colleges and universities in designing specialised courses in solar energy.

- A Government Fellowship programme to train 100 selected engineers, technologists and scientists in solar energy research in world-renowned institutions abroad.
- Setting up a National Centre for photovoltaic research and education at IIT Bombay drawing upon its Department of Energy, Science and Engineering and its Center of Excellence in Nanoelectronics.

C. Opportunities for research

This section will discuss opportunities that exist for basic research as well as for applied R&D at all stages of PV technology and its applications (based on my own understanding and so needs to be discussed).

- Process innovation to reduce energy consumption and cost of processing polysilicon and ingot making.
- Materials research to increase efficiency (η) and durability.
  - (i) Mono-crystalline Si (workhorse material whose η has been enhanced to 15 to 20%).
  - (ii) Microcrystalline Si (μcSi) (η at 8 to 10%) (2 to 3 μm film).
  - (iii) Amorphous Si (α–Si) (η at 8%) (2 to 3 μm film).
  - (iv) μcSi in tandem with α–Si (η touched 16% at lab level).
  - (v) Cadmiumtelluride (CdTe) (η up to 10%) (lab level attained 15%) (Least expensive of all thin films but Cd toxicity is an issue).
  - (vi) Copper Indium (Gallium) diSelenide (CIS/CIGS). (η ~10%) (19% at lab level).
  - (vii) Emerging (Dye-sensitized, Organic, Nano) materials.

- Thinning down mono-crystalline wafers using new technology such as plasma slicing (thickness at present down to about 200 μ and the aim is to go down to less than 100 μ). This will reduce the feedstock cost.
- Considerable opportunity for R&D and technology innovation in the course of indigenisation of balance of systems (like inverters and batteries).
- It is to be emphasised that limiting research to materials alone may not be the right approach. Experimental systems of the full technology package utilising every type of advanced material are to be investigated. This strategy has been followed by Japanese institutes and is worthy of emulation as it provides a first hand feel for performance of the whole package in each case of advanced material.
- Several plants could be assembled with imported materials and systems for field-testing under Indian conditions. Each of these plants shall be based upon one type of PV material. This is for evaluating continuous performance and durability. This is critical because it is already reported that mono-crystalline (which is the workhorse material) suffers degradation at a more rapid pace in hot weather conditions unlike α-Si which remains nearly stable. This factor favours α–Si inspite of its lower efficiency under standard conditions.
- Establishing facilities for characterising, quality control and durability testing in an accelerated testing facility. So also techniques for online diagnostics during production as well as subsequent usage.

The last four items among those listed above are best implemented by industry in partnership with a public funded institution which needs to be an academic institution or a national lab or both together.

The Dept of S&T is in the final stages of selecting proposals for collaboration under the INDO-EU programme. DST is best placed to provide updated information on this programme as well as their other initiatives in the area of solar energy R&D.

Annexure XII

Report of the ICTS program "Scientific discovery through intensive exploration of data"

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Executive Summary

There has been an explosion of data available for scientific investigations, coming from observations, new experiments, and numerical simulations. At the same time, there are sophisticated models of complex systems, based partially on physical principles,but increasingly also based on the data. The main aim of the meeting was to bring together researchers working on understanding the interplay between data – observational, numerical, and experimental – and the theories and models that need the data, and how this interplay illuminates the scientific questions being investigated – in short, *scientific discovery through intensive data exploration.*

The meeting was a programme of the International Centre for Theoretical Sciences, TIFR, held at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bangalore, during 02-11 February 2011. There were four keynote presentations, and about twenty invited presentations, by eminent researchers such as Tim Palmer, Michael Mahoney, Tony Cass, Ian Foster, Alok Choudhary, Srinivas Aluru, Ravi Kannan, Umesh Waghmare, and many others. They represented the following fields of research which make essential use of large data sets.

1. Computer science and statistical methods
2. Life and health sciences
3. Earth sciences
4. Astronomy
5. High energy physics
6. Materials science and chemistry

There were two panel discussions on "Development and Deployment of Infrastructure for Scientific Computing in India," chaired by N. Balakrishnan (IISc) and on "Computational Genomics," chaired by Niranjan Nagarajan (Genome Institute of Singapore).

Recommendations for Implementation

There was a general consensus on (i) the inadequacy of the existing computational infrastructure for research using large data, and (ii) the necessity of a comprehensive plan for developing such an infrastructure, and most importantly, for developing trained manpower. The following recommendations emerged out of the discussions during the meeting.

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1. Actively encourage new paradigms of doing science and new paradigms of collaborations between industry and government organisations.
   (a) There is need for computing infrastructure that can be shared and available for use by scientists across various institutes and universities.
   (b) Inter-disciplinary and inter-institutional collaborations on scientific problems using large data could be a focus area for agencies such as NSERB, DST, etc.

2. Encourage the growth of dedicated high-speed networks for the data intensive sciences.
   (a) Connectivity to international networks through collaborative efforts such as the GLORIAD should be pursued.
   (b) Strengthening of existing national academic and research network and creation of new ones should be a priority.
   (c) Local inter-institutional high-speed networks, coexisting with the above, need to be developed and existing campus networks need to be upgraded.

3. Innovation is required in the financial models under which academia and industry can work together.

4. Pilot projects, emulating the success of projects such as the Open Source Drug Discovery (OSDD), should be encouraged. Examples include,but are not limited to,
   (a) National Virtual Archive of data, including mirroring of datasets from around the world
   (b) A community-owned network for sharing large datasets

5. Capacity building and human resource development through short term workshops, and dedicated long term initiatives for masters and doctoral programs.

6. Setting-up of a task force consisting of national and international experts from academia, industry, and non-governmental organisations, to develop a plan to implement these suggestions on an urgent basis.

