सत्यमेव जयते
Ministry of Human Resource Development
Government of India

For further details please visit our website:
www.imprint-india.org

For queries please email us at:
imprint@iitk.ac.in

National Launch of IMPRINT

IMPACTING RESEARCH INNOVATION AND TECHNOLOGY

सत्यमेव जयते
Ministry of Human Resource Development
Government of India

IMPACTING RESEARCH INNOVATION AND TECHNOLOGY
IMPRINT
INDIA

An MHRD Initiative

Rashtrapati Bhavan, New Delhi
5th November 2015

IMPACTING RESEARCH INNOVATION AND TECHNOLOGY

IMPRINT

INDIA

The logo for IMPRINT depicted by a stylised visual of peacock, the National Bird of India, a symbol of the very essence of Indian philosophy and ethos. Peacock symbolises multiple notions in India - grace, beauty, prosperity and plurality of our culture and tradition.

Five wings on each side indicate the ten domains of research with different shades of colours signifying the myriads of subjects that IMPRINT is concerned with. Wings further implies aspiration and dynamism essential for any change. The symmetry and balance in the spread of wings is commensurate with the complementary relationship among research, innovation and technology. The logo truly depicts the spirit of IMPRINT - its objectives, mission and vision.

CONTENTS

IMPRINT - INDIA

FOREWORD

Smt. Smriti Zubin Irani
Minister of Human Resource Development
Government of India

Increasingly, the economic and social development of a Nation is being dictated by the innovations in technology and science. Innovation presupposes strong foundations of scientific research. Whereas research has been the basis on which the knowledge base of IITs has been built over time, there is an imperative need to make the research focused on the needs of society.

With these objectives in view, we have launched several new schemes like *Unnat Bharat Abhiyan, Rashtriya Avishkar Abhiyan, Uchchatar Avishkar Yojna, Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching, Swayam, Global Initiative for Academic Network*, and many more. One that stands head and shoulders above all these is the IMPRINT. **IMPacting Research INnovation and Technology (IMPRINT)** provides that overarching vision that guides research into areas that are predominantly socially relevant.

IMPRINT is scheduled to be launched by the Honourable President and Prime Minister of India on November 5, 2015 at the Rashtrapati Bhavan during the Visitor's Conference in presence of Directors and Chairpersons from all major science and technological educational institutions of the country (IITs, IISc, IISER, NITs, IIEST, etc) funded by Ministry of HRD.

IMPRINT is a first of its kind MHRD funded Pan-IIT and IISc joint initiative aimed at giving a *Research Roadmap* to address major engineering and technology challenges in ten selected domains relevant to our country's needs. These domains encapsulate the drive for *inclusive growth and self-reliance*. The first phase of IMPRINT is dedicated to creating a policy document defining the scope, strategy and mandate for pursuing engineering challenges in the country. The real engineering pursuit will ensue in the second phase.

The IMPRINT has been evolved through several stages and intense deliberation at various forums. The idea originated in the RETREAT with the Directors and Chairpersons of the Indian Institutes of Technology (IITs) in Goa on June 28-29, 2014. If science searches for the fundamental truth, engineering must apply the scientific principles to provide viable solutions to all the problems and challenges faced by the society. And who better than the most celebrated engineering institutions in the country can do this? Subsequently, His Excellency Shri Pranab Mukherjee, the Honourable President of India, in his capacity as the Visitor to IITs, convened a Visitor's Conference at the Rashtrapati Bhavan on August 22, 2014 with all the Directors and Chairpersons of the IITs in which the *'Ten Technology Domains and Goals'* have been outlined.

Engineering education and innovation must address problems and aspirations of the society and hence must bear a nation-specific character. Hence, the MHRD requested the top engineering institutions of the country to create a special initiative and address the engineering challenges faced by the fellow Indians. IIT Kanpur was designated as the national coordinator to lead the team *IMPRINT-India* comprising all IITs and IISc.

Besides defining the ten technology domains as engineering challenges or goalposts, deliberations in the last few months have helped to identify the coordinating and participating institutes with the concerned coordinators and team members to develop specific programmes for each domain.

Recently, a joint symposium on *'Engineering Education in the 21st Century'* held in New Delhi on 16-17 October, 2015 along with Indian National Academy of Engineering (New Delhi) and National Academy of Engineering (USA). While the domains under IMPRINT bear large overlap with the fourteen *Grand Challenges* defined by the NAE-USA, the scope and mandate of IMPRINT is much wider, much inclusive and more tuned to our country for obvious reasons. Each technology domain of IMPRINT along with the underlying themes, targets and topics embedded in them represent the immediate goals before the nation for engineering innovation and intervention.

Gurudev Rabindranath Tagore commented *'The highest education is that which does not merely give us information but makes our life in HARMONY with all EXISTENCE'*. IMPRINT is an opportunity before the engineering fraternity of the country to integrate with the society by creating conducive environment for spreading innovative thinking in the educational institutions and providing viable engineering solutions, and thereby establishing the harmony that Gurudev once dreamed and prophesied.

Jai hind!

IMPACTING RESEARCH INNOVATION AND TECHNOLOGY

IMPRINT - INDIA

A Flagship Initiative of MHRD

AN OVERVIEW

The Philosophy

Since time immemorial, necessity and aspiration has always driven mankind to discover, invent or innovate through individual or collective effort. The history of human civilization is replete with examples of how mankind has derived inspiration and learned from nature to overcome various challenges and meet the basic necessities of food-shelter-survival during the stone-age to begin with, and gradually progressed by leaps and bounds to reach the modern age of security and amenities over many centuries and millennia. Undoubtedly this phenomenal development has materialized through firm determination and urge to unravel and seek the truth, learn the art and implement them in practice. Realization of translation of knowledge to useful practices has always been a slow process through decades and centuries, occasionally aided by disruptive paradigm changes brought through unexpected discovery or laboured invention, but eventually integrating them all with humanity, converging for societal benefits. Myopic views would brand these pursuits as isolated scientific, engineering or technological interventions, but needless to mention that every such endeavour, individual or collective, emerge seamlessly from certain justified motivation and eventually amalgamate into a greater cause – the needs of the humanity. In the modern era, innovative technological developments that originate from societal demands and make far reaching impact to humanity warrant far more sound foundation in scientific principles and ethical values than before, and hence, pose a much bigger challenge to formulate a strategy and roadmap to attain the desired goal.

The Science-Engineering - Technology Nexus

If science is all about 'know-why' (fundamental knowledge), then engineering provides the principles ('know-how') to convert scientific knowledge into practicable solutions and overcome challenges while technology (know-what sells) makes such development commercially viable and sustainable.

Thus, science discovers and unravels the nature through curiosity driven act or necessity inspired effort, engineering invents and replicates by applying the fundamental laws and principles. Technology ultimately innovates new practices to translate a selected few of such discoveries and inventions into useful products and processes because the society needs, demands and consumes. While scientific knowledge is universal, engineering and technology often originate from local needs and aspiration. Thus science-engineering-technology-society nexus is a continuous and complementary cycle and the backbone of the eco-system through which humanity thrives and progresses.

The Motivation

In the years to come, engineering and technology will pivotally be called upon to address and resolve issues of sustainability and growth ranging concerning energy, habitat, resources, environment and transportation. Our country is large and diverse. Although saints of ancient India like Kanad (600 BC) or Aryabhatta (550 AD) gave the clues on anu/paramanu (molecule/atom) and decimal system (concept of zero) to the world, India has yielded that vantage position of scientific leadership.

We may demographically be a young nation, but at the same time an old civilisation with a heritage, and a legacy of innovative thought and action, of leadership in diverse fields. To usher in a technologically self reliant India a pragmatic and structured approach is needed, in particular to provide the quality engineering education and infrastructure necessary to pursue world class research and innovation for sustainable and inclusive growth.

While learning is a continuous process spanning over the entire lifetime, cumulative knowledge grows by stages from the elementary data, information or practices to the ultimate wisdom through a painstaking process supported by dedication, patience, discipline and persistence. The Ministry of Human Resource Development (MHRD) is now committed to create and implement an education policy, presently being inclusively and participatively evolved to transform the nation, and cater to the needs and aspirations of our citizens and country.

The Initiative

Adopting engineering and technology as the vehicle to addressing the societal needs and achieving national prosperity, MHRD has drafted a new and catalytic scheme called **IMPacting Research INnovation and Technology** or **IMPRINT**. IMPRINT is a first-of-its-kind Pan-IIT and IISc joint initiative to develop a *(a) New Education Policy, and (b) Roadmap for Research* to solve major engineering and technology challenges in selected domains needed by the country.

The ten domains represent the most important areas relevant to our country in order to enable, empower and embolden the nation for *inclusive growth and self-reliance*. The first phase of IMPRINT is dedicated to creating a policy document defining the scope, strategy and mandate for pursuing engineering challenges in the country and not developing a specific technological product or process. The real engineering pursuit will ensue in the second phase.

The Mandate

Each technology domain of IMPRINT along with the underlying themes, targets and topics embedded in them represent the immediate goals before the nation for engineering innovation and intervention. However, the principal motto remains the same for each domain: (a) to create an education policy for inculcating scientific temperament and innovation skill, and (b) to develop the research roadmap for technology preparedness. Competent manpower and robust strategy is a sure recipe to success.

Since IMPRINT is a national programme, initially steered by the IITs and IISc, ultimately the entire engineering fraternity of the nation including IITs, NITs, national academies, governmental ministries and departments, research organizations, strategic sectors, policy agencies and industry must join hands and own the collective responsibility. Given the proper commitment, no task can prove impossible.

The Domains and Coordinators of IMPRINT, steered by IIT Kanpur (as the national coordinator), are:

(I) Healthcare: IIT Kharagpur

(ii) Information and Communication Technology: IIT Kharagpur

(iii) Energy: IIT Bombay

(iv) Sustainable Habitat: IIT Roorkee

(v) Nano-technology Hardware: IIT Bombay

(vi) Water Resources and River systems: IIT Kanpur

(vii) Advanced Materials: IIT Kanpur

(viii) Manufacturing: IIT Madras

(ix) Security and Defence: IIT Madras

(x) Environmental Science and Climate Change: IISc, Bangalore

Each domain in IMPRINT is divided into themes, sub-themes, target and topics for educational orientation, research and innovation. In order to create and sustain an inclusive eco-system in science-engineering-technology-society, academia must pursue new knowledge, research organization should innovate and industry ought to absorb both knowledge and innovation to develop new technology to produce goods and services that would be both competitive and add value to ultimately serve the society and the nation. Before embarking on actual technology development, IMPRINT is designed first to map the strength and weakness in our system, define the goals, identify logical course and create a roadmap to champion the engineering targets.

The Genesis

The Honourable Prime Minister of India has always held the view that research shall be socially relevant. The higher educational institutions shall not remain islands of knowledge, untouched by the society around. Based on this idea, an initial brain storming deliberation was held in the RETREAT between the Human Resource Minister and leadership (Directors and Chairpersons) of the Indian Institutes of Technology (IITs) in Goa on June 28-29, 2014. Intense discussion led to the resolution that India today should aspire to be a *knowledge and innovation driven economy for employment generation and prosperity, and IITs and industries should join hands to solve the national challenges.* Innovative research and new technology development through industry-academia partnership may pursue the following course of action:

- Identify and select themes of national importance and challenge for technology development through MEGA research project which can provide complete system engineering solution and generate large scale employment
- Key to approach such objective is to forge formidable and effective partnership between industry and academia with mutual trust and dependence
- Identify domains and themes, hold wide discussion, define the scope/objective, select the partners to make a team, and pronounce the deliverables with clear roadmap and timeframe
- IITs must continue to pursue high-risk fundamental research of academic interest, but allow to create an eco-system that will enable the industry depend on academia for technology solutions, and even seek advice / guidance for future
- Closer interaction between IITs and Industry will promote entrepreneurship

As a way forward, it was decided to:

- Hold thematic workshop in a relevant industry with selected invitees from IITs to define the scope, objectives, roadmap, timeframe and deliverables
- Develop a joint project proposal for funding from industry and government
- Develop a team drawn both from industry and IITs with specific work elements / targets to be handled by a specific team (of students / faculty / engineers)
- Create an independent monitoring team and mechanism for periodic assessment of progress as per milestones and approve next phase of work
- The process ahead must be simple and urgent so that industry does not lose its patience and interest

The Visitor's Conference 2014

His Excellency Shri Pranab Mukherjee, the Honourable President of India, in his capacity as the Visitor to the IITs convened a Conference at the Rashtrapati Bhavan on August 22, 2014 with the Chairpersons and Directors of all the IITs. Both the Honourable President and Prime Minister addressed and urged the leaders to pursue excellence. While the Honourable President desired that IITs must rank among the top institutions in the world, the Honourable Prime Minister stressed upon greater need for optimum utilization of resources including young students and scholars for pursuing the engineering challenges relevant to India. Following presentations from each IIT, the afternoon was devoted to deliberations on specific themes. One of the themes presented and very intensely discussed in this conference was *'Ten Technology Domains and Goals'* that outlined the major engineering challenges faced by the country. It unanimously emerged that engineering practices should provide solutions to the problems and challenges faced by the society and hence must carry both a global as well as local (nation-specific) charter.

Interaction with NAE-USA

In December 2014, a delegation from Indian National Academy of Engineering (INAE) visited Washington DC to interact with the National Academy of Engineering (NAE), USA to deliberate on the theme *'Engineering Education in the 21st Century'*. The focus was on the 14 Grand Challenges defined and championed by NAE. The important outcome of this two-day event was: (a) Technology challenges are interdisciplinary, need based and seamless in nature, (b) Pursuing engineering/technology challenges can create healthy interest and motivate engineering students in India to make useful contributions, and (c) Efforts must percolate or begin from the grass root or school level by way of visit to the schools and colleges and mentoring students through projects and summer internships.

Subsequent discussion within the IIT community suggested that the engineering challenges in India must address issues like security (homeland/cyber), healthcare (rural, urban, diagnostics, water, sanitation), agriculture (productivity, storage, sensors), pedagogy (self/mass education), and energy (conventional, renewable including environment protection). India should aim to produce 10000 PhDs in these engineering domains in next 10 years. NAE-INAE collaboration may promote such initiative. Such a national program for five year with a national coordinator should be supported by DST.

As a reciprocal exercise, a joint symposium on *'Engineering Education in the 21st Century'* was held in New Delhi on 16-17 October, 2015 under the aegis of the MHRD, Indian National Academy of Engineering (New Delhi) and National Academy of Engineering (USA). While the domains under IMPRINT bear large overlap with the fourteen Grand Challenges defined by the NAE-USA, the scope and mandate of IMPRINT is much wider and more tuned to this country for obvious reasons. Each technology domain of IMPRINT along with the underlying themes, targets and topics embedded in them represent the immediate goals before the nation for engineering innovation and intervention.

The IMPRINT Activities

MHRD issued a memo in April 2015 asking the top engineering institutions of the country to create a special initiative and address the engineering challenges focused on India. IIT Kanpur was designated as the national coordinator to lead the team *IMPRINT-India* comprising all IITs and IISc. As the main coordinator, IIT Kanpur organized the kick off workshop to apprise the community and launch this initiative on May 11, 2015 (*Engineers' Day*). In order to pursue the twin mandates of IMPRINT (education policy and research roadmap), ten technology domains as engineering challenges or goalposts have been defined, coordinating and participating institutes with coordinators and participating scientists have been identified, and specific programmes are being developed. The second meeting of the theme/domain leaders was held through video conference on 15th July 2015 to provide suitable direction and instructions. The next workshop held at IIT Delhi on Aug 16, 2015 resolved that the first phase of IMPRINT should define the 'gap' between the available and desired level of manpower, technology and infrastructure in the selected domains so that the strategy, timeframe, roadmap and budget to pursue technological self reliance and leadership can be formulated in due course. Several rounds of follow up meetings over video or by actual gathering (on 15 Jul, 2 Aug, 1 Oct, 2015) allowed further deliberation and identification of Domain Coordinators and Members, selection of Institute Representatives, defining the scope, format and contents for the website, information booklet, launching of a national essay and logo contest, etc. Several domains organized their internal workshops with their own domain members to identify the themes, sub-themes, targets and topics.

The INAE-MHRD-NAE Symposium

On Oct 16-17, 2015, a joint INAE-MHRD-NAE symposium on *'Engineering Education in the 21st Century'* was held in the India International Centre, New Delhi. Smt. Smriti Zubin Irani, the honourable Human Resource Minister inaugurated and addressed the gathering as the Chief Guest. The symposium was attended by all the domain coordinators and some team members of IMPRINT along with a delegation from NAE-USA led by Professor CD Mote Jr, former President, University of Berkley and President, NAE-USA. The symposium was also addressed by the Secretary DST and Additional Secretary (HE), MHRD. The deliberations from the NAE centred on *Grand Challenges*, while each Coordinator of IMPRINT presented the scope, objective and mandate of IMPRINT, particularly the interventions desired with regard to engineering education and infrastructure readiness in their respective domains.

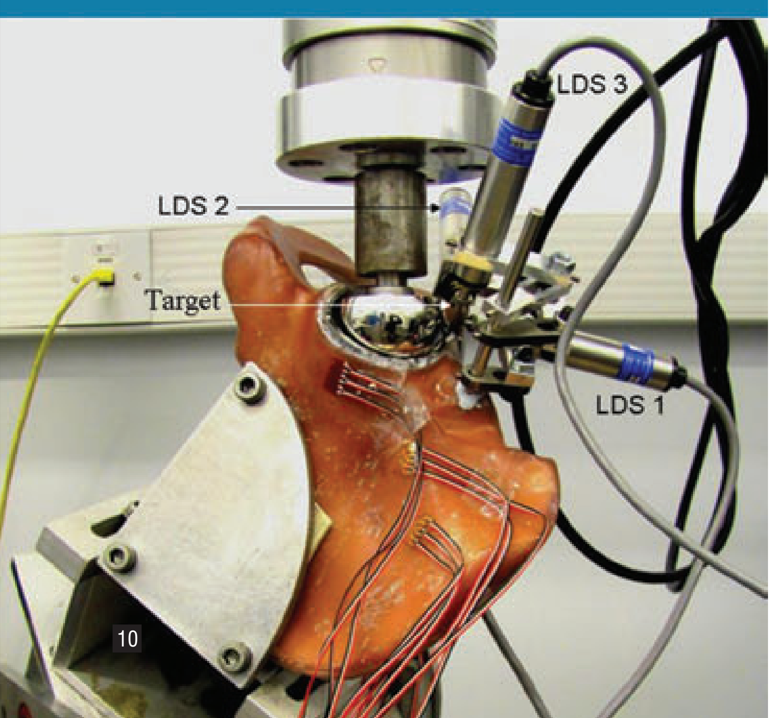
It may be noted that the domains under IMPRINT bear large overlap with the fourteen *Grand Challenges* defined by the NAE-USA. However, the scope and mandate of IMPRINT is much wider and more tuned to this country for obvious reasons.

