REPORT OF THE WORKING GROUP ON CROSS DISCIPLINARY TECHNOLOGY AREAS

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Submitted to the Steering Committee on Science & Technology for the Formulation of XI[th] Five Year Plan (2007-2012)

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EXECUTIVE SUMMARY

Preamble

Planning commission has set up a Steering committee on Science & Technology for the formulation of the Eleventh Five Year plan, under the chairmanship of Dr. R. Chidambaram, Principal Scientific Advisor to the GOI. To assist the Steering Committee and to finalize its recommendations, various working groups have been constituted. Apart from six working groups for S&T Departments, eleven working groups have been set up to address important issues. One of these Working group relates to the Cross Disciplinary Technology Areas, under the Chairmanship of Dr. Baldev Raj, Director IGCAR and Prof. M.S. Ananth, Director IIT-Madras. This paper presents the major recommendations of this Working group on Cross Disciplinary Technology Areas.

Introduction

The XI-plan approach paper clearly highlights the objectives and challenges for achieving a broad based higher economic growth rate in agriculture, industry and services, as also the initiatives needed to be taken for a more inclusive development that includes better health, clean drinking water, rural infrastructure etc.

It is well appreciated that Science & Technology is to play a crucial role in achieving the above objectives. Modern technology development is increasingly becoming dependent on research inputs from a large number of disciplines. A seamless and multi-sectoral flow of technologies and inputs from scientists and engineers from various disciplines is essential for making a visible societal impact and economic prosperity.

Here, under the umbrella of "Cross-disciplinary technologies" we identify those S&T areas, cutting across the traditional divides of sciences, engineering and medicine, where investments can pay rich dividends. The R&D being pursued in S&T departments and mission programs, which have followed a multidisciplinary approach, have contributed to our self-reliance in strategic sectors. In addition, there exists a strong scientific and technological base, spread over various academic institutions, R&D laboratories and industries, that can be leveraged for the economic prosperity of the nation.

Working in cross disciplinary technology areas is about inculcating the culture of translating the scientific knowledge to practical gains. Towards this, there is a need for building the interfaces amongst Academia, R&D laboratories and industries to create an environment for innovation and invention. This calls for adequate infrastructure for focused R&D, as also establishment of methodologies for financing innovation in the early stage of technology development.

Thus, this paper addresses the twin issues of topics on which emphasis needs to be placed, as also the mechanisms to be in place to utilise the existing S&T base in the country for the larger gain of the nation.

In preparing this document, we had sought inputs from leading scientists, engineers and doctors, both from Academia and R&D institutions, to suggest areas where emphasis needs to be placed as also the methodologies required to achieve the objectives outlined in the approach paper. A consolidated list of all the inputs received is contained in the Annexure 2. These inputs were extensively discussed and debated, to build a consensus, at two meetings of the Working group held at IIT-Madras. In addition, a brain storming session on "Advanced computing for scientific needs" was held at the office of Principal Scientific Advisor, GOI.

Based on the inputs and detailed deliberations, it is strongly felt that the following cross-disciplinary areas need to be supported during the XI-plan.

- Desalination and water purification technologies
- Nutrition
- Health care (Medical diagnostics, Medical devices, Vaccines)
- Advanced Computing
- Advanced Manufacturing
- Robotics and Automation
- Combustion Research
- Sensors & Integrated Systems
- Distributed Sensors and Networks
- Security Technologies
- Advanced Functional Materials

A brief summary of major recommendations for each of the above areas, and approximate financial outlay for implementation of the recommendations are presented in the following pages. In addition to the identification of topics, the Working group also deliberated on the mechanisms to be in place to ensure the success of "cross-disciplinary technology areas", and these are indicated at the end of the report.

The committee would like to note that while the above list is certainly not comprehensive, it represents a common denominator of cross disciplinary areas, where building the core expertise and competence will have far reaching consequences in the development of science based technologies for societal benefits, economic competitiveness and national security. The above cross disciplinary areas transcend more than one domain both in terms of expertise that is called for and the useful technology that is developed. The Working group also noted that while some of the topics indicated above are already being pursued by S&T ministries, their identification under cross-disciplinary technology areas is an endorsement of their importance and the need for focused support.

The total outlay required for all these areas is estimated to be Rs. **2335** Crores. This investment should be treated as a seed money for R&D and further investments required for products should involve the participation of industries and end-user organizations. Where the investment in any one of these areas appears excessive, it is important to consider the cost of not making such an investment at this stage. The decision to invest then becomes the wiser alternative.

DESALINATION AND WATER PURIFICATION TECHNOLOGIES

Water security is a fundamental requirement for a sustainable development. Increase in population and in the per capita demand are imposing tremendous strains on our water resources. Given this, a comprehensive R&D programme on various desalination and water purification technologies should be pursued. These include:

- R&D on thermal desalination plant optimised for Indian conditions with focused research efforts on energy reduction, cost optimisation, scale control, improved heat transfer coefficients, materials and minimising thermodynamic losses etc.
- Offshore desalination using Ocean Thermal Energy Conversion- Low Pressure Distillation.
- Waste heat based seawater desalination plants
- Water recovery and recycle from industrial effluents and sewage
- Development of solar energy/other renewable energy driven desalination plants,
- Advanced pretreatment & post treatment systems for desalination
- Work on Indigenous membrane development, in particular on the development of biodegradable membranes

It is estimated that a comprehensive R&D in the above areas will entail an investment of Rs. 200 Crores, as indicated in the Annexure 1.