1 Introduction – the need for data based scientific investigations

The ever increasing computational capabilities, not only the computational speed but also the data storage capacities, have lead to **an explosion of data available for scientific investigation.** One part of this data is **observational** in origin. For example, satellites and extensive observational networks now routinely provide huge quantities of real-time data about the earth system, many large and capable telescopes provide astrophysical observations, and medical records give data about human health and medical treatments of various kinds The other sources of large quantities of data are **laboratory experiments**. The most notable examples are the Large Hadron Collider (LHC), the genetic and biological systems experiments, and experiments in material sciences and chemistry. The third source of data is relatively new in origin and less conventional than the previous two – it is data obtained by **numerical experiments, through computer simulations** of realistic and more complex models of physical systems being studied.

The other repercussion of the increased computational capabilities is that it is now possible to **study sophisticated models of complex systems**, such as those mentioned above. There are two types of models for such systems – either based on previously well-established physical principles, or based purely on observations of the system. The former of the two types of models need to use data in order to be applicable in realistic situations. The latter of the two types of model are fundamentally dependent on data, without which their very construction will be impossible – the patterns and regularities, or lack thereof, in the observations lead to the models, which eventually are hoped to become part of a body of scientific theory. In both the above cases, **data give fundamental insights into the properties of the underlying physical system, its functioning and its dynamics.**

This discussion clearly points to a dire need to investigate the interplay between data, used in the broad sense described in the first paragraph above, and the theories and models that need the data, and how this interplay illuminates the scientific questions being investigated – in short, **scientific discovery through intensive data exploration.** This was precisely the theme of the ICTS program with the same title, organized in JNCASR during 02-11 February 2011.

This report will summarize, in the following section, the proceedings of the meetings including various formal and informal discussions, and in the last section, point to specific **implementable recommendations for developing infrastructure for scientific investigations based on the use of very large data and peta-and exa-scale computations,** which are fast emerging as a new paradigm in the scientific endeavor.

2 Organizing committee

The scientific organizing committee for this meeting consisted of the following researchers representing a broad spectrum of expertise in various scientific themes described above.

- Amit Apte, TIFR Centre for Applicable Mathematics, Bangalore
- Vivek Borkar,Tata Institute of Fundamental Research, Mumbai
- Vijay Chandru, Strand Life Sciences, Bangalore
- Ravi Kannan, Microsoft Research Labs, Bangalore
- Ravi S. Nanjundiah, Indian Institute of Sciences, Bangalore
- Roddam Narasimha, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore
- J. Srinivasan, Indian Institute of Sciences, Bangalore
- Spenta R. Wadia, International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bangalore/Mumbai

3 A summary of the proceedings of the meeting

3.1 Scientific themes

The following scientific themes were at the core of this program.

1. Technology and Statistical Methods
2. Life and health sciences
3. Earth Sciences
4. Astronomy
5. High Energy Physics
6. Materials Science and Chemistry

The first one focused on the mathematical, statistical, and technological methods and infrastructure necessary for and applicable to the analysis of vast data. As discussed in the previous section, the main focus of the remaining five themes was the investigation of scientific questions using large data sets and computational resources.

3.2 Keynote lectures

1. Tim Palmer, European Centre for Medium-Range Weather Forecasts and Oxford University, UK, **"Uncertainties in predicting our future weather and climate -from inadequate data to fundamental physics"**

   In this fascinating keynote lecture, Prof. Palmer described the fundamental mathematical and physical issues behind the uncertainties in climate and weather prediction problems. To quote the abstract of one of his lectures at The Isaac Newton Institute for Mathematical Sciences in Cambridge, UK:

   Putting this new science into practice, however, is not straightforward, and **will require new computing infrastructure hitherto unavailable** to climate science. Hence, I will conclude with a plea to the governments of the world. Let's take the current stalemate of opinion as justifying a renewed effort to do all we humanly can to reduce existing uncertainties in predictions of climate change, globally and regionally, so we can move the argument forward, one way or the other, for the good of humanity. This will require a new sense of dedication both by scientists and by politicians around the world: by scientists to focus their efforts on the science needed to reduce uncertainties, and by politicians to **fund the technological infrastructure needed to enable this science** to be done as effectively and speedily as possible. (emphasis added, Ref: http://www.newton.ac.uk/programmes/CLP/seminars/120617001.html)

2. Ian Foster, Argonne National Laboratory, USA, **"What the cloud really means for science"** Prof. Foster discussed how the biggest IT challenge facing science today is not volume but complexity. He argued that establishing and operating the processes required to collect, manage, analyze, share, archive, etc., that data is taking a large part of the scientists' time and killing creativity. With examples from the University of Chicago and ANL, he illustrated that in order to overcome this problem, we need to make it easy for **providers to develop "applications" that encapsulate useful capabilities and for researchers to discover, customize, and apply these "apps" in their work,** which would have the effect of dramatically accelerating scientific discovery.

3. Tony Cass of CERN, Geneva, Switzerland, **"Worldwide data distribution, management and analysis for the LHC experiments"** In this opening keynote lecture, Tony Cass discussed how the Large Hadron Collider at CERN tries to address the key physics issues such as the origin of mass, the nature of Dark Matter in the Universe and precise details of the asymmetry between matter and anti-matter. The talk described the **Worldwide LHC Computing Grid, designed to effectively distribute and analyze the unprecedented data volumes of 15-25 PB per year,** in particular reporting on the successes of the first year of LHC operation and on some possible future developments.

4. Michael W. Mahoney, Stanford University, USA, **"Algorithmic and statistical perspectives on large-scale data analysis"** Prof. Mahoney opened the lecture by comparing two complementary perspectives on data: one of computer scientists who tend to view the data as noiseless and focus on algorithms to speed up the computations, and another of natural scientists who often have, either explicitly or implicitly, an underlying statistical model in mind. He then described the ways in which, in recent years, **ideas from statistics and computer science have begun to interact for solving large-scale scientific and Internet data analysis problems, including examples of improved methods for** (i) structure **identification from large-scale** DNA SNP data and (ii) selection of good clusters or communities from a data graph.