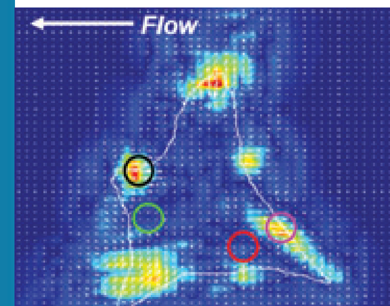
The Epilogue

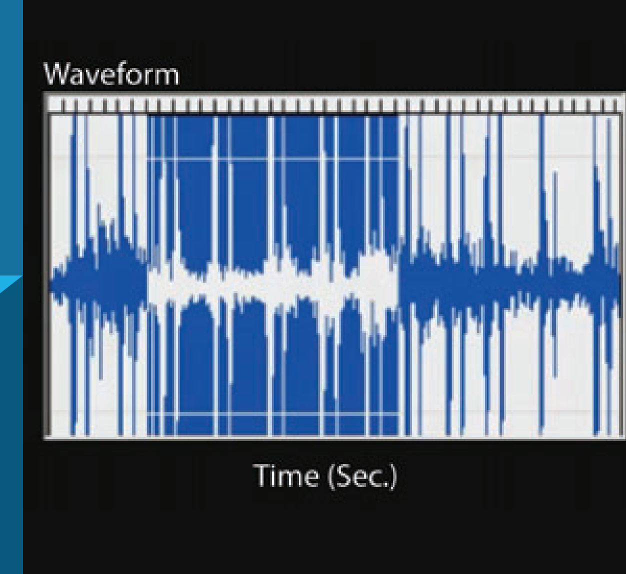
IMPRINT in its first phase is a policy developing initiative covering pedagogy, teaching, curriculum, technology-benchmarking and infrastructure readiness. IMPRINT is not meant only for IITs and IISc; it is a national movement providing an opportunity for the higher echelon institutes in India to integrate with all grass root level institutes, industry and organizations, mutually complement and deliver what the country demands and aspires. Policy is our immediate mandate; technology (products and processes) development and delivery will eventually follow.

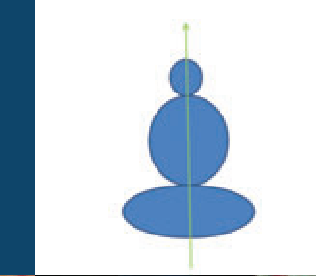
HEALTHCARE

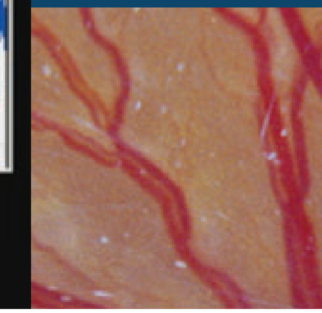
World Health Organization (WHO) statistics shows that India has made considerable progress over recent years in attaining Millennium Development Goals. However, its relative ranking among nations continues to remain poor. The challenges faced are many as well as complex, in ensuring healthcare is accessible, affordable and appropriate for all concerned. There is a need in developing technology based solutions, using traditional knowledge, and emphasizing on disease avoidance to reduce overall disease burden. The IMPRINT-India Healthcare road map building exercise, centers around educational and research perspectives on the concepts of healthy living, prevention, diagnosis, treatment, after-care, management, legal issues and innovation ecosystem.

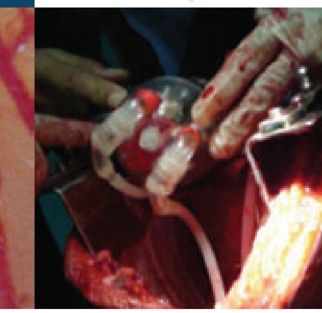


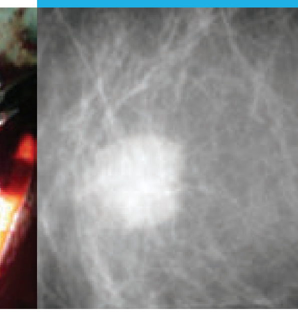












HEALTH LITERACY AND HEALTHY LIVING

Health literacy is required through school curricula for adoption of a healthy lifestyle from childhood that includes tackling substances that may be harmful, and giving stress on personal hygiene, sanitation, avoidance of road-injuries etc. Health literacy is directly related to health outcomes for both individuals and health systems, and has significant impact on healthcare costs. According to WHO, about 80% of cardiovascular disease and diabetes, and at least 40% of cancers are preventable by changing lifestyle. The focus of this theme is disease avoidance, rather than disease treatment.

PREVENTION AND PRIMARY, COMMUNITY HEALTHCARE

It involves an integrated team of primary healthcare professionals, social workers, nurses, pharmacists, dietitian, community based outreach workers like Anganwadi, ANM, ASHA, and community engagement specially, among vulnerable population like women, child and people from rural and underprivileged background. It requires measurement, monitoring and intervention that can be easily accessed by our population. This is to ensure that health problems, if any, are addressed early, before they become serious health issues.

DIAGNOSTIC IMAGING

Diagnostic imaging involves pathological and radiological image-guided medical decision making for disease diagnosis and prognosis. They include X-rays, CT scans, Nuclear medicine scans, MRI scans, Ultrasound, Microscopic imaging etc. These are among the most trusted aid to the physicians in today's healthcare. Majority of the diagnostic imaging procedures are expensive and mostly inaccessible in rural areas. The focus here is to provide innovative and cost-effective medical imaging technologies and medical software solutions.

WEARABLE DEVICES AND EMBEDDED SYSTEMS

Wearable healthcare devices are useful in monitoring pathophysiological parameters of an individual such as blood pressure, pulse rate, SpO_2, perfusion rate, activity profile. It consists of small physiological sensor, transmission modules and processing capabilities. Medical embedded system integrated with Computer-Aided Diagnosis (CAD) is useful in automated decision making, visualization and extraction of hidden complex features useful for disease screening and monitoring. This includes innovations around portable/ table-top devices for monitoring vital health parameters.

POINT-OF-CARE DIAGNOSIS

Conventional diagnostic practices are time consuming, labor-intensive; require elaborate infrastructures and on-field pathologists. The development of portable, inexpensive point-of-care (POC) diagnostic devices has the potential to be a useful platform for easy and spot diagnostics, without necessitating expensive infrastructures, expert personnel. POC devices also offer rapid and affordable diagnostics for mass population, at their convenience. It includes rapid test of blood, urine, electrocardiogram, heart rate, oxygen saturation etc.

HEALTHCARE ICT

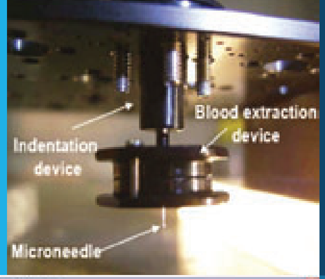
The advancement in Information and Communication Technology (ICT) in today's world not only connects, educates and empowers people but also ushers in services like e-Health, m-Health, e-ICU, Telemedicine, Virtual learning platform, Simulator Design, Health Grid, Health Data Exchange, Healthcare Data Analytics etc. ICT has an impact on many aspects of health care services in developed and developing countries. The most important are accessibility to healthcare services by citizens, economical aspect and, quality of care aspect, anywhere anytime.

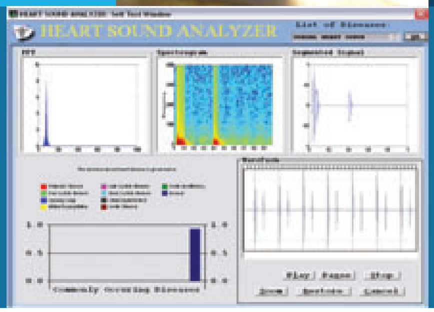
DRUG DISCOVERY, DESIGN AND DELIVERY

The focus of this theme is on the discovery, design and delivery of novel therapeutics as remedial agents. This will encompass recent techniques of drug design and delivery strategies that will be strengthened by novel methods and materials and, consider interfaces between nanotechnology and life processes. The other aim here is on targeted delivery to improve efficiency of treatment and reduce side effects. The long term goal is to find newer targets and molecules to provide novel effective drugs based on specific biological targets.

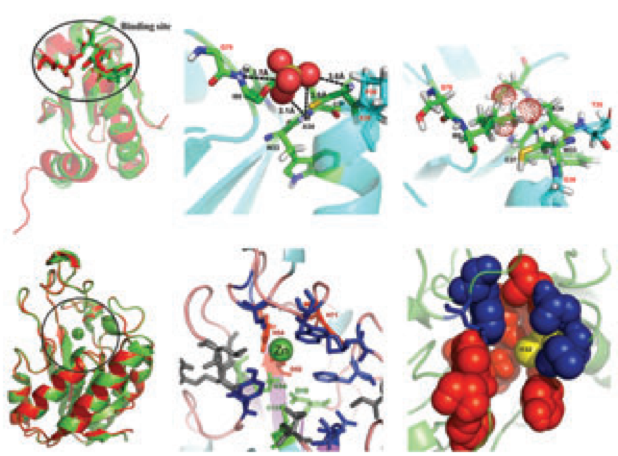
REGENERATIVE MEDICINE

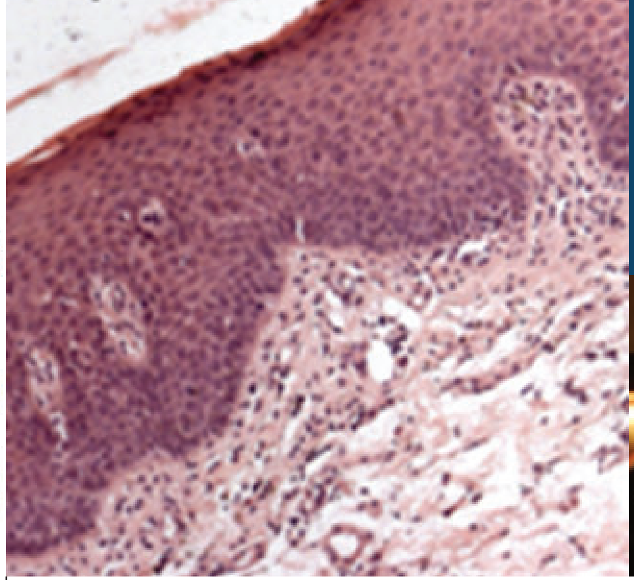
Regenerative Medicine has major emphasis on rehabilitation of mankind suffering from various life threatening diseases, trauma and degenerative diseases. Besides early diagnosis of lost tissue function, development of transient bioactive scaffold/ template,

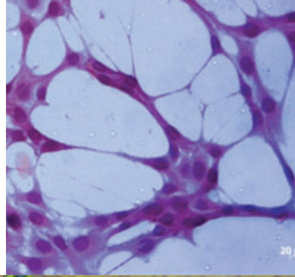


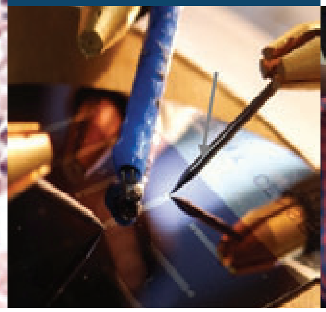


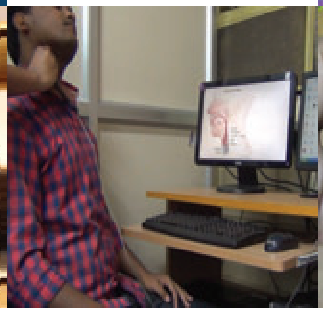
HEALTHCARE











disease specific novel therapeutic agents and delivery vehicles, synthetic tissue construct, xenogenic /allogenic decellularized or cellularized organ transplantation, stem cells therapy are the cutting edge therapeutic approaches. This is seen as an important area of interdisciplinary research in modern healthcare.

SURGICAL AND OPERATIVE SOLUTIONS

The hospital system is at the center of the tertiary, secondary and specialized healthcare system that includes emergency, intensive care, trauma, surgery, pre and post-operative care and allied diagnostics. The operating costs are dominated by manpower, consumables and overheads that include cost of equipments. The strategy to reduce operating cost includes minimally invasive procedures and research activities in this field include robotics, navigation systems, simulators, maps, smart materials, biomechanics, implants, prosthesis as well as analytics and effective consulting.

TRADITIONAL HEALTHCARE

An ancient country like India has its own traditional knowledge in Healthcare, and harnesses knowledge from other places like Ayurveda, Yoga, Naturopathy, Unani, Siddha and Homeopathy. The best of traditional and modern healthcare practices together can deliver a balanced Healthcare ecosystem. The benefit of traditional medicine in healthcare had the longest testing time since Athrbaveda. Their usefulness has and natural availability has made these medicines reachable to mass. The focus here will be on validation and formulation as required in the investigation of current era.

REDUCING COMMUNICABLE DISEASE BURDEN

Reducing infectious diseases like HIV, AIDS, Dengue Malaria, Typhoid, Hepatitis, Jaundice, Leptospirosis, Diarrhoeal Diseases, Amoebiasis, Cholera, Brucellosis, Hookworm Infection, Leishmaniasis, Influenza, Filariasis, Tuberculosis, nosocomial infections etc. need focused attention to develop advanced techniques in their early detection, treatment, containment. In population with low and middle income and in a country like India, communicable diseases are very dominant and are one of the major causes of mortality and morbidity.

REDUCING NON-COMMUNICABLE DISEASE BURDEN

Non-communicable diseases are the leading cause of death in the world and also accounts for majority of deaths in India. Treatment cost is almost double for these long duration diseases as compared to other conditions and illnesses. The increase in non-communicable disease burden in India, such as cardiovascular diseases, respiratory diseases, cancer, diabetes, renal failures, neurological disorders etc. need pooling of target-oriented solutions from different heads to prevent and control these diseases and their risk factors.

ASSISTIVE TECHNOLOGY AND SELF-MANAGEMENT

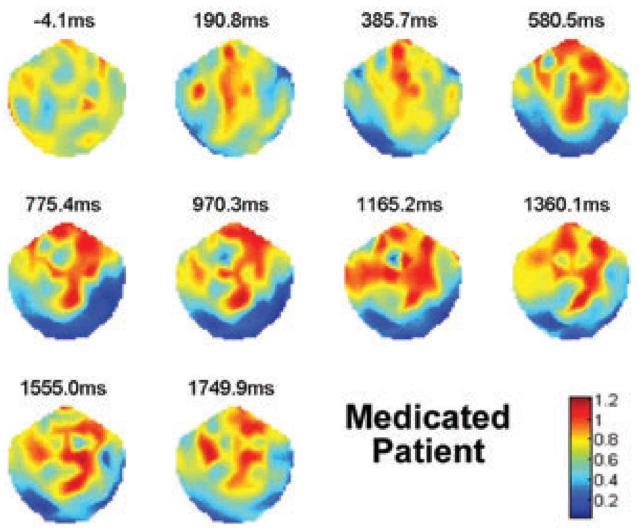
A significant section of our community have disabilities due to diseases, congenital, age or other factors, and require special healthcare assistances. They and people suffering in chronic diseases for years, are required to manage their healthcare at home or within their community. Targeted solution development is required in this area to make them as much independent as possible, without the need of visiting health centres on a regular basis which could be inconvenient and costly. Such patient-centric care can be found useful by other kind of population too.

HEALTHCARE MANAGEMENT AND LEGAL ISSUES

Though individuals are more of custodians and concerned of their own health and less of a consumer or a litigant, ethical and legal issues related to healthcare services are on the rise. This is more in a managed care scenario where insurance products and for-profit healthcare services are present. In addition, electronic health record, interoperability, data privacy have their own concerns. Management aspects in healthcare e.g. referral process from primary healthcare centres to tertiary healthcare centres are seen as important issues in ensuring timely and appropriate services.

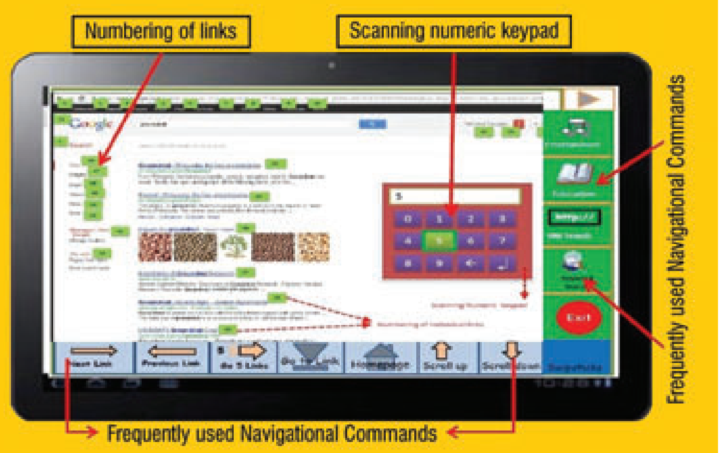
ACCELERATING HEALTHCARE INNOVATION

India today imports most of its medical devices which often is not affordable for majority of our population. In addition, there are many unique problems specific to the country and end-user requirements which are often not a priority of other nations wherefrom we import technology. There is a felt-need to accelerate the process by which inventions from Indian laboratories reach product stage and complete the innovation cycle. It needs developing proper interface for scientists, engineers, physicians and healthcare industry to come together and make 'Make-in-India' happen in Healthcare domain.

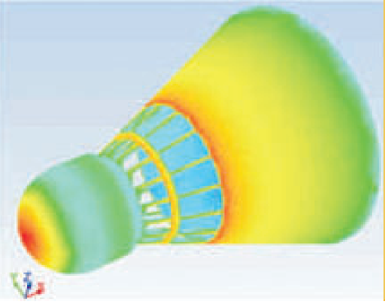


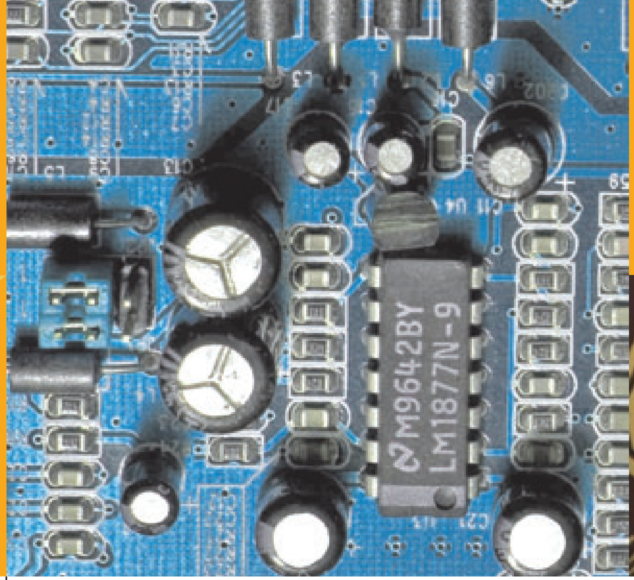
INFORMATION AND COMMUNICATION TECHNOLOGY

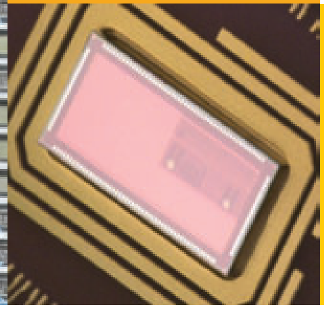
ICT & CS pervades almost all walks of life, including education, health-care, environment-management, water-resource management, to mention a few. The first task of information technology is to gather information omnipresent in different forms and languages, through sensing of data such as biological data, data pertaining to environment, education, heritage, land usage and cognitive information about users. Such information gathered from diverse field situations, has to be communicated to distant servers through secured, reliable and fast communication channels, followed by different types of processing and analytics. To carry out large scale and fast computations and in-place embedded-real-time computations, novel indigenous computational infrastructures are necessary. The IMPRINT program aims to identify the gaps and the "things to be done" in India to make India self reliant in these aspects.

