Report of
The Working Group on
Thrust Areas in Basic Sciences

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The Working Group on Thrust Areas in Basic Sciences met three times - on 27th May, 24th June and 12th August 2006 - at the Indian Institute of Science, Bangalore.

The draft report presented here is based on inputs received from all the members of the Committee and from colleagues across the scientific community. The Working Group recognizes that a strong public commitment to basic research in science, engineering, agriculture and medicine is essential for the overall growth of science and technology in India which in turn is critically important for the development of the country.

Keeping in mind the strong commitment of the Government of India to promote science and technology, the Working Group suggests that the 11th Five Year Plan provide a special thrust to basic science research in our academic and research institutions. There is a considerable body of evidence that now suggests that the growth of science in India is happening at a much slower rate than many other rapidly developing countries. This is, therefore, the appropriate time to step in and create fresh infrastructure and new schemes for attracting and retaining talent and to enhance funding of research activities in a major way. The report is divided into four sections listed below:

(1) Specific Thrust Areas
(2) New Funding Mechanism / Inter Institutional Linkages / New Infrastructure / Manpower Development
(3) Financial Summary
(4) Special Justification for Major Requirements

1. Specific Thrust Areas

Given below are the thrust areas classified under different disciplines. The list is only indicative and is not exhaustive.

I Biological/Medical Sciences

The future of biology lies in integrating the knowledge of classical biology, biodiversity, genomics, proteomics, metabolics and bioinformatics with computing skills, engineering mechanics, mathematics, physical and chemical sciences. The new composite research discipline (including modular and systems biology) termed "Integrative Biology" is already on the horizon. It is the science of discovering, modeling, understanding and ultimately engineering the dynamic relationships between biological molecules in terms of the interplays of different hierarchies of biological information such as DNA, RNA, proteins, macromolecular complexes, signaling networks etc. constituting living organisms within their environment. It will be a leading age of research in the 21st century. Although the total molecular functional description of the system may not be possible, the meso-scale integrative biology will help in establishing the correspondence between molecules and large scale physiology. The list below is representative of areas that need sustained support.

1. Integrative and Systems Biology
2. Genetics & Genomics
3. Infectious and metabolic disease: basic biology, biochemistry and drug design
4. Immunology and Vaccine Research
5. Structural Biology, Proteomics, Chemical Biology
6. Ecology, Biodiversity and Conservation
7. Plant molecular Biology and Basic Research in Agriculture

8. Nanobiology
9. Science Initiative in Ayurveda
10. Biotechnology and nano-technology based on biological systems:

In general, biological systems are less energy intensive and though the chemical conversion efficiency of each step may be low, through linked reactions better yields are achievable. Basic research support is thus required to facilitate replacement of energy intensive steps in chemical engineering by engineered enzymes. Tissue engineering, stem cell research bio-compatible materials and machine vision will emerge as the new thrust areas in the coming years for biotechnology and bioengineering.

II. Physical Sciences

Physical Sciences areas falling into this realm of "Tabletop Physics' are listed below. The large "Mega Science" projects are not considered in this summary except where basic science inputs are critical. In these areas basic research needs to be 'directed' and focused to achieve specific goals.

1. Nano and Meso-scale physics
2. Optical Physics:
   - Photonics
   - Physics and technology of ultra-intense lasers
   - Physics and technology of ultra-cold atoms
   - New generation of compact ultra-short pulses
   - Quantum computers and quantum information processing
3. Low temperature physics
4. Soft condensed matter including biologically inspired physics
5. Development of plasma and laser based accelerators: High energy particle beams or Lasers interact with plasmas creating extremely large pressures and electric fields . Since the fields one can see range

from 30 GV/m to 100 GV/cm, compact accelerators of TeV range are possible. The following schemes need to be followed up for determining the best scheme: Plasma Wakefield Accelerators (PWA), Beat Wave Accelerators (BWA), Laser Wakefield Accelerator (LWA), Self modulated Laser Wakefield Accelerators (sm LWA).

6. Research related to Fusion Program : Fusion is the ultimate source of energy with minimal environmental degradation. The Indian SSST and ITER programs are geared to give the much needed push to the fusion program in the direction of commercial fusion reactors. The two major directions that should be emphasised are the technology of superconducting magnets and plasma heating system (RF, beams).

