TIFAC

TECHNOLOGY VISION 2035

TECHNOLOGY INFORMATION, FORECASTING AND ASSESSMENT COUNCIL (TIFAC)

DRAFT

TIFAC

TECHNOLOGY VISION 2035

TECHNOLOGY INFORMATION, FORECASTING AND ASSESSMENT COUNCIL (TIFAC)

ABOUT TIFAC

Technology Information, Forecasting and Assessment Council (TIFAC), an autonomous organization under the Department of Science and Technology (DST) was established in 1988. TIFAC is a think tank within government setup which looks up to technologies on the horizon, assesses the technology trajectories and supports technology innovation in select areas of national importance.

DISCLAIMER

The information contained herein has been obtained from sources believed to be reliable. The information contained in sections of the document reflects data that was derived from both public and confidential information collected and received through various consultative processes like brainstorming meetings, workshops, surveys etc. TIFAC shall have no liability for errors, omissions or inadequacies in the information contained herein or for interpretation thereof.

TIFAC

Technology Information, Forecasting and Assessment Council (TIFAC)
An autonomous body of Department of Science and Technology (DST)
'A' Wing, Vishwakarma Bhavan, Shaheed Jeet Singh Marg,
New Delhi 110016, India.
Web: www.tifac.org.in

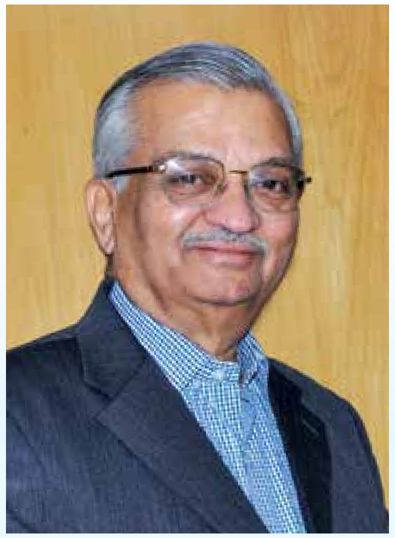
First print: 2015
Published by: TIFAC
Designed by: Alaka Chakraborty Designs

FOREWORD FROM HONOURABLE PRIME MINISTER

MESSAGE FROM MOS, S&T

MESSAGE FROM SECRETARY: DST

CONTENTS



DR. ANIL KAKODKAR
Chairman, TIFAC

TECHNOLOGY IS ONE OF THE KEY DRIVERS for empowering individuals, societies and countries. Technologies that facilitate development in all its dimensions and enhance human capabilities are of particular importance. This is of even greater significance for our country with its handsome demographic dividend. It is imperative that we embark upon an exercise to explore technological possibilities to attain our development goals taking into account new opportunities that we have in the emerging knowledge economy era. While doing so we should set our eyes even on new technology paradigms that might appear in the future and the game changing impact that some of them could offer. A technology vision exercise is thus aimed at capturing possible technology-society horizons through a comprehensive involvement of different stakeholders.

Such an endeavour was undertaken by TIFAC in 1996 with a view to sketch the scenario as of the year 2020. Decade and a half down the line, it is important to repeat such an exercise to review the actual state of play and take into account new possibilities and challenges that would take the country to the year 2035. Hopefully, such rolling exercises would enable a more calibrated approach to evolution of technology related national planning process. I believe this to be essential as new discoveries, innovations in techno-socio-economic space and international dynamics in a highly competitive environment could significantly alter the evolution of technology.

Broadly speaking, the key challenges before India are the following:

- **DEVELOPMENT:** Enhancing its pace in a manner that leads to greater happiness all around us.
- **EMPOWERMENT:** Empowering our youth to embrace emerging knowledge based globalised economy in the most competent manner possible.
- **INCLUSIVENESS:** Bridging the divide by accelerated inclusive access to the process of empowerment of the lower layers of the socio-economic pyramid.
- **SUSTAINABILITY:** Ensuring equitable access to the use of rapidly depleting natural resources or newly discovered substitutes in a sustainable manner while keeping in mind the increasing demands of the large population.
- **ENVIRONMENT:** Ensuring quality environment (air, water, soil and biodiversity) by synergising development and environmental enrichment.

While age-old human needs like food, water, healthcare, communication and energy have to be kept uppermost in mind for Indians in 2035 other aspects of development such as education, habitat, materials, manufacturing, infrastructure, transport and environment also assume considerable weight. Further, since impact of technology depends on the people harnessing it, particular attention would have to be paid to nurturing human resource appropriately.

Articulating some perspectives may be useful at this stage.

EDUCATION

Education being the key to empowerment of people, we have to enhance its quality and make it accessible to all. We need to prepare our youth to be effective and beneficiaries of the emerging A3 (Anyone, Anytime and Anywhere) society. Deployment of ICT, with the emergence of low cost knowledge access devices and rapidly expanding broadband connectivity, should make it possible for all learners throughout the country including in rural domains to access high quality education. Large scale participation of teachers and other experts in this process should raise the quality of our education to global levels. This can indeed lead to a paradigm shift in a more or less non-intrusive manner.

While ICT has the ability to transform quality and reach of education, it also broadens the horizons of individuals by bringing different cultures closer together. Emphasis on value education, pride for one's cultural identity while respecting other cultures and deeper engagement towards achieving higher goals is equally necessary during the formative years of students in order to prevent their undesirable drift as a consequence of the new found liberal environment.

URBAN INFRASTRUCTURE

Urban infrastructure is groaning under continuous and large increase in population caused by migration from the hinterlands. A major cause for this is growing non-viability of agricultural enterprise coupled with lack of adequate livelihood opportunities in rural areas. Leveraging new knowledge and technology to spur economic growth in rural areas can mitigate this situation by providing new livelihood opportunities and urban amenities to rural population. This could make it attractive even to a section of urbanites inclined to rural habitation. To ensure that the technologies are appropriate to local needs and remain competitive, it is important to link implementation of such technologies along with requisite skill training, with a live knowledge/research domain, active right in the rural area itself. Setting up 100 such Integrated Education, Research and Development Complexes (IERDC) where the best of researchers engage in addressing problems of the neighbourhood and engage in skill, technology and entrepreneurship outreach in the surrounding area can bring about radical transformation while enriching local human resource.

GLOBAL RESOURCES

We should rightfully have access to global resources commensurate with the fraction of world population that we constitute. Given our demographic advantage and the potential to enhance human capability, we could perhaps do with less provided we leverage appropriate technology. Such knowledge empowered wiser society, can adopt a more balanced lifestyle with concomitant increase in our happiness quotient. However, our large development deficit as of now cries out for a rapid economic growth even as we exploit our resources, material and human alike, without endangering our environment. This necessitates defining long term strategies and equipping ourselves with necessary technological capabilities. For example, gas hydrates are a major energy resource for India. Our ability to exploit this resource on a large scale could make a significant difference to our energy security.

Seen in the context of threat to climate change, a quick look at our energy resources and requirements in the long term would reveal that we must focus on solar energy and energy from Thorium for securing our sustainable energy future. Here again both require significant India specific technologies needing large scale indigenous technology development effort. Our R&D infrastructure and its linkages with industry should therefore be configured to achieve such an objective. We should also target reaching a significant fraction (say 50 %) of electricity supply coming from non-fossil sources like renewable (hydro included) and nuclear energy by the year 2035. To ensure our long term energy resource security, our effort to develop fusion energy and our participation in the International Thermonuclear Experimental Reactor is of crucial importance. Search for better resource use efficiency including need for technology shifts is another area that needs attention. For example, greater use of DC appliances in light of expected large scale growth in roof top solar generators could lead to significant energy savings and also cost saving in the long run. Similarly, there are possibilities for exploiting our large scale Ilmenite deposits as well as liquidating red mud dumps to produce titanium, steel and other outputs in a more competitive way with reduced environmental burden.

DEVELOPMENT POLICIES

Our development policies have to be holistic in nature as they often impact more than one sector at the same time. Demand/supply dynamics of any one sector cannot be the sole factor in devising policies as they impact those in another and vice versa. For example, supply of unmetered electricity for agriculture has led to over exploitation of ground water and higher tariff for industry. Instead, promotion of standalone solar powered pumps could correct the situation on both counts with significant gains in terms of carbon emission, conservation of ground water and competitive industrial production. Similarly, there are opportunities to promote solar lights in areas where grid electricity has not yet reached and save on corresponding use of kerosene and a substantial part of related subsidy. Proper management of bio-degradable urban and rural waste can lead to lowering methane emission, environment friendly energy, enriching of soils through replenishing carbonaceous matter and reduced public health management burden.

In the context of the need to grow manufacturing sector, we need to shift emphasis away from personalised vehicles running on fossil fuels to defence manufacture and manufacture of mass transportation systems that are resource efficient. Likewise greater thrust should be given to enhancing railway track density before adding to the train density. A number of Defence Economic Zones (say six) that can cater to around 80% of defence equipment produced indigenously, each linked with a knowledge domain (institution engaged in PhD level research) leading to unprecedented innovation environment, could lead to large scale boost to growth in GDP and reduction in current account deficit.

To enable such holistic approach to policy making, a process based on a comprehensive understanding of cross cutting issues involving multiple concerned departments in the decision making process would need to be evolved.

ENVIRONMENT ISSUES

Environment issues are often seen as impediments to project development. We need to recognise that growing population and consumption would lead to ever increasing environmental burden. On the other hand a properly conceived development project with due attention to minimising environmental impact could lead to wealth generation, some of which could be utilised towards enriching the environment. Environmental appraisal of a development project should thus be based on comparing a do nothing scenario that would invariably lead to some degradation of environment, with the environmental impact of the proposed project and a demonstration of net benefit to environment.

TECHNOLOGICAL SOLUTION

While the actual choice of a technological solution would be dictated by expectations and aspirations of society at large and also by considerations of cross cutting issues, one must be on the lookout for new technological possibilities that may appear on the horizon as a result of ongoing open ended research. There are several instances in the past when major paradigm shifts have taken place following adoption of such game changing technologies. Ability to be ahead of others in such areas would determine our competitive edge on the global stage. While one can never be sure of how the future would unfold, sustained efforts in some of the emerging areas of scientific research such as nanoscience, 3D printing, new materials and tailored precision processing, biological manufacturing, hand held devices could lead to very desirable outcomes.

ELECTRONIC COMMUNICATION

As we enter the ICT age, wide scale use of fast electronic communication systems, for accessing and exchange of information and data as well as for a variety of transactions, has resulted in complexities in the cyberspace leading to regional, national and even global security threats. Development of relevant security related technologies that are free from vulnerabilities is thus extremely important. National security issues today arise not just from economic and military strength as perceived by adversaries but also from ethnic, religious and ideological conflicts, trade and economic conflicts, potential misuse of technologies during inter personal conflicts and other such factors. Additionally there are global dimensions to security issues which include those arising out of transnational, trans-cultural and non-state actors. Technological solutions meeting these multifarious security requirements would also have to ensure that justice and privacy for all individuals and the society are not compromised. While all these issues of national security are discussed at some length in this document defence related technologies are not covered as a part of conscious decision.

QUALITY RESEARCH

Quality research, that pushes the knowledge frontiers forward and explores potential applications, should be a part of a conducive innovation ecosystem that links it to entrepreneurs and industry/society on one side and young students on the other. Nurturing industry institute interaction in a variety of ways such as; joint problem solving, participation in teaching/ learning and industry research park located on the institution campus with structured opportunities for participation of faculty and students, is thus of crucial importance. Incentivising industry to leverage such an ecosystem to develop new products should be part of the strategy to accelerate national technology capability build up.

MSMEs have contributed significantly to employment generation as well as exports. Most of these units are not in a position to invest in R&D. As a result, they run a risk of obsolescence and loss of competitiveness. Linking them up with knowledge institutions could lead to a win-win situation.

Twelve sector specific committees have discussed their perceptions as well as inputs collected/received pertaining to their sectors and come up with detailed reports. They along with this main document constitute Technology Vision 2035. The entire activity was overseen and guided by a national apex committee. I would like to thank everyone among the large number of individuals who have been involved in this extensive task and look forward to feedback on the document.

DR. PRABHAT RANJAN
Executive Director, TIFAC

TIFAC **INDIA'S TECHNO-LOGY** think tank keeps an eye on future technology trends and tries to delineate possible technology trajectory that the country needs to take. In 1993, TIFAC resolved to create a long-term vision for India and conducted a well known mega-exercise Technology Vision 2020. This was one of most comprehensive exercises ever undertaken with a realization that technology is the fastest way to make India developed. Reports covering 16 sectors of socio-economic importance were released in August 1996.

In response to the major changes in economic situation, geopolitics and technology domain at a global level in the last two decades, TIFAC is presenting a fresh perspective on technology imperatives for India as Technology Vision 2035. The document is prepared on a consultative framework and is being placed as a referential document to inspire all the stake-holders. It roots itself into the collective aspirations of the people of India, the ambitions of our youth and the likely expectations of Indians in 2035 as the country grows.

A blend of bottom-up and top-down approach lies in the design of this visioning exercise. On the one hand, people across the spectrum were consulted in multiple ways to anchor the vision, notably through regional brainstorming meetings, thematic interactive sessions with students, faculty and technocrats, open online surveys, etc. On the other hand, a large number of experts were consulted to get deeper technology insights and perspectives, at different stages of exercise. Inputs from both the channels were studied in detail and synthesized to evolve the technology vision for the country.

A vision by itself would not serve any purpose unless appropriate actions are outlined and acted upon, to realize the bigger objectives. Based on in-depth analyses and discussions during the scoping phase of the exercise, following 12 sectors were identified for sharper focus:

- Education
- Medical Sciences and Healthcare
- Food and Agriculture
- Water
- Energy
- Environment
- Habitat
- Transportation
- Infrastructure
- Manufacturing
- Materials
- Information and Communication Technology (ICT)

While this document foresees the type of Indians in 2035, identifies their needs and technologies needed to fulfil them, the roadmap of each of the above sectors would provide existing status, future projections and the gaps or challenges in detail besides plotting the future technology trajectories.

A massive exercise with a very wide landscape, spread well over three years, involved around 5000 experts directly and about 20000 indirectly. The exercise was conceived and guided all through by Dr. T. Ramasami, Former Secretary, Department of Science and Technology. Shri Sanjay Singh, the then Scientist-in-charge, put together a TIFAC team headed by Dr. Gautam Goswami to carry out the exercise.

A National Apex Committee under the Chairmanship of Dr. Anil Kakodkar, steered and guided the whole exercise. Dr. Kakodkar took keen personal interest and guided each step of the exercise. Besides this Committee, there were 12 Advisory Committees which provided sectoral perspectives and foresights for this definitive document.

The vision document emerging out of the exercise has been authored by Dr. G.P. Phondke, Professor Varun Sahni and Dr. Harit Santhanam after several sessions of deliberations with Dr. Kakodkar, Dr. Goswami and myself. Prof. Dhruv Raina, JNU provided valuable insights on technology and society while Dr. G.P. Srivastava shared perspectives on security technologies.

A dedicated team of TIFAC scientists comprising of Dr. Neeraj Saxena, Ms. Jancy. A, Dr. T. Chakradhar, Ms. Mukti Prasad, Mr. Manish Kumar and Ms. Swati Sharma provided comprehensive technology insights and foresights besides ensuring the final form that this document is in. Project Associates engaged for the exercise Mr. D.P. Singh, Dr. Harmanmeet Monga, Ms. Sandhya Singh, Dr. Vineet Thakur and Ms. Ananya Sharma, efficiently supported us through desk research, data collection and analysis. Other TIFAC colleagues also contributed at various stages, specifically participating in brainstorming sessions and scenario building.

I sincerely expect that this vision document will ignite the minds of all stakeholders and inspire them to respond to the 'call to action' this document issues, to turn the dreams of Indians into reality.