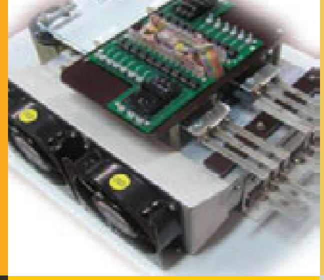


Special Web Browsing Interface for People with Neuro-Motor Disorder









DATA ACQUISITION AND PROCESSING

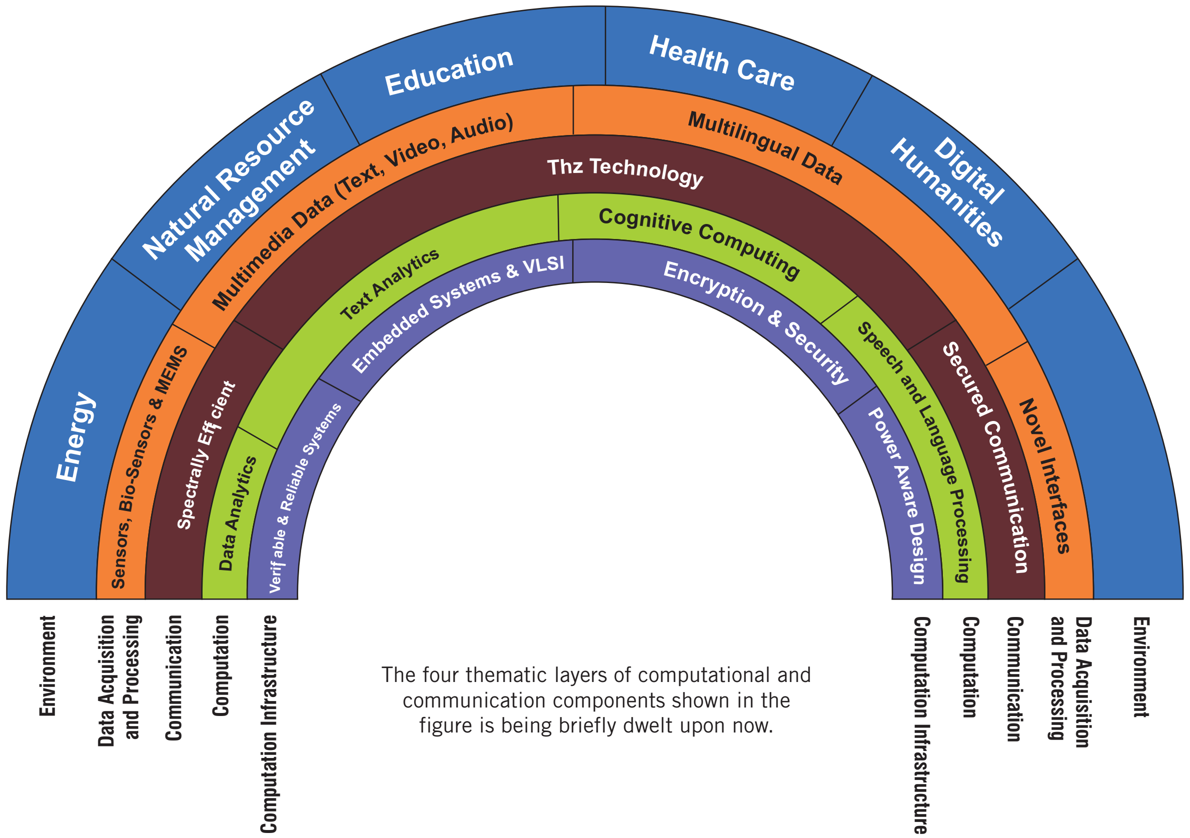
A major challenge to any information processing task is acquiring the information, which presents itself in different forms, including physical signals, biological signals, voice, text, image, video and even emotions. Accordingly different means of collecting and often inferring such data in the face of noisy and uncertain environment is required. Accordingly, the following sub-themes have been considered for Data Acquisition and Processing.

SENSORS, BIO-SENSORS & MEMS

Having access to indigenous sensors and actuators is of utmost importance to the process of data acquisition. Hence new ventures to develop different types of sensors and MEMS are called for. These include biomedical sensors for health care applications, chemical sensors for detection of hazardous contaminations, moisture sensor, image and video sensor etc. The sensors need to be rugged for use in extreme environment and of easy to use type.

MULTIMODAL AND MULTILINGUAL DATA: (TEXT, VIDEO, AUDIO)

Data and information is replete in the textual messages and social network exchanges, voice communication as well as video communication. In the Indian context, such information is also multilingual making it imperative to develop technology to properly acquire the information from such varied spectrum of data.



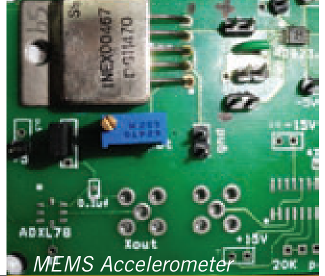
The four thematic layers of computational and communication components shown in the figure is being briefly dwelt upon now.

NOVEL INTERFACES

Keyboard, mouse and monitors being no longer the only means computer interaction, it is needed to natural interfaces for communication through touch, gestures, icons and signs. Interface design in these respects is of utmost importance, specially keeping in view the physically challenged users and the aged population.

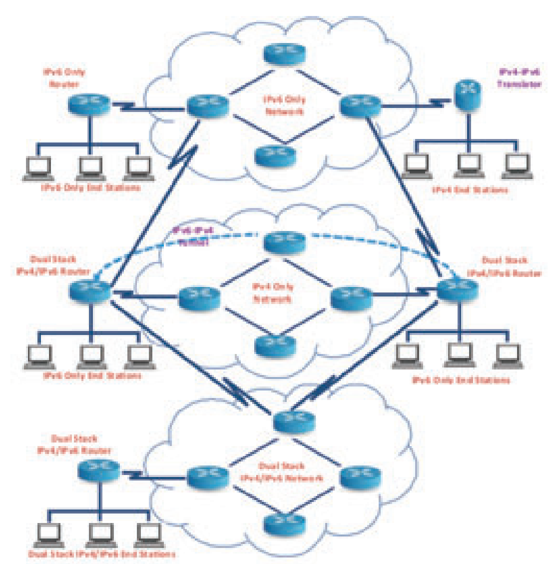
COMMUNICATION

The data and information acquired from distant, critical and difficult to access areas need to be transmitted to the computing sites in a reliable and secure manner. Bandwidth being at a premium, efficient use of bandwidth as well as speed of communication is of vital importance, in addition to reliability and security. Consequently, research thrust should be increased in:



MEMS Accelerometer

INFORMATION AND COMMUNICATION TECHNOLOGY



DATA COMMUNICATION AND NETWORKS

Over the years, data communication has gained a lot of importance due to its application in the areas of sensors and mobile nodes in addition to its usual role in computer-to-computer communication. Efficient communication between sensor to sensor and between mobile nodes is vital for energy and security related issues. Routing and aggregation of data also needs to be improved for optimal use of power, which in most cases is a non-renewable resource or is very difficult to replace.

SPECTRALLY EFFICIENT COMMUNICATION

Generation and transmission of huge data demands spectrally efficient communication techniques to deal with growing demand of bandwidth. As has been established through research by various leading groups, Optical Angular Momentum (OAM) beam is capable of providing huge bandwidth as it creates orthogonal channels for multiplexing of multiple beams.

SECURED COMMUNICATION

Security and reliability in data and information transmission is one of the key requirements. High security in data and information communication can be realized by infusion of principles of quantum mechanics and information theory.

THz TECHNOLOGY

Identification of hidden objects is a major challenge in homeland security applications. THz technology facilitates creation of high resolution images of hidden objects and detection of remote threats.

WIRELESS FRONTENDS

The whole domain of wireless technology works on the basis of smart as well as efficient frontends, antennas, and sensors. Several new challenges need to be addressed in view of making the devices more compact, more efficient, and compatible to wideband or ultrawideband systems, especially for secured/military applications.

ADVANCED EDUCATION

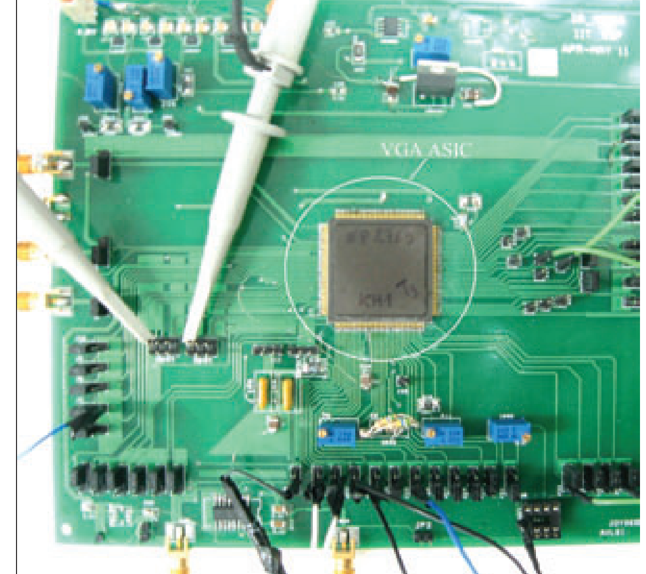
There are few specific areas in communication engineering which need high quality human resources in the country; but unfortunately, resource of knowledge is very very limited. Therefore, for the sake of alleviating such lacunae, a special effort is needed in the areas of 'Applied and Computational Electromagnetics" in the form of special training by international experts and thus by creating a knowledge bank.

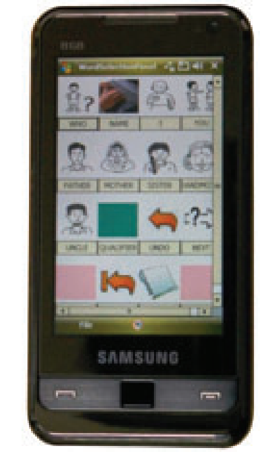
COMPUTATION

Data received at the computation end needs to be processed to crystal out the semantics of the data and calls for data and text analytics. Moreover, unlike the earlier days, the forthcoming systems will have to be user-centric and hence users have to be understood and their features and preferences should be integrated within the computation framework. Accordingly, the following sub-themes have been identified.

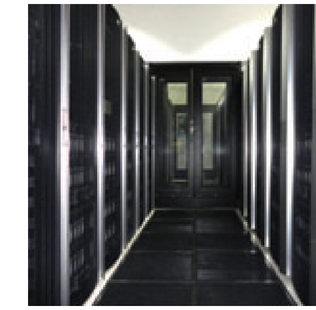
DATA AND TEXT ANALYTICS

This component is a vital component in extracting the real information, trends and hidden facts from the plethora of data and text available in different form and languages.





Phone based Communication Device



COGNITIVE COMPUTING

In order to provide effective education support or health advisories for example, it is necessary to *understand* the user, her personal preferences, cognitive abilities and emotional patterns among other things. The area of cognitive computing will employ intelligent and adaptive models of the user in an integration with the decision making process.

SPEECH AND LANGUAGE PROCESSING

Automatic speech recognition, text to speech synthesis, language translation, question-answering systems, answer evaluation systems etc. all depend heavily on speech and language technology research, and is critically called for in multilingual digital India.

IMAGE AND VIDEO PROCESSING

Vast information available in the form of images and videos are powerful resources that may be exploited through automated processing for knowledge creation, storage and dissemination. Advanced research in this area will enable digital preservation of historical monuments, creation of digital knowledge bank in the form of e-books (research on Optical Character Recognition will take a vital role), Homeland Security through research on video surveillance, biometric authentication, advanced image/video coding techniques for efficient use of limited resources and many others.

DIGITAL HUMANITIES

Preservation of the heritage in the country, its languages, dialects, art forms, architectural wonders, social and ethnic practices can be preserved and saved from the onslaught of 'modernization' through the intervention of ICT in the form of undertaking activities in the digital humanities area.

COMPUTATION INFRASTRUCTURE

The actual computation will be carried out on servers and systems enabled to carry out fast and distributed computation, done in real time, with reliability and predictability and the results should be available in a secured manner in the face of digital intrusions. To this end, research in the following sub components need to be further vamped up.

POWER AWARE DESIGN OF EMBEDDED SYSTEMS AND VLSI

To result in area effective, portable, low power consuming, omnipresent computing devices research in embedded systems and indigenous development of VLSI chips are necessary.

VERIFIABLE AND RELIABLE SYSTEMS

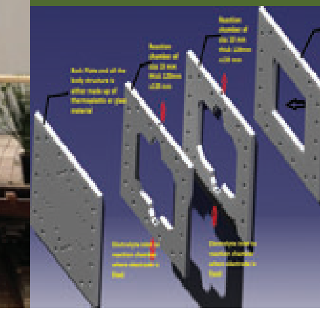
Since the systems will be omnipresent, it is necessary to ensure reliability and safety and consequently 'correct' and 'safe' systems should be designed, that should be verifiable at the design time.

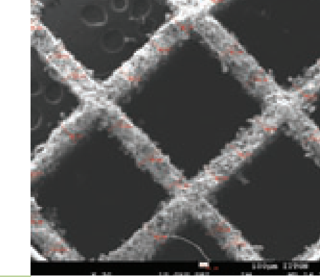
ENCRYPTION AND SECURITY

The computation infrastructure and the transfer of data and information must be protected from intrusions and data privacy is becoming all the more important in the present era. Hence, both theoretical and practical research in encryption and security (through hardware and software means) need to be geared up.

ENERGY

Energy is a critical input for India's development. Energy shortages and affordable energy access are major challenges facing India. Innovations in conventional energy supply systems (coal, oil, natural gas), energy efficiency and renewables are essential for India's growth. The IMPRINT Energy initiative plans to create a roadmap to enhance the competiveness of Indian industry in the energy sector by collaborative research, design and development, devise grand challenges for multidisciplinary research missions and enable disruptive technologies. The IMPRINT Energy theme will also articulate the needs for capacity building and manpower development for India's energy sector. India has the potential to achieve leadership in the Energy sector. Our goal is to create a framework to enable this.





ENERGY EDUCATION

The energy sector needs new skills, significant analysis and innovation. There is a need for re-training and upgrading the skill sets of existing energy sector personnel. Inter-disciplinary approaches and new curriculum / courses are needed to cater to technology development, system integration, diffusion of energy technologies. A spectrum of different courses and programme offerings involving engineering, science, economics and policy analysis needs to be drawn up.

CONVENTIONAL ENERGY SOURCES

Since their discovery, fossil fuels due to their ease of availability and utilization have been, and still are, the major source of primary energy. However, the energy security of India is challenged because of, for example (I) non-availability of high-quality coal, (ii) low reserves of oil and natural gas, and (iii) scarcity of fuel-grade Uranium. Industry-Government-Academia RD&D effort needed towards tackling these problems. The adverse environmental impact of fossil fuels leads to local pollution, health impacts and global warming and climate change. In order to meet the challenge of climate change there is a need for efficiency in extraction and conversion of fossil fuels and developing cost effective carbon capture and storage.

COAL

India's energy sector is mainly dependent on coal. Indian coal is high ash and low Sulphur and offers significant technology challenges.

Topic: (1) Clean Coal Technology (2) Carbon Capture and Storage

Title: Supercritical Boiler Design; Advanced coal cycles – IGCC; pre-combustion capture; oxy-fuel combustion

OIL & NATURAL GAS

Oil and Natural Gas are critical from an energy security viewpoint. Optimal utilization of the limited oil and gas reserves, exploration of unconventional oil and gas reserves and efficient upstream and downstream processing technologies are important from an energy security viewpoint.

Topic: (1) Efficient processing, (2) Enhanced Oil recovery, (3) Unconventional resources

Title: Low water fracking technology; Innovative drilling and discovery technology; Coal Bed Methane; Underground Coal Gasification

NUCLEAR

India has demonstrated indigenous capability in nuclear power plant technology. The challenge is to bring down costs, improve safety and have technologies for nuclear waste management.

Topic: (1) Inherently Safe Nuclear Reactors, (2) Advanced Thorium Power plants

Title: Reliability; Thermal Hydraulics; Nuclear Waste Management

RENEWABLES

The exhaustible nature of fossil fuels, coupled with the need for energy security of the nation and the climate change problem necessitates research and development in clean, green, renewable energy technologies (Solar PV, Solar thermal, Wind, Hydro, Biomass& Biofuels). Due to the tropical location of and distributed nature of renewable sources, India is in a position to utilize these resources for the overall development of the country. The mature, reliable, and cost-effective technologies in this group would still need a triple helix RD&D thrust as well as development of skilled manpower. Also, several technologies need fundamental, breakthrough research for cost effective solutions.

SOLAR THERMAL

Topics: (1) System Optimization, (2) Collector & Receiver Design, (3) Testing

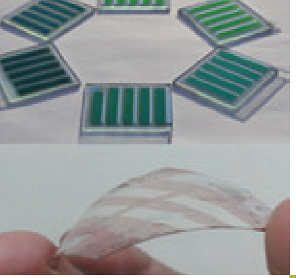
Titles: Application for process heat; Tracking heliostat; Optimization of heliostat field; Design of central tower receiver; Single tube receiver for LFR; Evacuated tube collectors; Cost effective Parabolic Trough System; High temperature selective coatings; System reliability analysis/testing.

SOLAR PV

Significant cost reductions have resulted in solar PV becoming almost cost effective. The challenges are to ensure the competiveness of Indian cell and module manufacturing. so that India is not dependent on cell and module imports.

Topics: (1) Module reliability & performance (2) High efficiency, indigenous Si solar cells, (3) Technologies based on new materials for thin film solar cells (4) Artificial Photosynthesis

Titles: Fast, efficient, in-field diagnostics; Indigenous Si solar cell manufacturing; Materials and technology for flexible solar cells. Emphasis on competitiveness of indigenous PV manufacturing: Cost effective foundations



ENERGY

BIOMASS / BIOFUELS

India has significant resources of agricultural residues, plant and animal wastes, fuelwood distributed across the country. Biomass technology offers the potential of local employment and is almost cost effective. There are several indigenous success stories, but widespread diffusion, standardisation has been a challenge.

Topic: (1) Efficient Gasification, (2) Pyrolysis, (3) Combustion, (4) Algal Biomass

Title: Efficient Process Development; Scale-up; Water management; Catalyst Development, Yield optimization, Liquid hydrocarbon transportation fuels (Green gasoline, diesel and jet fuel), Platform chemicals (eg. HMF, furfural etc), Bio-butanol

WIND / HYDRO

Topic: (1) Turbines for low wind speeds, (2) Offshore Wind,(3) Low head hydro turbines

Title: Vertical Axis Wind Turbines; Tidal stream Generators; Wind forecasting

ENERGY STORAGE

To reduce peak shortage and to avoid the mismatch between energy supply and demand. Research & technology development and demonstration of cost effective short term and long term storage systems is of utmost importance. This is likely to be more important with higher share of renewable energy in power systems and for vehicles and low power devices.