3.3 Invited presentations

The other invited presentations of the meeting discussed scientific research that is directly related to or makes use of large data and computations. The talks by Sandeep Sirothia and Yashawant Gupta, discussed challenges in signal processing and computations for astronomical surveys and studies, especially with the advent of next generation telescopes. The talks by Vijay Natarajan, Vipin Chaudhary, Soumen Chakrabarty, and Ravi Kannan illustrated various techniques for visualizing, annotating, indexing, searching, large data sets, as well as specific mathematical methods and hardware platforms for dealing with them. **UmeshWaghmare** gave an illuminating introduction to the interplay between theory and computations in Chemistry, in the context of the exciting research in designing new materials. A series of talks, by Vijay Chandru, Gyan Bhanot, Niranjan Nagarajan, Ramesh Hariharan, Rahul Raman, Srinivas Aluru, Andreas Dress, and Jayant Haritsa, spread over the whole duration of the meeting, discussed the development of computational tools and their use in biological research, in cancer biology, genetics, and computational genomics. The talk by G. Bala discussed the challenges in dealing with massive datasets generated by comprehensive numerical climate models.

The talk by Greg Cole of Center for International Networking Initiatives (CINI), University of Tennessee, USA, described in detail the GLORIAD advanced science internet network, which connects scientists in US, Russia, China, Korea, Canada, The Netherlands, India, Egypt, Singapore and Nordic Countries, in order to promote new opportunities for collaboration and cooperation among scientists, educators and students. He described the dynamic networks that change constantly with technology, the multitude of their uses in scientific endeavor, the partners in each of the countries, the possible way forward in Indo-US collaborations using this network, and community building efforts based on such a network. He also discussed the issues of the weakest link, metrics of performance, cyber security, monitoring networks, and the future network requirements for dealing with petabytes of data which is soon going to be very common in many scientific disciplines.

Most of these talks will be available in electronic format (the presentation files as well as videos of the talks) on the ICTS website for this program.

3.4 Panel discussion on Computational Genomics

There was a special panel discussion on "Computational Genomics" following the talk by Niranjan Nagarajan "Data integration in Computational Biology." It was organized to provide a forum for conference attendees and expert panelists to debate and discuss issues regarding computational challenges in biology and genomics and the unique role that Indian engineers and scientists can play in this increasingly data-intensive field. The panelists were Prof Sowdhamini of National Centre for Biological Sciences of TIFR, Bangalore, Prof. Nagasuma Chandra of IISc, Dr. Hariharan of Strand Life Sciences, Bangalore, Dr. Nagarajan of Genomics Institute of Singapore, and Prof. Aluru of Iowa State University.

The discussions began with a brief introduction of the panelists and their areas of interest -Prof. Sowdhamini and Prof. Chandra being biologists who have increasingly relied on computational tools for their work; Dr. Hariharan providing an industrial perspective and Dr. Nagarajan and Prof. Aluru the perspective of academics who work extensively in computational genomics. The discussions were free-flowing with active audience interest. Some of the topics discussed included, modes of interaction for computer scientists and biologists in the field, role of multi-level modelling ideas in genomics, the lack of adoption of parallel algorithms as a solution to challenges in computational biology, and funding modes in Indian science. Overall, the panelists felt that the discussions were thought-provoking and made the session more interactive.

3.5 Panel discussion on "Development and Deployment of Infrastructure for Scientific Computing in India"

This panel discussion was part of the ICTS program "Scientific discovery through intensive exploration of data" which was held during 02-11 February 2011: Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore. The panel was convened by (and this report has been written by) Amit Apte, **TIFR Centre for Applicable Mathematics, Bangalore, Leena Chandran-Wadia, ORF, Mumbai, and Ravi S. Nanjundiah, Centre for Atmospheric and Oceanic Sciences, IISc, Bangalore.**

The aim of the panel discussion was to explore the special scientific computing and infrastructure requirements of scientists in India working on the data intensive sciences. The broad areas include Atmospheric Sciences, Biological Sciences, Physics and Astrophysics. The infrastructure that is being referred to includes 1) hardware, software, and services for scientific computing, modelling and simulation, 2) management of large databases including mirroring of large public databases available in different countries around the world, and 3) dedicated high-speed networks to interconnect all of these.

The panelist are

1. Prof. N. Balakrishnan, IISc Bangalore: Panel Chair
2. Dr. SharatBabu, CDAC Bangalore
3. Dr. Tony Cass, CERN Geneva
4. Dr. Leena Chandran-Wadia, ORF Mumbai
5. Dr. Gregory Cole, GLORIAD, Tennessee U.S.A
6. Dr. Vasant Jain,GE Bangalore
7. Prof. E.D. Jemmis, IISER Thiruvananthapuram
8. Prof. Nagasuma Chandra, IISc Bangalore
9. Dr. A. Paventhan, ERNET Bangalore
10. Dr. Satyendra Rana, TCRL Pune
11. Dr. Yogish Sabharwal, IBM Bangalore

The panelists and other participants discussed various aspects of computational and network infrastructure with specific emphasis on

- Shared and local Infrastructure
- Role of government bodies
- Role of industry
- Entrepreneurship
- Training and capacity building efforts

The specific recommendations arising out of this discussion are included in the executive summary and a detailed report of this panel discussion is in the appendix 1.

3.6 Participation from students, industry, and government labs

We must stress that there was enthusiastic participation from the industry as well as government labs. All major players involved in High Performance Computing (HPC) or Large Data research such as CDAC, CRL, GE, Infosys, IBM, Microsoft, Intel participated. There was a special session where they highlighted the work being done by the industry in the field of research using large data. A session was organized for the student participants to present the work they are doing in this field and the problems being faced by them. The participants represented a broad spectrum of problems ranging from bio-sciences to oceanography.