7. Astronomy and Astrophysics: A recent stocktaking by the community, brought out as a decadal vision document by the Indian Academy of Sciences last year, suggests two major directions of investment; first, consolidation and continunous modernization of existing facilities, and second, focus on development of appropriate manpower.

III. Chemical Sciences

1. Synthetic Chemistry

- New methodologies.
- Conversion of natural products into small building blocks and vice versa.
- Reactions which avoid protection-deprotection methodologies.
- Solventless and "green" conversions.

2. Supramolecular and Materials Chemistry

- Structure and dynamics of intermolecular interactions.
- Control of molecular assembly into solids and supramolecular aggregates.

- Development of advanced functional materials and their utilization in new technologies.
- Polymorphism of pharmaceuticals and industrially significant materials.
- Chemistry of energy conversion processes and harvesting of different forms of natural energies.

3. Chemical Biology
    - Biomimetic synthesis.
    - Diversity oriented synthesis.
    - Molecular mechanism of drug action.
    - Chemical Ecology / Natural Products.
    - Interface areas of chemistry with biology and materials science.

4. Catalysis
    - Rational catalyst design
    - Chemistry at interfaces
    - Gateways between chemistry and chemical engineering

5. Fundamentals and frontiers
    - Chemistry of single molecules
    - Mesoscale species
    - Complexity in chemistry

IV Engineering Sciences

- Multiscale modelling for the relation between molecular/mesoscale structure and the macroscopic (thermodynamics and transport) properties of complex and structured materials.
- Quantum theory and experiments related to optics, computation, chemical reactions and nanosystems.

- Fundamental studies of turbulence, multiphase flows, computational fluid mechanics.

- Tools for analysis of complex systems such as networks, etc. Image analysis, soft computing.

- Systems analysis, optimization and control with applications in process industries, robotics, automobiles, aircraft, supply chains, biological systems.

- Algorithms for VLSI design, parallel computing, data structures, data mining. Bioinformatics, Signal processing and communication networks, Wireless communication.

- Fundamentals of microelectro-mechanical devices, microfuridic systems, colloidal systems and interfacial engineering. Applications as sensors, actuators, lab-on-a-chip for medical and engineering devices, biosensors.

- Structural mechanics, Health monitoring, Earthquake engineering, Dynamics. Prediction of natural disasters including earthquakes, cyclones, tsunamis etc., early warning systems, structural engineering for resistance to natural disasters and loss mitigation technologies.

- Energy engineering, including energy generation (renewable/non-renewable), energy storage, efficient utilisation and pollution control technologies.

- Cyber security: Analysis of new and existing algorithms, design of new algorithms, sensors for wide-area networks, monitoring and analysis tools, test beds, bayesian and other learning techniques. Several agencies are currently examining this area. There is a need for strong cyber S&T infrastructure and a report on the subject prepared by a Committee under the Chairmanship of Prof. S.V. Raghavan needs to be considered. The Knowledge Commission under Mr. Sam Pitroda is also considering initiatives in INFONET.

V. Cross-disciplinary Areas and New Emerging Research Fronts and Technologies

There is a constant need to review developments at the cutting edge of basic research. A grant of Rs. 100 crores over the Plan period for seeding new areas using a specially developed mechanism is recommended.

2. New Funding Mechanism

The Working Group strongly endorses the need for setting up the proposed National Science and Engineering Research Foundation at the earliest (NSERF). The NSERF may then be charged with the responsibility of formulating and implementing the new schemes for enhancing research infrastructure and for attracting a new generation of students and faculty into our research institutions and universities. The NSERF should function as an autonomous body in addition to the existing ministerial mechanisms for funding, which are being administered by the various arms of the Government. An allocation of Rs. 1000 crores per year during the XI Five Year Plan period would be necessary to inject fresh vigour into our basic research system. Specific schemes which may be taken up by the NSERF are listed below:

1. Schemes for funding new infrastructure in the University system and in National institutions: This is essential since much of modern research in science and engineering requires development, acquisition and up-gradation of sophisticated equipment facilities. Flexible mechanisms need to be evolved where funding is effected rapidly and installation and operation of equipment follows quickly. The NSERF should act both as a creator of facilities and also as a watch-dog to ensure efficient operation.

2. Special schemes to upgrade selected University departments in carefully chosen frontier areas of science: This scheme would draw upon the experiences of the COSIST programme of the UGC, DSA/CAS programmes of the UGC and the FIST programme of the DST. It is clear that the quantum of grant support to major departments needs to be increased by at least an order of magnitude if our institutions are to remain internationally competitive.