ELECTROCHEMICAL

Topics: (1) Large Scale Energy Storage, (2) Electric transportation, (3) Recyclability

Title: Safer/reliable batteries; Solid state batteries; Materials for next gen storage

MECHANICAL

Topic: (1) Compressed air, (2) Pumped hydro, (3) Flywheel

Title: Pump as turbine; Efficient compressors

CHEMICAL

Topic: (1) High storage capacity and kinetics, (2) Low T adsorption/desorption, (3) High cycle life

Title: Materials; Structural, chemical, and mechanical modifications; Integrated storage systems

THERMAL ENERGY STORAGE

Topic: (1) Latent Heat storage (2) Sensible Heat Storage

HYDROGEN

Topic: Hydrogen based infrastructure development

Title: Photochemical and Biological Hydrogen production processes; Solid State Hydrogen Storage Materials; High pressure hydrogen gas storage cylinders; Hydrogen pipeline; Hydrogen refilling stations; Hydrogen gas engine development; Fuel cells

ENERGY SYSTEMS & EFFICIENCY

There is a need for the development of efficient energy systems. Options like, energy efficient appliances, demand side management, smart energy distribution systems, in addition to better and implementable energy policy can significantly reduce the energy demand and thereby help in overall economic development.

SMART GRIDS

Topics: (1) Demand response implementation, (2) Intelligent microgrids

Title: Low cost communication; Market mechanisms; Stable microgrid operation technology

FUEL CELLS

Topic: (1) Fuel cells for transportation, (2) IT-SOFC for power generation

Title: CO tolerance; Electrolyte material for intermediate temperature operation

ENERGY EFFICIENCY

Topic: (1) Efficient appliances, (2) Industrial energy conservation (3) Product and process redesign

Title: Benchmarking; Smart appliances; Alternate processes

BUILDINGS

Topic: (1) Passive architecture, (2) Zero-energy building and Energy Positive Housing (3) Novel materials

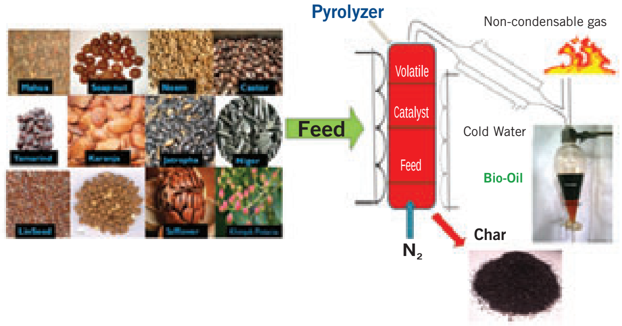
Title: Windows/envelope materials; Integrated design; Efficient lighting, Simulation/Optimization

TRANSPORT

Topic: (1) High toque density motor design for Indian roads (2)Flexible energy management and propulsion system design (3) Low cost electric vehicle design

IMPRINT ENERGY STRATEGY

A network of faculty members led by IIT and IISc faculty will draw up a roadmap for energy education and research for India. This will involve short term technology development and applied research in areas of relevance to Indian industry to enhance India's capability and competitiveness in energy areas: medium term mission mode collaborative projects and grand challenges and long term blue sky research. All these initiatives would need enabling and innovative funding and support structures and review mechanisms.



SUSTAINABLE HABITAT

India is at the threshold of a major shift in the way human habitation is perceived. By the end of 2030, 250 million new urbanites are expected to join in Indian cities. The agglomeration will certainly provide increased economic impetus but poses significant social and environmental threat. Places of India's habitation are already struggling with poverty, slum, informality, pollution, and resource degradation. Any significant transformation from status quo needs swift yet sustainable solution to extend a decent quality of life to every Indian citizen. In order to achieve the coveted livability in our habitat, the domain has envisaged an integrated and multidisciplinary approach. The output of this exercise will be disseminated as an education policy and framework to achieve quality education and research on sustainable habitat in India.

INTRODUCTION

Habitat, particularly urban habitat, is the epicentre of global economic growth and subsequent energy requirement. With increased economic and industrial activity, average global CO_2 emission is growing at 1.3% per year. Respite from this grave situation is not seemingly possible in the immediate future with the primacy in geopolitical consideration. With the business as usual, global cities which emits largest share of CO_2, will rise in its share of CO_2 emission from 71% in 2006 to 76% in 2030. This amount of energy and resource usage is not only due to increasing economic activity and behavioural changes, but also due to the current spatial planning of cities. Organisation of human habitat, both urban and rural, should not only imply design at a meta-level of cities and rural clusters, but also at smaller levels like neighbourhoods and communities. There is no gainsaying that human habitat needs energy and resources to survive and sustain its living standard, economic and social pursuits. It is known that proper habitat design has a direct impact on energy and resource consumption. But absence of awareness creates a situation where most approaches to sustainability concentrate on idealized energy rating systems of measurable components, such as buildings, building components and consumer goods. While it is important, such measures are on track to reduce total energy consumption by just 1-2%. And yet assembly of these hi-tech gadgets invariably increase carbon footprint, a dimension neglected in measuring energy efficiency. Energy performance at the habitat scale is often overlooked due to its complexity in modelling with available predictive models. But it is evident that optimization of energy consumption and maintenance of environmental balance is not possible without achieving the goal of sustainable habitat design.

Sustainability in its true sense does not only concentrate on maintaining the current environmental position, the popular perception. It also calls for socio-economic stability and prosperity. Economic growth affects socio-economic development but not entirely. Spatial reflection of socio-economic growth needs to be harnessed properly. Spatial networking between different economic factors reduce transaction costs and enhance superior economic output. Networking and ease of accessibility also enhances social connection to enhance societal development. Location and growth of human habitation and its complex relationship with its environment requires innovative design.

In general, habitat in India struggles with compound problems. In the past we have planned and design many habitats, including the newly developed urban habitats like Noida, Gurgaon, and Raipur and so on. All the newly designed habitats are struggling with various issues arising from poorly conceived habitat design, based on Western thoughts, while ignoring the ethos of Indian habitat design. Knowledge and developing human resources in habitat design are of utmost importance in today's emerging India. The objective of this study is to create a policy paper on delivering quality human resource with capable knowledge to transform Indian habitat through home-grown solutions within the constraints of our social, economic, administrative and political structure.

THE APPROACH

Our approach is to visualise habitat not only from the perspective of space but also its deep ecological and emotional values attached with spaces. Development doesn't always refer to be oblivion of the past and embrace the glittering present, but to harness the past in sustaining built environment in the present and the future. Sustainable habitat is the single most influencing factor which outlines a society's aspiration for living a sustainable life.

Habitat policies are government's response in understanding problems, perceived approach towards the remedies, and visualise future development of the society. Future habitat can only be sustainable and inclusive if we can replace the traditional ways of visualising policy merely with economic cost benefit outcome. This traditional capitalist approach often neglects superior ethical dimensions of equality and justice. Capitalist sector often restricts itself in GNP growth numbers and end up creating gigantic economic centres like metropolises. Increasing “metropolitanisation” in the globe is a direct manifestation of this lopsided economic aspiration, which is affecting imbalance in regional distribution and accelerating greater urban rural division. Already 53 urban agglomerations in India have a population of more than a million and it hosts almost 43 per cent urban population. Excessive concentration of economic benefits in urban region is invariably leading towards migration from rural hinterlands to urban core. Furthermore, rural regions in the neighbourhood of urban areas are becoming peri-urban areas. Thus, a continuous sprawling of edge-less cities is happening more than ever before.

A recent discussion organized by IIT Roorkee touched on a variety of issues and concerns regarding sustainable habitat. Discussions or government policy today compartmentalises habitat into either urban or rural ecosystem. The linkages between these two ecosystems and its interdependence are neglected both by the western and eastern scholars. The first workshop foresees the domain's approach both from top down and bottom up. Once we can create quality of life to be the benchmark to evaluate human development, all such spatial divisions between rural and urban become obsolete. Of course, this will require a paradigm shift in the thinking process about sustainable habitat design.

SUSTAINABLE HABITAT

Source: http://www.pensamentoverde.com.br /wp-content/ uploads/2015/ 02/Depositphotos _10491489_m.jpg

WAY FORWARD

It is evident that no single discipline can integrate the aspirations set out in our approach to education and research policy of Sustainable Habitat for India. It is also evident that "once size fits all" policy cannot work given the diversity in social and cultural ethos across the country. There is a necessity to create benchmarks that would identify sustainable development of habitat. The benchmarks need to be validated based on "people-level" discussions. Therefore, the education and research policy needs to emphasise equal priority to practice and application of research on the "ground-level" (Figure 1).

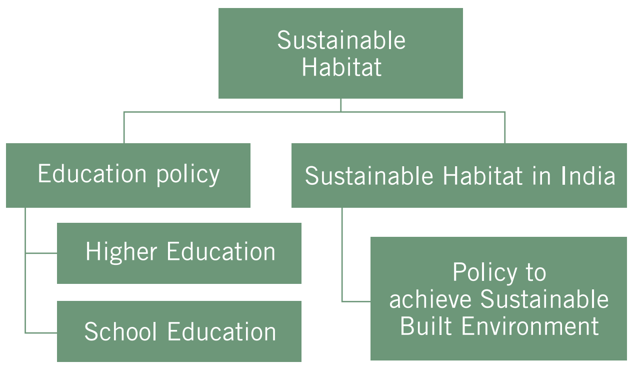


Figure 1: Way forward for IMPRINT Sustainable Habitat

So far we have identified eleven themes, although the cross-links between the themes are evident and need to be emphasized.

I. Architecture & Built form;
ii. Urban Planning & Design;
iii. Physical Infrastructure;
iv. Social Infrastructure;
v. Water & Sanitation;
vi. Transportation;
vii. Economy;
viii. Energy & Environment;
ix. Governance;
x. Housing and
xi. Resilience.

ARCHITECTURE & BUILT FORMS

Architecture & built form are the fundamental unit of all built environment. It includes various sub-themes such as archaeology of human habitation, contemporary architecture, space making in architecture and energy studies in architecture.

URBAN PLANNING & DESIGN

Urban planning & design help in integrating human habitation with physical, social, economic and virtual functions. The relevance sub-themes instigated during initial discussion are; planning for old towns & new towns, urban space design, conservation & heritage, city image and local area planning, urban regeneration & smart growth.

PHYSICAL INFRASTRUCTURE

Physical infrastructure serves to provide basic minimum requirement for survival and maintenance of health and hygiene for society to flourish. In addition to the traditional infrastructure, the domain introduces regional infrastructure covering urban and rural areas, infrastructure efficiency, and smart infrastructure.

SOCIAL INFRASTRUCTURE

Education, health, culture, religion and society form the basis of social infrastructure. The domain will concentrate on social infrastructure and its role in space making.

WATER & SANITATION

This subject was initially conceived as a part of physical infrastructure theme. But recognizing its extreme importance among Indian citizens, it has been decided to create an independent theme for water & sanitation. Sub-themes like potable water supply, waste water treatment, sanitation, public hygiene will be discussed under this theme.

TRANSPORTATION

Transportation consist one of the major domain for sustainable habitat. It enables movement and has implications in economy, environment and societal development. Transportation planning & traffic engineering, transportation policy & economics, environment, non-motorised transit, and smart transit system are the most prominent inclusion in sub-themes.

ECONOMY

Habitat planning is spatial manifestation of socio-economic development of any country. Therefore,

understanding economic issues are very important for habitat planning and its sustainability. Subjects like regional economics, formal & informal economy, equity, cluster and networking, innovation and creative economy are significant part of this theme.

ENERGY & ENVIRONMENT

Energy and environment are grouped together as a theme for deliberation under sustainable habitat domain. Human activities are completely dependent on energy and its affordable supply. Environment which is the mother of our very existence needs special care to continue our existence. Increasingly human beings are threatened with energy security and various consequences due to environmental degradation. Sustainability, pollution, urban greening, heat island, are the major sub-themes to be addressed.

GOVERNANCE

Effective legal and administrative framework extends the benefit and addresses various concerns in an effective manner. Physical, social and economic benefits can only be distributed effectively in a society if existence of an effective governing system is already functioning. People's participation, smart governance, complexity between different governance hierarchies will be deliberated within this theme.

HOUSING

More than 80% of built environment belongs to housing and human habitation. Physical, social, governance and economic aspects related to housing needs emphatic attention, particularly in the extent of government policy like 'Housing for all 2022'. Affordable housing, informal settlement and slum, real estate, materials & construction method, durable housing, temporary housing are some of the sub-themes include in housing.

RESILIENCE

Increase in intensity of natural disaster of various forms in this globe, resilience has become an important issue. Resilience is an innovative idea which discusses about flexibility, adaptation and knowledge to survive during disaster and harness knowledge of post disaster physical, economic and social development.

All these themes have strong direct and indirect consequences both vertically and horizontally in this matrix. Housing has strong linkage with transportation and infrastructure which in turn has strong linkage with economy, environment and energy. These mutual linkages are undeniable within the domain of sustainable habitat. It creates more insight to opt for "experiential model" in education and research. Education in sustainability and habitat are more focused on indoor teaching and learning of models and then validate the model based hypothesis with outdoor samples. The approach is restricting in true understanding of human habitat of different genre.

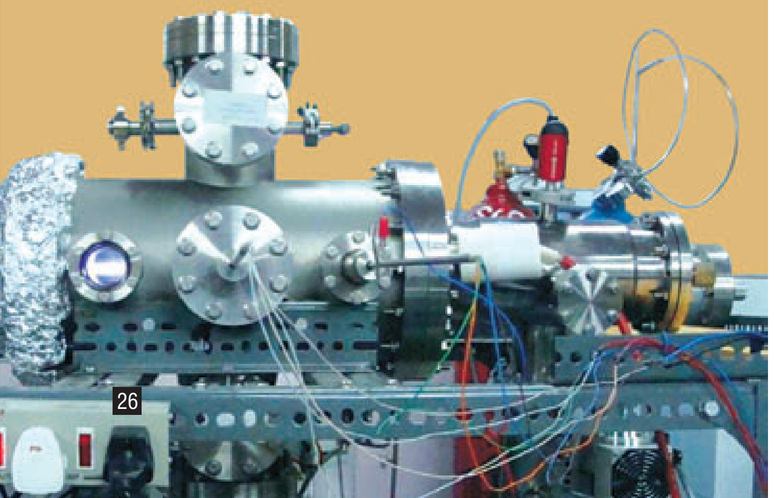
Education and research policy may not be open ended. As policy designers, we will work out mechanism to foresee the possible consequences of the policy implementation. Identification of themes, sub-themes, titles and topics would provide the foundation to identify all the necessary instruments in great detail which influence habitat. It won't be surprising if we find out that many of these topics eventually need multidisciplinary team to solve the real life problem. The future education and research to provide effective solution may well lie with interdisciplinary approach rather focusing to solve the immediate problem. This greater interdependence among the themes is already instigating ideas of creating institutions which offer multiple disciplines instead focuses on isolated discipline. Strong communication and collaboration among these discipline is also needs to be ensured.

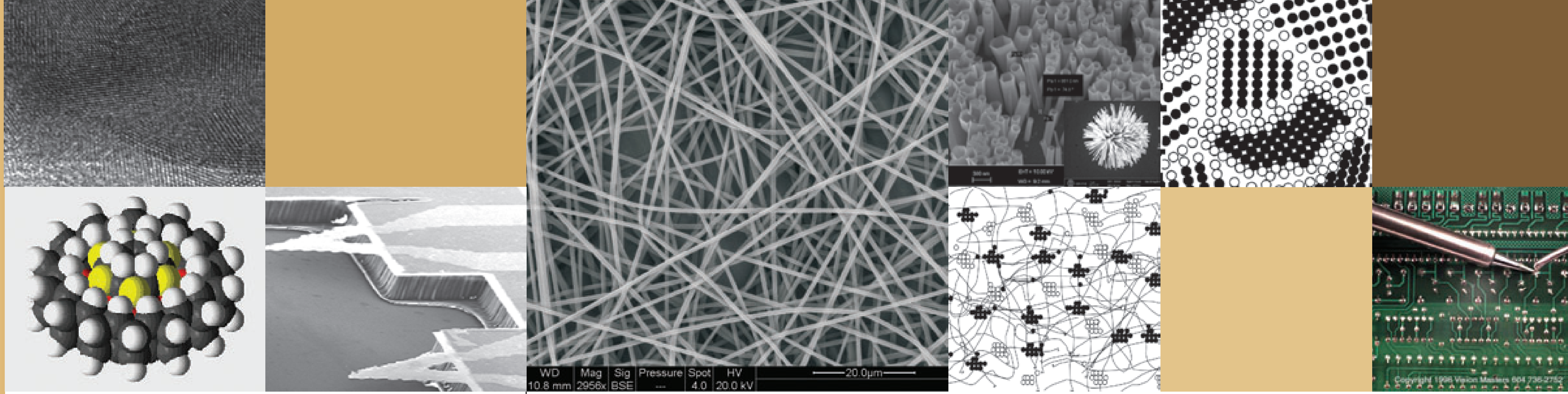
Policy scientists often criticise policy designers for narrowly focused means end rationality of policy analysis. We assimilate this criticism and will work on to come up with specific strategy which would gratify the spirit of policy. One such measure would be to introduce specific policy measurement methods. Proposed policies will not be floated freely without any evaluation matrix.

Sustainable Habitat domain will establish a pragmatic index to measure the progress of the proposed education and research policy. It may have both short term and long term measurement options to provide government enough opportunity to measure the gravity of the situation. The policy will be flexible enough to enable modifications depending on short term feedback to make it more effective in long term.

NANOTECHNOLOGY HARDWARE

India ranks third in the world in terms of research publications and second in terms of patent filing in the field of Nanotechnology. The goal therefore must be to convert some of this excellent work and IP into tangible prototypes and products meeting the societal requirements. The IMPRINT program is expected to lay down a roadmap for India to achieve a leadership position in Nanotechnology product development. Identifying Grand Challenges faced by the society and addressing these challenges through a top-down approach is the best way to deal with these problems. The five problem areas to be addressed through the IMPRINT India Nanotechnology Grand Challenges initiative will be based on the concept of "high technologies at an affordable cost, addressing the societal needs".





SECURITY
From homeland security to cyber security, security is going to be a major concern for the country.

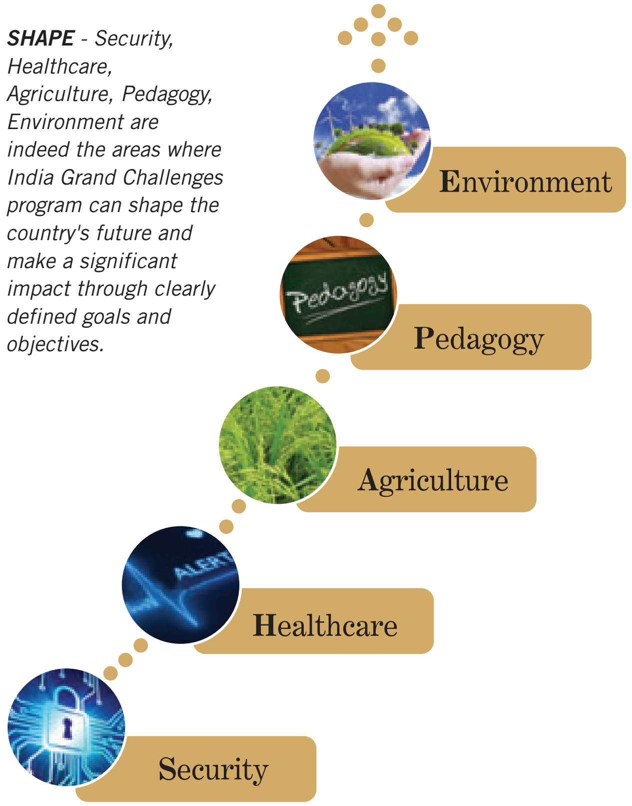
HEALTHCARE
Specifically looking at web enabled healthcare initiatives, diagnostics, rural healthcare etc. Providing clean water, meeting the sanitation requirements of population are an important part of any healthcare initiative in the country.