EXECUTIVE SUMMARY

THE DOCUMENT BEGINS with a retrospective glance at Technology Vision 2020, TIFAC's first attempt to envision India's technology future. In analogy with the four gaits of the horse, various technological sectors have been categorised into galloping, cantering, trotting and walking India.

The document articulates a vision for all Indians in 2035. This is not a vision of technologies available in 2035 per se; rather, it is a vision of where our country and compatriots should be in 2035 and how technology would bring this vision to fruition. In order to explore the technology dimensions of this vision, this document is divided into six sections.

The first section focuses upon the needs of Indians in 2035. It analyses the basic needs – security, prosperity and identity – of various segments of our vast population in 2035 and also proposes multiple ways in which the relationship between these needs could be envisaged.

The second section delineates twelve 'prerogatives' of all Indians in 2035 that (i) emanate from the vision, (ii) are linked to basic needs and (iii) can be expressed as specific targets. Starting with the most elemental and individual and culminating in the most comprehensive and collective, the twelve prerogatives are: (i) clean air and potable water; (ii) food and nutritional security; (iii) universal healthcare and public hygiene; (iv) 24x7 energy; (v) decent habitat; (vi) quality education, livelihood and creative opportunities; (vii) safe and speedy mobility; (viii) public safety and national security; (ix) cultural diversity and vibrancy; (x) transparent and effective governance; (xi) disaster and climate resilience; and (xii) eco-friendly conservation of natural resources.

Critical technologies that would help achieve these prerogatives are identified and also placed on a timeline made up of four stages: technology that already exists and is therefore ready for deployment, technology in pilot scale that must be scaled up in order to move from lab to land, technology in the R&D stage that involves further targeted research, and technology that is still in the imagination and could come about as a result of curiosity driven, paradigm shattering ('blue sky') research.

The third section assesses three critical 'transversal' technologies – materials, manufacturing, and information and communication technology (ICT) – that provide the sub-stratum upon which the edifice of all other technologies is constructed. In addition, this will require robust supportive infrastructure. Technology development cannot take place in isolation; it depends upon an enabling ecosystem and a culture of teamwork. It also has to rely heavily on cutting edge fundamental research. Hence, the section highlights the importance of fundamental research in achieving the technology vision.

The fourth section focuses on the capabilities and constraints in India's technological landscape. It categorises technologies along a six-fold classification from an Indian perspective. Technology leadership relates to those niche technologies in which we have core competencies, availability of trained and skilled manpower, supportive infrastructure, intellectual environment and traditional knowledge base, and in which we can therefore seek to assume a leadership role. Technology independence pertains to those technologies that we would be forced to develop on our own because they are of critical importance and would simply not be available from elsewhere. Technology innovation is about linking disparate technologies together or taking a breakthrough in one technology and applying it to another. Technology adoption involves obtaining technologies from elsewhere either by purchasing them or by collaborative approach and then modifying them to suit our needs, thereby reducing permanent reliance on other sources.

The next category is technology dependence: those technological areas in which our country would remain dependent either for reasons of infancy (technologies in which India is at the infancy stage and is likely to remain behind the curve in the longer run), insignificance (technologies which are not likely to have a significant imprint on India's trajectory of growth in the next 20 years) or redundancy (technologies which could easily be purchased from elsewhere and whose development would only tantamount to reinventing the wheel at a high cost). Finally, technology constraints pertain to those areas in which technology is threatening and problematic, either because of its negative environmental or social impact or because of serious legal and ethical issues.

The fifth section is about the principal actors and key activities that would be critical to India's technological transformation. Apart from the 'who' and 'what' issues, the section also focuses on the 'what' question by proposing a set of ten Grand Challenges – some purely technological, other involving an admixture of technology and implementation – that have the capacity to capture the imagination, focus on energies and talents, and transform the country. It also addresses the issue of implementation modalities and suggests that national mission approach could be one such implementation modality.

The sixth section concludes the vision documents by reflecting upon the impact of technology on comprehensive national power. The thrust of this section is that technological transformation would not only change India for the better internally by improving the lot of all compatriots, it would also fundamentally alter India's external environment for the greater advantage of the country.

Finally, a glossary explicates the various technologies mentioned in the vision document for the benefit of both experts and laypersons.

Along with the Technology Vision 2035 document, TIFAC is also bringing out parallel comprehensive Technology Roadmaps on 12 select sectors: Education, Medical Sciences and Healthcare, Food and Agriculture, Water, Energy, Environment, Habitat, Transportation, Infrastructure, Manufacturing, Materials, Information and Communication Technology. Technoscape, a snapshot of the 12 roadmaps is included as a separate handout along with the document.

While this vision document walks toward the future taking into consideration the country as a whole, the technology roadmap of each sector would provide details outlining future technology trends, R&D directives, pointers for research, anticipated challenges and policy imperatives pertaining to each sector.

RETROSPECTION: TECHNOLOGY VISION 2020

TECHNOLOGY VISION 2035 (TV 2035) is not the first articulation of a Technology Vision for India. In 1996, Technology Vision 2020 document prepared by TIFAC, under the leadership of Dr. A.P.J. Abdul Kalam, then Chairman, TIFAC, was released by the Hon'ble Prime Minister. The explicit aim of TV 2020 was to provide directions for national initiatives in science and technology to make India a developed country by 2020. Sixteen sectors and more than 100 sub-areas of technology were assessed, including food and agriculture, agro food processing, life sciences and biotechnology, healthcare, electronics and communications, telecommunications, road transportation, waterways, civil aviation, engineering industries, materials and processing, chemical process industries, strategic industries, electric power, advanced sensors and services. Inspired by this exercise, many ministries, departments and organisations subsequently undertook similar vision exercises in their own areas. In line with the recommendations of TV2020, TIFAC undertook specific projects in agriculture and fisheries, agro food processing, road construction and transportation equipment, textiles, healthcare and education. These projects were successfully implemented through collaboration with industry, R&D institutes and other stakeholders. Some industries used these projections to develop their own niche areas of strengths.

TV 2020 was issued in the backdrop of liberal reforms underway in our economy in the early 1990s. From the brink of economic bankruptcy, Indian economy had made a strong comeback and for the first time since independence, it looked as if India would finally be able to do justice to its huge size, rich resources and human potential. The changes in the domestic sphere were buttressed by transformations in international politics (the end of the Cold War) and international economics (the rise in volume and velocity of globalisation). In the context of these massive transformations, India with its strong democracy and resources – both human and material – was particularly well placed to harness the new opportunities. TV 2020 was a response to the expectations that this new narrative of India's growth had raised and the challenges that India was expected to confront in the next two and a half decades. While India's self-imposed isolation had proved beneficial in achieving self-reliance in a number of industries, on the balance its offsets proved to be more daunting since cutting-edge technological research remained a pipedream in many spheres. TV 2020 was therefore in some ways also the affirmation of a new vigour in Indian technological universe.

In the two decades that have passed since that exercise, India has quickly moved up the global power ladder. It is today counted in the league of actors poised to have a significant influence on the world in the coming decades. Fittingly therefore, the nature and the mandate of the current exercise is different from the one conducted two decades ago. TV 2020 spoke from the point of view of India of 1996, while TV 2035 speaks from the standpoint of India of 2014. Post-independent India has never been more different in any two decades than between 1996 and 2014. In these intervening years, India's GDP has multiplied more than six times. Consequently, while TV 2020 spoke to an aspiration of a developed India in 2020, TV 2035 speaks to the realisation of a developed India in 2035.

Like every vision, TV 2020 was a prisoner to the imagination of its own times. One could argue that it could not have been otherwise. Any retrospective exercise must necessarily be a humble effort aimed at assessing our advances and taking stock of our lacks. The historian J.P. Maitland's words – 'what is past today was once in future' – alert us to the pitfalls of beating the past with the sticks of present. Alive to this realisation, technology forecasting must necessarily look at the past with chromatic lenses. The past should serve as a prologue, but it should not unnecessarily encumber the vision for future. In that spirit we must view TV 2035 both as a sequel and as a completely independent exercise that moves beyond the mandate and the vision of TV 2020. This retrospective section speaks to TV 2020 from the standpoint of a follow up, while the following sections elucidate on a vision that is future driven, not past situated.

For our purposes of stock taking, the metaphor of horse gait may serve us as a fitting analogy for how India has progressed on the expectation meter of TV 2020. There are mainly four ways in which a horse moves – gallop, canter, trot and walk [*see infographic*]. Similarly, on the parameters of TV 2020, India has galloped in some areas and cantered to keep pace with the expectations in others. There are some others where India has trotted to come significantly far away, however it has not been enough to reach the desired destination in time. And finally, there are areas where India has only walked to make little progress. The reasons for each of these gaits have been both internal and external. Much as international technological advancements as well as embargos have helped or impeded our growth, our own technological prowess has made us confident gainers in some sectors. Similarly, the lack of indigenous technologies or endogenous strengths in some other sectors has left India in a situation which is not to be desired.

Lessons Learnt

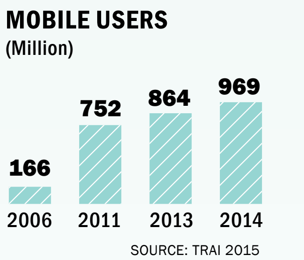
The reasons for India's progress or the lack of it in the past two decades could be attributed to a number of factors. In some of the sectors where India has galloped, such as information technology (IT), it was the coming together of several facilitating factors, internal and external, that helped India catapult into the centre of global computer revolution. Among these were the building of advanced indigenous communications and computing capabilities in the late 1980s, resulting in the development of India's large young talent pool as well as targeted investments in developing a satellite communications network. The large technically qualified Indian diaspora helped bring a synchrony between developments in India and economic and technological changes at the global level. While these investments did eventually seem to pay off in the 1990s, it was soon realised that the prioritisation of these sectors had also come at the cost of low investments in other sectors such as primary education and health. What is particularly worrisome is that despite India's rising economic power, India continues to remain at the bottom half of most of the HDI indicators.

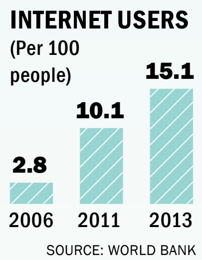
The foregoing account however also alerts us to the reality that in most sectors ranging from ICT to transport to agriculture, while we have made quantitative leaps, the concomitant qualitative technological improvement is still only a desire. In most of the industries, Indian expertise still remains at the basic or intermediate level of technology and we have not adopted global standards of design and performance.

RETROSPECTION: TECHNOLOGY VISION 2020

GALLOPING INDIA

TELECOMMUNICATION
India has the second highest telecom subscriber base (2010)





SPACE TECHNOLOGIES
India has emerged as a significant player in building & launching satellite to both polar and geo-synchronous transfer space orbit

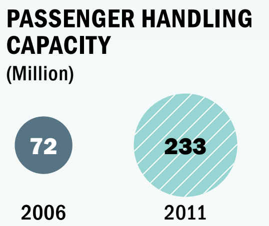
NUCLEAR TECHNOLOGIES
Leads with advanced nuclear technology like Fast Breeder Reactor

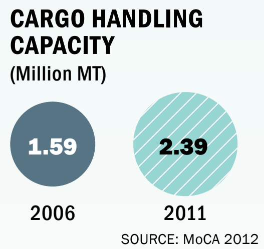
MISSILE TECHNOLOGIES
Self reliance in missile technology with successful completion of Integrated Guided Missile Development Programme (IGMDP).

LIFE SCIENCES, BIOTECHNOLOGY
Spearheading low cost drug delivery to deprived sections in India and other parts of the world.

CANTERING INDIA

CIVIL AVIATION
Ninth largest civil aviation market in the world, still no indigenous aircraft manufacturing capability.



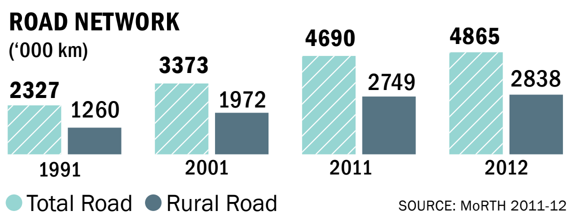


SERVICES
Contributes to 60% of the country's GDP, but skewed IT enabled services (ITeS) in rural India.

CHEMICAL PROCESS INDUSTRIES
12th largest producer in the world & 3rd largest in Asia in terms of volume, but a net importer of chemicals.

SOURCE: TV2035 MANUFACTURING TECHNOLOGY ROADMAP

ROAD TRANSPORTATION
Notable progress in road infrastructure, but economic losses due to inadequate maintenance, poor handling of congestion and increasing accidents

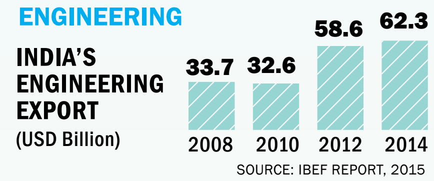


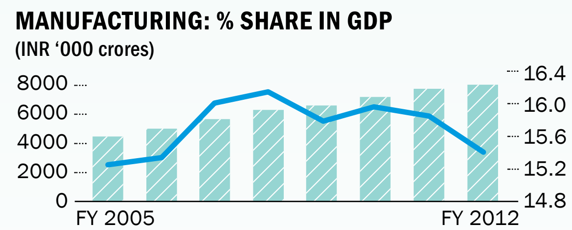
TROTTING INDIA

FOOD & AGRICULTURE
Wastage of one-third of the produce hinders growth, but still manages to contribute 10.3% of India's total exports in 2013-14.

SOURCE: MINISTRY OF COMMERCE, 2013-14

ENGINEERING





ELECTRONICS & COMMUNICATION
Leader in software export; on the flip side, is also a large importer of critical hardware & general use electronic items.

15.64% India's share in world software market in 2013-14

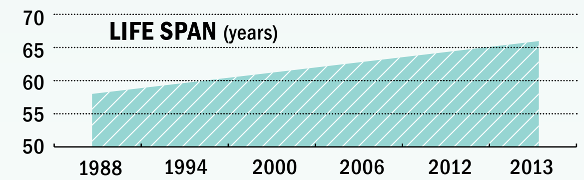
<2% India's share in world electronic equipment production in 2013-14

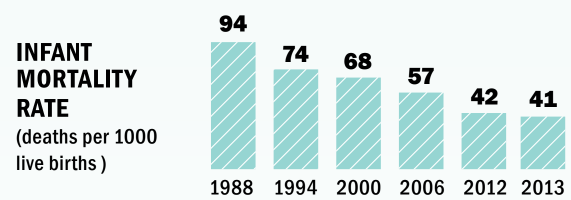
SOURCE: ESC REPORT

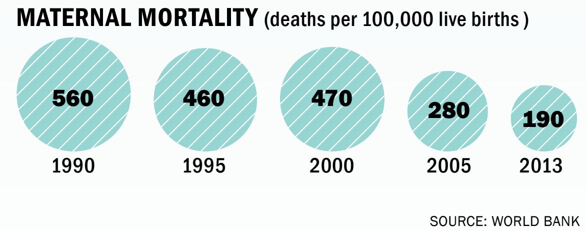
MATERIALS & PROCESSING
Industry rising in sectors like Steel though technology breakthroughs in metals like Titanium, Nickel, Magnesium etc still awaited; De-growth in mining sector prevails

WALKING INDIA

HEALTHCARE
Lack of affordable healthcare systems, inadequate infrastructure and expensive diagnostics



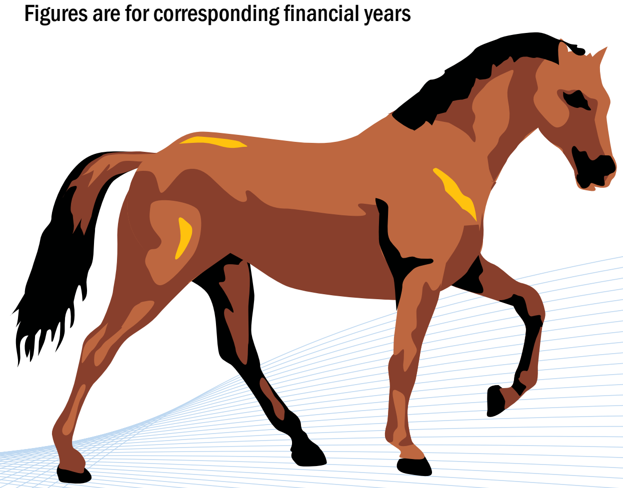




ADVANCED SENSORS
Low indigenization, banking solely on import.