It was also felt that apart from R&D in the above areas, there is also a need for suitable governmental policy measures that should encourage and promote (a) setting up of dual-purpose plants for power and desalinated water production along the coastal areas, (b) incentives/subsidies for the industries to retrofit desalination units using the waste heat, wherever possible, (c) appropriate technologies to recover water from spent streams and effluents for reuse. Further, environmental norms with respect to desalination and water recycle plant location and discharges need to be established and notified.

In suggesting the above recommendations, we have drawn heavily upon the position paper and technical report on Desalination and water purification technologies, prepared based on a brain storming session convened by PSA, GOI. This involved a meeting on 23rd August 2005 with the representatives of R&D organisations and academic institutions, such as BARC, Mumbai, CSMCRI, Bhavnagar, RRL, Bhuvaneshwar, NIOT, Chennai, IITs etc, as also the concerned industries such as BHEL, Ion Exchange (India) Ltd., ROCHEM Separations etc., and a subsequent national level discussion meet, organized by BARC at Anushaktinagar, Mumbai on February 27, 2006.

NUTRITION

Nutrition for all age groups, from pediatrics to geriatrics, is a necessity for the well being of the country. Anemia, malnutrition, low birth weight, unhygienic living conditions etc., are areas that need technological as well as social intervention. It is imperative that during the first formative years of the child, in particular the girl child, a high class nutrition be provided that can make a huge difference later. This preventive approach to good health, through nutrition, can obviate the need for expensive damage control at later times. The success of implementation of the programme on Nutrition calls for the participation of various governmental organizations and NGO's.

A comprehensive R&D programme on Nutrition needs to look into several aspects such as (1) the important role of micro-nutrients (Fe, Zn, I ..) and their fortification, (2) Genes and diet (3) Neutraceuticals and functional foods, (4) To exploit the value of traditional Indian foods – perhaps for future markets etc. Further, the power of food processing and value addition must be carefully and strategically used for production, protection and extension of shelf life.

There is a need to establish a referral centre for nutrition analysis. This high-tech analysis centre would carry out a variety of important analysis such as Macro and Micro Nutrients, Calorific value, Food allergens, Food pathogens and pesticide residue. The estimated cost of establishing the referral nodal centre for nutrition analysis is Rs. 25 Crores, as indicated in the Annexure 1.

HEALTH CARE TECHNOLOGY-
MEDICAL DEVICES & VACCINES

Healthcare technology is probably one of the most important cross-disciplinary areas. Today, healthcare delivery is dependent on three major product groups, namely: (1) Drugs, (2) Biological - vaccines, blood components, etc and (3) Medical Devices. While the Indian drug industry is well established, biologicals, especially vaccines require technological improvements and refinements. But most importantly, the bulk of MEDICAL DEVICES, that include Life saving implants, High tech diagnostic equipments and instrumentation, Diagnostics test kits, Surgical instruments and accessories etc., continue to be imported (estimated at over 80% of the country's market). Further there is very little control over their safety and quality before being placed on the market.

Given that medical devices form one major cost-component of healthcare, ignoring this sector and depending on imports will continue to make it difficult - if not impossible for a majority of our people to have reasonable access to safe and adequate healthcare. Hence, the Working group calls for a Mission Mode Development of Medical Devices and Vaccines. The major recommendations are:

1. A MAJOR THRUST for development & delivery in selected high impact segments (a) Medical Instrumentation (b) Orthopedics (c) Diabetes treatment. The programme on Medical instrumentation will take into cognizance the report on Instrumentation published by INSA, under the chairmanship of Dr. S.K. Sikka.
2. A MAJOR THRUST for development of Vaccines under Good Manufacturing Practice conditions with an integrated approach; a major initiative in Tissue engineering, - an emerging frontier area.
3. Set-up an INDEPENDENT Medical Devices Regulatory framework; develop infrastructure for safety testing and evaluation to support this.
4. Promote the growth and formation of:

- *Strong interdisciplinary R&D centres / groups / consortia*
- *Infrastructure for the training of the much needed Clinical and Biomedical Engineers.*

The above programme will entail an expenditure of 350 Crores, as indicated in the Annexure 1, and calls for a cross-disciplinary approach involving Medicine and Engineering.

ADVANCED COMPUTING

Advances in computational technology continue to transform Science and Technology research, practice, and allied education. Computing has become the third pillar of Science and Technology, complementing the traditional activities of theory and experimentation. There has been a tremendous increase in the volume of data that scientists working in physics, chemistry, biology and many areas of engineering need to analyse in real time. Scientists in many disciplines have begun revolutionizing their fields by using IT information, computers, digital data, and networks to replace and extend their traditional efforts. For example, High Energy Physics community is able to carryout today calibration, reconstruction, simulation, analysis in collaboration with their partners located any where across the world. The processing, mining and visualization of large volume of data in areas spanning medical, nano sciences, material sciences and space sciences would be one of the major cross disciplinary areas of the future.

Currently, there is a shift in the philosophy of computations and the trend is to share the computing power rather than own it. This has become possible due to a new & upcoming technology called "Computing Grid", which is being developed using the Internet and the World Wide Web technology. By integrating this distributed environment using low cost Internet, very high speed technology, now it has become possible to provide supercomputing power in the hands of individual users that until now could only dream of affording such power without having to make an exorbitant capital investment. Furthermore, information processing activities, such as data base indexing and financial modeling, emails, data mining via search engines through Internet etc., are becoming more computationally and I/O intensive and require high performance computing facilities.