AGRICULTURE
Fundamentally addressing the precision agriculture areas, sensors etc. to improve the contribution of agricultural sector to national GDP. Reducing water wastage is another major requirement in agriculture.

PEDAGOGY
With a million young people joining the work force every month, India needs to address their training needs, educational requirements etc. This needs a major effort in the educational sector.

ENVIRONMENT
In a growing economy like India, every effort must be made to protect its environment. Use of renewable sources for energy, sensor networks to regularly monitor and transmit information related to the pollution, ground water quality etc. need to be part of this initiative. Along with the exploration of applications, we must also be aware of the environmental impact of nanomaterials that are released from nanotechnology embedded products into the atmosphere.

***SHAPE** - Security, Healthcare, Agriculture, Pedagogy, Environment are indeed the areas where India Grand Challenges program can shape the country's future and make a significant impact through clearly defined goals and objectives.*

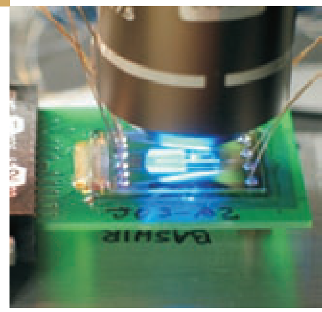


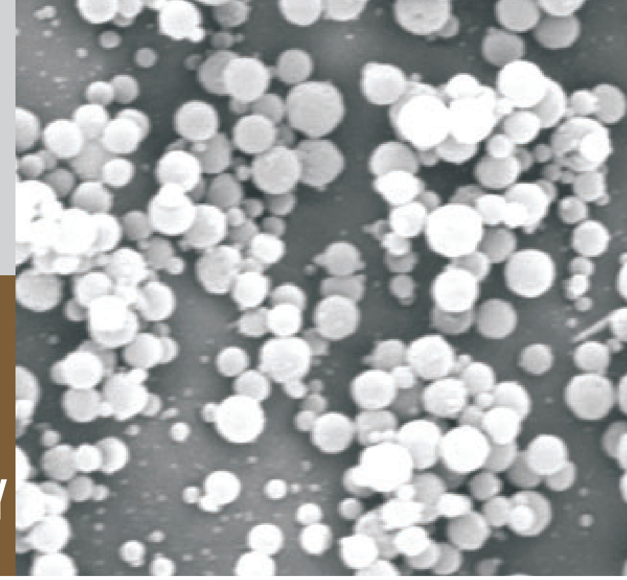
SECURITY

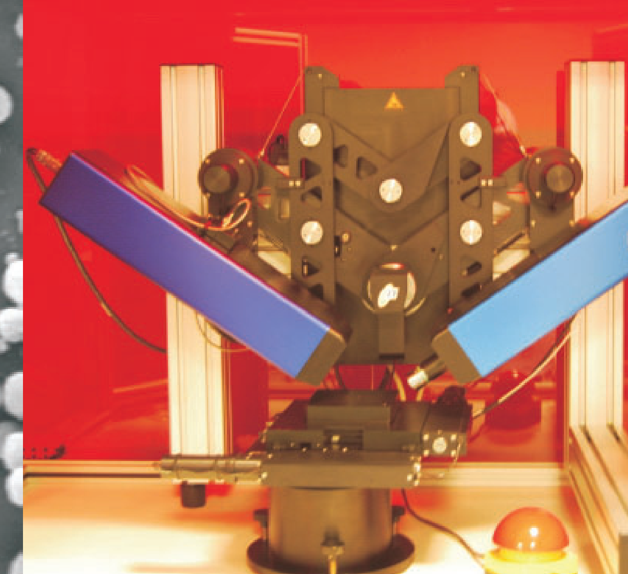
- Hand held & standoff detectors for less intrusive monitoring of trace quantities of chemical, radiological and biological threats for airports, railway stations, bus stands, baggage and vehicle screening
- Security sensor networks for major installations, transport applications, border security including the integration of energy harvesting techniques
- Low cost missile warning systems
- Development of cost-effective, high-frequency, and high-power devices for next generation communication devices, military and commercial applications
- Low cost systems for landmine detection, aerial surveillance
- Assistive technologies for security forces & commando operations
- Encryption/decryption technologies, intelligent video surveillance techniques, and cyber security

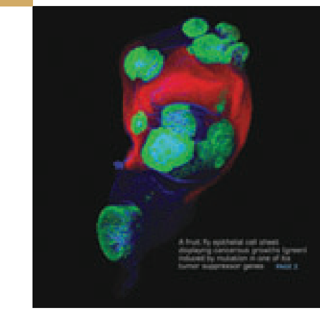
HEALTHCARE

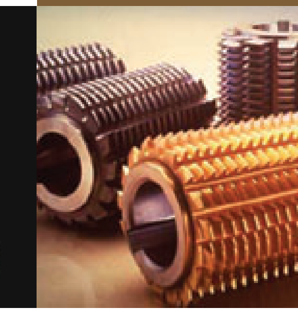
- Networked healthcare kiosks in rural areas for non-invasive monitoring & screening of population for essential body parameters (such as BP, ECG, Blood sugar levels etc.) and communication to specialists in bigger hospitals
- Low cost point of care diagnostic systems for cardiac, TB, Malaria, Dengue and other diseases
- Networked real time water quality monitoring systems for ground water contamination monitoring in villages
- Clean water filtration & sanitation systems for rural areas











NANOTECHNOLOGY HARDWARE

AGRICULTURE

- A low cost point of use systems for soil macro-nutrient (NPK) and Micro-nutrients (B, Zn, S, Mn.) to promote soil fertility and balanced crop nutrition
- Portable point of use systems for detection of plant viruses and early stage disease diagnosis
- Low cost soil moisture, soil temperature, pH sensors for improved productivity
- Electronic nose platforms for detection of ethylene (for fruit ripening detection), methane and H_2S for paddy fields, detection of volatile aldehydes during seed storage for seed quality monitoring etc.
- Low cost systems for other precision agriculture applications, pesticide and drug content in food products, antibiotics and growth promoters in meat, milk quality monitoring.
- Nanomaterials for Food packaging applications to prevent oxygen and other gases from passing through.

PEDAGOGY

- Special manpower development programmes in core areas such as VLSI design, Embedded systems, micro/nano-fabrication, nanomaterials and their applications, Nanoelectronics, Safety aspects of nanotechnologies, Incubation
- Web enabled learning modules for all the above areas
- 20 X increase in Quality Improvement Programmes (QIP) for faculty in second tier educational institutions

ENVIRONMENT

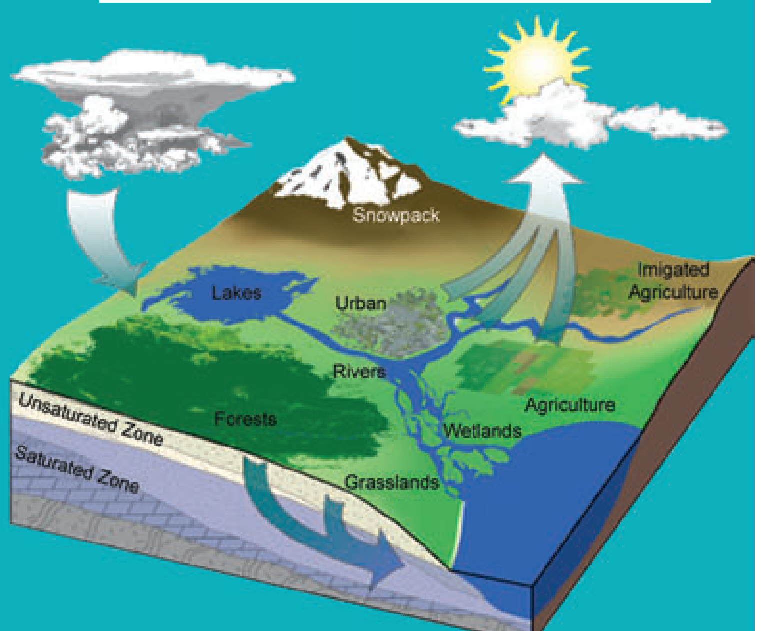
- Air Pollution monitoring systems in traffic junctions with a mobile phone readout
- Green synthesis of Nanomaterials
- Improving the energy conversion efficiency of renewable sources, Advanced materials for flexible, cost-effective, and environment-friendly renewable energy sources
- Novel and cost-effective hybrid sensing materials to monitor toxic and pollutant gases and chemicals in the environment
- Energy efficient devices and systems
- Use of extraordinary electric conductivity of nanomaterials for application in electric cables and power lines for reducing transmission losses
- Structural health monitoring of civil structures & pipelines

METHODOLOGY FOR IMPLEMENTATION

- This initiative is expected to change the paradigm of how research is conducted in academic institutions in India. This will be more on the lines of directed basic research, with clearly defined goals and objectives resulting in a prototype or technology development.
- The programme will be time bound with a 5 year timeline. The team shall identify specifications for a minimum of five products in each of the SHAPE areas, having a societal relevance, including the cost estimates. That will be a total of 25 large multi-disciplinary, multi-institutional projects, with clearly defined specifications involving some aspect of Nanotechnology in the solution. The projects need to be regularly reviewed every 6 months. Each of the projects must have a theme coordinator, who will be responsible for overseeing the activities.
- It is expected that all activities end with a proof of concept/prototype ready for field trials. Such activities tend to be inherently multi-disciplinary, so the teams will be encouraged to seek expertise of people with diverse backgrounds. The projects therefore will be inter-disciplinary and multi-institutional with product as a focus.
- The programme team will look at the existing facilities, identify gaps that exist in the R&D infrastructure and address these. The team will identify at least a dozen institutions where state of the art infrastructure facilities for micro/nano-fabrication can be created, including augmenting the existing facilities.
- Through a national level search, the team will identify at least 50 outstanding Ph.D. students per deliverable and commission them to work on these projects. That would be 25 deliverables X 50 high quality Ph.D. students =1250 Ph.D. students working on the 25 multi-disciplinary/multi-institutional SHAPE projects through the IMPRINT India Nanotechnology Grand Challenges Program.
- The programme will encourage the students and the faculty involved in these projects to look for incubation/start-ups as a means to commercialize their technologies. There will be a provision for supporting these start-ups through a national level fund during their incubation period.
- There will be Technology parks created in many of the leading institutes where these start-ups can be anchored. The goal is to create at least 10 startups out of this initiative in the Nanotechnology area, over a 5 year period.
- The IMPRINT Nanotechnology program will be led by a National Coordinator (a leading researcher with expertise in translational research) who reports to the IMPRINT India Chief Coordinator or the ministry.

WATER RESOURCES AND RIVER SYSTEMS

An impending water crisis stares the country in her face today. To illustrate: many of our rivers and water bodies are heavily polluted, posing severe health problems; many cities and towns face acute water shortage every year; much of the population has no access to safe drinking water; overexploited groundwater resources are affecting agricultural output in large tracts of the country; and rapidly vanishing water bodies have gravely damaged aquatic ecosystems and their resilience. The low efficiencies of irrigation water use and poor water management practices and policies at all levels have contributed to the overall aquatic crisis. The focus of the IMPRINT initiative in this domain is to evolve appropriate educational and research policies that can complement efforts to overcome the critical challenges of water resources and river systems.



Source: MSU (Michigan State University) 2013, "Hydrogeology". Accessed on October 2015 form: http://hydrogeology.glg.msu.edu/wordpress/wp-content/uploads/2008/10/ILHM conceptual_diagram_3D.png

THEMES

RIVER BASINS

A river basin is a closely connected hydrological-ecological system characterised by a web of interactive natural resources that sustain healthy rivers and terrestrial life. Holistic and scientific river basin management plays a key role in sustainable development.

WATER IN URBAN SYSTEMS

Urban habitats are drastically modified ecosystems — often in a state of flux. Anthropogenic water use, safe wastewater disposal or reuse, water scarcity, drainage, flood management, ecosystem needs and micro-climate control are key challenges of urban water management.

WATER IN RURAL ECOSYSTEMS

With small clusters distributed over landscape scales, rural habitations have been transiting from their past stable states. Their pressing concerns include potable water needs, water security, sanitation, flood protection and community water management.

WATER & AGRICULTURE

Conventional modern agriculture has ushered in unsustainable resource use and increased agroecosystem vulnerability. Groundwater depletion, water-logging, increasing soil degradation, and pollution of rivers, water bodies and groundwater are key concerns of Water & Agriculture.

WATER & INDUSTRY

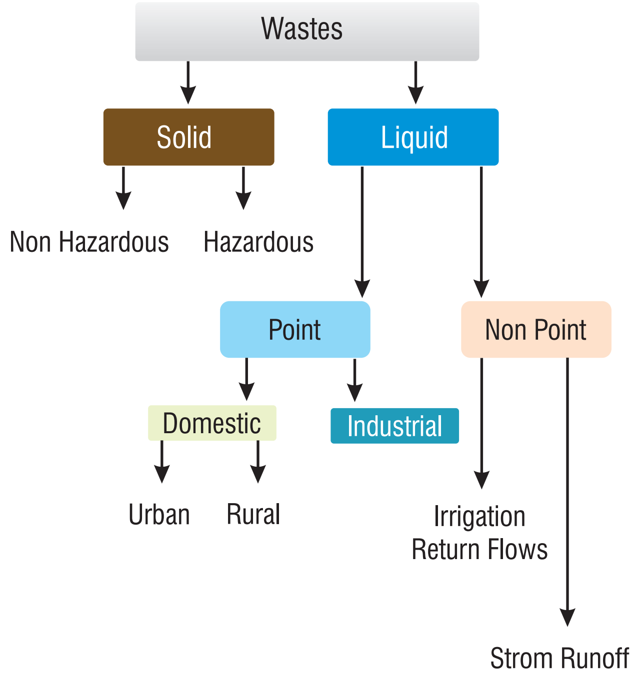
Industrial growth in a developing country like India is imperative; hence, so are increasing water use and waste generation. Re-use and recycling practices thereby internalizing environmental damages in industrial development along with appropriate siting define the new paradigm.

SPATIAL REAL-TIME DATA INFRASTRUCTURE

With huge gaps in data and scanty real-time data, water resource and river management lie at the mercy of thumb rules and guesstimates. A robust quality-controlled data collection system with real-time open access underlies all future knowledge-based approaches.

GRAND CHALLENGES

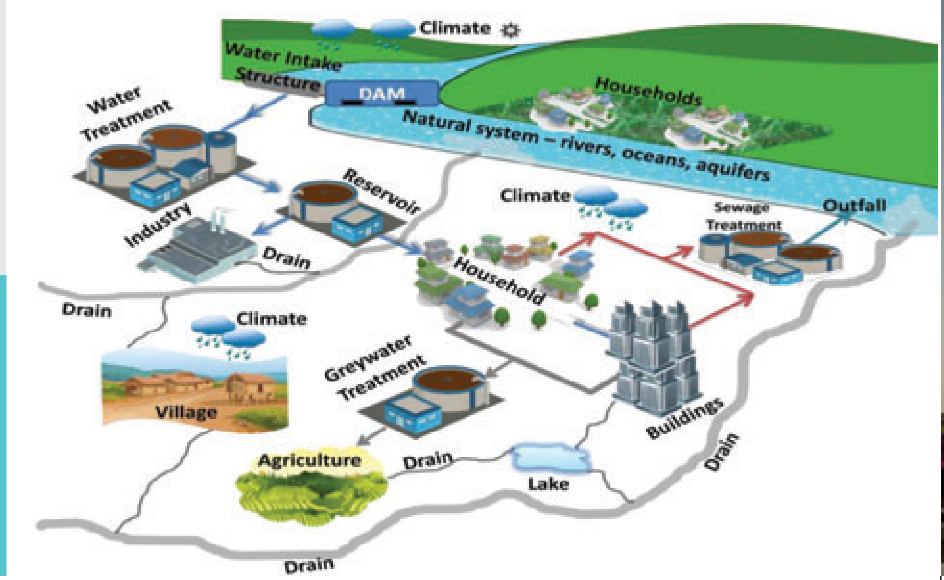
- Define, maintain and improve the health of water bodies
- Convert rapid flows to sluggish flows to increase water availability for human and ecosystems
- Locally close water and nutrient loop in agriculture, rural, urban and industrial systems
- Recognize and disseminate traditional knowledge and practices regarding management of water and water bodies
- Increase water-use efficiency through cost effective technology, interventions, measurements, pricing mechanisms, informed opinions and public policies

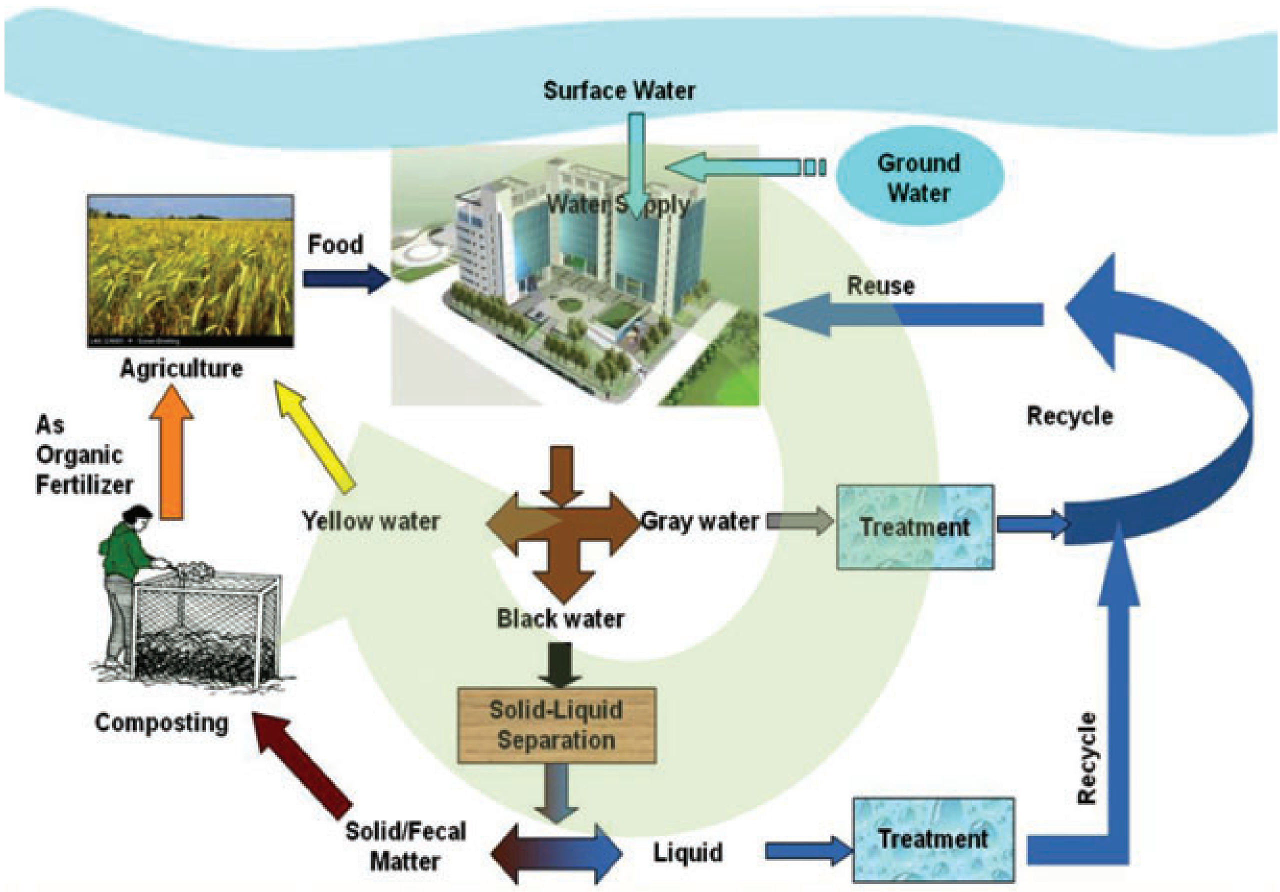


MAJOR SCIENCE QUESTIONS

- What are the key gaps in data availability, monitoring and dissemination at various spatial and temporal scales that affect water resources and river systems?
- To what extent water availability and water demands changed historically and how these are likely to change in future?
- How sensitive are the river basins towards changes in land-use/ land- cover and climate?