WATERWAYS
Less than 1% share of cargo; short of fairways, terminals, navigation aids and fleets

Figures are for corresponding financial years



We are still heavily dependent on foreign advanced technologies, at times even at the cost of disregarding the indigenous potential. While the R&D institutions across the country must share some of the blame, a weak R&D and innovation culture in the country is glaringly disempowering to the scientific community. With less than 1 per cent of the GDP spent on R&D, most of which is out of public funds, the translation of research to commercialisation remains forever strapped for funds. However, the increasing private investment in R&D in the past few years is a healthy development. Further, although India has a huge pool of human resources, it has not invested enough in creating skilled manpower. This could prove to be a significant dampener for India's much acclaimed demographic dividend, if among other things the education system is not recalibrated.

This suggests more generally to the slack at top of the chain. Wherever policy formulation and implementation has been quick with a clear political vision, such as in case of the roadways, the results are for all to see. However, this has more or less been the exception rather than the rule.

Bureaucratic bottlenecks, lack of inter-departmental synergies, prioritisation of continuity over innovation, and a laidback management style are some of the bureaucratic issues that plague implementation of various schemes. Consequently, in some areas the Indian scientific community is faced with an unpleasant scenario in which even after requisite technologies are developed and demonstrated, little efforts are taken to replicate or scale them up. Further, in the past few years, environmental and public concerns have become central to any development-related policy planning and impose additional constraints. They have to be wedded into any policy planning exercise rather than added later on.

> Wherever policy formulation and implementation has been quick with a clear political vision, the results are for all to see.

Finally, any technological audit must also take into account the rapid transformation of global publics in terms of their consumption patterns, lifestyle needs and expectations from technology. One could argue that the 21st century is a 2.0 version of the previous century. Like all 2.0 versions, not only are some of the needs of this version different from its previous version, but it is also expected to provide efficiency and speed that the previous version never promised. Consequently, TV 2020 may not actually be the ultimate basis of how we judge the advancements in the new century.

In this synoptic overview of the technological landscape – the highs, the plateaus and the lows – of India's progress in the last two decades, the emphasis was on devising technological solutions that would ultimately benefit the people. TV 2020 was undoubtedly a very useful and fruitful exercise, pathbreaking in the sense that it was the first such exercise and also in the sectoral initiatives that it spurred. Since visions evolve, it is necessary that the next vision exercise should be initiated even before the duration of the last exercise expires. Also, emphases change subtly with the passage of time: one, the aspirations of people change, but so too does the capacity of the system to create and absorb technologies. The TV 2035 exercise therefore first identifies people's aspirations and then looks for the optimum technological options to meet them. It considers the technological 'peoplescape' of India to be as important as its technological landscape. Fully cognisant that there is no India without Indians, TV 2035 speaks to – and of – all Indians.

VISION FOR 2035

"Technology in the service of India: ensuring the security, enhancing the prosperity and strengthening the identity of every Indian."

INDIA NEEDS TECHNOLOGY. That much is obvious. But why do we need a technology vision for India? After all, vision is a very nebulous, amorphous entity. Even in mind-space, vision refuses to take a distinct shape with sharp outlines. The Nobel Prize winning psychologist Daniel Kahneman articulated this best when he stated that 'we perceive our future as anticipated memories'. The innate survival instinct that dominates our thought processes, if not our actions, makes it imperative for us to find an anchoring point even when we wish to fly freely. Even when we look far ahead into the uncertain future, we tend to have our feet firmly placed in the present. That is why most forecasts are mere extrapolations of current situations. That would not do for a vision statement which requires elements of dreaming to be brought to the fore.

Before we specify precisely what this document is, we must emphasise what it is not. Firstly, this document is not a prediction exercise. It does not seek to say: 'This is what is likely to happen.' Secondly, nor it is a foresight exercise along the lines of 'This is what we can envisage.' Thirdly, it is not even a projection exercise: 'Given where we are, this is where we will be.' Instead, this document is a culmination of the vision exercise: 'This is where we would like to be.' A vision exercise is forward looking; it is about aspiration and inspiration. The danger in this approach, of course, is that it can end up being completely disconnected from reality. We need to have our head in the clouds, but our feet firmly planted on the ground. In order to create a junction between aspirations and reality, we seek to answer five broad questions in this document:

1. Where are we now?
2. Where would we like to go?
3. What is the best way to get from here to there?
4. What technological interventions can help us to get from here to there?
5. What impediments will technology throw up along the way?

Where would we like to be positioned in 2035, both by ourselves and on the world map? This can perhaps now be stated with a certain degree of clarity with the vision statement:

"Technology in the service of India: ensuring the security, enhancing the prosperity and strengthening the identity of every Indian."

OUR ASPIRATION

WE, the People, would like to be citizens of a united and vibrant democratic country that is self-confident and is strategically, physically and financially secure. In our country, universal and easy access to all type of financial services would be considered a basic right of the citizen. We would like to see all those factors that create divisions among us to be eliminated by ensuring that real tangible growth spreads to all sections of our society in an equitable and inclusive manner. We would like to see our country transformed such that there are no severe extremes of income distribution. Towards this goal, we would like to see in our government a caring institution that we can trust, relate to and communicate with and which provides us with a blanket of assurance. We would like to ensure that all public expenditure is transparent and accountable. At the same time, all transactions of the government and administration, be they collection of revenue or payments of subsidies in cash or kind, are carried out through technological means. In other words, we would like to see genuine e-governance albeit with a human face. We would have a system which ensures universal availability of legal protection and speedy justice delivery.

We would like the country to be self-sufficient, both qualitatively and quantitatively, in meeting basic human needs of nutrition and health, energy and habitat, education and connectivity. Habitats that provide us with climate neutral ambience would thus be a prerequisite. We would want sufficient quantity of nutritious food that satisfies our biological needs for leading a healthy life. Our farming communities would benefit from climate resilient, environmentally benign, financially remunerative and globally competitive agricultural practices. We would like to live in a country in which there are no sharp urban-rural divides on issues relating to quality of life. Every citizen, irrespective of his/her place or residence, will get clean drinking water in adequate amounts, enough power 24x7 and facility to communicate with not only fellow citizens but brethren in any part of the world.

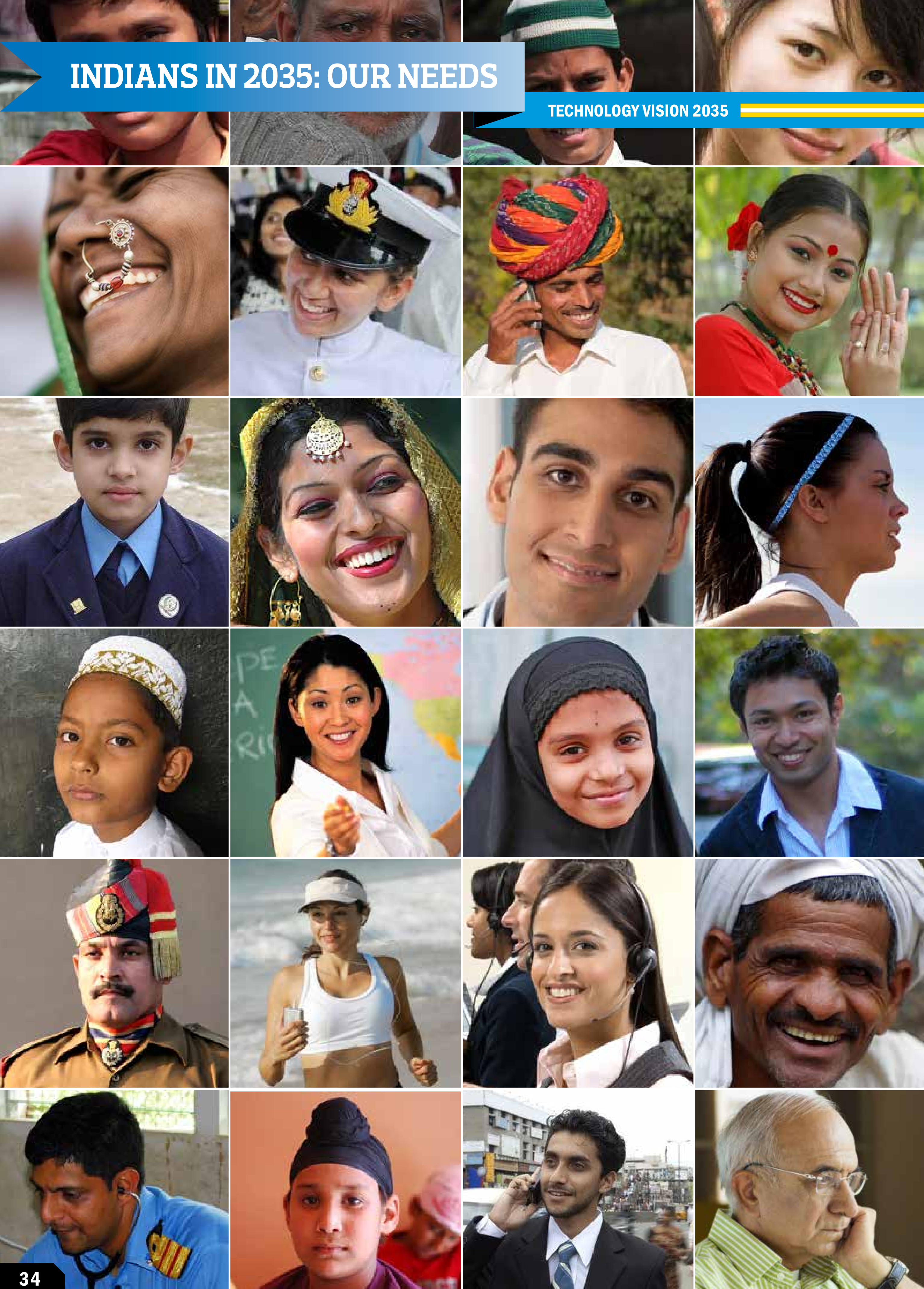
We would like to ensure that every expectant mother enjoys healthy and incident-free period of gestation and delivers a hale and hearty child. Every new born child would be free from any debilitating or life threatening disease or disorder throughout the early development period, thereby helping it to live up to a ripe old age with dignity, implying cradle to grave healthcare with personalised and targeted service at affordable cost. Our country would be able to respond to all disasters—whatever their provenance—swiftly and effectively, so as to minimise human, social and economic losses.

We would want to be assured that all human beings inhabiting our nation are afforded equal opportunity to nurture their innate talents and to overcome inherent handicaps, whether physical, psychological or social, so that they, in turn, become responsible contributing members of our society. This empowerment of individuals with an enlightened approach to life would be the root of positive social transformation. Language independent customised education anywhere and anytime would be available to meet this end. We would like to live in a clean country with pride in our natural heritage, lead the world by reconnecting with our ancient wisdoms, carve out a niche for ourselves on the global stage, and thereby contribute to the resolution of urgent global problems.

ASSAMESE	ভাৰতৰ সেৱাত প্ৰযুক্তি বিদ্যা ঃ প্ৰতিজন ভাৰতীয়ৰ নিৰাপত্তাৰ নিশ্চিতিকৰণ, সমৃদ্ধিৰ বৃদ্ধি আৰু সুদৃঢ় আত্মপৰিচয়ৰ হকে।
BENGALI	ভারতের পরিসেবায় প্রযুক্তি : নিরাপত্তা নিশ্চিতকরণ, সমৃদ্ধি বৃদ্ধিকরণ এবং প্রতি ভারতীয়র পরিচয় শক্তিশালীকরণ
BODO	भारतखौ अनसायनायाव बिरोंदामिन : साफ्रोम भारतारिखौ रैखाथि होथारनाय दावगाखांहोनाय आरो बिसोरनि सिनायथिखौ फोरानाय
DOGRI	भारत दी सेवा च टेकनालोजी : हर भारतवासी दी सुरक्षा यकीनी बनग, खुशहाली गी बढावा मिलग ते उनदी पहचान सुदृढ ओग
GUJARATI	ભારત ની સેવા માં ટેકનોલોજી : દરેક ભારતીય ની સુરક્ષા ની ખાતરી, સમૃદ્ધિ વધારો, ઓળખ મજબૂત
HINDI	भारत की सेवा में प्रौद्योगिकी : प्रत्येक भारतीय की विश्वस्त सुरक्षा, समृद्धि वर्धन एवं अखंड अभिज्ञान हेतु
KANNADA	ಭಾರತದ ಸೇವೆಯಲ್ಲಿ ತಂತ್ರಜ್ಞಾನ : ಭದ್ರತೆಯ ಖಾತರಿ ಏಳಿಗೆಯ ವೃದ್ಧಿ ಮತ್ತು ಪ್ರತಿ ಭಾರತೀಯನ ಗುರುತು ಬಲಪಡಿಸುವುದು
KASHMIRI	ٹیکنالوجی ہندوستانہ کہِ خدمتسِ منز: ہرہندوستانیِا سندِ خاطر سلامتی ہِند ضمانت، پاپرجاءی منز ہریر تہِ پرزُنَتک درَیر۔
KONKANI	भारताच्या सेवेतले तंत्रगिन्यान : प्रत्येक भारतीयाच्या सुरक्षतायेची खात्री, समृध्दील वाढ, अस्मिलेत घटाय
MAITHILI	भारतक सेवा मे प्रौद्योगिकी : प्रत्येक भारतवासीक विश्वस्त सुरक्षा, समृद्धि वर्धन एवं अखंड अभिज्ञान हेतु
MALAYALAM	സാങ്കേതികവിദ്യയുടെ സേവനം ദേശത്തിന് : ഓരോ ഭാരത പൗരന്റെ സുരക്ഷയും, പുരോഗതിയും, സ്വത്വവും ഉറപ്പ് വരുത്തുന്നതിന്