3. Initiative for recruitment of faculty/scientists: At present, the most pressing problem in our institutions is the growing shortage of newly recruited faculty members. As a consequence, most institutions have aged collectively with a consequent decline of their research profile. Vigorous and attractive recruitment policies need to be introduced without any further delay within the Indian S&T system. It is absolutely essential that the ground rules for recruitment which are in force for administrative positions in Government should not be applied to the S&T departments. New recruits to positions of scientists/faculty usually enter several years later than their compatriots in the civil service. This is a consequence of the need to obtain Ph.D. degrees and several years of post-doctoral experience before entering our academic institutions. Flexibility in the salary support and start-up grant is necessary in order to attract the best scientists to work in India. The

NSERF, armed with autonomy, should be free to develop new schemes in which new recruits to the academic S&T system can be centrally funded and placed in institutions under programmes which are designed to provide suitable incentives for growth and development.

Inter-institutional Linkages:

India's scientific research output is largely determined by the activities carried out in centrally-funded academic research institutions and national laboratories. The vast university system no longer contributes to scientific research output in a major way. This is largely because of the decline of research activities in the science departments of universities. In order to quickly enhance the scientific activity within the university system, a new programme to promote inter-institutional linkages is proposed in the XI Five Year Plan. This programme should seek to provide grants support for creating common infrastructure, research facilities and collaborative projects between national institutions and universities.

(a) Mechanisms for Linkages between Basic Research and Technology

New technology is normally closely linked with basic research. Often ideas for new technologies are generated by researchers working in basic research and these can spawn new products and processes. There also may be situations where advances in basic science can be implemented to improve current practice. There already exist several schemes of the government for promoting technology transfer. The following new schemes are proposed with a University focus:

- A programme be initiated to promote the establishment of technology business incubators in Universities. The incubators will provide support to scientists to start businesses based on technology developed in the lab. This type of technology transfer can be very effective in terms of implementation, particularly for low initial capital startups.

- Industries with active R&D divisions should be encouraged to recruit research students working in basic science areas related to new technology areas by some incentives. New techniques and methods are most easily transferred to practice in this way.

(b) Cooperation between Mission oriented Departments/ National Laboratories and Universities

Currently the linkages come primarily through sponsored projects. These should be significantly increased in number and value. The following new scheme is proposed patterned along the lines of CNRS, France.

Mission oriented departments and national laboratories may consider setting up basic research laboratories in different Universities. A Senior Scientist may be deputed to the laboratory along with one or two additional scientists. A few faculty members and research students may be associated with the laboratory. The deputed scientists should be adjunct faculty of the University and should have some teaching load. The laboratory should be engaged in fundamental research related to the parent Department/Laboratory, and should be liberally funded. Each laboratory should exist for a fixed duration.

New Infrastructure:

The rapid advancement of science in all areas necessitates that research infrastructure be constantly upgraded. The creation of specialized laboratories and advanced instrument facilities is essential if India's research is to maintain a competitive edge. The list of possible areas is identified below:

* Physical Sciences:	• Nano-fabrication facilities • Synchrotron and Accelerator Facilities • Ultra high magnetic field facilities • Lasers and photonics facilities
* Biological/Medical Sciences:	• Molecular and Medical Imaging Centres • Institutions to bridge the gap between basic biological research and clinical research • Nanobiology laboratories
* Chemical / Pharmaceutical Pharmaceutical Sciences:	• Analytical Instrumentation Centres
* Mathematical Sciences:	• Centre of Cryptology
* Engineering Sciences:	• Computer Clusters for large scale modelling
* Directed Basic Research:	• Technology Utilization Centres

3. Summary of Financial Requirements (2007-2012)

		Rs. (Crores)
1.	National Science and Engineering Research Foundation (NSERF)	5000
2.	Initiative for Recruitment of New Faculty / Postdoctoral Fellows	
	(a) New Faculty (1000 positions over 5 years)	50
	(b) Start-up grants for new faculty (~ 20 lakhs per faculty)	200
	(c) New Postdoctoral Programs (500 Research Associates / PDF per year)	80
3.	Special Scheme to upgrade Select University Departments (25 Universities at 40 crores per university)	1000
4.	Inter-Institutional Linkages to promote National Institution / University Collaborative Programs	100
5.	New Research Infrastructure	
	(a) Nanofabrication Facilities (5 Centres at 80 crores per centre)	400
	(b) Synchrotron for Basic Research in Materials Biology, Chemistry, Physics and Particle Accelerator Based Research	800
	(c) High Magnetic Field Laboratory	50
	(d) Molecular and Medical Imaging Centres (2 centres)	200
	(e) Institutions to bridge the gap between biological and clinical research (Translational Facilities) (2 Institutions)	200
	B/F	8080