WATER RESOURCES AND RIVER SYSTEMS





COMPLEMENTING SCIENCE AND TECHNOLOGY MEASURES

VALUING WATER

Water is not only a commodity, but its true value also includes social, cultural, environmental and economic values. All of these must be considered in appraising different policies and initiatives to realize the goals of Integrated Water Resources Management (IWRM) – social equity, environmental sustainability and economic

efficiency. Unfortunately, this is rarely done in many developing countries where poor people often pay much more than the rich for the same water services. Further, the value of water embedded, directly or indirectly, in various products and services also needs recognition. World over this concept of virtual water now influences production and trade policies, especially in water-stressed areas, enabling the most economic and efficient use of scarce water supplies.

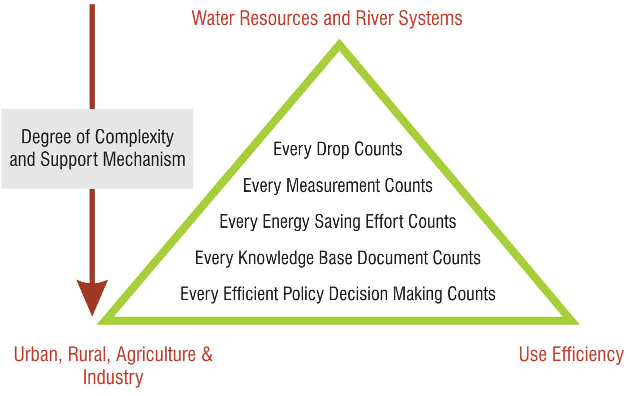
GOVERNANCE

The water crisis in many countries today is largely a governance problem. National responses to water-related disasters and shortages, allocation of transboundary water resources, management of national water resources, and building capacity and knowledge should all be jointly shared by governments and civil society. In reality, effective and equitable water management is impeded by many factors, such as sector fragmentation, corruption, insufficient aid and investment in the water sector, institutional shortcomings, and lack of stakeholder participation. An integrated approach to water management is the best way to overcome these obstacles.

KNOWLEDGE & CAPACITY DEVELOPMENT

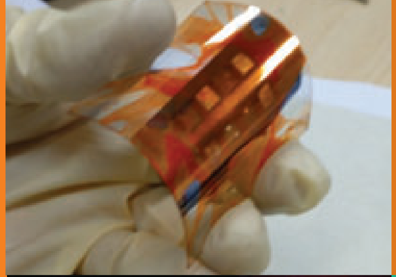
The lack of data and sound knowledge-based systems, combined with inequitable access to and sharing of scientific, local and indigenous knowledge, comprises the major stumbling block to sound water management. This is especially true for low-income and in-transition countries. Yet, we have the knowledge and capacity to solve many – and probably most – of our pressing water-related problems if water issues are properly governed.

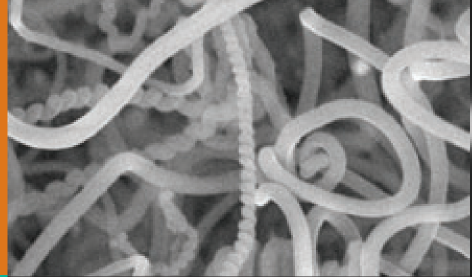
Globally the strategy to improve the overall quality of water resources is based on local level actions. Lessons learned — successes and failures — are invaluable sources of information and, if properly shared, will help us to solve some of our most pressing freshwater-related problems.

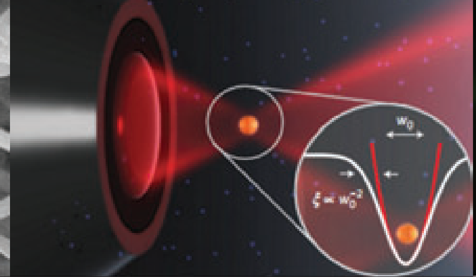


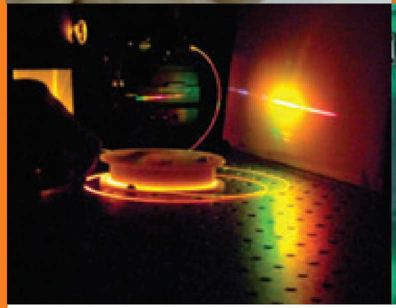
DELIVERABLE: DOMAIN SPECIFIC POLICY DOCUMENT ON EDUCATION & RESEARCH

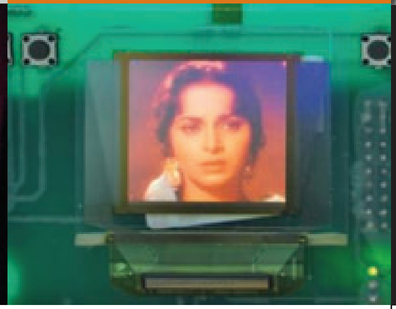
- Assessment of present status and setting benchmarks for engineering, innovation and education
- Identification of - R&D gaps, policy gaps and implementation issues
- Articulation of shift in human resource development policy at various levels - school to higher education, vocational, etc.
- Re-adjusting focus, identifying needs (infrastructure, financial and human resources) and timelines for R&D
- Suggestions for addressing implementation issues

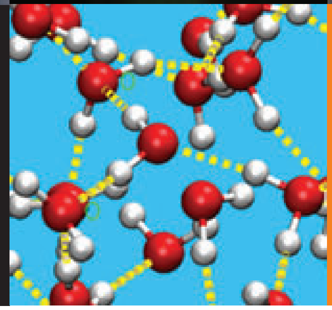






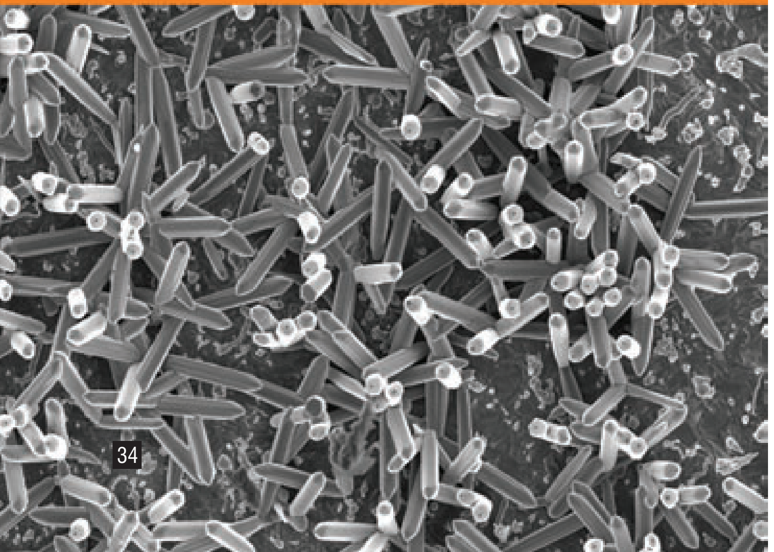






ADVANCED MATERIALS

Ability of a nation to harness nature as well as to cope up with the challenges posed by it is determined by its knowledge of materials and its ability to develop and produce them for various applications. Advanced Materials are at the heart of many technological developments that touch our lives. Electronic materials for communication and information technology, biomaterials for better health care, sensors for intelligent environment, energy materials for renewable energy and environment, light alloys for better transportation, materials for strategic applications and more. India has its own unique set of resource and technological challenges. The objective of the Imprint India Initiative in this domain is to come up with research and education policies which will provide the developmental path for Advanced Materials for our nation.



STRUCTURAL MATERIALS

The engineering materials are divided into two themes: Structural and functional. As India is developing rapidly, the requirements of quality structural materials is on the rise. High level of demands are placed on various sectors including steel, cement, light metals and alloys, etc. This, in turn, requires quality raw materials and availability of power at affordable price. At the same time, there is a need for newer structural materials such as advanced composites and particulate materials. The objective of this theme is to provide a technology roadmap for the nation to meet the ever growing requirements in this sector.

STEEL

India is the fourth largest producer of steel in the world with annual production of nearly 87 million tonnes and aims to produce 300 million tonnes by 2025. Corresponding to this, high targets have been set on production of raw materials such as iron ores, coking coals, ferro-alloys, etc. Innovations are needed to mitigate challenges faced by the nation on raw materials front, technologies for utilization of non-coking coal, for example. Apart from the technological challenges, there are challenges associated with trained manpower and infrastructure. In terms of product mix, there is a need to develop indigenous technologies for the development of advanced high strength steel (AHSS) and cold rolled grain oriented (CRGO) steel for critical sectors.

LIGHT ALLOYS

Light metallic materials consist alloys based on aluminium, titanium and magnesium, their foams / honeycombs and related fabrication technologies. They are of utmost importance in defence and space applications, since a large proportion of defence/space systems structural weight is made of light alloys, allowing higher payload to be used. Extraction of the respective pure metals to the required purity levels is equally important.

ADVANCED COMPOSITE MATERIALS

Availability of lightweight, high-strength, and high-stiffness materials is a key requirement for efficient transportation, efficient power generation, efficient energy storage, reduced emission and better protection of army personnel against variety of threats. The design flexibility provided by advance composite materials makes them most suited for many diverse applications such as structural applications where high stiffness is needed, and high energy absorbing applications where larger dissipation of energy is required. However, efforts from research communities are needed to mass produce these materials in order to reduce cost and broaden the area of application.

PARTICULATE MATERIALS

The use of particulate materials or powders as starting material provides the advantage of formulating novel compositions and tailoring microstructures. This makes it well suited to process a range of advanced materials in demanding applications. Particulate materials are formed using powder metallurgy (P/M), a net-shape processing technique offering several economical and ecological benefits for manufacturing small and medium-sized components. A unique attribute of this technique is high material utilization (>98%) and the flexibility that it provides in consolidating parts at processing temperatures well below the melting point. This theme aims at providing a comprehensive understanding of the various application areas of particulate materials using P/M technique with an emphasis on processing components for strategic (ordinance, aerospace and nuclear) and automotive sectors.

ULTRAHIGH TEMPERATURE MATERIALS

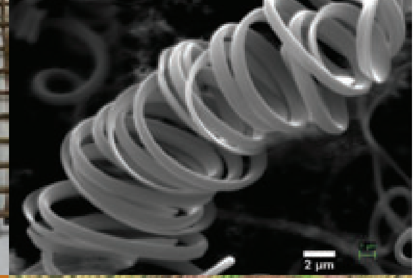
Ultra-high temperature ceramics (UHTCs) are a class of materials that can be used under extreme thermal environments (>2400°C) as they display high melting temperatures (> 3000°C) while showing high temperature strength, resistance to oxidation/chemical reactivity, radiation damage and high temperature erosive attack. Materials research and technology development in this field is mandated for developing the UHTCs needs for hypersonic aerospace application.

FUNCTIONAL MATERIALS

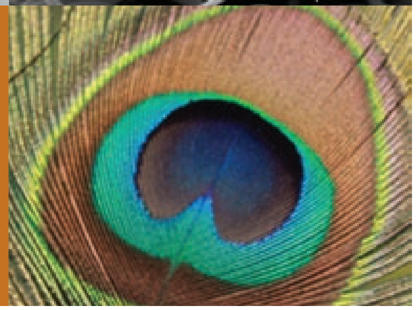
In addition to structural materials, electronic, opto-electronic, energy and functional materials are needed for variety of applications such as electronics, photovoltaics, communication and information technology, sensors, etc. They are equally critical for the devolvement and security of the nation.

ELECTRONIC MATERIALS

Electronics is omnipresent in today's world. From VLSI circuits to light emitting diodes (LEDs), photo detectors and photo voltaic devices, its applications are immense. In addition to conventional semiconductor (silicon), several new emerging materials have shown unique property-portfolio to facilitate future electronic devices.



ADVANCED MATERIALS



ENERGY MATERIALS

The key to sustainable growth and general well-being of Indian population relies on energy security. Accordingly, the thrust in scientific research and technology development should encompass development of cost-effective, robust, high performance and eco-friendly energy conversion technologies, such as solar photovoltaics, fuel cells, thermoelectrics and energy storage technologies, such as rechargeable batteries, redox flow batteries, supercapacitors.

OPTOELECTRONIC MATERIALS AND DEVICES

That sub-field of photonics wherein light-matter interaction results in the development of light sources, detectors, and control of light is typically defined as the field of optoelectronic materials and devices. In this context, light can be used in the broadest sense of the entire electromagnetic radiation. Such optoelectronic materials and devices can have far reaching applications ranging from ultra-high band communication and renewable energy on one end to defence and health care on the other end.

SMART MATERIALS

Smart materials are those materials that possess both intrinsic and extrinsic capabilities to respond to stimuli and environmental changes. They respond to changes in temperature, stress, pH, magnetic field, electrical field, etc. The term smart materials encompasses a wide variety of materials, such as shape memory alloys, piezoelectric materials, smart gels, electrostrictive materials, magnetostrictive materials, rheological fluids, electrochromic materials, conducting polymers, MEMS, optical fibres, pH-sensitive materials, etc. Smart materials are still to become popular as evidenced by the smaller extent to which they find applications in different domains in India today. The full potential of smart materials is yet to be tapped. They can be used from very simple to very sophisticated applications.

EARTH ABUNDANT ELEMENT BASED FUNCTIONAL MATERIALS

Elements with low abundance in earth's crust (including rare-earth elements) form an important ingredient of a wide variety of advanced functional materials critical for self reliance. Typical application areas include Heat Resistant Permanent Magnets, Exchange-Spring Magnets, Solid State Lighting, Solid State Display, Catalysts for Artificial Photosynthesis, Photovoltaic Materials, Electrodes Materials for Batteries and Fuel Cells, etc. Sustained R&D is needed for development of advanced functional materials from earth abundant elements and deployment of these materials for end applications across various sectors including energy, manufacturing, defence, etc. This is crucial for our self-reliance in functional materials.

EMERGING MATERIALS

While there have been tremendous improvement in engineering materials over decades, materials scientists and engineers have been coming up with newer and better materials every few years. Therefore, a theme on emerging materials has been included. Most of these materials are at research stage but could lead to new products and better lives for the future generation.

NANOMATERIALS

Nanomaterials represent a field of vigorous activities in recent times and is key to the success of many advanced technologies for critical sectors like defence, healthcare, agriculture, environment and so on. It is increasingly realized that reducing the scale and distribution of grains and phases yields properties which is significantly different from the bulk properties. The main focus of this sub-theme will be to develop the understanding of effect of size on the materials properties, to develop nano-materials for different application domains and to provide roadmap for scaling up of nano-materials production at industrial scale.

BIOMATERIALS AND DEVICES

The theme of biomaterials and devices proposes to address some of the existing clinical challenges, relevant to Indian population. For example, musculo-skeletal disorders, cardiovascular and neurological diseases. In order to address human diseases, there is a need to manufacture 'make-in-India' medical devices and implants, which should help in the repair and replacement of diseased and damaged parts of the human skeleton, heart, bone, teeth and joints, thereby restoring the function of the otherwise functionally compromised structures.

POLYMERIC AND SOFT MATERIALS

From its inception until today, polymeric materials have enhanced our quality of life. Other soft materials include gels, self-assembled molecular and biomolecular structures. These classes of materials have a wide range of applications depending on the functional groups incorporated into the basic units. In a short span of time these materials have gained tremendous impetus over other type of materials because of their interesting physical properties and ease of tailoring of properties through molecular engineering.

GLASSY AND AMORPHOUS MATERIALS

Glassy and amorphous materials, specially metallic glasses and amorphous alloys have gained considerable attention due to their intriguing structure, exciting properties which in many ways are much better than the existing engineering crystalline alloys, and possibility of their use in many applications, ranging from structure materials due to their excellent mechanical properties, corrosion and wear resistant coating, magnetic material, electrode materials, catalyst, etc.

BIO-INSPIRED AND PATTERNED FUNCTIONAL MATERIALS

Bio-inspired materials are man-made materials, the structure, geometry and functionality of which mimic natural materials. The focus/objective of research on this specific theme are the following: 1) developing knowledge about multi-functionality of natural materials,2) exploring bio-mimetic, self organization processes for synthesizing such materials, 3) exploring fabrication and deployment method of such materials in large and economical scale for the benefit of the society.

MATERIALS GENOMICS AND INTEGRATED COMPUTATIONAL MATERIALS ENGINEERING (ICME)

Progress in materials science and engineering has made great strides in recent years as our understanding of phenomena at various length scales has improved. Increased computational powers and our ability to model various phenomena at different length and time scales have made it possible to design and develop new materials and processes. Materials Genomics and ICME aim at accelerated discovery, design, realization and deployment of new materials and has many components ranging from ab-initio calculations to higher length scale modelling (multi-scale modelling), multi-scale experiments for development, validation and verification of models, materials informatics, computational materials science, computational materials design, enabling platforms to facilitate integration and carry out integrated computational materials engineering. India needs to discover, realize and deploy modern materials at a rapid pace to gain technological leadership. The objective of this exercise to take stock of where we are, where we want to be in next 5, 10 & 20 years, identify the gap areas & and develop educational and research roadmap for the country so that we meet the needs of the nation in accelerated discovery, development and deployment of new materials.

MATERIALS EDUCATION

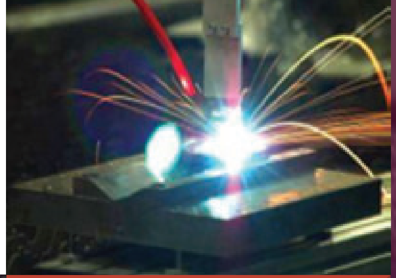
All four themes of this domain require skilled manpower, engineers, scientists, etc. Therefore, a theme on materials education is included to prepare a roadmap of Materials Science and Engineering education in the country.