MANIPURI	ভারতকী তেন্বাংদা শিনশারল : সি-নগ্নাম্দানা নগাকপী সেন্বীবা, নুনগায়-য়ায়ফা হেনগাথান্বা অমসুং ভারতকী মীপুম খুদিনগী সাক্তাম কানখাথান্বা
MARATHI	भारताच्या सेवेसाठी कटिबद्ध तंत्रज्ञान : प्रत्येक भारतीयाच्या सुरक्षिततेची हमी, सुबत्तेची वृद्धी आणि अस्मितेची पुष्टी
NEPALI	भारत को सेवा मा प्रविधिको : हरेक भारतीय को सुरक्षा आश्वासन, समृद्धि वृद्धि, पहिचान बलियो
ORIYA	ଭାରତର ସେବାରେ ବୈଷୟିକ ଜ୍ଞାନ : ପ୍ରତ୍ୟେକ ଭାରତୀୟର ନିଶ୍ଚିତ ସୁରକ୍ଷା, ସମୃଦ୍ଧି ବର୍ଦ୍ଧନ, ଏବଂ ସୁଦୃଢ ପରିଚୟ ଗଠନରେ ନିୟୋଜିତ.
PUNAJBI	ਭਾਰਤ ਦੀ ਸੇਵਾ ਵਿੱਚ ਟੈਕੱਨਾਓਲਜੀ : ਹਰ ਭਾਰਤ ਵਾਸੀ ਦੀ ਸੁਰਖਿਆ ਨੂੰ ਯਕੀਨੀ ਬਣਾਏਗੀ, ਖੁਸ਼ਹਾਲੀ ਵਿੱਚ ਵਾਧਾ ਕਰੇਗੀ ਅਤੇ ਉਸ ਦੀ ਪਹਿਚਾਣ ਨੂੰ ਮਜ਼ਬੂਤ ਕਰੇਗੀ
SANSKRIT	भारतस्य सेवायाम् प्रौद्योगिकीयं : भारतीयानां सुरक्षाया: प्रतिभूति:, समृद्धि विवर्द्धनं, सशक्तिकमभिज्ञानञ्च
SANTALI	*भारोत दिसोम सेवारे जोन्त्रो बिदा : जांगे दाराम दाडे गोटा उरिच, लहान्ती उतनाव राकाब आर मिमित गोटेच् भारोत बासी आक् उपरूम दाडे तेयार राकाब*
SINDHI	भारत जी सेवा में तकनिकी : हर भारतीय जी सुरक्षा जी सुनिश्चितता, समृधि में वाधारो, सुन्जाढ़त खे मजबूत करणो
TAMIL	வருங்கால இந்தியாவின் சேவையில் தொழில்நுட்பம்: ஒவ்வொரு இந்தியனின் பாதுகாப்பை உறுதிப்படுத்தி, செல்வ செழிப்பை அதிகரித்து, தனி அடையாளத்தை வலுப்படுத்தும்
TELUGU	భారతదేశ సేవలో సాంకేతిక విజ్ఞానం : ప్రతి యొక్క భారతీయుడి భద్రతా పరిరక్షణ, సంపద పెంపొందింపు మరియు గుర్తింపు బలోపేతం చేయడం
URDU	ہندوستان میں ٹیکنالوجی کی خدمات: ہرہندوستانی کی سلامتی یقینی ہوگی،خوشحالی میں اضافہ ہوگا،اور پہچان مضبوط ہوگی۔

INDIANS IN 2035: OUR NEEDS



DRAFT

NEED FOR TECHNOLOGY, TECHNOLOGY FOR NEEDS

TO SURVIVE, TO THRIVE, AND TO BE ONESELF: these basic needs are the life force of countries just as they are of individual human beings. These needs are basic, in the sense that they are essential, common and shared: all human beings, all families, all communities and all nations have this very same set of needs. Nevertheless, how these needs are defined, articulated and manifested in concrete terms depends upon the specific attributes of the individuals and societies that crave security, seek prosperity and cherish identity. To identify India's needs in 2035, be it in the realm of security, prosperity or identity, we need to first understand the needs of Indians in 2035.

There are two persuasive reasons for the people-centric thrust of this technology vision. The first, and most important, is that India is a democracy, so the people must necessarily come first. But there is another, less obvious reason why the tenor of this technology vision is 'We, the People...' and why we are reflecting about people in 2035. Prediction is, by its very nature, a risky intellectual enterprise. In the memorable words of J.P. Hartley, 'The past is a foreign country: they do things differently there.' If the past is a foreign country, how much more foreign must the unknowable future be? How do we overcome the problem of prediction? The most fruitful approach would be to ask if there is anything that we could possibly be certain about as we peer into the mists of India's future. Are there any aspects of the future of our massive and diverse country that we can be certain about? Yes, there are: we can be certain of two things, that India will continue to be very large, and that it will continue to be very diverse. The certitude of massive diversity: these two unmistakable, instantly recognisable, characteristics are the solid foundations upon which we have chosen to erect our technology vision of India in 2035. Thus, strictly speaking, our technology vision is not about India in 2035 but about Indians in 2035.

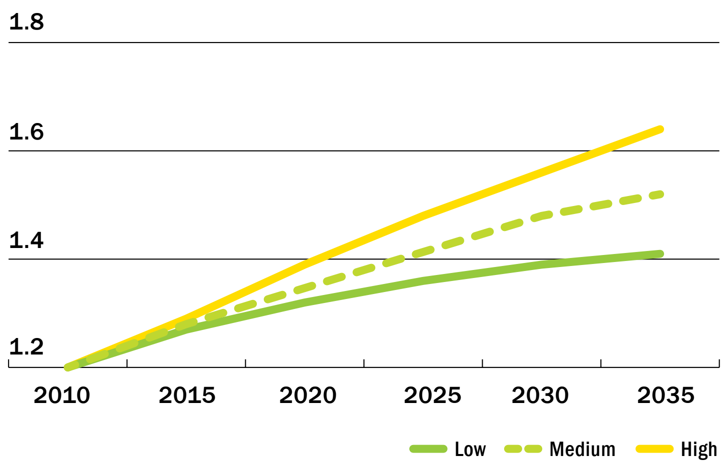
We can be certain of two things, that India will continue to be very large, and that it will continue to be very diverse.

According to the United Nations, by 2035 we Indians will probably number anywhere between 1.41 and 1.64 billion (*Figure 1*); throughout this report, we will consider the medium variant of 1.53 billion for our estimates. The sheer weight of numbers will pose challenges for India that only one other country on our planet will have to face. In India's size will reside not only a multitude of problems but also the solutions to its problems.

FIGURE 1

INDIA: POPULATION PROJECTIONS, VARIED SCENARIOS, 2010-2035

(in billions of people)



Source: UN Population Division, 2012

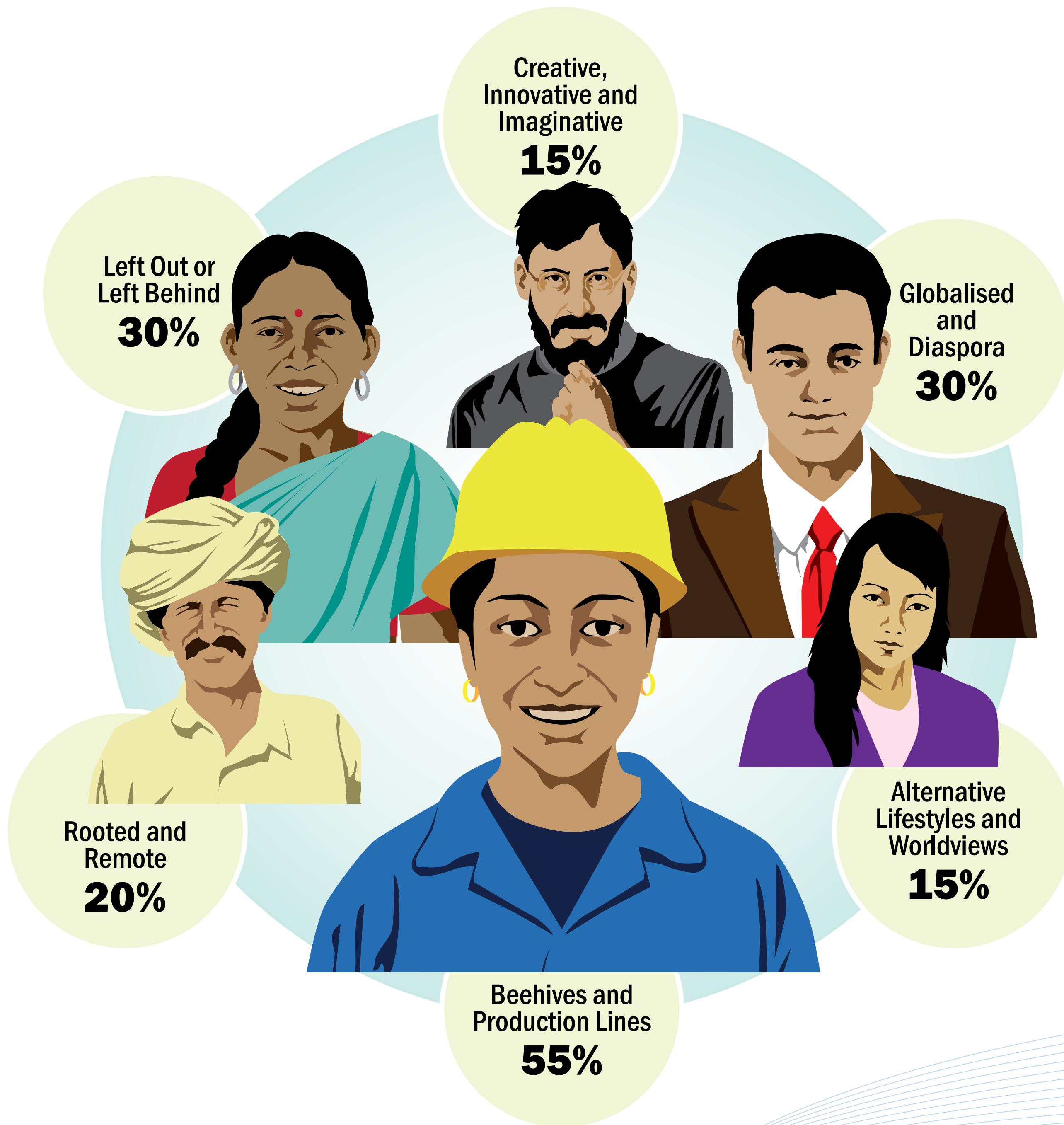
THE DIVERSITY OF INDIANS

NO OTHER COUNTRY ON THE PLANET, now or in the future, will be able to match India in terms of sheer diversity. Indeed, the diversity of our country is one of its core strengths. Given the rich cultures with which our country is blessed, we often conceive of our diversity in ethno-cultural terms. While this is undoubtedly true, we should also be aware of the enormous socio-economic, demographic, topographical, and agro-climatic diversities of our country. Taken together, what they imply is enormous variety in the needs of our compatriots.

A significant minority of Indians in 2035, perhaps as high as 20 per cent, would be Rooted and Remote. Most would be rooted by choice, although some will not have the choice. The rooted and remote will not all be rural, although most of them will be. This would be a segment of the population that adheres to old values, although the values too will evolve as circumstances change. As has been witnessed in urbanised societies around the world, this segment will be seen by others not as backward but as emblematic of the good old days, a throwback to pre-urban India. The biggest danger this segment would face is that they could become cultural exhibits disconnected from the national mainstream, just like many tribal groups were unfortunately treated in the past. It is also important to keep

FIGURE 2

PROJECTED NON-EXCLUSIVE SEGMENTS OF INDIANS IN 2035



Perhaps the segment most deserving of technology policy attention would be those Left Out or Left Behind.

in mind that the notion of remoteness would also have changed by 2035, by which time there would be road connectivity to every village, and internet connectivity in every household.

In direct contrast to, and much larger than, the rooted and remote would be the globalised and diaspora segment, who would be perhaps 30 per cent of the population. This segment would consist not only of Indian origin people living overseas but also their families living in India. Indians would be the largest diaspora community in the world by 2035, and the Government of India would have to devote considerable resources upon this group and deploy these resources worldwide. For this segment, comparisons across countries would be routine and the notion of 'best practices' would be commonplace. The concept of citizenship itself would be significantly transformed. This segment would be extremely assertive about its rights, have a strong sense of entitlement and would not hesitate to hold government accountable for all manner of ills, real and imagined.

Perhaps the segment most deserving of technology policy attention would be those Left Out or Left Behind. By 2035, this group will hopefully not comprise more than 30 per cent of India's population. Despite much greater openness and many improvements, India would continue to be an unequal society in which many would simply not get a chance in the first place, or not be able to keep pace. Our society would therefore have to be acutely sensitive about inclusion issues, and our various government systems would have to proactively service the needs of this segment of our compatriots.

As India develops, a significant segment of our population, perhaps as many as 15 per cent, will choose Alternative Lifestyles and Worldviews. They are those who will choose to opt out of the system, advocating and pursuing alternate lifestyles, and having radically different ideas about society and the good life. A sensible system would not interfere with their choices but would nonetheless seek to remain engaged with them, since social benefits can often accrue from individual mavericks.

A small yet significant segment of Indians, probably not more than 15 per cent of our population, will be the Creative, Innovative and Imaginative. These compatriots will refuse to be constrained in the straitjacket imposed by our various social, educational and governance systems. Much needed innovation will come from this segment of our population which, although small in size, will be critical to the health of our country because it would be the fount of economic and social dynamism.

The largest segment of our compatriots, perhaps 55 per cent of our population, will comprise the Beehives and Production Lines of our country. The productive process, that is the source of all resources and underlies all social existence, would be due to this vast segment of our population. Catering to their needs, keeping them skilled, satisfied and involved, would be the biggest challenge for all our systems.

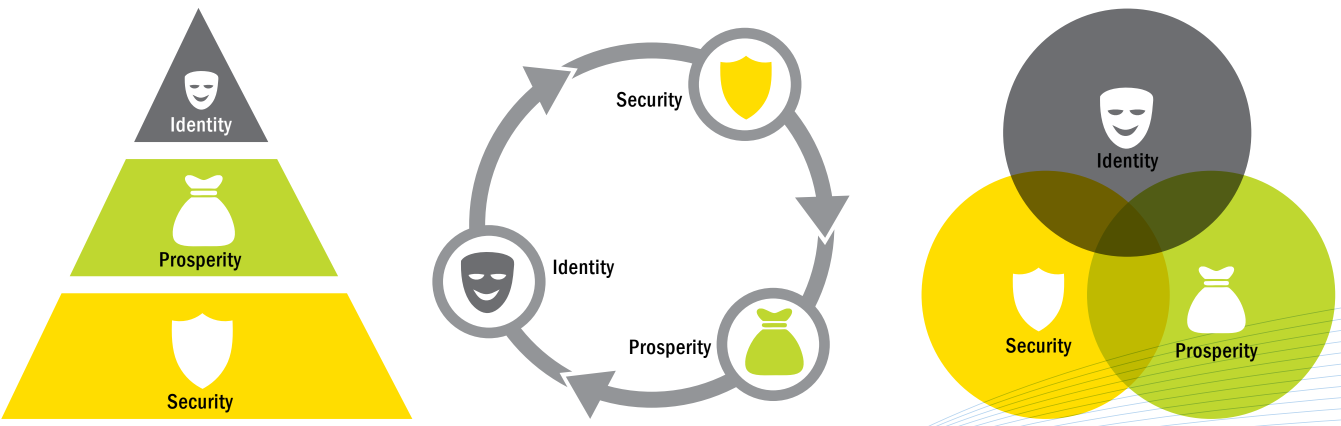
Thus, in this technology vision exercise we have envisaged six broad, non-mutually exclusive, categories of Indians. (Non-exclusivity of these categories results in an overlap between them, resulting in a total which is more than 100%.) Our guesstimates of the population shares of each segment in 2035 are illustrated in *Figure 2*. While some of their needs would be common and shared, other needs would be distinct and unique. We need to ascertain to what extent technology will be able to service these needs. Our viability and dynamism as a nation will depend crucially upon how technology is deployed to serve the real needs of our compatriots.

NEEDS: BASIC YET DIFFERENTIATED

BY NEEDS, WE MEAN THE LACK OF SOMETHING that we require or desire. But why should we take a needs-based view of technology? Necessity, the proverb tells us, is the mother of invention. Technology arises because scientific knowledge, which often arises out of curiosity about the natural world, can be employed to service some individual or group need. However, the relationship between society and technology is not one-sided but reciprocal: in the process of technological evolution, new human and social needs get created.

FIGURE 3

RELATIONSHIP BETWEEN BASIC NEEDS



All individuals and societies need to have the sense that they are safe and secure; to believe that their circumstances are satisfactory; and to be sure about who they are and how and where they fit in the larger scheme of things.