	C/o	8080
(f) Facilities for interdisciplinary areas like nanobiology, cognitive science, photonics and systems biology		500
(g) Analytical Instrumentation for Chemical/ Pharmaceutical / Forensic Sciences		150
(h) Centres for Mathematical and Computational Sciences including Computer Clusters and Centre for Cryptology		500
(i) Directed Basic Research involving collaboration of academic laboratories and mission oriented laboratories (Technology Utilization Centres) Five centres		350
(j) Basic Research in Earth Sciences (Advanced Centres for Seismology, Ocean Research, Atmospheric Sciences including long range weather forecasting)		250
(k) Special initiative at the interface of biological sciences and agricultural sciences to promote collaboration in plant molecular biology and transgenic animal research		200
(l) Science Initiative in Ayurveda (This activity is based on the outcome of a SAC-C coordinated meeting and will bring methods of modern science to further our understanding of Ayurvedic practices, hopefully triggering research in "Ayurvedic Biology")		50
(m) Cross-disciplinary Areas and New Emerging Research Fronts and Technologies		100
Total		10180

(Rupees Ten thousand one hundred eighty crores only)

4. Justification for Specific Inputs

1. National Science and Engineering Research Foundation:

The need for a new autonomous funding organization with an appropriately flexible operating structure has been articulated by the SAC (PM) and accepted in principle by the Union Cabinet. This structure must be operationalized at the start of the XI Plan Period if plan objectives are to be met in the area of basic science and engineering research. NSERF must be the catalyst for infusing new rigour into the academic research system in India. The budget of Rs. 1000 crores annually during the XI Plan should facilitate a rapid increase in scientific research activity in academic institutions.

2. Items 2-5 in the 'Financial Requirements' will be additional to the activities of the NSERF and are projected as new activities under the XI Plan. These initiatives are critical if the basic research system is to be dramatically strengthened.

3. Justification for the Synchrotron facilities:

Two complementary efforts need to be simultaneously pursued during the XI Plan period. These proposed efforts are outlined below.

Strengthening of activities around Indus - 2

1. The DAE, particularly the colleagues at Indore, deserve appreciation for the stupendous effort that they have put in, especially during the last couple of years. The setting up of NCUIR has helped to improve the interface between the scientists at Indore and the user community. Other granting agencies such as the DST and the DBT, who are directly involved with the users, should formally to some extent share with DAE the responsibility for the smooth functioning of Indus-2.

2. Much of the responsibility for the construction of beamlines have been so far shouldered by DAE institutions. In the future, the responsibility for setting up beamlines should substantially rest with users who should work in coordination with the concerned DAE scientists at Indore and elsewhere. Funds for it should be provided, at least partly, by the concerned funding agencies in the project mode. The users know best the number of beamlines needed in a given area, specifications etc. Furthermore, their involvement with beamlines obtained through competitive funding would serve to enhance the sorely needed ability of the user community to deal with instruments and their accountability in terms of performance.

3. Each beamline or each set of beamlines needs to be associated with appropriate measuring instruments and laboratories. This issue should be addressed sufficiently in advance. Again, substantial responsibility for instruments and laboratories should lie with appropriate agencies, who naturally need to work in close coordination with DAE.

Setting up of a new facility

In strategic terms as well as in terms of an appreciation of the probable level of usage, India needs at least two high energy light sources. Once synchrotron sources become available in the country, they are expected to be heavily used. As has happened with other facilities, they would also become indispensable for day-to-day functioning. In such a scenario, exclusive dependence on a single facility would be extremely unwise. Further, considering the gestation period in setting up of light sources, enough work to effectively use at least two facilities is expected to develop by the time the second source is ready. What is required is a 3GeV source with features complementary to those of Indus-2. That is expected to cost around Rs. 600 crores. The new facility should be set up primarily by an appropriate segment of the user community. Detailed discussions among concerned experts confirm that this is a perfectly feasible undertaking. In addition to providing a much needed facility, this undertaking is expected to raise the level of scientific and technological competence of the community to a higher level.