The working group on cross disciplinary technology strongly endorses the setting up of a Indian Grid for Science & Technology (IGST), a Nation-wide "Hierarchical networks of High Speed Computing & Communication systems" based on an open platform. It will be very high bandwidth multi 10Gpbs backbone primarily to cater to the Science & Technology applications, such as weather forecasting, bio-informatics, high energy & condensed matter physics, sharing of digital libraries, information on education, Video meeting etc.

This proposal for establishing IGST is based on the meeting of cross disciplinary technologies held at IIT-Madras on 17-6-06, followed by a brain storming session held at PSA's office on

July 20, 2006. Dr. Chidambaram chaired this meeting, that was attended by specialists like Dr. B.K. Gairola of NIC, Dr. S.V. Raghavan of IIT, Madras, Dr. R.K., Shyamsunder of TIFR, Shri. P.S. Dhekne of BARC, Shri. S.Ramkrishanan of C-DAC, Dr. A. Kembhavi of IUCA, Dr. Baldev Raj of IGCAR, Dr. S.K. Dash of IIT, Delhi and Shri. Neeraj Sinha of PSA office. The Brain storming meeting suggested that the proposal on setting up of IGST is to be overlaid with another proposal for the creation of a nationwide high-speed e_infrastructure, that is being submitted separately.

Setting up of IGST will take India into the next century of research and education by supporting advance research in S&T by developing state-of-the-art technologies in information technology, computing and advanced computational modeling. It is planned to explore new modes of computing by extending the concept of clusters to that of wide-area grids of supercomputers allocated dynamically to a common problem over both wide distance and multiple organizations. Establishing Indian Computing Grid for S&T (IGST) would require funds to the tune of Rs. 500 Crores, as indicated in Annexure 1.

ADVANCED MANUFACTURING

The XI-plan approach paper highlights the importance of increasing the growth rate in the manufacturing sector to achieve economic prosperity. The deliberations at the Working group, with inputs from earlier brain storming sessions suggested that there is an urgent need for

- Providing a sound scientific and technological support to the Indian manufacturing industry from conceptual design to prototyping of components in general engineering as well as strategic sector.
- Developing innovative materials, processes, products and practices that can help the manufacturing industry to be a leader in the global market.

Some of the specific areas where emphasis need to be placed include: (1) Manufacturing Technologies for Multi Material Microsystems, (2) Capability Building of Advanced Materials Processing for value added engineering / smart components, (3) Optimization of Process Parameter for Net-Shape Manufacturing through Rheo-casting, and (4) Rapid Manufacturing of Customized Biomedical implants and precision engineering components from functionally graded materials (FGMS), and (5) Development of magnesium components for automobile applications, that includes Pressure Die Casting, Twin Roll Casting, Sheet Making, Hydroforming etc.

In order to meet the above mission, a three layer approach involving Universities, R& D laboratories and Industries is to be followed. This calls for an investment of Rs. 160 Crores and the details are indicated in the Annexure1.

ROBOTICS & AUTOMATION

Robotics and automation play a crucial role in a wide variety of areas ranging from manufacturing, inspection and repair to medical and bio-engineering technologies. So far, in India, R&D on robotics has been pursued by strategic sectors like Atomic Energy, Space and Defence. These technologies also have important roles in advanced manufacturing, disaster management, rescue and surveillance in addition to extensive applications in strategic sectors.

Robotics and Automation calls for inputs from a number of areas like mechanical, electrical, electronics, instrumentation and software engineering, and parallel developments in the field of sensors like micro-vision, MEMS, touch-sensitive skins, etc. To meet the objectives of indigenous technological and scientific growth, and to facilitate strong interaction of experts in various domains of interest, it will be beneficial to establish a national centre devoted to work on Robotics and Automation. The prime objectives of this Centre will be in the development of Robotics in manufacturing, Robotics for extreme environments and Autonomous miniature robots which can be customized for a variety of applications.

The proposed Centre, apart from having in-house R & D, will encourage collaboration with academic institutes, with small and medium scale industries for proto-type building, manufacturing, integration, testing and validation and offer customized solution for industry/institutes. It is estimated that a comprehensive R&D centre on Robotics and Automation will entail an expenditure of 150 crores, as indicated in Annexure 1.

COMBUSTION RESEARCH

The technologists and researchers working in the area of automobiles are confronted with the challenges of the requirements of fast combustion processes and intricate system geometries mainly driven by emission legislations, fuel economy and the need for alternative fuels. The need for focused research and accurate measurements in these areas is fast growing. For example, the use of laser diagnostics facilitate improved understanding of a wide variety of combustion phenomena in modern engines from efficiency and emissions standpoint. These techniques provide remote, non-intrusive, in-situ and spatially and temporally precise measurements. The non-intrusive laser based measurements are becoming essential for validation of the in-cylinder computational results produced through CFD analysis of the engine combustion system. Besides improving the competitiveness of our engine technology in terms of fuel economy, emission compliance, these scientific research input would benefit the nation in its urge to achieve energy security and cleaner environment.

Currently, there is a very limited activity in combustion research, diagnostics and modeling leading to indigenous development of modern automotive engines and enhanced fossil energy systems. In view of this, the working group strongly feels that there is a need to establish a state of art research centre for combustion technology with a view of ensuring energy and environment security, and global competiveness . This Centre, housed in an academic institution, will work in the public-private partnership mode, and will help to build upstream and downstream interfaces, with R&D institutions engaged in fuel research and manufacturers of energy system. This calls for an investment of 100 crores, as indicated in the Annexure.