As depicted in the illustration in *Figure 3*, there are three possible ways in which we can envisage the relationship between the basic needs of security, prosperity and identity. The first is to view human and social needs in hierarchical terms. However, if needs are hierarchical, some needs have greater priority than others, thereby inevitably leading to the privileging of some needs (usually, security) and consequent neglect of other needs. Secondly, the relationship between the three basic needs could be a cyclical process terms. Thus, while security is essential for prosperity (one must survive in order to thrive), a strong sense of identity gives one a sense of security. But a cyclical process is unidirectional, while the basic needs feed into each other reciprocally, greater security increases the possibility of prosperity, greater prosperity also makes one more secure (although, by increasing one's assets, greater prosperity also increases one's vulnerability). This suggests a third way of viewing the basic needs, which is that they are overlapping and mutually implicating. All individuals and societies need to be in a place that gives them a sense that they are safe and secure; that leads them to believe that their circumstances are satisfactory and, in some cases and on some occasions, that they are doing well; and that they are sure about who they are and about how and where they fit in the world and the larger scheme of things. In this perspective, the basic needs either cumulate or detract from one another: one either has all three simultaneously, or is to a degree deprived of all three.

How do the six non-exclusive population segments that we have identified in the earlier section relate to the basic human and social needs of security, prosperity and identity? (See *Figure 4*)

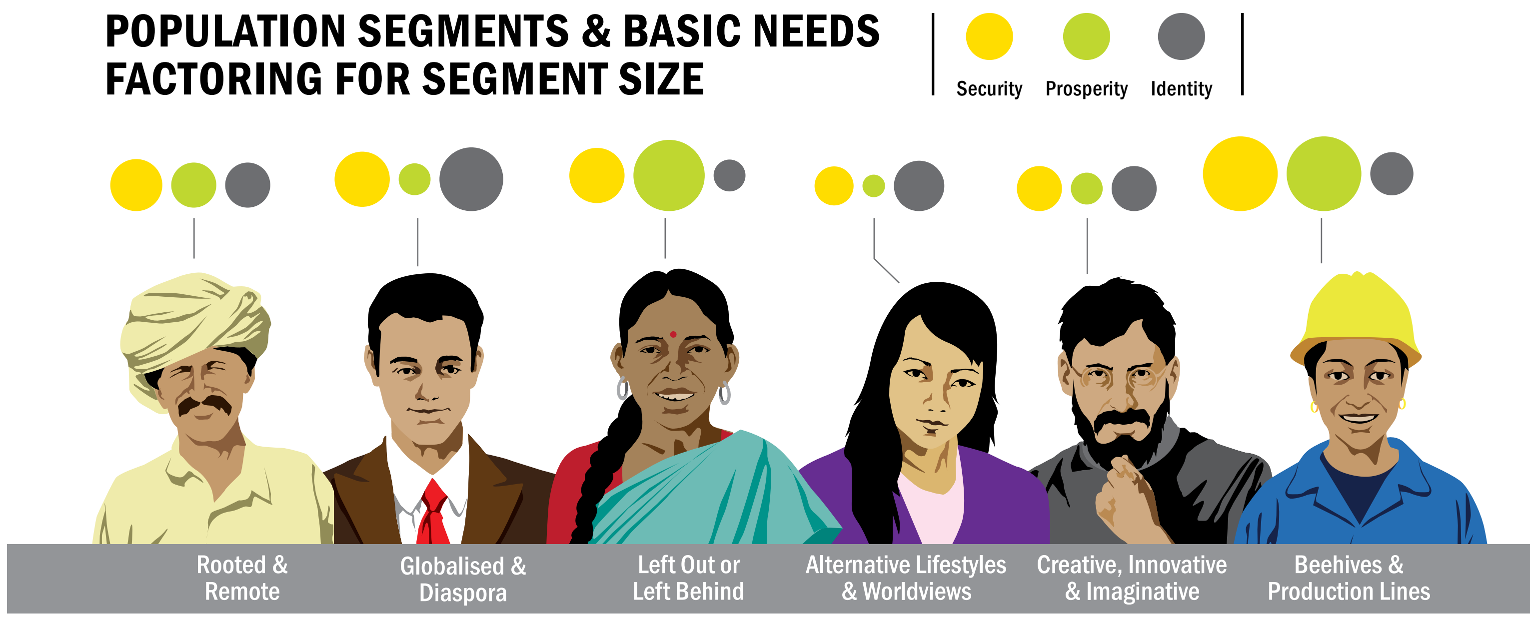
- The Rooted and Remote segment of India's population would be expected to have severe security needs due to their remoteness, as also significant prosperity and identity needs related to its rootedness.

- The Globalised and Diaspora segment of our population would have severe identity needs, given its globalised orientation, significant security needs due to its exposure to overseas developments; its prosperity needs, on the other hand, would be minimal because it would already be benefitting hugely from its global connections.

- The segment of our population that is Left Out or Left Behind would have desperate prosperity needs, significant security needs and minimal identity needs.

FIGURE 4

POPULATION SEGMENTS & BASIC NEEDS FACTORING FOR SEGMENT SIZE



- For the segment of our population with Alternative Lifestyles and Worldviews, identity needs would be at desperate levels because these needs would define their very existence. This segment would have significant security but only minimal prosperity needs, both of which would flow out of its deliberate choices of living in a particular way.

- The Creative, Innovative and Imaginative segment would have severe security and identity needs but only moderate prosperity needs, since it would be expected to economically benefit from its novel contributions to knowledge, economy and aesthetics.

- Finally, the Beehives and Production Lines, consisting of the bulk of our country's population, would have significant security and prosperity needs but only minimal identity needs.

Thus, there are considerable variations among the different population segments as far as the relative salience of the three basic needs is concerned. While security needs remain relatively stable across all population segments, this is not the case with prosperity needs and identity needs, which vary widely. We also need to take account of the wide variations in the projected sizes of the various population segments: for instance, it is expected that the Beehives and Production Lines would be more than 3.5 times as large as the Creative, Innovative and Imaginative

By enhancing the participation possibilities for women, technology is intrinsically and deeply intertwined with the empowerment of women.

segment, while the Rooted and Remote would be two-thirds the size of the Globalised and Diaspora. The matter is further complicated by the fact that the population segments are non-exclusive, i.e. an individual citizen could fall into more than one population segment.

THE GENDER DIMENSION

ANY ANALYSIS OF TECHNOLOGY and society must also be alive to the gender dimension, for the simple reason that neither technology nor society is gender neutral. Bringing gender into our analysis has three important ramifications. First, gender brings with it a diversification of perspective. Very often, what passes for the mainstream view is in fact a masculine understanding of an issue, problem or situation. A feminine perspective inserts a different set and mix of values into the analysis, leading to a different prioritisation of human and social needs and solutions. From a feminine perspective, different appliances, diseases, sources of energy, stages of life and social relationships, to give only a few examples, would be emphasised. While dichotomising the masculine-feminine difference would be false, it is nevertheless undeniable that the feminine perspective brings other values (nurturing alongside controlling) and priorities (social reproduction over social order) into the public domain. For instance, the feminist insight that 'the personal is political' forces us to revaluate the cherished scientific notion of 'objectivity' and also leads us to question any sharp differentiation of the public and private spheres.

Secondly, the gender dimension requires us to focus on the participation of women in the public life of our country and its various institutions. Since women are half the population (although technology and social attitudes have adversely and regrettably altered the gender composition of our country in recent decades), the inclusion of women as full participants in society at all levels of planning, decision making and policy execution is a force multiplier in every sense. As engineering education becomes more gender sensitive, the female proportion of technology workers in our economy will also undoubtedly increase.

Finally, by enhancing the participation possibilities for women, technology is intrinsically and deeply intertwined with the empowerment of women. Technology empowers women in multiple ways: by creating labour saving devices and appliances that reduce daily domestic chores, thereby helping to balance work and home; by facilitating quick, safe and reliable travel over long distances; by providing the means for knowledge and skills enhancement even in situations of exclusion from formal educational systems; by allowing greater control over reproductive choices; by targeting diseases that lead to high rates of female fatality or morbidity; by making potable water easily accessible and by providing alternate energy sources to traditional biomass; and most importantly, by evening out and even nullifying the relevance of certain physical advantages that men have over women.

It must also be recognised that technology can have a negative impact upon women. In certain social contexts, technology can make life more difficult and dangerous for women. Certain technological choices can lead to the exploitation, degradation and even elimination of women. Being alive to the gender dimension makes us aware of the adverse impact of certain technologies upon women and the imperative to find mitigating strategies and benign alternatives.

TECHNOLOGY AND SOCIETY

THERE ARE TWO DISTINCT WAYS in which the relationship between technology and society has been conceived. Several technological critiques have raised the spectre of technological determinism, emphasising thereby the internal logical momentum of technology that pushes society to the brink of alienation and catastrophe. This demonization of technology allows little scope for human agency or any possibility of proactively adopting alternative trajectories of societal development. On the other hand is the framework of technological neutrality, according to which society has the complete freedom to shape its technological present and future, suggesting thereby the quasi-infinite plasticity of nature and materials employed to assemble technology.

In this technology vision we have consciously rejected a strict adherence to both technological determinism and technological neutrality. Instead, an appropriate interpretive position is to be found between these, wherein the boundary between society and nature, technology and human bodies is not drawn so clearly. For quite some time now, historians of technology have suggested that our understanding of technology and society may have to be embedded within the framework of biological evolution: not just human beings, but chimpanzees and fish have been known to construct tools to act upon and manipulate nature. As prosthetic devices and medical aids are implanted within human bodies and extend the lifespan of human populations, the analytical distinction between technology and society, knowledge and bodies, becomes increasingly difficult to sustain. The next generation of technological intervention into human bodies, due to the confluence of nanotechnology, biology, IT and cognitive science (NBIC), will make the distinction between bodies and knowledge even more difficult to

The next generation of technological intervention into human bodies, due to the confluence of nanotechnology, biology, IT and cognitive science (NBIC), will throw up new and perhaps intractable ethical dilemmas.

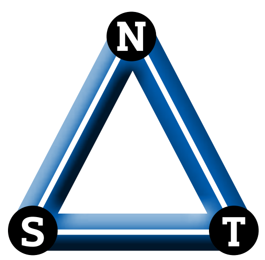
With judicious policy and conscious planning, technology is a wonderful instrument for perfecting democracy and empowering the people.

discern, thereby throwing up new and perhaps intractable ethical dilemmas. As societies transform and technologies emerge, in India and across the world, a social constructivist perspective on technology, in which society and technology are mutually impacting, will in the coming decades deepen. This will reveal the complex ways in which technologies, societies, lives and bodies are mutually shaped by each other.

From the early days of our Independence, there has been a general tendency in our country to pit the debate on technology, and especially the social impact of technology, as capital intensive versus manpower intensive. Indian industry – whether manufacturing, construction or resource extraction – has historically opted for labour intensive modes of production by leveraging India's large, low skilled and underemployed rural population. In a country like ours with abundant human resources, capital intensive technology is projected as being detrimental to the use of 'manpower'. Technology, it is argued, reduces the number of jobs.

However, some sort of creative destruction is intrinsic to economic prosperity. As the economy moves up the development ladder from agriculture intensive to manufacturing and services, there is a concomitant value enhancement in human resources. A rising economy thrives not only on new skills of manpower but also new needs of the population. Technology not only creates new skills but also leads to creation of new needs. The real policy and technology challenge in a country like ours is to ensure that technology plays the role of being a great leveller rather than as an enhancer of stratification. With judicious policy and conscious planning, technology is a wonderful instrument for perfecting democracy and empowering the people.

To better understand the interrelationship between society and technology, it would be helpful to view nature (or the physical environment) as the third apex of a triangle consisting of society, technology and nature. Each apex of the triangle has an impact on the other two and gives rise to certain valid concerns. From a technology perspective, we need to ask: How will technology modify individual and social behaviour? For instance, mobile telephone technology has fundamentally altered our sense of time, even in rural areas. What impact will technology have on culture? The social apex of the triangle raises another set of pressing issues. For instance, we need to ask in what ways Indian society is changing and would have changed by 2035, and what impact these changes would have on social (and hence technological) needs. From the perspective of the natural and physical environment, we would need to ask what changes are likely in them and what impact these changes, as well as the availability of resources, would have on social and technology needs.



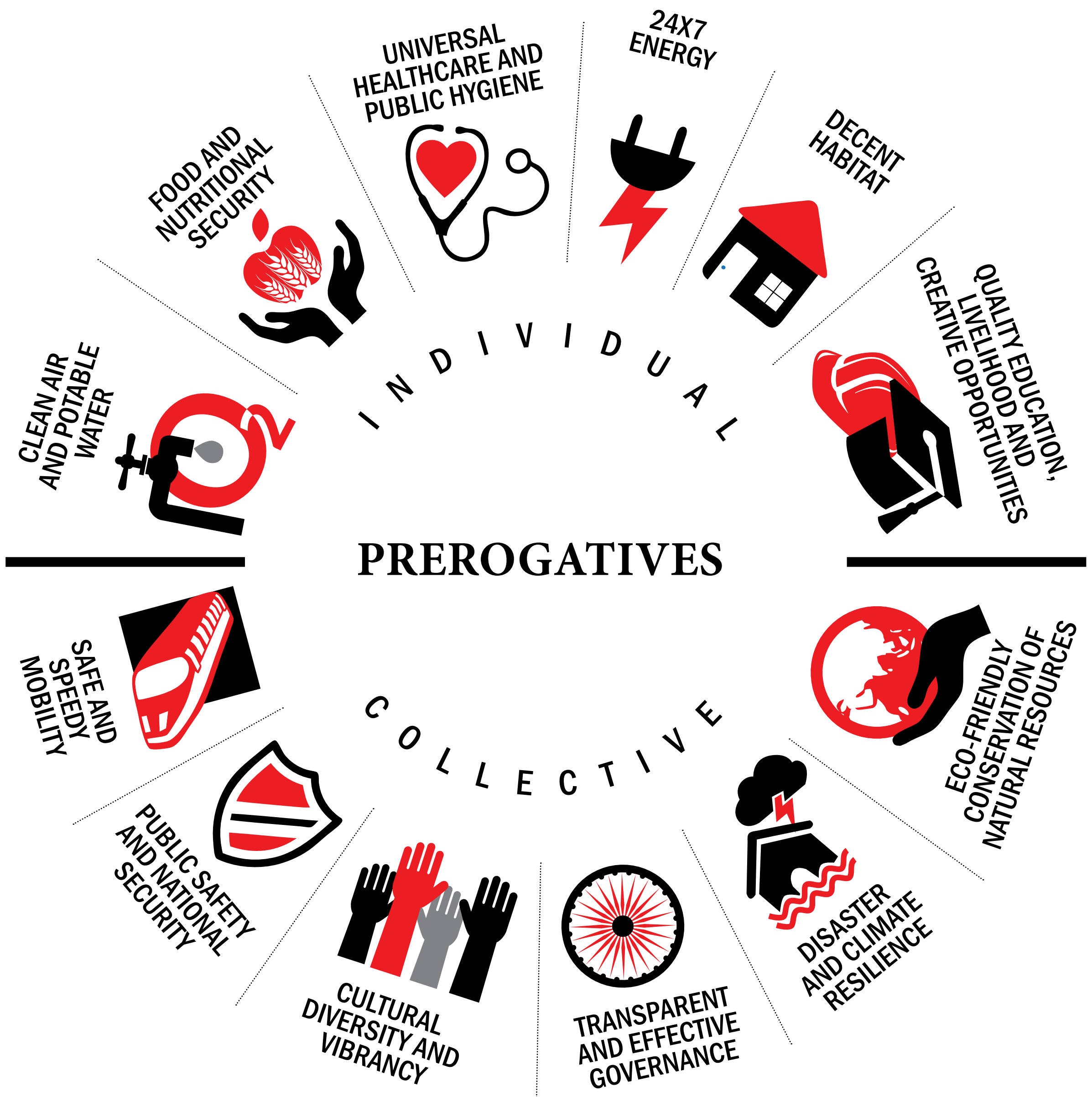
PREROGATIVES AND ENABLING TECHNOLOGIES

PREROGATIVES AND ENABLING TECHNOLOGIES

TO FULFIL OUR VISION TO BE CITIZENS of a modern country, we would have certain prerogatives with regard to ourselves, our nation and our planet. We have to define specific targets with regard to these necessities as also technologies needed to achieve them. We need to set these targets at multiple levels taking into account widely varying necessities of our very diverse population and their time lines may vary. There would be minimum expectations that every Indian must be assured of and a gross picture that should be in place in the year 2035 is depicted here. Simultaneously, commensurate with the rise in India's stature and expected technological advances there would be aspirations that a vision like this must capture.