4 Discussion and implementable recommendations

From the opening keynote lecture by Tony Cass describing the worldwide computing infrastructure developed by CERN for the data from Large Hadron Collider experiment in Geneva to be available to scientists across the globe, to the talk by Greg Cole describing the GLORIAD network and its utility and potential in connecting the global scientific community, until the last talk by G. Bala describing the peta-and exa-scale computing required for scientific use of the numerical data generated by the next generation of climate models, the discussions during the meeting made it clear that a new paradigm of scientific research based on the use of very large data and complex numerical models needs **a computational infrastructure on a scale which is much larger than currently available in the country,** as well as development of **skilled manpower in order to make its effective use.**

Specific implementable recommendations:

1. There is need for computing infrastructure that can be shared and be available for use by scientists across various institutes and universities. At least some of this must be of the highest quality, and it needs to be upgraded frequently to keep up with the fast changes.

2. The access to the infrastructure must be through a unified interface which is easy to use. There must be ways for researchers affiliated to organizations which by themselves may not have adequate computational resources to access a "shared" infrastructure.

3. Networking is a key area that needs immense focus and major thrust. End-to-end connectivity issues need to be tackled, since the weakest (or the slowest) link in a network ultimately determines its performance from the users' perspective.

4. A unified solution needs to be found for dealing with (non-)availability of licensed software or to find open source solutions, for a large section of the scientific community, especially those sharing a common hardware infrastructure.

5. We also suggest development of 'national virtual archives' for data on various topics including but not limited to biology, earth sciences, engineering, social sciences, astronomy, and other sciences. These could be archives where all data generated within the country with public funding could be deposited (after a statutory period during which the researcher who has developed the dataset gets exclusive usage). This could also include data generated by various public agencies through public funding (such as those generated by GSI/IMD etc). This along with good connectivity through NKN could go a long way in improving the quality of research in the country which at times is stunted due to lack of access to good data/connectivity.

6. Development of virtual communities and setting up infrastructure for it could be encouraged, a prime example being the Open Source Drug Discovery (OSDD) project, which very effectively uses the high-bandwidth connectivity to bring together scientists, students, etc. A pilot project that could be taken up is the Earth Sciences Virtual Community, which shares observational, experimental, and numerical data, using common computational infrastructure, to work on inter-related scientific questions.

7. Masters and/or Doctorate courses in "applied computer science" could be developed at various universities, in order to deal with the issue of lack of trained human resources.

8. New methods have to be devised for recognizing the contributions of scientists who create or archive databases of great scientific value. Such methods may include new practices in citation procedures and modification of current evaluation criterion to include credit for human resource development as well as creating public goods, which include novel computational infrastructure development, new methods of providing access to data, etc. This gives recognition to the time invested by the researchers in these activities.

9. There is a immediate need to set up a dedicated research centre focusing on computational approaches to questions from several basic and applied sciences. This centre could be located in an institution which has expertise in various engineering and scientific disciplines. This could be along the lines of the Computation Institute (a joint institute of the University of Chicago and Argonne National Laboratory), which is "an intellectual nexus and resource center for scholars from multiple disciplines building and applying computational platforms for science," but needs to be tailored to the needs of the country.

10. There needs to be a conscious effort from the scientists as well as funding agencies to promote interactions between computer scientists, mathematicians, and those working in other disciplines, through frequent workshops or working meetings and also through calls for collaborative research proposals. A new multi-disciplinary journal or bulletin, focusing on data intensive scientific discovery, could be started in an effort to disseminate the results of such interactions.

11. The immediate next step could be the setting-up of a task force consisting of national and international experts from academia, industry, non-governmental organisations, to develop a plan to implement these suggestions on an urgent basis.

Annexure XIII

Launching of SAC initiated Mission to Develop National Exascale Supercomputing Capability, Capacity and ICT Infrastructure on Integrated National Knowledge Network (iNKN)

Dr. Vijay Bhatkar

China leapfrogs!

Holding its breath every year, supercomputing community awaits the announcement of Top-500 list in the SC Supercomputing Conference. This year, when Top-500 list was unveiled at SC-10 in New Orleans, China topped the list with its massively parallel supercomputer NUDT YH MPP X5670 with a LINPAC benchmark of 2.56 Petaflop and peak performance of 4.70 Petaflop installed at National Supercomputing Centre in Tianjin. The third position was also claimed by China with Dawning TC360 at National Supercomputing Centre in Shenzhen. In fact, China claimed 41 positions in Top-500 list as against India's barely 4! Miffed by India's emerging prominent position in high performance computing, China had launched a massive Supercomputing Initiative almost ten years later than India but it has now emerged as a major player next only to US. Clearly, India has lost its initial momentum and is lagging significantly behind. Even Russia and many countries in Europe are now ahead of India in this strategic technology.

Exascale: the next frontier

In the meantime, supercomputing has moved from gigaflop in the late 80s, to teraflop in the late 90s and now petaflop level in 2010. The new frontier launched by the US in 2008 is Exascale supercomputers – computers that can perform 1000,000,000,000,000,000 mathematical operations per second! It is visualized that Exascale systems will become a reality by 2018 or 2020. Developing Exascale computers will have to spur several disruptive innovations. "It's not the technology of Exascale that is disruptive, but the things Exascale makes possible that will be disruptive", says Thomas Thurston, CEO of Growth Science International. "Exascale isn't a disruptor; it is a foundation upon which a million disruptions can be based." The US has now launched an Exascale supercomputing race and the major players are US, China and Europe. In fact, US now believes China, with its meticulous national planning and committed national funding of several billion dollars, might overtake it in this super race, paving way for a series of next generation technologies which the world will have to chase.