SENSORS & INTEGRATED SYSTEMS

Ultrasensitive and miniaturized sensors and actuators are crucial to a host of domains from advanced science and technology to the security of the nation. Conversion of physical, chemical and biological parameters to measurable electrical signals and their integration with electronic measurement system is at the heart of modern science and technology. These have impact on every segment of human endevour that includes agriculture, environmental monitoring, industrial processing, medical diagnostics, strategic sectors and so on. Constant innovation with respect to the development of new sensing materials and devices, multifunctional sensors, array sensors for imaging, sensors integrated with actuators etc., are being pursued worldwide as they contribute to the critical technologies. Advanced sensors that can detect ppb levels of chemicals, in atmosphere, remote sensing of weak electrical, magnetic and vibrational signals buried in a noise are major challenges that push the frontiers of science and technology. Competence in the development of sensors and integrated systems is one of the core technologies that will pay rich dividends in a variety of sectors from agriculture, manufacturing to healthcare, help build national economy and contribute to the security. For example, ultra sensitive sensors have become very important in the context of terrorism of various forms that calls for remote detection of explosives such as TNT, RDX etc, and dirty bombs wherein a conventional explosive material is packaged with radioactive material etc.

In India, a vast amount of research is being pursued on novel sensor materials that includes solid state materials, polymeric materials, biomaterials, nano materials etc. These have shown the potential for sensing and measurement of physical parameters such as pressure, temperature, humidity, magnetic field etc. Extensive research is being pursued in advanced sensors and methodologies based on piezoelectric effect, MEMS devices, magnetoresistance, SQUIDs etc. However, a major lacuna seems to be translating the gains of this R&D, being carried out in Universities and Mission departments, into devices and systems that can be used in various sectors. This calls for efforts at tailoring these materials in desired configurations (thin films etc), integration with suitable electronics, packaging, interfacing with measurement systems etc.

It is recommended that a focused R&D on advanced sensors be pursued. To facilitate this, a Center for Advanced Sensor Technology be established that will enable the translation of the R&D that is being pursued in the universities and institutions into final sensors and systems of required configuration. This center may also be entrusted with the mandate of testing, calibrating and certifying the sensors that are developed.

Terrahertz Technology

All molecules, biological, organic and inorganic, have their characteristic vibrational and rotational spectra that lie in the terahertz (0.1 to 10 THz) range. These wavelengths are short enough to enable millimeter imaging whilst long enough to penetrate many materials, allowing hidden objects to be imaged. The front line area of Terahertz technology finds a variety of applications in areas such as remote sensing, medical diagnostics, and recognition of hidden objects for national security and to combat terrorism. Given the wide range of applications including the strategic sector, India should enter into this nascent technology. There is a need for establishing a developmental synergy across the academic institutions and industries towards a common goal of terahertz technology. This will carry out indigenous development of semiconducting heterostructures for microwave and Terahertz devices, Terahertz radiation sources based on photo-mixing devices, Superconducting nanostructures for Terahertz detection, Integrated circuits for Terahertz radiation etc.

Thin Film Transistor Technology

In the world of information and communication technologies, large area electronics based on Thin Film Transistor (TFT) is going to play a crucial role in information collection, transfer and interface with societies. TFT based sensors, images, electronic papers and displays are expected to become a part of our lifestyle in the years to come. Information is critical in military enagagement and national security. While commercial requirements would be met by globalised economy, the strategic needs still require to be home grown in which Indian industry need to take up the challenge.

In contrast to microelectronics industry, large area electronics is still an emerging technology in which India has the capability to get in the race. The recommendation is for setting up a flat panel display facility- that will work in conjunction with high-technology industries.

Development of a National Facility for VLSI Testing and Failure Analysis

Having established itself in the Software field, India is looking towards the engineering of electronic products as the next milestone. This typically involves three stages, namely, i) Design, ii) Fabrication and iii) Testing. While the country has already become the preferred destination of major multinationals for the Design stage, there are relatively few manufacturing facilities and virtually no testing or failure analysis facility. Fabrication of electronic products requires major investments which can be justified only by commercial consideration, and is therefore better left to the private sector. Further, in the overall South-east Asian region, there are a number of manufacturing units, many of which are running far below their installed capacity. In contrast, there are just a few test facilities which are accessible to them. Even when such a facility exists, the needs of the defence, space and atomic energy sectors cannot always be outsourced due to strategic reasons. Organisations like SITAR, SCL and GAETEC do fabricate ASICS for these sectors in India and require testing and Failure Analysis (FA) facilities. It can therefore be seen that there is an urgent need for such facilities to be established within the country, which will cater to the existing and upcoming manufacturing facilities not only in the country, but also be able to take up contracted jobs from abroad in order to become self-supporting in the long run.

DISTRIBUTED SENSORS & NETWORKS

Distributed sensor network is an emerging cross disciplinary technology bridging materials research, electrical engineering, computer science etc. An integrated system comprising of sensing, computing and communication, geographically distributed on a network can be used for a plethora of applications such as monitoring, surveillance, disaster management, health care etc. There are challenging technological issues related to miniaturisation, power consumption, ruggedisation, networking etc., and India should enter into this technology domain of far reaching ramifications.

The area of Intelligence and security informatics spans areas such as Wireless sensor and actuator networks, data mining and knowledge discovery from unstructured data. This area is also prompted by the fusion of computing, communicating and sensing elements all into one single electronic device.