Twelve prerogatives should be available to each and every Indian, and ensuring the attainment of these prerogatives is the core of our technology vision for India. Nevertheless, the inherent and enduring diversity of our people would also have to be factored into our policies to meet these prerogatives. Firstly, different targets would need to be set for different population segments: while the clean air challenge is more severe in our cities, the potable water challenge is more severe in our rural areas. Secondly, the technology delivery mechanisms for different population segments would also be different: for example, ensuring water availability in our arid zones would raise a series of challenges pertaining both to technology creation and delivery. Lastly, success in attaining our technology targets would have differential social impacts, depending upon the characteristic of the population segment: connectivity, for instance, would be far more enabling in our countryside compared to our metropolitan areas.

DRAFT



CLEAN AIR AND POTABLE WATER

AIR AND WATER are the basic necessities of life. The essential difference between the two is that air, unlike water, is ubiquitous. For this reason, air is free while water frequently is not. The core technological challenge with regard to air is about ensuring its quality through effective gaseous effluent management right at source. Air quality has a local, regional and global dimension and is important for sustaining life on Earth and the health of Earth itself.

Overall water demand in several regions of our country is far exceeding the supply, calling for better water resource management strategies. Though we are endowed with large reservoirs of fresh water, it has not been possible to make potable water available on tap in every household. There are basically four sources of water in our country: Monsoon precipitation, glacial melt, subterranean aquifers and oceans. These are fairly vast but distributed unequally. Increasing demand poses a number of challenges. Hence, we would have to continuously try to augment available quantity of water by identifying and exploring new resources, especially underground. At the same time effective management of the newly found as well as the existing resources would have to be undertaken in order to optimise their utilisation. Towards this, constant testing and replenishment of all resources would have to be ensured. Quick runoffs of rainwater results in depletion of its availability as a source of fresh water. This can be prevented

We would have to continuously try to augment available quantity of water by identifying and exploring new resources, especially underground.

TABLE 1

	are readily deployable	needs to be moved rom Lab to Field	require targeted research	are still in the imagination
ADVANCED CLEAN COAL TECHNOLOGIES		●	●	
ALTERNATE FUEL BASED TRANSPORTATION	●	●	●	
NOVEL PROPULSION TECHNOLOGIES		●	●	
GREEN MANUFACTURING	●			
INTELLIGENT TRANSPORTATION SYSTEM	●			
LOW DUST CONSTRUCTION TECHNOLOGIES	●	●		
REAL TIME DENSE SPATIAL AIR QUALITY MONITORING		●	●	
REAL TIME AQUIFER MONITORING INCLUDING SALINITY INGRESS		●	●	
INSTANT PORTABLE WATER QUALITY TESTING	●	●	●	
AFFORDABLE DESALINATION TECHNOLOGY		●	●	
MEMBRANE BASED WASTE WATER TREATMENT	●			
AFFORDABLE DE-SILTING OF WATER BODIES		●	●	
TECHNOLOGY FOR RUN-OFF CONTROL	●	●	●	
SCALABLE POINT-OF-USE WATER TREATMENT TECHNOLOGY		●	●	
DEW HARVESTING		●	●	
IN-SITU WATER PURIFICATION IN PIPELINE			●	
SELF HEALING PIPELINES			●	●

Technologies, concepts and approaches relating to clean air and potable water that—
- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

The emphasis should be both on optimum utilisation of available water and making potable water available at prices that all Indians could afford.

by taking adequate harvesting measures including facilitating percolation to supplement subterranean water tables. Further, all accessible water, including recycled waste water would have to be rid of organic and inorganic contaminants thus making it perfectly safe for drinking.

Depicted in *Table 1* is a basket of technologies, some awaiting deployment while some others in various stages of development towards meeting these challenges fair and square.

Air quality is impaired as a result of certain industrial activity as well as a massive increase in urban vehicular traffic. Aggressive implementation of green manufacturing, transportation and mining technologies would be required for improving air quality. Biomass is still a significant energy source for cooking and other heating purposes especially in rural areas. Replacing this energy source with gas including bio-methane and deployment of smokeless Chulha where this is not possible is an urgent necessity for ensuring better air quality.

As regards potable water, we must make sure that everyone is able to access safe drinking water through tap either within or in close proximity of the habitat. The emphasis should be both on optimum utilisation of available water and making potable water available at prices that all Indians could afford. That is why technologies that help reduce industrial use of water and that do not cause unacceptable pollution of water bodies should be selected. However, wastage of water at consumer level is also an important issue and needs to be addressed by educating the people. A number of technologies are already available waiting to be deployed. Appropriate policy intervention would spur this effort. Lab-on-a-chip is a novel concept needing intensive research. It is as if a whole laboratory is placed on a single microchip. Of course, research in several allied fields, for example agriculture and materials, would go a long way in attaining targets set for providing potable water.

FOOD AND NUTRITIONAL SECURITY

ALTHOUGH THERE ARE DISCERNIBLE SIGNS that the rate of increase of our population is slowly diminishing, we are still likely to end up with around 1.53 billion citizens in 2035. However, to translate that prowess into meaningful reality, every single one of us would have to be fit and healthy physically as well as intellectually. To achieve that desirable state we should be assured of adequate and nutritional food intake. Adequacy has to be addressed both in terms of calorie and protein requirements irrespective of our diverse food preferences. Indian women, in particular, are chronically anaemic. We would have to see that protein calorie malnutrition and/or non-availability of micronutrients in required amounts do not remain principal causes leading to this detrimental outcome.

Towards these goals we will have to see that our agricultural production keeps pace with demand. Hence all resources, especially

TABLE 2

Technology	Are readily deployable	Need to be moved rom Lab to Field	Require targeted research	Are still in the imagination
VERTICAL FARMING	●	●		
DEVELOPMENT OF PERENNIAL CEREAL CROPS			●	
CONVERSION OF NON-EDIBLE PLANTS INCLUDING SEA FLORA INTO FOOD			●	
BIO-FORTIFICATION (BOTH CONVENTIONAL AND GENETIC)	●	●	●	
GENOMICS AND PHENOMICS	●	●	●	
TRANSGENIC CROP PLANTS AND ANIMALS	●	●	●	
RAPID DIAGNOSTIC TOOLS FOR DETECTION OF ZOONOTIC DISEASES		●	●	
TECHNOLOGIES FOR INCREASING SHELF-LIFE OF PERISHABLE FOODS		●	●	
ELECTRON BEAM FOOD IRRADIATION	●			
OIL TO POWDER TECHNOLOGIES FOR FOOD		●	●	
HIGH VALUE NUTRACEUTICALS AND PHARMACEUTICAL PRODUCTS FROM AQUATIC ORGANISMS AND ALGAE	●	●	●	
REAL-TIME MONITORING OF QUALITY AND BIO-TRACEABILITY RELATED TECHNOLOGIES		●	●	
CLIMATE-SMART AGRICULTURE	●	●	●	
CONVERSION OF C3 PLANTS TO C4 PLANTS.			●	
NANO FORMULATIONS OF PESTICIDES AND FERTILIZERS		●	●	
INTERACTIVE FOODS				●
SMART FOODS				●
3D PRINTING OF FOOD			●	
EXPLOITING MICROGRAVITY AND SEA FOR CULTIVATION OF CROP PLANTS				●

Technologies, concepts and approaches relating to food and nutritional security that—
- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

A key aspect enhancing food productivity relates to creating a large scale ecosystem in rural areas that connects farmers with knowledge and technology domain on one side and professionally managed value addition and marketing framework on the other.

water and land, would have to be utilised optimally. A significant amount of our agricultural produce is lost at different stages, especially at post harvest stage. We have to adopt a zero-tolerance policy in this regard to see that there is absolutely no wastage of food from farm to kitchen. Of course unless farmers find that agricultural endeavour is remunerative with the produce being competitive in the global market, agricultural production cannot continue to show an upward trend. This can be achieved, provided swift movement of farm produce to all markets, local or global, is guaranteed.

Not all of the farm produce is immediately consumed. Also some of it is perishable. Therefore, we will have to enhance value addition and take measures to prolong shelf life of all kinds of farm produce. Our livestock constitutes a valuable resource. That is why special care will have to be taken to see that it is not transported under inhumane conditions. Initiating cold chains at the farm itself will mitigate these problems. In view of our biodiversity and traditional knowledge base, special attention would have to be given to protect our Geographical Indicators. Formidable as this task is a number of technologies can be pressed into service to complete it.

Given the small landholdings flowing out of our social structure, technologies that are globally available for improving farm productivity need to be modified and adapted to suit our needs. Almost all the technologies tabulated in *Table 2* will become available only in the medium- to long-term. Value addition by ingenious processing technologies has the potential of extending utilisation of perishable food items. Further, integrated handling and speedy transport of these items, assisted by smart packaging, can help retain their nutritional value and reduce wastage. Food traceability from farm to plate needs both technological and policy interventions. Development of safe agrochemicals can enhance the acceptability of our agricultural produce in global markets. Safeguarding Geographical Indicators of our native and specific agricultural produce is an issue related to the global IPR regime and should be addressed both at the technological and policy levels.

A key aspect of enhancing food productivity relates to creating a large scale ecosystem in rural areas that connects farmers with knowledge and technology domain on one side and professionally managed value addition and marketing framework on the other. Such an ecosystem should be able to maximise benefit to farmers as well as consumers through efficient technology and management. Stability of prices and better risk management brought about through such an approach should lead to larger investments and consequent higher food production.

UNIVERSAL HEALTHCARE AND PUBLIC HYGIENE

A primary health centre would have to be established in every gram panchayat with telemedical access to specialists and super-specialists. Every district would have a multi-speciality hospital with air ambulance and trauma centre.

CITIZENS OF A MODERN COUNTRY rightfully expect to live a healthy and productive life. Easily accessible good quality healthcare facilities coupled with well maintained public hygiene system have to complement adequate food availability, quantitative as well as qualitative, in order to fulfil these expectations. There are a number of crucial goals that would have to be met in this regard.

A primary health centre would have to be established in every gram panchayat with telemedical access to specialists and super-specialists. Every district would have a multi-speciality hospital with air ambulance and trauma centre. Notwithstanding this, it would be possible to speedily transfer a patient to a well equipped hospital within an hour. Considerable person-hours are lost due to avoidable occupational health hazards, the total eradication of which should be our avowed goal.

While we have come a long way since Independence in achieving average life expectancy of 69 years, this would have to be pushed upwards to 80 years at birth. Likewise there is significant reduction of maternal mortality rate and under-5 mortality rate in the country. We can therefore now raise the bar and achieve maternal mortality rate better than 15 per 100,000 and U-5 mortality rate better than 6 per 1,000 live births. Public hygiene considerations require that every household has at least one modern toilet. Likewise, treatment of effluent water and biodegradable solid waste would not only ensure public hygiene but also make valuable resource in the form of water and carbonaceous matter available for safe recycling. Our attempts to address the above issues have floundered due to the lack of well engineered and cost effective systems, having a deleterious effect on public health and environmental integrity.

We envisage a number of challenges that would have to be met before we reach the desired state. We have succeeded in eradicating a number of infectious diseases that used to take considerable toll especially of vulnerable segments of society like the very young and the old. The most recent example is eradication of polio. Howsoever satisfying that scenario is, a number of dark clouds loom large on the horizon. Some of the infectious diseases that presumably were well under control, like malaria and tuberculosis, have started rearing their heads again in the form of multi-drug resistant varieties. At the same time, some totally new ones that were never encountered in the past, for example SARS and swine flu, have emerged. We will have to find ways and means of combating these menaces with total control and possible annulment. Increasing life expectancy, urbanisation, prosperity and changing work environment

DRAFT

TABLE 3

Technologies, concepts and approaches relating to universal healthcare and public hygiene that—

Technology	are readily deployable	needs to be moved rom Lab to Field	require targeted research	are still in the imagination
NEW VACCINES FOR MULTI DRUG RESISTANT AND NEWLY EMERGING DISEASES			•	
m-HEALTH	•	•	•	
BODY FLUID MARKERS FOR EARLY WARNING OF LIFESTYLE DISEASES		•	•	
INTEGRATION OF INDIAN SYSTEM OF MEDICINE (ISM) WITH MODERN SCIENCE	•	•	•	
PERSONALIZED MEDICINE		•	•	
REGENERATIVE THERAPIES				•
SYNTHETIC BIOLOGY		•		
3D PRINTING (ORGANS AND PROSTHETICS)		•	•	
NOVEL AND COMPOSITE MATERIALS FOR DEVELOPMENT OF PROSTHETICS AND BODY PARTS			•	
BRAIN-COMPUTER INTERFACE FOR DEVELOPING ADVANCED ASSISTIVE DEVICES	•	•	•	
IMPLANTED SENSOR BASED DRUG DELIVERY			•	•
NANO-ROBOTS			•	•
TELEMEDICINE AND TELE-SURGERY	•			
OPTOGENETICS			•	
WEARABLE DEVICES	•	•	•	
MEDICAL TEXTILES	•	•	•	
AUTOMATED ALERTING SYSTEMS FOR MEDICAL EMERGENCIES		•	•	
AFFORDABLE DRY SANITATION TOILETS	•			
SELF STERILISING HOUSEHOLD FITTINGS	•			

are leading to lifestyle diseases reaching an alarming proportion. This cannot be allowed to continue and effective mitigating strategies would have to be deployed. Chronic anaemic condition among Indian women is a serious threat to their life and a significant impediment to their effective contribution to national development efforts. Combating this silent menace would have to be accorded greater priority. Senior citizens are a valuable national human resource whose health and wellbeing must be taken care of. Some citizens are born with some kind of disability or become disabled due to an accident or pathogenic attack. Adaptive and assistive technologies would enhance their quality of life and productivity.

Affordability of healthcare is a major problem facing a large section of society. We will have to take steps on several fronts to address this issue. While decentralisation of healthcare can be achieved through administrative measures, other aspects need technological solutions. Development of affordable non-invasive diagnostics and surgical procedures, inexpensive drugs and targeted delivery mechanisms would have to be on top of the list of priorities. We have so far relied heavily on western systems of medicine for providing adequate healthcare both in the public and private sectors. A vast treasure of traditional knowledgebase that constitutes alternative prophylactic and curative regimens has been languishing for want of attention. As the flip side of the western system in the form of adverse reactions and serious side effects comes to light, it is time to stop this neglect and turn to this knowledgebase, test its efficacy by subjecting it to method of science thereby enhancing its value. An integrated approach, rather than separate development, is essential. A list of technologies for this prerogative is given in *Table 3*.

We are experiencing a paradoxical situation today. On the one hand, the most developed and highly sophisticated healthcare backed by world class expertise is available in the country making it a much sought after medical tourism destination. On the other, those of our compatriots residing in areas not too far from these high end centres are deprived of some very primitive and basic medical interventions. One reason for this is the high cost of the former as the technologies as well as the equipment for the advanced healthcare regimen are mostly imported. To alleviate this dichotomy we need to encourage rapid indigenisation with concentrated multidisciplinary research effort, including the integration of traditional medical systems. The training of a sufficient number of skilled paramedical personnel as a second line of defence, especially in telemedicine applications in rural areas, is essential.