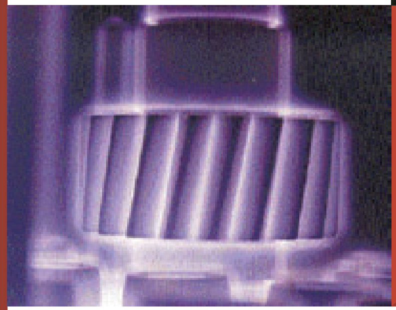
The modern materials scientist or engineer is expected to accelerate the deployment of new, customized materials. This requires a thorough understanding of (I) the effect of atomic composition and structure on material properties, (ii) engineering principles for designing "green" unit operations for the production of materials with desirable properties, and (iii) evaluating material performance under real-life conditions. Consequently, the conventional microstructure-properties-processing based curriculum should be supplemented with topics such as quantum mechanics, transport phenomena, solid mechanics and numerical simulation. In fact, the Materials Science and Engineering (MSE) curriculum should be designed in a manner such that the lectures and laboratories gives students a good grasp of the entire materials life cycle, from materials design to recycling/disposal. The PG curriculum should specifically account for the wide variation in the academic background of its students. In addition, a research strategy should be devised, which would help fulfil the country's current materials needs while simultaneously propelling India towards global materials leadership.

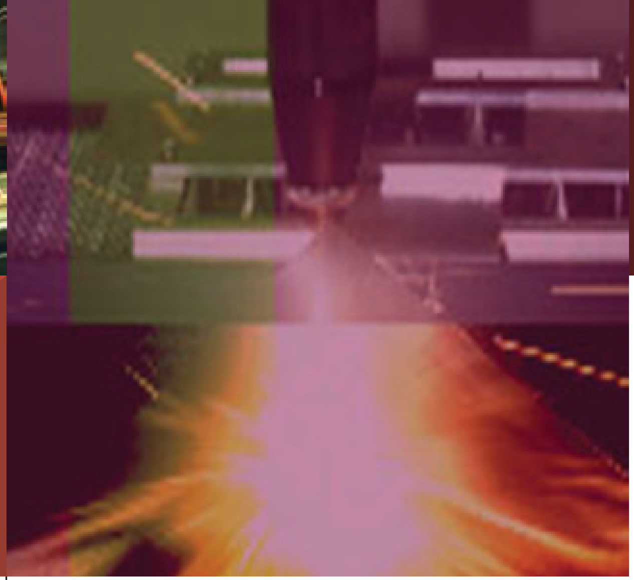
MANUFACTURING

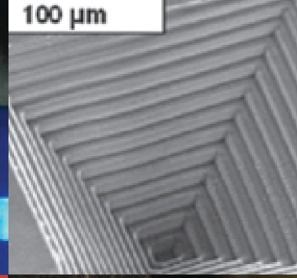
...converting ideas into useful products...

Manufacturing encompasses all the activities of making discrete engineering products from raw material by various processes and operations following a well-organized plan for all the aspects involved. Advanced manufacturing refers to the application of enabling technologies in manufacturing. It is important to realize that the advanced manufacturing systems also require input from the traditional manufacturing, many times with stricter control of dimensions and other technological properties. Therefore, it becomes important to select proper manufacturing processes and strategies to deliver the products with right quality at the right time to the customers at a competitive price in a sustainable manner. The challenges faced by the manufacturing engineers differ from sector to sector depending on the variety and quantity required. Typical manufacturing intensive sectors are automobile, space, health care, energy, textile and defence. It is a well-known fact that manufacturing is a wealth-creating activity. Besides encouraging large scale industries, efforts must be focused on setting up small and micro scale industries. Under the right conditions, young professionals will be able to setup their manufacturing enterprise anywhere in the country. Manufacturing has a distinct advantage of engaging people with different skills, as the activities vary from traditional to advanced levels.









MANUFACTURING PROCESSES

... bringing about changes in shape and property...

PROCESSES FOR SHAPE CHANGES

Processes such as casting, molding, forming and powder metallurgy processes produce net-shape parts. The parts can also be produced by additive methods either by traditional joining processes and advanced processes like laser beam welding, electron beam welding, friction stir welding, or incremental processes such as layered fusion deposition, 3-D printing and laser sintering. To enhance the productivity and to maintain stricter control of dimension and property, continuous improvements and innovations are necessary in the net-shape manufacturing processes. It is possible only through a fundamental understanding of process mechanics and influence of different variables on the process outcome.

Subtractive processes involve removal of excess material to produce parts with required shape, size and finish. For realization of quality parts, the parts made by net-shape or additive processes also require the application of subtractive processes on selected areas. Shearing action by sharp edges on a cutting tool or abrasive grains on a grinding wheel removes material in the form of chip or swarf in traditional processes. When it becomes difficult to shear the material, non-traditional processes based on other sources of energy such as chemical, electrical, laser, plasma and high velocity jet, and different hybrids are used. Further improvement in finish is achieved by honing and super-finishing processes that use abrasive sticks and also by lapping, extrude honing, abrasive flow finishing and magneto-rheological abrasive finishing processes that use abrasives in different carrier medium. In certain applications, chemical, electro-chemical and hybrid processes are used to improve the surface finish. The basic mechanics involved in the subtractive processes are also to be understood thoroughly to improve the productivity and part quality.

PROCESSES FOR PROPERTY CHANGE

Certain parts require changes in bulk material properties at different stages of manufacturing and the material is therefore subjected to suitable heat treatment cycle. For example, molds and dies are easily machined in annealed condition, while through-hardening is done before the final grinding or die-sinking. Changes in the properties of surface layer alone can be achieved by burnishing, peening, surface hardening, laser treatment, coatings, plating, and protective painting. Selection of appropriate method depends on the service requirements.

The manufacturing engineer is expected to know the material properties and the changes that can be brought about by suitable treatments. It is essential to know the charaterization of treated surface and the functional requirements.

VERIFICATION OF MANUFACTURED PARTS

...checking conformance to specification...

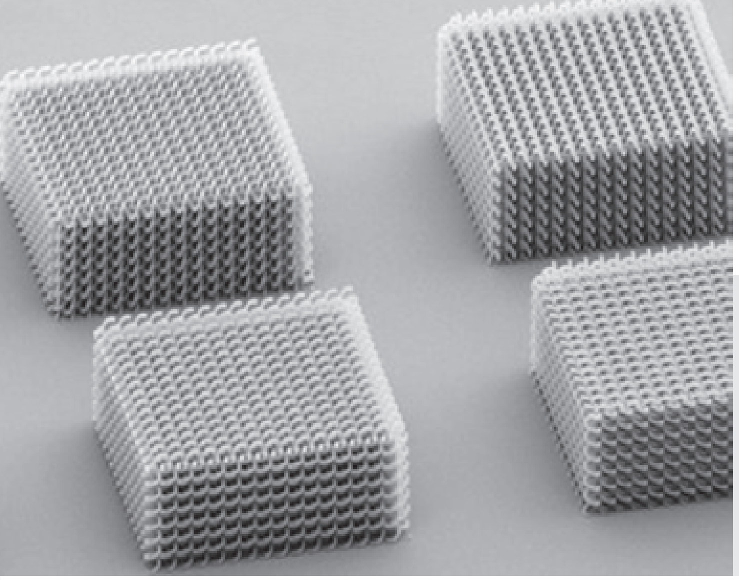
Different characteristics of the manufactured parts are measured by metrology instruments to verify their conformance to specification. It is mandatory that the results are quoted along with the uncertainty in the measurement. For many critical characteristics, 100% inspection is necessary. For non-critical characteristics, sampling inspection is good enough as it reduces the inspection time and cost. It is prudent to introduce verification at intermediate stages and make the operator responsible to produce quality parts.

Systematically carried out measurements are also useful to ascertain the process capability from time to time. A good background in statistics is necessary for the people involved in the measurement and analysis. A suitable training is necessary for people involved in the metrology and inspection tasks. The skill level required is one order higher than that of the process people.

MANUFACTURING EQUIPMENT AND TOOLING

...making machines and accessories to facilitate manufacturing...

The equipment necessary for different processes such as casting, forming, machining and other non-traditional processes are designed and developed by the respective equipment manufacturer. Standard tools and accessories are also available to meet the manufacturing requirements of simple parts. However, industries buying these machines for production of parts with complex geometry have to develop required production tools, namely dies, moulds, special cutting tools and work-holding devices for each part. Sometimes, dedicated machines are needed to enhance the quality and productivity. Manufacturing engineer faces the challenges in developing not only the dedicated machines, but also a number of production tools for the parts. All the machines and tooling are subjected to rigorous inspection by appropriate metrology equipment for qualifying them.



MANUFACTURING

It is seen that many courses on manufacturing have been removed from the curriculum to make way for latest topics that are more descriptive. With the available resources, one can learn them on their own. However, certain core-courses require rigorous classroom teaching and practical training. For example, a course on machine-building must be revived with more emphasis on machine tools development. Also a course on tool design and engineering must be made as a core-course.

ENABLING TECHNOLOGIES

...making machines sense and act intelligently...

The metrology which has remained mostly as a post-manufacturing activity can now be moved closer to manufacturing process as a result of technological advancement. Measurement, automation and information technologies are required to take the manufacturing to the advanced level. Measurement technology must be built into the system with metrology and sensing devices for online monitoring of the process. The process automation is then achieved by signal processing and appropriate feedback control. Automation of tool path movement is done using CNC technology and part or tool changes are handled by robotic arms and such devices. Information technology is useful in CAD-CAM integration and process simulation, and to take manufacturing to web-based and virtual reality environment.

The manufacturing engineer is expected to be familiar with sensor technology, automation and information technology. Unfortunately, even the existing mechatronics courses do not meet the growing demands in the manufacturing sector. Tailor-made programs need to be floated and skill upgradation is done depending on the type of industry.

MANUFACTURING STRATEGIES

...deciding system configuration and practices...

Based on the product design, data analysis and life cycle analysis, configuration of manufacturing system must be arrived using system simulation and intelligent decision support system. Among the approaches like best practices, world-class manufacturing, lean manufacturing, agile manufacturing and other hybrid methods, appropriate practices have to be identified for small, medium and large scale manufacturing. Proper mix of manufacturing and managerial aspects must be ensured for healthy manufacturing environment.

APPLICATION IN DIFFERENT SECTORS

...facing challenges posed by other sectors...

Manufacturing covers almost all the sectors; typical ones being automobile, space, electrical and electronics, energy, health care, textile and defence. Since newer and advanced materials are used in these sectors and the product sizes vary from several meters to few millimeters with feature sizes ranging from millimeter to micrometer, the challenges have to be met only with innovations in processes and practices. In the present context, life cycle cost will be deciding factor in global competiveness. Therefore, it is necessary for a manufacturing engineer to have an in-depth knowledge of cost estimation and control.

The product performance must be monitored throughout its life and this is possible through appropriate sensor technology and data analytics. To cater to these challenges, research and development must be encouraged within the organization. Strong tie-ups with leading research and academic institutions in the country are necessary to promote development of newer products and processes.

EDUCATION POLICY

...Catch them young...

The education and training policy must be evolved to achieve excellence in manufacturing in all sectors. The best approach will be to “Catch Them Young”. Abundant curiosity inherent in the children, as evident from the way they build sand-castles in beach and temporary shelters using discarded material, must be nurtured in the school level. To start with, the children can be asked to make demonstration models using easy-to-cut materials. As they grow, they can make functional parts using locally available materials. In senior level, they can make parts by 3-D printing. School curriculum must have a provision for this practical work.

School-level competition on make-your-part can be held as an annual event. Like popular “science” books on different topics, popular “engineering” books on manufacturing must be brought out. In college/university level, existing completely descriptive or highly theoretical courses on manufacturing must be replaced by courses that include practical aspects in addition to the basic concepts. Even manufacture of a device can be considered as a free-elective and given appropriate credit. At the post-graduate level, a course on manufacturing planning and cost estimation must be introduced.

Special training programs can be offered to students to inculcate entrepreneurship skills and prepare their minds right from the senior school level. Government must encourage young graduates to get into entrepreneurship by removing procedural bottlenecks and offering incentives. Working professionals in manufacturing also require continuous skill upgradation and they may be given certificate on completion of each program.

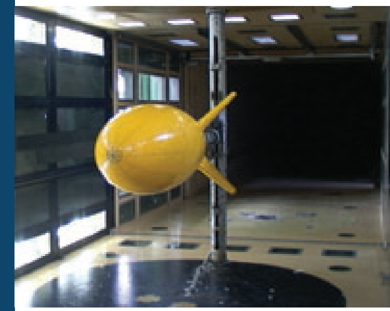
CONCLUDING REMARKS

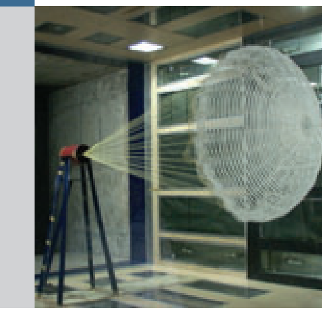
...roadmap for research and education...

With the outline presented above, a roadmap for Research and Education in Manufacturing will be drawn. It is sincerely hoped that the roadmap will provide the directions for students, researchers and practitioners, and ensure progress for our country.

SECURITY AND DEFENCE

SCOPE: Protecting national resources including humans from invasion of any form is crucial to any country and is carried out by its *Defence*. Role of Science and Technology in building a nation's defence infrastructure is the key. In future, attacks may be more *Technical, Information based* and *Accurate*. It may neither involve human beings nor arms and ammunitions (for eg., a Cyber attack). The technological requirements to fight the "Modern War" necessitates a large multi-disciplinary Research and Development framework spread across the Academia and Industry that envisages, formulates and solves the challenges to "fight" the "Modern war" as well as terrorism. The Imprint India initiative will attempt to develop a blueprint of this framework including education policies aimed to generate skilled manpower needed to work on the challenges posed. Defence requirements can be broadly classified into four themes, namely, Life Sciences; Materials; Electronics and Communication Systems; and Combat Engineering Systems. Grand Challenges in each of these themes are presented below.





LIFE SCIENCES

The soldier is as important as the weapon. Ensuring the well being of a soldier is paramount to enable best performance at wartime, which continues to be a challenge that needs to be addressed

HEALTH CARE

Welfare of the soldier on the battlefield is of prime importance. The challenges are to protect them from different forms of attacks; devise effective ways for reaching medical assistance to the site; and, medical treatment procedures for quick healing of the injury. Continuous monitoring of health parameters of a soldier in action is also of prime importance. Specific challenges in this area are as listed below.

- Portable Health Care for quick and accurate diagnosys and First-Aid
- Development of "Regenerative Medicine" for "Rapid Wound Healing", "Rapid Bone-Reconstruction", Injectable scaffolds for bone loss and repair
- Defence health care instrumentation monitoring and expert systems using big Data analytics
- Wearable medical devices for army personnel health monitoring
- Dermal-protection for on-field soldiers

NUCLEAR BIOLOGICAL CHEMICAL DEFENCE

One of the toughest challenges today is to develop capabilities to protect soldiers and common people from the consequences of Nuclear, Biological or Chemical attacks. The toughness is primarily due to the fact that these attacks may not be as *explicit* as a conventional attack like a gunfight and can take place silently. These attacks can cause much widespread damage than the conventional ones. Specific challenges in this area are as listed below.

- Contamination Avoidance, Protection and Decontamination
- Water and food purification systems
- NBC Protective clothing
- Large portable protective tents
- Medical Management of Biological and Chemically Contaminated Casualties
- Hazard estimation
- Radiological Monitor/Survey
- Radiological Hazard Prediction
- NBC Defence Training through simulations and war games

MATERIALS

Materials that aid in development of effective defence technologies are the most vital. The effectiveness is measured in terms of enhanced safety that it provides to systems and personnel.

SMART MATERIALS

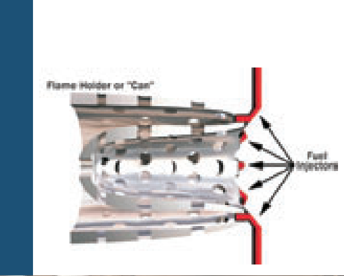
Intelligence need to be built at every level to win a war and that includes the materials used to build defence weapons and systems. The challenge is to understand and model the environment in a battlefield and study the behavior of materials under such environments. Specific challenges in this area are as listed below.

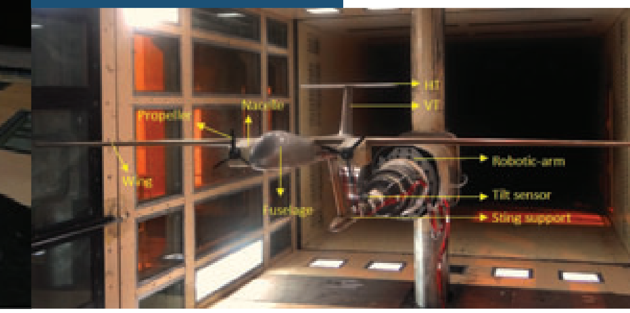
- Design & development of Bullet proof and Blast proof light weight material systems
- Design & development of high frequency/high temperature semiconductor devices & circuits for harsh environments
- Soft magnetic materials for high frequency applications, magnetic markers
- Fabrication of high energy and high power density hybrid supercapacitor
- Explosive Detection, Chemical screening, Super-hard materials, GaN and Ga2O3 material growth and device fabrication, 2D materials and devices
- Development of rejoinable polymeric materials with high healing efficiency
- Development of surface coatings for better corrosion resistance properties under aggressive environment
- Fatigue studies of advanced composite materials for structural application in aircrafts
- Organic molecular electronic materials
- Development of Functional Materials and Light Weight Composites for Stealth Applications in
- RF, Microwave and THz Frequency Range
- Micro Fuel Cell in MEMS used in Missile systems
- Composites with improved electrical conduction, Stealth composites, sandwich structures

SENSORS

In the age of *informed wars* wherein, monitoring of the battlefield need to be done remotely based on different real-time parameters inside the battlefield and guidance provided from a central control center, the challenge is to build weight, size and power optimized sensors that can *accurately* sense these in-field parameters. Specific challenges in this area are as listed below.

SECURITY AND DEFENCE





- Development of RF Sensors, Thin film/Nano sensors, Magnetic Sensors, Self-powered sensors, wearable sensors/textile based technologies for army men
- Sensors for improvised explosive device detection, organic sensors for explosive device detection, Handheld gas sensing system to selectively detect toxic gases.
- Morphing structures, energy generation from vibrations to power up small electronics/sensors

ELECTRONICS AND COMMUNICATION SYSTEMS

All modern defence systems are electro-mechanical as supposed to mostly mechanical systems of the past. Electronics, computing and communication systems form an integral part of the backbone of any defence system. Every system comprises a combination of one or more of the following, namely, hardware, system software and application software.

HARDWARE DESIGN

Effective Hardware design is crucial for building any system. The effectiveness is measured in terms of reliability, weight, performance and power consumption. In addition, in any compute or communication systems the hardware is the *Root of Trust*. This necessitates formal verification of the hardware units. The formal verification process, in turn, requires complete details of all the hardware components driving the need for *total indigenous* development. Specific challenges in this area are as listed below.

- Building modern digital communication modems and network
  - Homeland Security Networks, Boradband Tactical Communication System
  - DTN based messaging Systems and P2P based collaboration Systems
  - Secure Routers and Switches
  - Communication with long range missiles for direction control and target accuracy.
- Formally verified secure systems
  - Framework for guaranteeing end-to-end security, Trojan detection tools and mechanisms
  - Indigenous Microprocessors with High Assurance Boot and Tamper Detect
- Real-time Embedded Signal Processing Systems for RADAR and SONAR applications
- RF, Microwave and Millimeter &Thz Wave Imaging Techniques for Security

Applications

- Real-time Embedded Signal Processing Systems
  - VLSI Architectures for long range Imaging Systems
- Indigenous renewable energy devices
- High performance computing cluster of many-core processing systems
  - Computationally intensive problem solving

SYSTEM SOFTWARE

In the design of any compute or communication system the entire stack ranging from hardware, system software to applications need to be secure. The system software, namely, compilers and operating systems are complex and difficult to analyze from a security viewpoint. In addition, these layers provide the necessary high-performance libraries for development of application software. Specific challenges in this area are as listed below.