India's initial lead

US President, Barak Obama in his Central Hall Address in the presence of Dr. Manmohan Singh, India's PM and members of Parliament, had made a special mention to India's capability in Supercomputing along with Space Research. Indeed, when India developed its first Supercomputer PARAM in 1990 through SAC recommended national initiative in the form of C-DAC, India became world's third country to develop this capability and capacity next only to US and Japan. Not only this represented India's crowning glory on its fast growing IT capability but also along with its acclaimed Space and Nuclear Research Programmes, it gave a golden hallow to India's scientific achievements. This accomplishment was unmistakably mentioned by successive PMs in their important international addresses. Today, if one accomplishment stands out in India's emergence as a global superpower, it is India's strides in USD 180 Billion ICT industry topped by its capability in Supercomputing.

The credit for launching India's Supercomputing initiative goes squarely to Science Advisory Council (SAC) then chaired by Prof. C.N.R. Rao and its key members who piloted this initiative (Dr. R.A. Mashelkar, et al) when Mr. Rajiv Gandhi was the PM, in the backdrop of US denial that time. In 1987, SAC had identified Parallel Processing as a scientific area in which India could not only excel but also lead in the global context. Launch of C-DAC about 20 years back marks the start of India's voyage on to the turbulent seas of Supercomputing. India's first gigaflop supercomputer PARAM 8000 was unveiled in 1991. It was built at a cost less than that of Cray YMP, in a span less than three years, the time taken then to import and install large computing systems in India. The whole technology was developed from scratch including Hardware, Software and Applications, except for processor and memory. Further, developments of Flowsolver by NAL, ANUPAM by BARC and ANURAG by DRDO, India chose the Cluster Architecture as early as in 1994 when it was not clear which architecture will eventually win the race; India achieved the terascale architecture capacity in 1998. PARAM Padma, built in 2002, reached the peak 1 teraflop performance and made it to the Top 500 list. Several high performance computing facilities were set up at that time at C-DAC, Pune and Bangalore, NAL, BARC, IISc, CMMACS, DRDO, NCMRWF and other institutions. The IISc supercomputing facility emerged as one of the largest supercomputing facilities in the country then.

The focus then shifted to connecting the facilities as a grid. C-DAC proposed the creation of Garuda Grid with a nationwide WAN. The long voyage in HPC was of course not a smooth sailing by any reckoning. It was punctuated with several turbulences, with embargos on critical components, irregular funding, architectural debates, make versus buy dilemmas, loss of key talents to multinationals, self doubts, government apathy and bureaucratic hurdles during certain periods, and mad rush to build different systems without attaining a critical mass at a national level. Nevertheless, India had by 2005 firmly established its capability to design, develop and use terascale supercomputers. At this time several industries in the field of geosciences, VLSI design, biosciences, animation and gaming installed large supercomputers reaching terascale range, many of them then made into Top 500 List.

March towards petaflop

In 2005, DARPA announced its new initiative to develop next generation petaflop class supercomputers before the end of 2010 as a part of its High Productivity Computing system Program (HPCS). DARPA believed that HPCS is critical in the design and development of advanced vehicles and weapons, planning and execution of operation of military scenarios, the intelligence problems of crypto-analysis and image processing, and maintenance of nuclear stockpile besides contributing to US leadership in science and technology. In November 2006, DARPA chose IBM and CRAY for phase III of HPCS to build petaflop supercomputers with a funding of USD 250 Million each to build prototype petaflop systems by 2010. Not to lag behind the US, Japan also announced its plan to build petaflop supercomputers. The new entrant to join the petaflop was China, having built a few teraflop computers earlier. It is widely believed that China launched its National Program in Supercomputing to beat India and emerge as a world leader in this field. It is understood that over a billion dollar funding has been committed to this initiative under a highly acclaimed Chinese origin supercomputer architect, operating from both US and China.

The year 2007 was a golden year for India when at the Supercomputing Conference SC-07 at Reno, Eka developed by Computational Research Laboratory (CRL), a unit of Tata Sons, made into Top 10 List as the world's fourth largest Supercomputer achieving LINPAC benchmark of 117.9 teraflop. PARAM Yuva of C-DAC, Pune had reached LINPAC benchmark 38 Teraflop at that time. Both India and China had nine Supercomputers in the Top-500 List. In the coming years, India started sliding back in the global race due to lack of vision, inadequate investments and non-coordinated or rather fragmented approach at a national level.

Building a petascale supercomputer first

Before embarking on Exascale research, India will have to build a machine and facility that can provide a sustained petaflop performance in benchmarks and applications to reclaim its position in the supercomputing arena. Current Eka machine at CRL has a LINPAC benchmark of 132 Teraflop and C-DAC's PARAM Yuva 38 Teraflop. Even the aggregate performance of top 10 supercomputers in India does not add to petascale! C-DAC and CRL certainly have capability to build petaflop machines. The main hurdle has been inadequate funds for building the machine and sustaining the operational costs year after year.

The most affordable and viable way from both cost and power perspectives is to build a hybrid or heterogeneous system. We have already experimented with these systems both at C-DAC and CRL. Chinese system that topped the Top-500 list employs a hybrid architecture based on popular Intel X86 CPU blades with NVIDIA general purpose GPUs (GPGPUs). Many of the petaflop class systems being built are using NVIDIA GPUs. AMD also has an offering on GPGPU. Using high performance FPGAs can also be considered for specific applications, like C-DAC has done. The major challenge would be to build a scalable switching fabric. C-DAC has developed its PARAMNet-II &III switching fabric which is a major accomplishment. We can also employ available infiniband switches and build a scalable network that can provide 8000 ports, as many as needed depending upon sustained performance planned. Developing an integrated development and operating software environment is already within our reach. Current petaclass applications that we are working on include direct numerical simulation of complex fluid flows, weather modelling and monsoon prediction at 1 km resolution, climate modelling for long term prediction, seismic data processing for oil exploration, whole cell simulation for computational biology, genome sequencing, drug design, cryptography and graphics and animation. A large scale applications development programme involving academic and national labs, has to be catalysed. International community from Russia and other countries could also be invited in this effort.