Development of affordable non-invasive diagnostics and surgical procedures, inexpensive drugs and targeted delivery mechanisms would have to be on top of the list of priorities.

24X7 ENERGY

ALL CITIZENS OF A MODERN COUNTRY are entitled to uninterrupted access to energy. It is therefore possible for us to formulate a set of common targets to meet the energy needs of our compatriots. Some of these targets will include capacity creation for reaching 1,000 GW of power generation at the national level, with 50% of this target coming from renewable resources. Transmission and distribution losses would be less than 3%. Availability of quality power would be a basic right. We face enormous challenges for achieving the above targets. Grid management needs to be improved, low cost energy storage systems need to be developed for better control on the phase gap between generation and need, and energy pilferage needs to be eliminated. To start with,

DRAFT

TABLE 4

SOLAR PV	●	●		
ALGAL ENERGY			●	
NUCLEAR FUSION			●	
FUSION FISSION HYBRID REACTOR			●	
FAST BREEDER REACTORS FOR THORIUM			●	
SUPERCRITICAL COAL	●			
ADVANCED COAL CYCLES			●	
ADVANCED FOSSIL FUELS EXTRACTION TECHNOLOGIES				●
SHALE GAS	●	●		
TIGHT GAS		●	●	
GAS HYDRATE			●	
HYDROGEN ENERGY			●	
BIOREFINERIES			●	
HYBRID STORAGE		●		
FUEL CELL		●	●	
MICROBIAL FUEL CELL				●
DC GRIDS		●		
SMART GRIDS	●			
ICT BASED SMART MONITORING SYSTEMS	●			
WIRELESS POWER TRANSMISSION			●	
GREEN AND NET ZERO ENERGY BUILDINGS	●	●	●	
SMART WINDOWS		●		
ZERO ENERGY ARTIFICIAL LIGHTING (e.g. BIOLUMINESCENCE)			●	●
MICRO-GASIFIER COOKSTOVE		●		
BRUSHLESS DC (BLDC) MOTORS	●			

Technologies, concepts and approaches relating to 24x7 energy that–

- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

efficiency of energy use needs to be increased. This will also require movement towards decentralisation of energy generation from the current centralised and network approach.

Other challenges include the search for new energy sources and resources. The biggest challenge of all will be developing technologies for quantum leaps in emission free energy generation and in ensuring that the quality of available power is up to global standards. Some of the technology developments that will facilitate in overcoming the challenges and meeting the targets are given in *Table 4*.

Initiatives need to be put in place to promote private industry involvement in all the above areas. Technology developments in sectors such as water, food, healthcare and habitat are dependent on availability of assured energy. This is especially the case for promoting non-conventional energy sources that will require symbiotic developments in food and agricultural technology. Developments in low cost energy storage are a non-negotiable need for promoting developments in electric mobility that will in turn reduce carbon footprint. Technology interventions would be required to reduce dependence on traditional biomass for meeting the energy requirements of rural Indians. This would indicate emphasis on decentralised energy generation.

Our energy targets will include capacity creation for reaching 1,000 GW of power generation at the national level, with 50% of this target coming from renewable resources. Transmission and distribution losses would be less than 3%.

DECENT HABITAT

A DECENT HABITAT IS A BASIC RIGHT of all human beings. By the year 2035, we should be a country of zero slums. Half of all houses would be net zero in terms of energy use and waste generation. We should also be in a position to have all dwellings to be disaster resistant and climate resilient.

For a country with limited natural resources, providing decent and affordable habitat for all will be constrained by availability of raw materials; thus the necessity of developing alternative building materials will be one of the key issues. Technology developments will need to ensure that we are able to build faster and more efficiently, maximising the use of recycled materials. Some of the biggest issues that we need to address for meeting these challenges will be standardisation of construction systems that deliver on quality and reduce the use of scarce materials such as sand as also explore alternatives. We also need to plan on smarter, sustainable cities and buildings. The technology developments that will be required to meet our habitat necessities are identified in *Table 5*.

One of the major factors that will help limit or reverse the move from rural to urban areas will be the availability of urban habitat standards in rural areas. These technological developments will go a long way towards achieving this. In addition, development of sustainable cities will reduce the stress on the rural environment. Technologies for the manufacture of building materials would have to be modernised to facilitate faster construction and to minimise environmental degradation.

TABLE 5

4D CAD FOR OPTIMIZING CONSTRUCTION	●			
SENSORS BASED DESIGN, CONSTRUCTION AND INTELLIGENT OPERATION OF BUILDINGS	●	●	●	
CALAMITY AND FIRE RESISTANT STRUCTURES	●	●	●	
UNDERWATER BUILDING CONSTRUCTION THROUGH MINERAL ACCRETION			●	●
LOW COST DESALINATION TECHNOLOGIES FOR CONSTRUCTION			●	
3D PRINTING OF HOUSES	●	●	●	
BIO-MIMETIC CONSTRUCTION				●
ANTI-GRAVITY DEVICES FOR CONSTRUCTION				●
FILLER SLAB ROOFING WITH VARIOUS ECO-FRIENDLY FILLER MATERIAL	●	●		
CEMENT FREE/WATER FREE CONCRETE			●	
NOVEL CONCRETE SUCH AS FLEXIBLE, TRANSPARENT, BIO-CONCRETE AND SELF-HEALING		●	●	●
NOVEL STRUCTURAL MATERIALS SUCH AS LIQUID GRANITE, TRANSPARENT ALUMINA AND SUPER ALLOYS	●	●		
LOCAL AND RECYCLABLE MATERIALS FOR CONSTRUCTION	●	●		
NANOTECHNOLOGY FOR PAINTS AND SURFACE COATINGS; DURABILITY OF MATERIALS	●	●	●	
GREEN AND NET-ZERO ENERGY BUILDINGS	●	●	●	
ARTIFICIAL LIGHTING BY USING ABSORBED ENERGY			●	●
TOUCH PANEL WALLS AND SMART WINDOWS	●	●	●	

Technologies, concepts and approaches relating to decent habitat that—

- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

QUALITY EDUCATION, LIVELIHOOD AND CREATIVE OPPORTUNITIES

SCHOOLS, COLLEGES AND UNIVERSITIES as currently constituted will be redundant in 2035. Instead, we will have institutions of learning that are virtual/meta/open in character. Although the actual education needs of different segments of our population would vary enormously based upon life circumstances and livelihood opportunities, certain core targets in the area of education would be critical to achieve. The most important target would be 100% literacy, including operating knowledge of devices, instruments and machines. There would be no school dropouts. All children would have access to quality and affordable education, independent of social, economic, geographic, physical and even mental constraints. Due attention would be paid to their cognitive development even before informal education begins at age 3. All people would have affordable re-skilling opportunities to meet the changing requirements of the job market. In a longer-living and ageing society, everybody would have access to second careers and lifelong learning.

Ubiquitous online access to reliable educational resources and services, through multiple mobile devices, would be available to all either free of cost or at an extremely affordable price. Schooling would no longer consist of large classrooms, grade wise stratification, common and rigid curricula, syllabi and textbooks, and an overbearing presence of examinations. An essential vision for 2035 will be the delivery of language neutral content to all individuals, at the press of a button, 24x7. All learners would be able to study in the language of their choice, thanks to cheap real-time translations services.

Most important of all, predetermined content would be a thing of the past: all students would choose their own team, scheme, content and pace of learning, thereby eliminating the distinction between curricular, non-curricular and extracurricular learning. This would open the possibility of peer-to-peer learning. Thus, delivery of content that is configurable to the need of the individual would be a focus, as would the use of technology to make educational content 'real time'. Education itself would have to be contextually reinvented and not dictated by academic and educational bureaucracies.

Based on the above targets, we will face a number of critical challenges in terms of education provision. The most important of these would be to make quality education available in all areas. Whatever may be the projections for rural-urban issues, education will be an all pervasive need, for all age groups. For this to happen, we would have to develop applications and collaboration tools for all areas of education. Students

An essential vision for 2035 will be the delivery of language neutral content to all individuals, at the press of a button, 24x7. All learners would be able to study in the language of their choice, thanks to cheap real-time translations services.

A fundamental challenge would be to mainstream vocational education and to recognise non-formal innovators and master crafts persons as teachers. Empowering the master-apprentice relationship for the learning of skills would therefore be essential.

would have to be provided seamless access to courseware and technology based curriculum. Thus, open content, data and resources to promote creativity and self-expression would have to be developed. Integrating interactive, adaptive and multimedia courseware and simulation into teaching and learning would therefore be another core challenge. Enhancing the cognitive and mental abilities of learners with disabilities would be extremely important from both an educational and livelihood perspectives.

In order to strengthen the link between education and livelihoods, industry/user organisations would have to be integrated into educational systems in a seamless and unobtrusive manner. A fundamental challenge would be to mainstream vocational education and to recognise non-formal innovators and master crafts persons as teachers. Empowering the master-apprentice relationship for the learning of skills would therefore be essential. Technology intervention to provide formal training for unorganised sectors such as construction and many small scale industries in the rural areas will not only improve the efficiency of operations but will also create other avenues for employment in both urban and rural areas.

Apart from its link to livelihoods, education is also the arena in which individuals come to realise and understand their unique abilities, strengths and weaknesses. Technology should provide educational tools for self and society to enhance and make effective use of their unique strengths, as also to overcome their weaknesses. Sports education is a critical area in which ICT tools could provide sportspersons with training on simulators, evaluation and regimens.

Knowledge itself would have to be fundamentally reorganised in order to break down existing disciplinary barriers. History, theory and data (laboratory and field) would have to be seamlessly integrated in all branches of knowledge. We will have to create modular education packages in order to give students much greater mobility and flexibility. We will also have to build enabling pedagogies to transmit knowledge that exists in living traditions and social practices, including marginal knowledge traditions.

Examinations as they currently exist would be yesterday's nightmare. The purpose of educational evaluation would be to measure a much wider range of talents, skills and knowledge through technology based assessments. Evaluation would be a continuous exercise in which learners will get several opportunities to improve their competence levels. Establishing certification repositories that are secure, efficient and authentic would be a core challenge.

TABLE 6

MASSIVELY ONLINE OPEN COURSEWARE (MOOCS)	●	●		
GAMING/GAMIFICATION	●			
INTERACTIVE REMOTELY CONTROLLED LABORATORIES	●			
PERSONALISED VIRTUAL TEACHERS			●	
4G AND 5G COMMUNICATION	●	●		
IMMERSIVE VIRTUAL REALITY	●	●	●	
BRAIN COMPUTER INTERFACE AND MACHINE AUGMENTED COGNITION	●	●	●	●
WEARABLE DEVICES	●	●	●	
DIGITAL IDENTITY AND LEARNING ANALYTICS	●			
AUTOMATED EVALUATION AND ASSESSMENT SYSTEMS	●	●		
DIGITAL HOLOGRAPHY, 3D IMAGING AND VOLUMETRIC/3D DISPLAY	●	●		
3D PRINTING	●	●		
REAL TIME TRANSLATION FOR INDIAN LANGUAGES	●	●	●	

Technologies, concepts and approaches relating to quality education, livelihood and creative opportunities that–

- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

The availability of trained personnel will always be a constraint, particularly at primary and secondary levels of education. Thus, providing content that gives the same human touch and feel would be a fundamental technology challenge. That said, teachers will remain central to education, although their role would be fundamentally transformed to that of orienting the learner; teachers would become navigators and pathfinders, counsellors and confidants. Keeping teachers extremely motivated and maintaining teacher morale at a high level would be a core challenge. Building databases of teachers with similar expertise for knowledge sharing would therefore be essential, as would be taking advantage of social networking to enhance teacher capabilities and the learning experience.

It is evident that ICT will be the backbone for the much needed root-to-branch transformation of Indian education. In terms of individual possibilities and national prospects, the transformation of education through technology (*Table 6*) would be a game changer in every conceivable way. Interestingly, many of the transformative technologies already exist and await deployment, which suggests that at least some of the bottlenecks in the transformation of education relate to policy and not technology. Some

Teachers will remain central to education, although their role would be fundamentally transformed to that of orienting the learner; teachers would become navigators and pathfinders, counsellors and confidants.

technologies of the future, relating to machine augmented cognition and personalised virtual teaching, are promising areas of blue sky research. Education customised to individual talents and preferences would lead to all sorts of creativity and innovation, resulting in greater self-actualisation as well as concrete social benefits.

SAFE AND SPEEDY MOBILITY

MOBILITY ENHANCES THE QUALITY of an individual's life and binds the nation together. Different segments of our population will face different transportation necessities. While time will be the basic constraint in cities, in the countryside distance will remain the primary barrier. By the year 2035, technology should enable us to access public transportation within one km from our home. No place will be more than three hours away from a district headquarters, five hours from the state capital and eight hours from our national capital. Inter-modal mobility should ensure that no two points in a metropolitan area would be more than an hour away. Every settlement will be connected with an all-weather road and every panchayat will have a helipad for delivery of services such as emergency healthcare. Also, from safe mobility perspective we must ensure zero pedestrian fatalities in all parts of the country. This would require mandatory, technology-assisted driver training.

By the year 2035, technology should enable us to access public transportation within one km from our home. No place will be more than three hours away from a district headquarters, five hours from the state capital and eight hours from our national capital.

With growing population in urban areas, and increasing influx of industrial zones to semi-rural neighbourhoods that require 25-50 km of one way travel, providing last mile connectivity through multi-modal means is a huge challenge. Use of ICT to tackle traffic congestion will be essential. Development of vehicles that are twice as fuel efficient but emit half the current emissions will be required. High quality infrastructure, road transportation technologies and traffic management systems are organically interrelated and should be treated in an integrated manner. In addition, there will be a need for intercity connections through cost-effective modes such as semi-high speed and bullet trains for faster intercity access. Multi-modal mobility for goods and services will need to be enhanced with development of dedicated, high speed freight rail corridors. Transportation modes that prioritise movement of perishable commodities will be required to control waste. Last, but not the least, will be the great challenge of developing and producing a powertrain for an indigenous transport aircraft.

TABLE 7

INTELLIGENT TRANSPORTATION SYSTEM	●	●	●	
ALTERNATE FUEL BASED TRANSPORTATION	●	●	●	
ADVANCED POWERTRAIN TECHNOLOGIES		●	●	
AFFORDABLE ENERGY STORAGE AND INFRASTRUCTURE FOR FAST CHARGING		●	●	
ACTIVE AERODYNAMICS		●		
HEAT RECOVERY SYSTEMS		●	●	
INTELLIGENT ROADS		●	●	
LONG LIFE, LOW MAINTENANCE ROADS AND STRUCTURES		●	●	
SELF HEALING ROADS				●
FOG VISION SYSTEM FOR ROAD AND RAIL	●	●		
ACTIVE AND PASSIVE SAFETY TECHNOLOGY	●	●	●	
MAGNETIC LEVITATION TECHNOLOGY		●	●	
TILTING TRAIN TECHNOLOGY			●	
AUTONOMOUS VEHICLES		●	●	
NOVEL MODES OF TRANSPORT (e.g.EVACUATED TUBE TRANSPORT, HYPERLOOP)			●	
AMPHIBIAN AND FLYING VEHICLES	●	●	●	
BIOMIMETICS DESIGN FOR SHIP			●	

Technologies, concepts and approaches relating to safe and speedy mobility that—
- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

Technology interventions will involve trade-offs with the need for sustaining and growing the quantum of land under cultivation. Indigenous capabilities would need to be enhanced, especially with regard to transportation infrastructure and equipment. Involvement of private sector will contribute to cost-effective execution and quality of delivery. In addition, a major need will be implementation of the technologies, as mentioned in *Table 7*, in such a manner that provides for very affordable, comfortable, clean and punctual transportation for all strata of our citizenry. Special focus on inland waterways and coastal waters for transportation is needed. The technological challenges associated with transportation links between India and its neighbouring countries also need to be addressed.