Transportation -Wireless Technologies

One of the focus areas related to this technology is the Skybus Telematics System. Research and development in this area has included implementation of telematics technologies that would enable multimedia-rich communication between vehicles and stations in a metropolitan-area rapid transit network. This involves developing a new system of Intelligent and Interactive Telematics for Transport Systems using WiFi-based wireless mesh networks and embedded in-vehicle information appliances. The key attributes of this system will be security, safety, reliability, performance, multimedia user interface, viable revenue model, and relatively low cost. Advanced research is focused on Vehicular Ad hoc Networks and Vehicular Sensor Networks.

R&D on the front line area of Wireless and distributed networks calls for establishing facilities for Electronic Design and Automation Tools, Production of custom built chips at Fabs, both in India and abroad, and integration with front-end electronics. It is estimated that this enterprise would call for an investment of 200 crores.

SECURITY TECHNOLOGIES

Transportation systems, viz., Road, Maritime and Air, is a vital backbone of any nation's economy and its security must be of great concern. In the recent times this sector has become a potential soft target. Emergence of new threats from organized terrorism has made this task very challenging and recourse is taken to technology based solutions. Further, protecting industrial infrastructure, critical to nation's economy, and strategic system's protection are vital requirements.

The modern security technologies encompasses a gamut of advanced technologies related to sensors, signals, image processing, mobile system security, Network and information security, crypto analysis etc. While it is necessary to work with other countries to develop these technologies in order to save time and money, it is also essential to develop our own solutions unique to our own requirements.

The proposal under cross disciplinary technologies is for establishing basic technologies that is common to, and serve most of the security and strategic system's needs, that is vital to national security. In addition to Sensors and Distributed systems, which already are emphasized in the report, there is a need for investment for R&D in Basic surveillance systems, Distributed and Mobile systems security, Network and information security which includes cryptology and crypto analysis and fast searching of massive remote distributed data bases. This calls for an investment of 200 crores, as indicated in the Annexure.

ADVANCED FUNCTIONAL MATERIALS

Here under the category of Advanced Functional Materials, we consider those new materials that have interesting electronic, optical or magnetic properties with considerable potential for application in a variety of technologies that include energy, health care, communications and security. Silicon exemplifies the classical functional material, that has heralded the modern electronics and communications technology.

Materials science, one of the most active areas of research, has thrown open a variety of new materials, that hold considerable promise for performance in a variety of technological domains. These include:

1. Solid state materials that include superconducting materials, magnetic oxides exhibiting giant magnetoresistance, ferromagnetic semiconductors for spintronics, piezoelectric, pyroelectric and ferroelectric materials.
2. Functionalised nano materials for sensors and Biomedical applications
3. Organic semiconductors for electronic devices.
4. Membranes and strategically important Elastomers
5. Complex fluids with interesting rheological properties including ferro fluids and nanofluids

One of the promising approaches is to combine in one material different physical properties to achieve rich functionality. For example, attempts at combining ferromagnetism and ferroelectricity – the multiferroics, optics and electronics the photonic materials etc. All the above areas are at the forefront of research today, and India has a strong scientific presence in many of these areas.

The recommendation is for focused R&D that aims to explore and exploit the potential of Advanced Functional Materials. The focus will be on Design and synthesis of novel materials including computer based design, materials processing for performance, and materials integration for devices. This recommendation is for an investment of 200 crores for R&D in various functional materials, with further investments for the development of devices and products to come through active industry participation.

R&D on functional materials has an enormous potential for wealth creation. It is a vital investment that can interface academia and industry at the cutting edge to enhance nation's industrial and economic competitiveness.

MECHANISMS

Success in cross disciplinary technology areas is about inculcating the culture of translating the scientific knowledge to practical gains. This calls for several mechanisms to be in place to ensure the success of "cross-disciplinary technology areas". The major recommendations of the Working group include:

- Establishment of research parks to facilitate cross disciplinary research. These science parks will act as the hub for interfacing of universities, R&D centres and industries.
- Empowered panel of experts, with financial control, that can suggest and implement mid-course corrections to the programme, to facililitate and exploit breakthroughs in R&D.
- For the success of these interdisciplinary areas, such as robotics, medical devices etc, there is a need to have an education system that integrates Science, Engineering and Medicine.
- For areas such as Desalination and Nutrition, Public-Private Partnerships must be encouraged
- Need for adequate legislations to ensure progress in some of the cross disciplinary technology areas, such as Desalination.
- Need for an autonomous regulatory authority in the area of Medical instruments.
- India is on the threshold as a hub for clinical trial, especially for vaccines. This must be exploited.
- It was also felt that in several of the cross disciplinary technology areas, collaborative venture with Scientists and Technologists of Indian origin Abroad, and foreign institutions of repute should be actively encouraged. This will pave the way for crucial inputs both by way of science and technology and work practices that will help us to leap frog in the development of science based technologies. The identification of the collaborating scientists and institutions will be carried out when the detailed proposals are submitted.