Building a full-fledged petaflop machine will require a budget provision of USD 100 Million or Rs. 500 Crores in the next 2 years, including funding for research and applications development. Power requirement would be 6 MW with hybrid architecture. Petascale development should be led by C-DAC in partnership with CRL and NVIDIA, all located in Pune. Simultaneously, a national program involving IISc, IITs, IIITs, users such as IITM, IMD, ISRO, NAL, DRDO, BARC, CSIR Labs as well as industries such as ONGC, IOC, auto industries, and animation industry has to be launched with 100+ application developers across India with PhD and Post-Doctoral researchers. Such an initiative will surely place India in petascale league to embark on the Exascale mission.

Launching India's Exascale supercomputing mission

Simultaneously with building the petascale machine and facility on a national knowledge network, India needs to launch its Exascale supercomputing mission. The US HPC Advisory Council has already published a white paper, 'Toward Exascale Computing' that outlines a broad framework for exascale. The goal of Exascale is to be accomplished by 2018. Already the software roadmap has been worked out. According to the Institute for Architecture and Architectures and Algorithms (IAA), the architectural challenges for reaching Exascale are dominated by power, memory, interconnection networks and resilience. The 3P's will continue to dominate the architecture namely, Power, Performance and Programmability.

Several disruptive technologies will have to be innovated to reach Exascale. Some of these include multicore processor architectures, memory connects, packaging technology, interconnection network with integrated optics, programming environments, storage area networks, zettascale storage systems, and most importantly power. Power is one area in which significant breakthrough will be the most difficult to achieve. At current architecture, an Exascale machine will require 7000 MW! Most Exascale architects think that the power has to be brought down to the level of 20 to 50 MW at most! Clearly, disruptive innovations are required at several levels to achieve this. India should prepare a 10-year perspective on Exascale and join international HPC community in exploring the exascale. It is hard to make a guess of the budget required for exascale mission, but a provision of Rs. 5000 Crores (over USD 1 Billion) will have to be made for the next 10 years.

Driven by applications

India's petascale and exascale computing initiative should be driven by applications from day one. It should not be a monster machine waiting to bite applications. Since end users are likely to be researchers in leading academic institutions and national labs, they will have to be brought on board as the machine or facility is being built. At present, as stated earlier, some of the peta-class HPC applications in India are direct numerical simulation of complex fluid flows, weather modelling and monsoon prediction at 1 KM resolution, climate modelling for long term prediction, whole cell simulation in computational biology, computational nanoscience, drug and vaccine discovery, agricultural biotechnology, and the like. The grand challenge problems of HPC will continue to be problems from computational chemistry, physics and biology, human genome , human vision simulation, brain research, laser optics, aerodynamic analysis, numerical weather prediction, global climate modelling, computational cosmology, and the like. The 21st century has been called the century of biology and indeed biology will be the major user of petascale computing. Potential applications are bio molecular structural modelling, modelling complex biological systems, genomics, infectious disease modelling and customized patient care. Major industrial applications include oil exploration, automotive design, aircraft design, circuit simulation in VLSI design, advanced materials development, and drug design. Cryptography is another driving application. Real media applications include animation, gaming, special effect generation, and creating immersive virtual reality. Enterprise applications will be in very large databases, data warehousing and data mining. With next generation network spreading across the country providing convergence of data, voice and video as well as emergence of 3G and 4G mobile networks, whole new range web services applications will emerge requiring powerful music, video and gaming servers. Providing software as a service is already before us. Many game changing applications are expected to emerge that will require massive scalable IT infrastructure. We see media convergence and image-video-audio text based social networking as a disruptive application. If we are able to create next generation social networking sites such as Facebook.com or Myspace.com with 100 plus million subscribers then these could be killer applications of initially petaflop-petabyte and then exaflops-zettabyte facility. Applications development must be pursued with a strong partnership program with ISRO, BARC, DRDO, CSIR labs and DoT as well as with industry such as ONGC, IOC, automotive and other industries and academia covering TIFR, JNCASR IISc, IITs, IIITs, IISERs, proposed Central and Innovation Universities and the likes.

Engine for discovery and innovation

Traditionally, scientific discovery was done using the two pillars of theory of experiment. With ubiquitous deployment of high-performance computers (HPCs), a third pillar of 'simulation' has been added. The exascale mission can become an engine for discovery and innovation for India. Besides, India can spur several disruptive innovations in ICT through this mission. Innovation will be the single most important factor in determining success of an enterprise or competitiveness of a nation through the 21st century. It is now believed that high performance computing is becoming an instrument for competitiveness not only in traditional areas but also for entering into new areas such as nanotechnology, biotechnology and cognitive sciences. The emerging convergence of Nanotechnology (NT), Biotechnology (BT), Information Technology (IT) and Cognitive Technology (CT), what is known as NBIC Convergence, opens up entirely new opportunities for discovery and innovations. India is aspiring to emerge as the R&D hub of the world and to fulfil this aspiration and address unprecedented opportunities for innovations and address global problems of climate change, international security and availability of high-performance computing scaling to petascale first and exascale by 2020 would be most critical for India.

Machine, infrastructure or service?

Since exascale supercomputing will be a unique and unparalleled programme starting from petascale and reaching to exascale over a decade, whether it should be pursued as a machine, or as a data centre infrastructure, or a service needs to be seriously considered. Since not only the Capital Expenditure (CAPEX) but also the Operational Expenditure (OPEX) are going to be extremely high with a need for continual system up-gradation and replacements, it is imperative that the project is planned for economic sustainability and commercial viability with several spin off benefits emerging for all stake holders. In view of a variety of applications and workloads, the machine must be built not only for scientific and technical applications but also for business and enterprise applications including the emerging real media web applications with a powerful immersive virtual reality, animation and special effect generation facility. The project therefore should be planned simultaneously as an exascale supercomputer, a national high-performance supercomputing cloud infrastructure and as a commercial information utility service. It should be simultaneously planned as an Infrastructure as a Service (IAS), Platform as a Service (PAS) and Applications as a Service (AAS).