- Object code modelling and software verification
- Toolkits for parallel and concurrent programming

APPLICATION SOFTWARE

Software to model environments that are highly multidisciplinary in nature is crucial for defence related design and development. Specific needs are listed below.

- Deep-learning based anomaly detection in dense populated areas
- GPS development, Video Analytics for Surveillance, Compressive Sensing and Imaging
- Virtual Reality for Terrain Exploration, Flight simulation, theater war games
- Artificial Intelligence based applications
  - Planning, Knowledge Representation and Reasoning

COMBAT ENGINEERING SYSTEMS

Combat systems form the front-end of military operations. They need to handle multi-sensor data fusion leading to higher situational awareness with partially or fully autonomous decision-making capabilities. Engineering state-of-the-art combat systems that ensures sophisticated fighting capabilities, mobility and protection is crucial for winning wars. These include the following:

AIRCRAFTS AND SUBMARINES

- National Airspace Systems
- Indigenous Designs
  - Fighter Aircrafts, Flight controller for surveillance quadcopters, Submarines, Micro-aero vehicles and backpack rockets for mobility of soldiers in mountainous areas.
  - Fuel-cell Powered Submarines

BATTLE TANKS

- Automated target recognition
- Battlefield surveillance, guidance and control of vehicles

AUTONOMOUS SYSTEMS

- Terrain exploration and surveillance UAVs of 2000Kg class, high speed, long range and long flight duration
- Autonomous Soldier bot, Command and Control Infrastructure, Collision detection and avoidance.
- Autonomous Systems Certification and Techniques to validate correctness of robotic systems

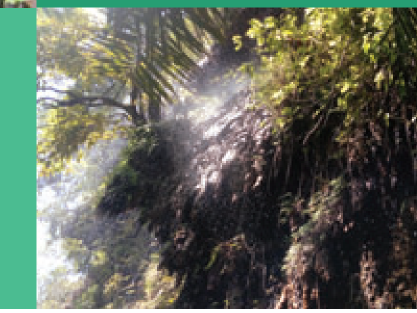
ARMAMENTS AND ENGINEERING SUPPORT SYSTEMS

- Stealth paints, long lasting mini batteries, Blast resistant vehicles, shields and structures
- Fabrication of RFID, LIDAR, Infra-Red optics, Plastic Electronics and Silicon Photonics
- New age engines with solid fuels for gas turbines
- Non destructive testing and assessment techniques
- Hybrid air-water ballistic missile development, underwater acoustic instruments

Smart weapons, Rail gun, Ground Effect Vehicles (Ekranoplane), Super Cavitating Torpedo

ENVIRONMENTAL SCIENCE AND CLIMATE CHANGE

Environmental change, specifically climate change, has emerged as a major concern in the 21st century. Demand for energy, water and food for raising the standard of life are driving the environmental changes. Deforestation and CO_2 emissions from fossil fuels such as coal and petroleum are the main causes for climate change. The major environmental problems for India in the coming decades include air and water pollution, heat waves and changes to monsoon rainfall and glacier retreat due to climate change, impacts of climate change on our food, water and forestry resources, biodiversity loss, sea level rise and the consequent impacts on our coastal communities. Ocean acidification, often referred to as the evil twin of global warming, is also likely to cause disturbance to marine life including corals and fisheries in the Indian Ocean. India has already taken major initiatives to improve our scientific understanding of environmental change and to adapt to and mitigate these changes. Some of the urgent scientific and engineering challenges in the area of environment change are discussed below.



CLIMATE SCIENCE

Locally generated knowledge on climate sciences is strategically crucial for providing sound guidance on the impacts of climate change on various sectors in India. In the last 3 decades, several countries have developed mathematical models to project future climate change but India lags behind in model development. Since climate model development is essentially a scientific and engineering exercise and since there is plenty of expertise in science and engineering in India, India should identify the development of one or more earth system models as a key national priority. Creation of a long term climate observation network and objective assessments of extreme events and climate change impacts on agriculture, forestry, water resources, glaciers, health, coastal zones, corals and fisheries should be also considered as national priorities. Resources for creating skilled manpower in this domain should be provided by the government of India.

MONSOON PREDICTION

Simulation and prediction of the Indian Summer Monsoon on seasonal and intraseasonal scales is one of the major challenges in weather and climate sciences. Skill of numerical and empirical models in predicting monsoons has improved in recent years but there is still considerable scope of improvement. Forecasting skill can be improved by better representation of physical processes in climate models. Dedicated research into numerical methods is also required if India were to develop its own model for weather and climate. With increasing amounts of data available from satellites and other sources, studying monsoons is also a 'Big Data' challenge. Newer machine learning techniques can be used to mine this data and obtain new insight. Improved utilization of this data also requires extensive research into data assimilation to provide better initial conditions for forecasts. All this would require interdisciplinary research combining skills of various IITs and IISc in weather, climate, turbulence studies, applied mathematics and computational science.

OCEAN STUDIES

Oceans play an important role in modulating monsoons. Understanding the interplay between the atmosphere and oceans requires in-situ data collection and modeling. Hence, more oceanic expeditions and high resolution ocean modelling capability would be needed to understand the complex thermodynamic structure and circulation in the Indian Ocean. By taking up anthropogenic carbon dioxide, oceans help to mitigate climate change. They also support corals and fisheries in coastal regions. However, invasion of anthropogenic carbon dioxide into ocean water leads to ocean acidification which is often referred to as the "evil twin of global warming" or the "other CO_2 problem". The acidified waters could be detrimental to marine organisms as calcification rates in marine calcifying organisms could be reduced. Hence, there is an urgent need to study the chemistry and biology of Indian Ocean waters using extensive observations and complex earth system models that simulate the ocean biogeochemistry.

AIR POLLUTION

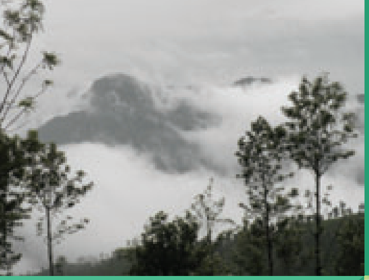
Air pollution continues to remain a public health concern despite various actions taken to control air pollution. The problem becomes more complex due to multiplicity and complexity of air polluting source mix (e.g., industries, automobiles, generator sets, domestic fuel burning, road side dusts, construction activities, etc.). The urgent needs in this theme are extensive data compilation, management and interpretation of the monitored air quality, development of grid based emission inventory of the specified pollutants (PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, benzene, metals and PAHs), meteorological and air quality modeling of these pollutants with prediction capabilities.

AEROSOLS AND CLIMATE

Aerosols are suspended particulates in the atmosphere and they are believed to be mitigating global warming by increasing the planetary albedo, although the sign and magnitude of aerosol effects on climate are uncertain. In addition to contributing to air pollution, aerosols could alter precipitation and winter fog patterns in India. The problem becomes complex when the interaction of aerosols with clouds, their chemical composition and vertical distribution are considered. Resolving the role of aerosol on Indian summer monsoon rainfall and winter fog and mitigation of the undesired effects of aerosol should be priority areas for research.

WATER RESOURCES & WATER POLLUTION

Climate change is likely to affect the Indian Summer Monsoon Rainfall and hence water resources in this country. Climate change impacts in the water sector include potential shortage of fresh water and inadequate ground water recharge. Climate warming is likely to increase the evaporative loss of water from our reservoirs. Increase in irrigation and the consequent decline in ground water storage is also another major challenge in the water



ENVIRONMENTAL SCIENCE AND CLIMATE CHANGE

sector. Further, our water ways are highly polluted by nitrates and heavy metals as a result of excessive fertilizer and pesticide usage in the agriculture sector and by industrial wastes. A rigorous scientific program for improved understanding of water cycle in a changing climate, adaptation of water management strategies to climate change and waste water recycling is essential for the country.

FORESTS AND CLIMATE CHANGE

Forestry is one of the most important sectors in the context of climate change, both from the point of mitigation as well as adaptation. It lies at the centre-stage of global mitigation and adaptation efforts. Yet it is one of the least understood sectors, especially at the regional level - many of its fundamental metrics such as its mitigation potential, its vulnerability and the likely impacts of climate change on forests and carbon stock are not well understood. There is synergy between mitigation and adaptation when considering forest sector: while forests are projected to be adversely impacted under climate change forests also provide opportunities to mitigate climate change. Thus, there is a need for research and field demonstration of synergy between mitigation and adaptations that the cost of addressing climate change impacts can be reduced and co-benefits increased.

GLACIER RETREAT

The Himalayas is home to one of the largest glacier-stored waters outside the Polar Regions. Melt water from these glaciers and seasonal snow form an important source of run off into the north Indian rivers during critical summer months. However, this source of water is likely to decline because of global warming. Therefore, monitoring and modeling the changes in distribution of seasonal snow, glaciers and glacial lakes are important. However, lack of trained manpower and rugged terrain pose major challenges to collection of data on snow and glaciers. A rigorous scientific program on satellite remote-sensing, field observations and modelling is urgently needed to provide guidance on the impacts of potential glacier retreat in the coming decades.

GLOBAL LEADERSHIP

Research in environmental science and climate change in India has been so far mostly limited to the Indian geography. Assessments of climate change adaptation and mitigation have been also limited to India. For India to take global leadership position in the 21st century, this barrier has to be crossed. Merely receiving inputs on global environment and climate change from reports from global agencies would not be sufficient. India should start generating its own knowledge on global energy scenario and global environmental and climate change. Hence, as a long term strategy, Indian government should start promoting observational and modeling research into energy and environmental issues that concerns the entire planet.

CAPACITY DEVELOPMENT

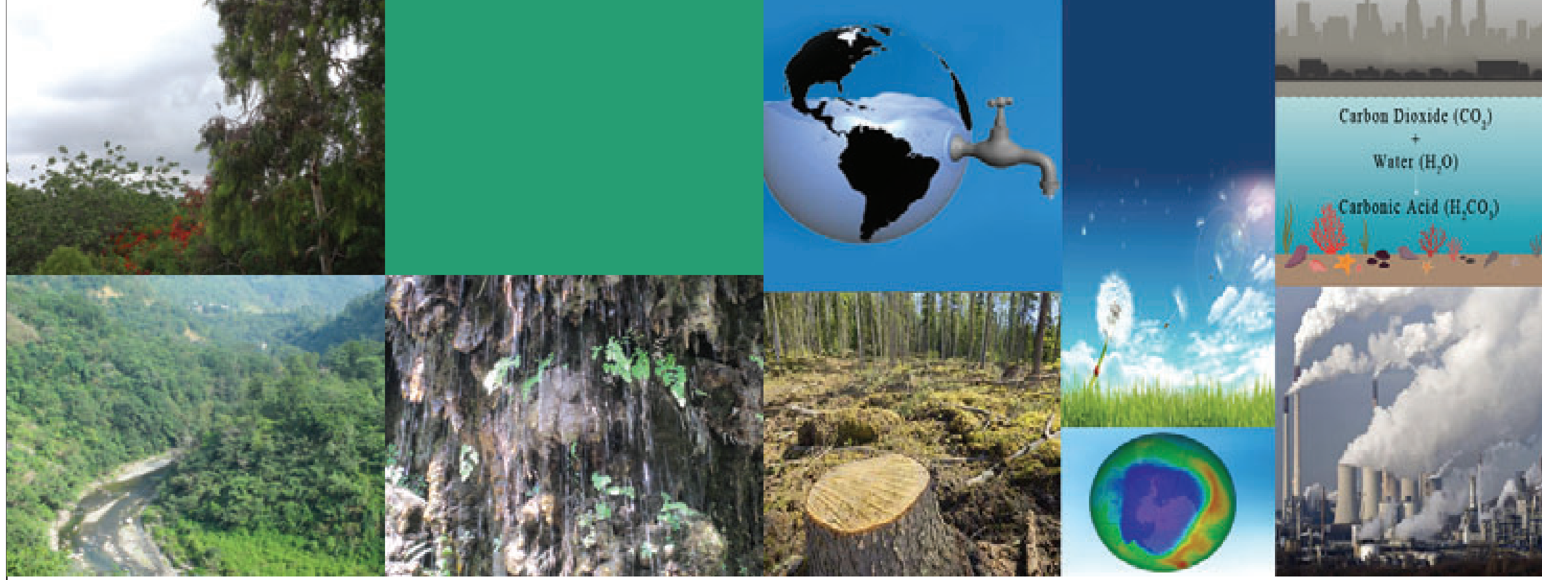
Climate and environmental sciences are fast emerging new sciences around the world. These are interdisciplinary or multidisciplinary sciences that require multiple skills to succeed. Collaboration is the key for success in these sciences and hence mechanisms to promote collaborative research across individuals, disciplines and Institutions need to be formulated. Following is a short, but not an exhaustive, list of mechanisms that are needed to promote the capacity development in this domain.

CREATE CENTRES OF EXCELLENCE IN CLIMATE SCIENCE

Create centres of excellence in climate science at all IITs, IISERs, NITs and central universities for generating the scientific expertise required in this domain.

PROMOTE COLLABORATIONS & TEAM WORK

Create mechanisms or incentives so individuals with expertise in hydrology, atmospheric science, climate science, radiative transfer, aerosol science, satellite meteorology, etc. come together for developing strong modelling and observational capabilities. For example, special funds can be created to allow short term faculty exchange visits across the institutions. More financial support should be provided to groups rather than individuals in order to promote inter-disciplinary work. Such incentives are likely to promote the execution of "big science" projects in this theme.



CREATE NATIONAL DATA CENTRES

Observational and model data collected by individual scientists should go into National data centres for climate and environment related variables. The data should have open and free access.

CREATE NATIONAL SUPERCOMPUTING FACILITY

To promote a true spirit of team work across institutions, initiate mechanisms for creating a National supercomputing facility (which could be part of the National Supercomputing Mission) which can be accessed by scientists working in institutions across the country.

PROMOTE A STRONG POST-DOC PROGRAM

Major research is usually performed by young scientists around the world right after the grant of Ph.D. To tap this vast potential, a comprehensive national policy to encourage post-doc employment should be initiated. These positions should come with the same attractive benefits that are normally offered to permanent employees in research Institutions except that the post-doc positions are temporary in nature. At present, this crucial research link between studentship and faculty is missing because of the lack of an attractive post-doc program in the country.

Illustration of "Environmental Change" Theme
Environmental Issues of 21st century

Illustration of"Climate Change" Theme
Climate Change Impacts

Coordinators

NATIONAL IMPRINT COORDINATOR

Professor Indranil Manna
Director, IIT Kanpur (director@iitk.ac.in)

Convenor

Professor A. K. Singh
Department of Materials Science & Engineering, IIT Kanpur (amarendra@iitk.ac.in)

email: imprint@iitk.ac.in | website: www.imprint-india.org

DOMAIN COORDINATORS

Healthcare

IIT Kharagpur

Domain Leaders:
Professor Suman Chakraborty
Professor Goutam Saha

Contact Details:
suman@mech.iitkgp.ernet.in
gsaha@ece.iitkgp.ernet.in

Energy

IIT Bombay

Domain Leaders:
Professor Rangan Banerjee
Professor Balasubramian Kavaipatti

Contact Details:
rangan@iitb.ac.in
bala.ramanathan@iitb.ac.in

Information and Communication Technology

IIT Kharagpur

Domain Leaders:
Professor Anupam Basu
Professor P. K. Biswas

Contact Details:
anupam@cse.iitkgp.ernet.in
pkb@ece.iitkgp.ernet.in

Sustainable Habitat

IIT Roorkee

Domain Leader:
Professor Pradipta Banerji

Contact Details:
director@iitr.ernet.in

Nanotechnology Hardware

IIT Bombay

Domain Leader:
Professor V. Ramgopal Rao

Contact Details:
rrao@ee.iitb.ac.in

Manufacturing

IIT Madras

Domain Leaders:
Professor M S Shunmugham
Professor N Ramesh Babu

Contact Details:
shun@iitm.ac.in
nrbabu@iitm.ac.in

Water Resources and River Systems

IIT Kanpur

Domain Leaders:
Professor Vinod Tare
Professor P. P. Mujumdar (IISc)

Contact Details:
vinod@iitk.ac.in
pradeep@civil.iisc.ernet.in

Security and Defence

IIT Madras
IIT Delhi

Domain Leaders:
Professor V Kamakoti
Professor Naresh Bhatnagar

Contact Details:
kama@cse.iitm.ac.in
nareshb@mech.iitd.ac.in

Advanced Materials

IIT Kanpur

Domain Leaders:
Professor Monica Katiyar
Professor A K Singh

Contact Details:
mk@iitk.ac.in
amarendra@iitk.ac.in

Environmental Science and Climate Change

IISc Bangalore

Domain Leaders:
Professor G. Bala
Professor Ravi S Nanjundiah

Contact Details:
gbala@caos.iisc.ernet.in
ravi@caos.iisc.ernet.in

Institute Representatives

INSTITUTE	INSTITUTE REPRESENTATIVE(S)	CONTACT DETAILS
IISc Bangalore	Professor G Bala	gbala@caos.iisc.ernet.in
IIT BHU	Professor Prabhat Kumar Singh Professor B. Mishra	psingh.civ@itbhu.ac.in bmishra.phe@itbhu.ac.in
IIT Bhubaneswar	Professor R K Panda	deanrd@iitbbs.ac.in
IIT Bombay	Professor V. Ramgopal Rao	rrao@ee.iitb.ac.in
IIT Delhi	Professor Kushal Sen	kushal@textile.iitd.ac.in
IIT Gandhinagar	Professor Vikrant Jain	vjain@iitgn.ac.in
IIT Guwahati	Professor SRM Prasanna	prasanna@iitg.ernet.in
IIT Hyderabad	Professor Zafar A Khan	zafar@iith.ac.in
IIT Indore	Dr. Bhupesh K Lad	bklad@iiti.ac.in
IIT Jodhpur	Dr. V Narayanan	vnara@iitj.ac.in
IIT Kanpur	Professor A K Singh	amarendra@iitk.ac.in
IIT Kharagpur	Professor Goutam Saha	gsaha@ece.iitkgp.ernet.in
IIT Madras	Professor V Kamakoti	kama@cse.iitm.ac.in
IIT Mandi	Dr. Bharat Rajpurohit	bsr@iitmandi.ac.in
IIT Patna	Dr. Preetam Kumar Dr. Arijit Mondal	pkumar@iitp.ac.in arijit@iitp.ac.in
IIT Roorkee	Professor Arindam Biswas	arndmfap@iitr.ac.in
IIT Ropar	Professor Subhendu Sarkar	sarkar@iitrpr.ac.in

PARTICIPATING INSTITUTIONS

IIT Kanpur, National Coordinator

IIT BHU

IIT Bhubaneswar

IIT Bombay

IIT Delhi

IIT Gandhinagar

IIT Guwahati

IIT Hyderabad

IIT Indore

IIT Jodhpur

IIT Kharagpur

IIT Madras

IIT Mandi

IIT Patna

IIT Roorkee

IIT Ropar

IISc Bangalore