ANNEXURE-1

1. DESALINATION & WATER PURIFICATION TECHNOLOGIES

1	For setting up a few medium size demonstration plants (say 10 nos. of about one million litres/day (MLD) capacity) for seawater desalination in coastal zones/ offshore OTEC-LPD desalination plant.	75
2	For retrofitting waste heat based seawater desalination plants of 1 MLD capacity to the existing coastal power stations.	20
3	To install and operate several small size (say 20 nos. of 20–50 kilolitres/day (KLPD) capacity) brackish water desalination plants at select locations to demonstrate the potential role of desalination to the local community.	50
4	To install 1MLD plants for water recovery and recycle from industrial effluents and sewage.	20
5	Towards development and demonstration of point of use and small sized community water purification system (LPD to KLPD capacities)	10
6	For development of solar energy/ other renewable energy driven desalination plants, advanced pretreatment & post treatment systems for desalination, cost reduction strategies through technological innovations, reject brine management, haloculture, recovery of valuable elements from brine, development of new technologies such as soil-B technology remediation of contaminated water, clay membrane filter for water purification, nanotechnology, carbon aerogel etc.	25
	TOTAL	**200 crores**

2. NUTRITION: Referral Nodal Centre for Nutritional Analysis

1	Analysis of Macro Nutrients: Linear Chromatograph, GCMS, LCMS, Nitrogen Analyzer Digesters / Automated Titrator, Amino Acid Analyzer Capillary-GCMS, Near Infrared Spectrometer	
2	Analysis of Micro Nutrients: HPLC, Fluorescence Spectrophotometer, Atomic Absorption Spectrometer, Induction Coupled Plasma Spectrometer, Isotope Ratio Mass Spectrometer	
3	Analysis of Water, Total Dissolved Organics, Analyzer Intelligent Water Analyzer Assembly, Turbidity and Conductivity Transducer, Chlorophyll and Algae Detector, Ion-Chromatograph	
4	Calorific value: Isoperibolic Bomb Calorimeter	
5	Basal Metabolic Rate: BMR Indirect Calorimeter	
6	Food allergens: ELISA Spectrophotometer	
7	Food Pathogens: HPTLC System, Thermocyclers, Automated DNA Prep Station	
8	Pesticide residue: Nuclear Magnetic Resonance Spectrometer, MALDI-TOF	
	TOTAL	**25 crores**

3. HEALTHCARE TECHNOLOGY - MEDICAL DEVICES & VACCINES

Mission mode for Orthopaedic Devices And Implants

1	Development of new materials, especially composites, for innovative designs	
2	CAD/CAM and rapid prototyping – capacity building	
3	Clinical Evaluation and testing Infrastructure	
4	"Enabling Technology Centres" for pilot production and incubation	
5	Precision fabrication and special purpose machining capability	
6	Rehabilitation engg- materials for better quality prosthetics and orthosis	
7	Rehabilitation engg- better manufacturability with automation and quality control in cottage industry mode and low cost of operations	
8	Rehabilitation eng- new centres for clinical delivery and user training	
9	Academic-industry consortium for rapid product development	
	Orthopaedic Devices And Implants	**70 crores**

Mission mode for Medical Instrumentation & Diagnostics; telemedicine

1	Instrumentation for improved, low cost, clinical monitoring and diagnosis; development of sensors; low cost screening instrumentation in areas like cervical & breast cancers, cardiovascular diseases, etc	
2	Clinical Engineering Programme: manpower to professionally maintain, service and upkeep sophisticated medical instrumentation in hospitals	
3	Medical diagnostic kits and consummables	
	Medical Instrumentation & Diagnostics	***100 crores***
	Low cost (to scale to all villages) tele-diagnostic kits supporting telemedicine initiatives	***20 crores***

Mission on Diabetes Technologies

1	Novel Delivery systems for Insulin- transdermal, oral, aerosols and other innovative routes for delivery, including Development of biomedical devices like an automated programmable insulin pump.	
2	Footwear and foot care products for diabetic patients; some of the experience / expertise from treating leprosy patients could be utilised in a larger scale here.	
3	Rehabilitation of diabetic patients with disabilities (can be linked to the orthopedic programme)	
4	Improved wound dressings for treating diabetic ulcers	
	Focus On Diabetes Technologies	***30 crores***

Mission on Vaccine Development & Tissue Engineering :Initiatives & Programmes

1	Modernisation of existing vaccines & newer vaccines for respiratory diseases in children, pneumococcal, etc.	
2	Vaccines against HIV, TB, Malaria & Cancers, etc	
3	Combination vaccines development	
4	Vaccine stabilisation and delivery	
	Focus on Vaccine Development	**50 crores**
	Tissue engineering: replacement for cartilage, cornea, skin, heart valves, etc	**30 crores**

Mission on Medical Device Regulation

1	***Independent regulatory system and authority***	**20 crores**
2	***Testing and evaluation infrastructure***	**30 crores**
	GRAND TOTAL	350 Crores

4. ADVANCED COMPUTING

	Setting up of an Indian Grid for Science & Technology (IGST) Hierarchical cyber-infrastructure supporting Grid Computing with the following five layers of computing & communication set ups	**500 Crores**
1	Single processor workstations (with 100 Mbps connectivity) distributed among the key faculty and graduate students, participating R&D and Educational units, with a software environment tailored for development of computational models, visualization, and daily project requirements;	
2	Multiprocessor Computing System, with substantial memory, disk storage and high speed (100 Mbps) connectivity are shared by single research groups for jobs requiring greater computing capacity. These shared-memory multiprocessor (SMP) systems provide the entree to parallel processing	
3	Clusters, each node comprised of several SMPs connected by a state-of-the-art high-speed switch with 1 Gbps network, are shared by one or two labs or used by single research groups with substantial computational requirements and parallel computing needs	
4	One very large Cluster for the most demanding computational modeling activities, shared by the entire City via 10 Gbps backbone network	
5	A global computing layer built upon the collection of Campus Clusters inter-connected to a Terabit All-optic-Network (AON) backbone of NCIST that allows fast, easy access and sharing of work between any groups across the country.	