The proposed Exascale Supercomputing facility should be seamlessly connected on the proposed Integrated National Knowledge Network (iNKN) and C-DAC's Garuda grid linking all high performance computing facilities in the country. Next, it should be integrated with the national network of universities and colleges planned under the National Mission on Education through Information and Communication Technology which envisages 1 gigabit of bandwidth for 100 central/premier institutions of excellence, 10 Mbps for each of the university departments of 360 universities and 10 Mbps for 18,000 colleges using all possible means including EDUSAT and other broadband satellites of ISRO, and wired and wireless infrastructure planned by BSNL using Next Generation Network (NGN). It should also be connected to various State Wide Area Network (SWANs) funded by Department of Information Technology for e-Governance. The Exascale supercomputing facility thus can become a National Information Infrastructure connected on its national knowledge network.

End note

In 1987, Scientific Advisory Committee (SAC) under the leadership of its Chairman, Prof. C.N.R. Rao, had initiated India's supercomputing mission based on parallel processing architecture. Through the launch of C-DAC in 1988, India built its first giga scale supercomputer PARAM 8000 in 1990.

Simultaneously, several parallel supercomputers were built, namely ANUPAM by BARC, ANURAG by DRDO and Flowsolver by NAL which was first to embark on the parallel processing path. By 1998, India started building terascale systems and now several such systems are operational. At the beginning of the 21st century, IISc's National Supercomputing Centre became India's largest supercomputing facility. The year 2007 was a golden year for India's HPC, when CRL's EKA system became world's 4th most power supercomputer with 9 terascale systems in the Top-500 list. Coming from behind, China had caught with India in this year. With massive and sustained funding and visionary perspective, in SC-10, China has claimed the No. 1 position in Top-500. India is now way behind China. China has 41 systems vis-à-vis India with only 4 systems in Top-500. Lack of visionary leadership, subcritical funding, without long term road map, fragmented and uncoordinated approach are the main reasons for India's punctuated achievements.

As demonstrated amply, India has capability and capacity to once again globally lead in supercomputing. SAC should now launch India's 10 year mission to build its Exascale system by 2020. Led by C-DAC with CRL playing a commercial and production role and involving a network of academic and national labs, this should be a nationally coordinated mission. A full-fledged petascale machine and facility should be built first at C-DAC with CRL engaging the industry. Simultaneously, exascale mission should be launched. The exascale system should be planned as a machine, infrastructure and service on an integrated knowledge network connecting India's premier academic and research institutions. Exascale mission can be a foundation on which India can build several disruptive innovations in the 21st century.

Launched by SAC, this mission can become India's crowning glory of its USD 120 Billion ICT industry and of its advanced science, education and research. With multicore architectures now common place on laptops, desktops and even mobiles, parallel processing is already having a pervasive impact on the ICT industry. Multicore programming is a new software opportunity for India and India can lead in this new software field. Exascale initiative can also launch India's hardware research, in VLSI, embedded systems, mobiles, networks and high performance computers.

A budget provision of Rs. 500 Crores is immediately required for the next two years to build a full-fledged petascale facility and spur a broad based applications development and advanced research and education programme. Eventually, a budget of Rs. 5000 Crores (about USD 1 Billion plus) would be required to reach the exascale supercomputing capacity and capability by 2020. The exascale projects have already been launched by USA, China and Europe. Its time India launches its Exascale Supercomputing Mission, once again as a SAC initiative.

There was a general consensus on (i) the inadequacy of the existing computational infrastructure for research using large data, and (ii) the necessity of a comprehensive plan for developing such an infrastructure, and most importantly, for developing trained manpower. The following recommendations emerged out of the discussions during the meeting.

Annexure XIV

सत्यमेव जयते

PROFESSOR C.N.R RAO
CHAIRMAN

GOVERNMENT OF INDIA

SCIENTIFIC ADVISORY COUNCIL
TO THE
PRIME MINISTER

FAX: 011 23086857/23019545

SAC-PM/02/2010-592
June 18, 2010

Dr. Manmohan Singh
Hon'ble Prime Minister of India
South Block
NEW DELHI 110 001

Sub: Topics for discussion in the National Development Council (NDC) meeting on Science and Technology

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Dear Dr. Manmohan Singhji,

As discussed with you, I enclose a possible list of topics that can be taken up for discussion in the proposed meeting of the National Development Council devoted to Science and Technology. By the time we have the meeting, the document on 'India as a global science power' will also be available and can be used for possible discussion. I do hope that meeting on NDC on Science and Technology can be organized in the near future.

With best wishes and personal regards,

Yours sincerely,

(C.N.R. Rao)
National Research Professor
&
Linus Pauling Research Professor

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POSSIBLE TOPICS FOR DISCUSSION IN THE NDC MEETING ON S&T

1. Presentation of the vision document on India as a Global Power in Science prepared by SAC to PM

2. Science and Technology in Socio-Economic Development: Some Concrete Examples (MOST)

3. Science, Technology and Innovation inputs for Water, Food, Solar Energy and Health Care: Launching some mega initiatives

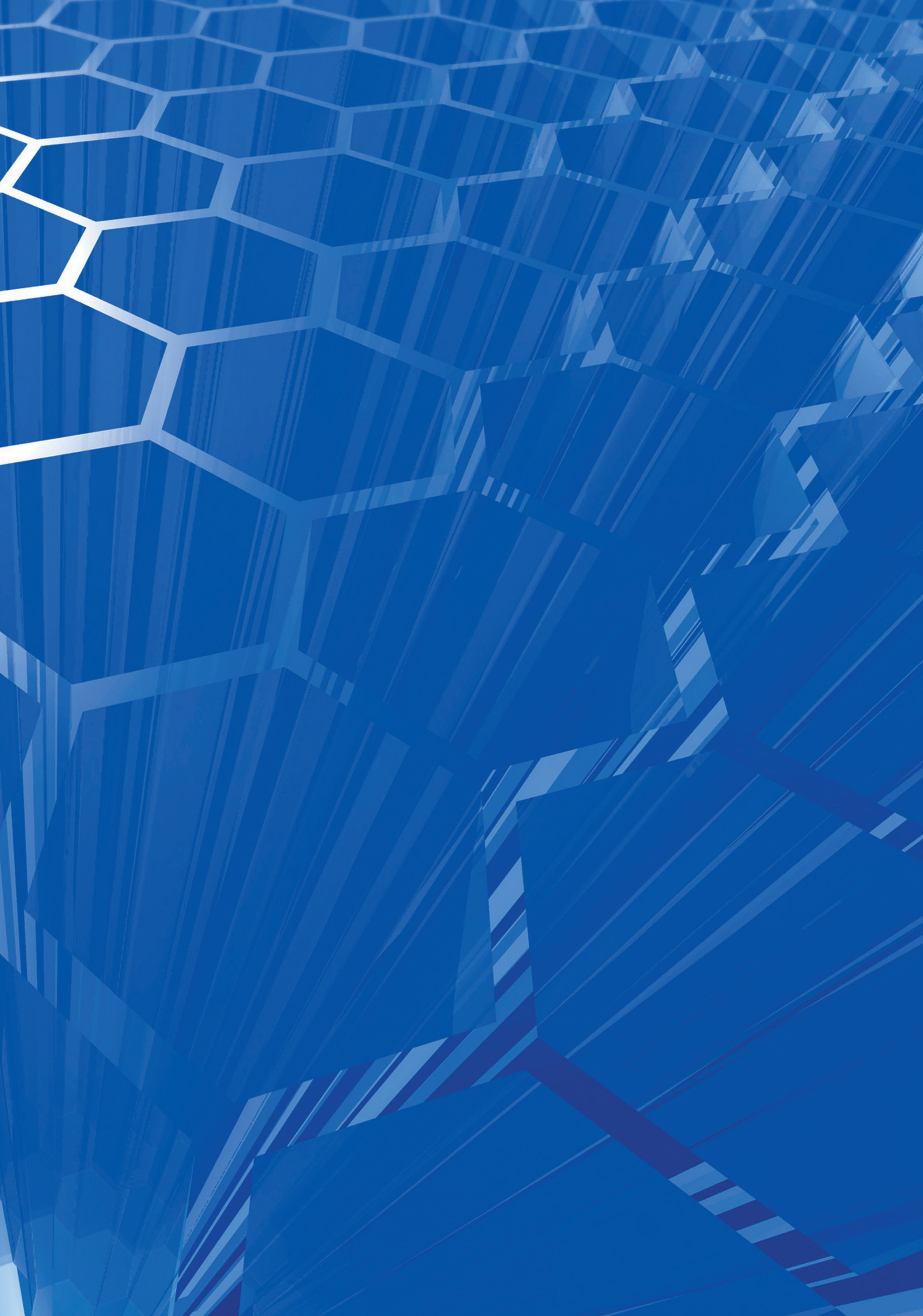
4. Formulation of S&T Road Map by States and Vision for Technology led Development

5. Formation of State Level Science Advisory Councils (to the Chief Ministers)

6. State – Centre Partnerships in Promotion and Utilization of Science (including rural development)

7. Strengthening of Science Education and Research in State Universities.

Compositions



Composition Of Scientific Advisory Council To The Prime Minister (SAC TO PM) (01.04.2008 till January, 2009)

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19. **Professor T.V. Ramakrishnan**
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MEMBER SECRETARY

28. **Dr T Ramasami**
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1. **Professor C.N.R. Rao** — Chairman
   National Research Professor
   Linus Pauling Research Professor &
   Honorary President
   JN Centre for Advanced Scientific Research
   Jakkur,
   Bangalore – 560 064.

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   Principal Scientific Adviser to the
   Government of India
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4. **Dr Bikash Sinha**
   Homi Bhabha Professor, DAE
   Former Director
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6. **Professor Devang Khakhar**
   Director
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   Mumbai – 400 076.

7. **Professor P. Balaram**
Director
Indian Institute of Science
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8. **Professor Goverdhan Mehta**
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9. **Professor S.E. Hasnain**
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University of Hyderabad
Central University P.O.
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MEMBER SECRETARY

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Chronological Dates Of The Meeting

Meetings of the Previous Council

1.	28th Meeting	21.04.2008 at Bangalore
2.	29th Meeting	06.06.2008 at Bangalore
3.	30th Meeting	04.09.2008 at New Delhi
4.	31st Meeting	25.11.2008 at Bangalore
5.	32nd Meeting	16.01.2009 at New Delhi

Meeting of the Previous Council with Hon'ble Prime Minister

1.	5th Meeting	17.07.2008

Meetings of the Present Council

1.	1st Meeting	12.12.2009 at New Delhi
2.	2nd Meeting	25.01.2010 at Bangalore
3.	3rd Meeting	12.02.2010 at Kalpakkam
4.	4th Meeting	27.03.2010 at New Delhi
5.	5th Meeting	23.04.2010 at New Delhi
6.	6th Meeting	22.05.2010 at Bangalore
7.	7th Meeting	16.07.2010 at New Delhi
8.	8th Meeting	18.09.2010 at New Delhi
9.	9th Meeting	28.10.2010 at Bangalore
10.	10th Meeting	22.11.2010 at New Delhi
11.	11th Meeting	24.12.2010 at Bangalore
12.	12th Meeting	10.02.2011 at New Delhi
13.	13th Meeting	09.04.2011 at New Delhi

Meeting of the Council with Hon'ble Prime Minister

1.	1st Meeting	29.01.2010
2.	2nd Meeting	18.09.2010

Meeting of the Council's Sub-Committee with Hon'ble Minister for Human Resources Development

1.	1st Meeting	27.02.2010

Meeting of the SAC to PM with State Councils' of S & T

1.	1st Meeting	27.03.2010