The desktops, servers, parallel systems and application software will run on Grid related open source software such as Linux, MPI-CH, Globus, gLite, PBS, Condor and other tools to facilitate development of home grown products. The NCIST will follow standard information security implementation and will have single sign on facility.

5. ADVANCED MANUFACTURING

1	**Materials Development**: Advanced Materials, coatings and characterization facilities	15
2	**Materials Processing**: Thermo-mechanical simulator, Advanced metal forming, hot-isostatic pressing, welding and Laser processing facilities, Set ups for the nano-technologies	35
3	**Manufacturing**: Advanced machining, metrology, virtual manufacturing capabilities, prototyping and intelligent manufacturing	50
4	**Human Resources**: Man power, Regular Master's courses on Manufacturing, Continuing Education programmes on Manufacturing	5
5	**Development of Magnesium Components for automobile applications :** Pressure Die Casting, Twin Roll Casting & Sheet Making Hydroforming and Bending of Tubing	5
6	**Manufacturing Technologies** for Multi Material Microsystems	22
7	Capability Building of Advanced Materials Processing for value added engineering / smart components	10
8	Optimization of Process Parameter for Net-Shape Manufacturing Through Rheo-casting	8
9	Rapid Manufacturing of Customized Biomedical implants and precision engineering components from functionally graded materials (FGMS)	10
	Total	**160 Crores**

6. ROBOTICS & AUTOMATION

1	Centre for Robotics including Mechatronics, Software and controls, Modelling, analysis, and simulation, Advanced materials, MEMS, Nano-technology, Precision engineering, Manufacturing, Devices for high temperature, corrosive and radiation environments, Sensor development.	
2	Design and development of Vision Guided Mobile Robotic Systems .	
3	Development of self-learning adaptive controller on embedded platform using computational intelligent technique for mecha-ronics application	
	Total	**150 Crores**

7. COMBUSTION RESEARCH

	Establishing a centre for excellence in Combustion Research comprising of	
1	Facilities for Combustion and Instruments for: Velocity Measurement, Spray Diagnostics, (Droplet size and velocity), Temperature measurement, Time resolved temperature Fuel-Air Mixing, Reacting Zone Imaging, Major Species Measurement, Soot Measurements, Particulate Measurement, Engine Pressure and Emissions Measurement Systems, Flow and other auxiliary measurement devices, Engine dynamometer, Data Acquisition System, Image and Data Processing Software	
.2	Computational Facilities including CFD Codes	
	Total	**100 Crores**

8. SENSORS & INTEGRATED SYSTEMS

	R&D on High sensitivity Sensors and Systems	
1	Physical Sensors (SQUID, CMR, Piezo, MEMS..)	
2	Chemical Sensors	
3	Terrahertz Technology	
4	Miniaturistion, Packaging, instrumentation and validation	
5	National facility for VLSI Testing and Failure Analysis	
6	Thin Film Transistor Technologies	
	Total	**250 Crores**

9. DISTRIBUTED SENSORS & NETWORKS

1	Electronic Design Automation Tools	
2	Custom built Production of Chips at Fabs in India and Outside	
3	Packaging	
4	Integration with front end Electronics	
	Total	**200 Crores**

10. SECURITY TECHNOLOGIES

1	Basic Technologies for Surveillance systems, Distributed and Mobile systems security, Network and information security which includes cryptology and crypto analysis and fast searching of massive remote distributed data bases.	
	Total	**200 Crores**

11. ADVANCED FUNCTIONAL MATERIALS

1	Centre for synthesis of advanced functional materials in a variety of forms that includes single crystals, thin films etc. Superconducting and magnetic oxides, Multi ferroics, organic semiconductors, Membranes and Bio polymers, Elastomers, Complex fluids, Nanomaterials	
2	Processing of materials: Laser processing, plasma processing, ion beams etc.	
3	Materials integration for devices, Micromachining etc.	
4	Computer simulation and design of materials	
	Total	**200 Crores**

ANNEXURE -2

The above report is based on the inputs received from several leading scientists, engineers and doctors, both from Academia and R&D institutions. While some of these inputs were on specific topics that need to be pursued, other write-ups provided us with general framework of the topics that need to be covered under the umbrella of cross-disciplinary technologies. All the inputs were deliberated at the two Working group meetings held at IIT-Madras on 17-6-06 and 24-7-06. We thank all of those who spared their precious time to provide us with valuable inputs and participate in the deliberations. A consolidated list of all the inputs received by us is enumerated below.

1	RECOMMENDATIONS FOR DESALINATION & WATER PURIFICATION TECHNOLOGIES Dr. P.K. Tewari, BARC	Incorporated in the consolidated write-up by Dr. P.K. Tewari
2	SOLAR ENERGY FOR OFFSHORE DESALINATION Dr. A.E. Muthunayagam, Kerala State Council for Science Technology & Environment	
3	INTEGRATED APPROACH & MULTI DISCIPLINARY PARTNERSHIPS FOR NUTRITION & HEALTH Dr. V. Prakash, CFTRI	Incorporated
4	HEALTH CARE TECHNOLOGIES: BIOMATERIALS AND MEDICAL DEVICES Dr. G.S. Bhubaneswar, Sree Chitra Tirunal Institute, Thiiruvanthapuram	
5	HEALTH CARE Prof. M.S. Valiathan, National Research Professor, Manipal Academy of Higher Education	
6	VACCINE TECHNOLOGY Prof. G. Padmanaban, IISc, Bangalore	Incorporated in the Consolidated report by Dr. Bhubaneswar
7	11TH PLAN: HEALTH SECTOR Dr. Mrs. Indira Nath, Director, Blue Peter Research Centre, LEPRA Society, Hyderbad	
8	HEALTH CARE Medical–Bioscience park for R&D on Medical Devices and Imaging, Tissue Engineering, Leadless-pacemakers, Biodegradable–stents.... Dr. K.M. Cherian, Dr. Soma Guhathakurta Dr. K. Jai Shankar, Frontier Lifeline, Chennai	
9	NATIONWIDE CYBER-INFRASTRUCTURE INITIATIVE FOR SCIENCE & TECHNOLOGY Dr. P.S. Dhekne, BARC	Incorporated in the write up on Advanced Computing
10	CROSS DISCIPLINARY TECHNOLOGY AREAS Prof. N. Balakrishnan, IISc	

11	INTER DISCIPLINARY TECHNOLOGY AREAS Prof. R.K. Shyamsundar, TIFR	
12	ADVANCED MANUFACTURING CAPABILITIES ENHANCEMENT INITIATIVE (AMCEI) Dr. Baldev Raj, Prof. M.S. Ananth, Dr. K. Bhanu Sankara Rao, and Prof. B.S. Murthy	Incorporated in the write up on Advanced manufacturing
13	PROPOSAL TO SET-UP A "CENTRE OF EXCELLENCE IN MAGNESIUM" UNDER ADVANCED MANUFACTURING Dr. Anil K. Gupta, NPL, New Delhi	
14	ADVANCED MANUFACTURING & ROBOTICS Dr. Gopal Sinha, Central Mechanical Research nstitute, Durgapur	
15	RESEARCH & DEVELOPMENT IN MACHINE TOOL SECTOR, MINUTES OF THE MEETING AT VIT, VELLORE, Dr. S.K. Sikka, Secretary, Office of PSA, GOI.	
16	ROBOTICS AND AUTOMATION Dr. Kasiviswanathan, IGCAR	Incorporated in the section on Robotics and Automation
17	ROBOTICS Dr. Manjit Singh & Dr. Prabir K Pal, BARC	
18	ULTRASENSITIVE CHEMICAL SENSORS Dr. P.R. Vasudeva Rao, Dr. T. Gnanasekharan, IGCAR, Kalpakkam	
19	NATIONAL INITITIVE FOR TERRAHERTZ MATERIALS & DEVICES TECHNOLOGIES Prof. S.B. Krupanidhi, IISc	Incorporated in the section on Sensors and Integrated Systems
20	DEVELOPMENT OF A NATIONAL FACILITY FOR VLSI TESTING AND FAILURE ANALYSIS Prof. A. Patra, IIT-Kharagpur, Prof. Enakshi Bhattacahrya, IIT-M	
21	THIN FILM TRANSISTOR TECHNOLOGIES Prof. Y.N. Mohapatra, Prof. Satyendra Kumar, IIT-Kanpur & Dr. K.R. Kumar SAMTEL	
22	CURRENT AREAS OF CROSS DISCIPLINARY RESEARCH Transportation- Wireless Technologies, Biomedical Technologies, Healthcare information Suite and Nano- Biomedical Technologies Prof. P. Venkatarangan, VC, Amrita Vishwa Vidyapeetham Deemed University	Included in the respective sections on Wireless Technologies and Health care
23	CONSORTIUM FOR MATERIALS RESEARCH Dr. Baldev Raj and C.S. Sundar	Incorporated in the section on Advanced Materials

24	ADVANCED FUNCTIONAL MATERIALS including nano materials and nanofluids for thermal engineering, sensors, coatings and device applications P. Shankar, IGCAR Prof. B.S. Murthy, IIT-M	
25	CROSS DISCIPLINARY TECHNOLOGIES Dr. K.V.S.S. Prasada Rao, OSD, National Security Council Secretariat, New Delhi	Incorporated in the Executive summary
26	CROSS DISCIPLINARY TECHNOLOGIES TO BE PURSUED Prof. M.M. Sharma, Emeritus Professor, IICT, Mumbai.	All his major points have been incorporated in relevant sections, except " Underground coal gasification at depths more than I km"
27	AREAS TO BE CONSIDRED UNDER CROSS-DISCIPLINARY TECHNOLOGIES AND MECHANISMS FOR EXECUTION Dr. P.S. Goel Secretary, Department of Ocean Development, N. Delhi	Incorporated in the Executive summary
28	SCIENCE & TECHNOLOGY FOR RURAL INDIA Ashok Jhunjhunwala and Kiran Karnik, IIT-M	Forwarded to the Working Group on Rural Technology

Working Group members

- Dr. Baldev Raj, Director, Indira Gandhi Centre for Atomic Research
- Prof. M.S. Ananth, Director, Indian Institute of Technology, Chennai- 600 036.
- Dr. (Mrs) Indira Nath, Director, Blue Peter Research Centre, LEPRA Society, Hyderbad
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- Dr. C.S. Sundar, Head, Materials Science Division, IGCAR, Kalpakkam 603 102

- Desalination and water purification technologies
- Nutrition
- Health care (Medical diagnostics, Medical devices, Vaccines)
- Advanced Computing
- Advanced Manufacturing
- Robotics and Automation
- Combustion Research
- Sensors & Integrated Systems
- Distributed Sensors and Networks
- Security Technologies
- Advanced Functional Materials