PUBLIC SAFETY AND NATIONAL SECURITY

While public safety is a concern for everyone in general, in the context of women it becomes all the more crucial. A very important target would be to minimise violence against women, especially rape, for which technology would have to be deployed.

WHILE SAFETY IS SHELTER from harm, security is protection from existential threats. Like all other countries, we will have to ensure that all citizens are safe and the nation is secure at all times. Security is in a fundamental sense non-negotiable; it is a prerequisite that cannot be traded off with other necessities. In this technology vision, we have deliberately excluded the aspect of military security. However, since safety and security are core necessities, there are a number of non-military aspects of national security that we must envision and provide for.

There are three different ways in which technology will interface with safety and security concerns. Firstly, the emerging cyber domain, as an area of emerging technologies, carries within itself fundamental vulnerabilities that would need to be addressed. A subset of these threats pertains to personal identity because of their impact on individual privacy. Secondly, threats emanating from the cyber domain would have a deleterious impact on public safety and national security in the physical world. Thirdly, there are a number of threats to public safety and national security in the physical world that do not emanate from the cyber domain but which could be mitigated or even eliminated through deployment of appropriate technologies.

There are several important facets of public safety, the most important of which is the maintenance of law and order. Technological interventions could be extremely beneficial in maintaining general law and order. This has important implications for public safety in terms of day to day living. An important issue under this category would be speedy and error-free criminal investigation. Technologies that would help the police and other agencies in maintaining order, preventing crime and securing convictions are essential for public safety. Cyber forensics for economic and other crimes would be extremely important, as would surveillance by law enforcement and intelligence agencies.

While public safety is a concern for everyone in general, in the context of women it becomes all the more crucial. A very important target would be to minimise violence against women, especially rape, for which technology would have to be deployed. Similarly, as a society we must be extremely sensitive to the safety needs of children and senior citizens – in the latter case, especially those who live by themselves.

Fire and other emergency rescue services would require particular attention. Developing proper infrastructure and then facilitating it with advanced technology to help fight emergencies like fire effectively are an important aspect of public safety. This would include expanding and upgrading infrastructure and having skilled fire fighters who would be able to assist in additional hazardous emergencies as well. Focus has to be on reducing the reaction time to the minimum, so that help can reach as soon as possible. In addition to this, effective medical emergency services would also go a long way in ensuring public safety.

Animal protection and control is another important area of public safety. Measures can be taken to ensure that humans are adequately protected against animals. The other important issue would involve ensuring that the animals are also protected against human atrocities. Care has to be taken to ensure that animals are not mistreated in any way while ensuring protections for human beings.

Proper lighting at night and in dark places is a very rudimentary yet extremely important aspect of public safety. Adequate and proper street lighting has to be ensured on the city roads as well as the rural pathways.

Public safety networks, which basically pertain to proper communication and sharing of information between different agencies charged with the responsibility of ensuring public safety, therefore assume critical importance. This sort of an infrastructure becomes extremely crucial when faced with public safety incidents, especially in the event of threat from terrorism or natural disasters.

Setting aside military security, there are four broad thematic areas of national security that would be crucial to our future as a nation: information and communication security, infrastructure and physical security, financial and economic security, and natural resources and environmental security.

There are several important aspects of information and communication security that must be ensured. Of them, improving software and hardware security, including operating systems, computing platforms, mobile devices, browsers and firewalls, is especially important. Security of telecom networks and industrial controls (SCADA, PLCs) would remain a constant concern. Response to threats from cyberspace (malware, viruses, Trojans, botnets, social networking, e-mails) would also be crucial. Security of citizen data (personal, financial, social, health) and policy formulation for cross-border data flows is an important issue. We must develop a capability for surveillance of internet and communications to detect and block threats of all kinds as well as cyber forensics for post incident analysis. Providing graded security to cyber infrastructure based on threat perception and evolving cyber security audit standards would be essential. Security certification of indigenous and foreign equipment would also be required.

In terms of infrastructure and physical security, we would have to focus on the security requirements of national borders and all ports of entry, as also nuclear installations, power plants and grids, and water supply

We must develop a capability for surveillance of internet and communications to detect and block threats of all kinds as well as cyber forensics for post incident analysis. Providing graded security to cyber infrastructure based on threat perception and evolving cyber security audit standards would be essential.

TABLE 8

	Are readily deployable	Needs to be moved rom Lab to Field	Require targeted research	Are still in the imagination
DEVELOPMENT OF INDIGENOUS SECURITY LAYERS PROTECTING COMPUTING AND COMMUNICATION PLATFORMS		●	●	
NATIONAL CYBERSPACE BORDER SURVEILLANCE, PRIVACY PRESERVING SURVEILLANCE AND DEEP PACKET INSPECTION (DPI) TECHNOLOGIES	●	●	●	
INDIGENOUS, SECURE NETWORK BACKBONE AND STORAGE DEVICES		●	●	
EQUIPMENT CONTROL SECURITY TECHNOLOGIES	●	●		
INDIGENOUS DEVELOPMENT OF BEHAVIOURAL, PHYSIOLOGICAL, BIOMETRIC AND CYBER FORENSIC TECHNOLOGY	●	●	●	
TECHNOLOGIES TO SECURE BODY IMPLANTS			●	●
TECHNOLOGIES TO PROTECT AGAINST REMOTE MIND CONTROL SYSTEMS			●	●
ADVANCED SYSTEMS FOR ENSURING PEDESTRIAN SAFETY	●	●	●	
RAPID SENSING MECHANISM TO DETECT CHEMICALS TO PREVENT DRUGGING CRIME	●	●	●	
SENSORS FOR PROTECTION AND SECURITY OF ELDERLY & PERSONS WITH DISABILITY	●	●	●	
FRUGAL FIRE DETECTION AND FIRE FIGHTING DEVICES	●	●		
ADVANCED FIRE AND SMOKE DETECTION AND RETARDATION IN TRAINS		●		
SENSORS AND PROTECTIVE DEVICES TO PREVENT SPREAD OF PANDEMICS AND EPIDEMICS			●	●
BIOLUMINESCENT/ZERO ENERGY STREET AND PATHWAY LIGHTING			●	●
DETECTION AND PROTECTION SYSTEM AGAINST CHEMICAL, BIOLOGICAL, RADIATION AND NUCLEAR (CBRN) ATTACKS	●	●	●	
EFFICIENT CROWD MANAGEMENT AND COMMUNICATION SYSTEMS		●	●	

Technologies, concepts and approaches relating to public safety and national security that–

- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

systems. Video surveillance of cities and critical infrastructure is essential. National Chemical-Biological-Radiological-Nuclear (CBRN) monitoring and response infrastructure would have to be set up.

The financial and economic security of citizens and organisations for electronic financial transactions (payment systems, banking transactions, e-commerce) would be extremely important. Protection of the financial system would focus on cyber threats to financial systems (malware, security holes in software, insider threats, etc.), confidentiality, integrity, authentication, traceability, and non-repudiation in financial transactions.

Finally, natural resources and environmental security would depend upon surveillance through sample/regular frequency inspections of water, forest, food and minerals. The technological scope in these areas is indicated in *Table 8*.

In order to save lives during train collisions and accidents, technologies similar to deployable airbags need to be developed. Given the age of our country's transportation infrastructure, technologies for sensing and predicting bridge and tunnel collapse would also be extremely important. Use of technology to predict crowd behaviour and identify miscreants in crowded areas would enhance public security. Low cost, reliable sensor networks that link individual dwellings to police, medical and other emergency services would go a long way in making our cities more secure for residents. Increasing the surveillance capabilities of law enforcement agencies, while respecting civil liberties, would significantly reduce the incidence of crimes and misdemeanours. 3D printing will raise a host of public safety issues that would need to be elaborated and addressed technologically. The importance of preserving personal privacy in the course of developing cyber security technologies and methodologies would be essential.

Low cost, reliable sensor networks that link individual dwellings to police, medical and other emergency services would go a long way in making our cities more secure for residents.

CULTURAL DIVERSITY AND VIBRANCY

DIVERSITY IN CULTURE AND LANGUAGES are a key defining feature of India. These are at the very core of India's existence and are its very soul, giving our country its various hues of differences and harmony and making us a vibrant nation. A vision for India in 2035 hence cannot be complete without envisaging how this core aspiration-expectation would influence or be shaped by the realities of that time. Regarding cultural diversity and vibrancy, we would like India to be as advanced as possible technologically and as rooted as possible culturally.

Cultural practices have an enduring element to them and yet are never static. They define our choices and yet are defined by our choices. Cultural practices have very strong tendencies to influence us. More often than not these influences are subtle and hidden and this is where the power of cultural practices truly lies.

We need to be especially vigilant that no one culture is able to dominate others. Ever since the invention of the printing press, the advancement of technology in society has tended to promote monocultures. Caution has to be exercised to ensure that technology guided cultural practices enrich the existing cultural diversity of the nation and do not replace it. However, given the right direction, technology could help us in preserving and enhancing the rich cultural diversity of India. Properly deployed, cultural diversity is a national asset and power multiplier.

One of the key challenges related to the issues addressed above would lie in preserving traditional knowledge and intangible heritage. This would involve conserving documents and scriptures that already exist in a digital form. Preserving traditional knowledge that is not already available in a documented form could involve having extensive oral history recording. In addition, various music and dance forms could also be benefit from technological intervention for their preservation and promotion.

Conserving our tangible heritage is another eminent challenge. Preserving monuments and other cultural entities is of crucial importance as heritage sites are a very tangible and visible aspect of our cultural past and also in many cases irreplaceable. It is also an avenue in which technological advancement and our knowledge of reconstruction could prove to be of utmost importance. Revitalising our languages and scripts is a challenge that is especially worthy of our best efforts. Technology could play a key role in ensuring that the different regional languages of India get incorporated into the mainstream instead of being at the sidelines and fringes. This would help check the elitism associated with the English language and will also facilitate the reach of technology to remote areas of the nation. It would also facilitate the process of people (who speak languages other than English) engaging with these technological advances. Consequently, it would be a huge step towards integration and yet at the same time it would help in preserving the linguistic diversity of the nation.

India has tangible and intangible heritage going back millennia. This heritage is intrinsically and integrally linked to our living culture. Conserving and preserving this heritage is a duty towards our succeeding generations and is especially important for our national identity in a world that is, with every passing day, increasingly integrated. We must work to prevent cultural homogenisation and resist monocultures: both external cultural challenges to our millennial history as well as the domestic domination of some cultures over others. Technological interventions indicated in *Table 9*, include digital scanning; portable translating devices (to translate written material or audio files from one regional or global language to another, or having cheap and easily accessible audio devices that could translate a live conversation into another language) and digital reproduction of handicraft skills. Other aspects of intangible heritage, such as cuisine, oral traditions and the performing arts, must also be preserved and promoted through documentation and reproduction.

Given the right direction, technology could help us in preserving and enhancing the rich cultural diversity of India. Properly deployed, cultural diversity is a national asset and power multiplier.

TABLE 9

	Readily deployable	Lab to Field	Targeted research	Imagination
ADVANCED COMPUTATIONAL PHOTOGRAPHIC TECHNIQUES			●	●
DIGITAL DOCUMENTATION ON OPEN SOURCE PLATFORMS			●	
3D IMAGING	●	●		
HOLOGRAPHY	●	●		
VOLUMETRIC DISPLAY DEVICES		●	●	
IMMERSIVE VIRTUAL REALITY	●	●	●	
GIS APPLICATIONS FOR ARCHAEOLOGY	●			
ADVANCED CHEMICAL TREATMENT AND PRESERVATION OF TANGIBLE HERITAGE	●			
GROUND PENETRATION RADARS FOR INVESTIGATING HEALTH OF MONUMENTS	●			
AFFORDABLE LASER CLEANING OF METALLIC SURFACES OF MONUMENTS	●	●		
AFFORDABLE PORTABLE INTERPRETATION DEVICES			●	
NATURAL LANGUAGE INTERPRETATION		●	●	
DIGITISATION AND REAL TIME TRANSLATION OF ORAL AND WRITTEN MATERIAL	●	●	●	
SYNCHROTRON RADIATION TECHNOLOGY	●	●		

Technologies, concepts and approaches relating to cultural diversity and vibrancy that–
- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

TRANSPARENT AND EFFECTIVE GOVERNANCE

IN A DEMOCRATIC COUNTRY, citizens expect government to be responsive to their needs. Moreover, they expect to have some influence in government decisions and an insight into the bases upon which government decisions are made. It would not be an exaggeration to say that citizens in a democratic country view these three aspects of governance – accountability, transparency and efficacy – as their entitlement.

Human Rights principles provide a set of guiding values for good governance while also indicating parameters on which good governance might be evaluated, like ensuring housing, health, education, justice and public safety. A related key issue is that these targets have to be fulfilled by the government in a manner that upholds public probity and civic virtue. This makes transparency in the working of government essential. Fundamentally, transparency is about ensuring proper flow of information from the government to the people and vice-versa. Good governance, with proper

TABLE 10

	Readily deployable	Needs to be moved rom Lab to Field	Require targeted research	Still in the imagination
SAFE, SECURE AND AUTHENTIC NATIONAL DATABASE VAULTS	●	●	●	
DIGITISATION AND STORAGE OF PERSONAL AND PUBLIC RECORDS IN OPEN STANDARD STORAGE FORMAT	●	●	●	
INTEGRATED EMERGENCY RESPONSE AND ASSISTANCE	●	●	●	
LOCATION AND ABILITY INDEPENDENT VOTING FACILITY	●	●		
NETWORKING OF ALL LEGAL DOCUMENTS	●	●		
ADVANCED FORENSICS	●	●	●	
WEARABLE DEVICES FOR MONITORING AND INTERROGATION UNDER DUE PROCESS OF LAW	●	●	●	
DIGITAL HOLOGRAPHY & 3D IMAGING (VIRTUAL LAWYERS)	●			
REAL TIME TRANSLATION	●	●		
ADVANCED BIOMETRICS FOR DIGITAL IDENTITY	●			
HUMAN INDEPENDENT DECISION SUPPORT SYSTEMS			●	●

Technologies, concepts and approaches relating to transparent and effective governance that—

- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

Speedy justice delivery would be a core expectation: all criminal cases would be adjudicated within six months and all civil cases within four months.

checks and balances, provides an enabling environment for realisation and promotion of economic growth and sustainable human development.

By 2035, the citizens of India will expect all public services to be delivered online and linked to secure digital identity. There would be context sensitive resource allocation and optimum utilisation of public funds. Speedy justice delivery would be a core expectation: all criminal cases would be adjudicated within six months and all civil cases within four months. All decision-making processes would be person independent without becoming impersonal. There would be zero tolerance towards crime, especially crime against children, women, senior citizens and persons with disability. Secure access to insurance and financial services would be available to all.

In order to achieve these targets, courts, prisons and police stations would be interconnected through secure high speed network. All court records and proceedings would be computerised and updated in real-time. Along with ICT-enabled courtrooms, these technological interventions would guarantee speedy justice delivery. Creating and maintaining national digital identity database would be essential, as also guaranteeing the security, safety and integrity of all national databases. Creating location independent, fraud-proof voting procedure would help in retaining the integrity of our elections while enhancing their vitality and minimising disruption of routine life. Digitising all procedures relating to law and order would also be necessary.

Some of the technologies that could be deployed to meet these targets and challenges are tabulated in *Table 10*.

Almost all the technologies that would make governance in our country more transparent, speedy and effective already exist and await deployment. More advanced versions of these extant technologies would require scaling up as well as basic research. Human independent decision support systems are an important area of future blue sky research.

DISASTER AND CLIMATE RESILIENCE

NATURAL DISASTERS TAKE A HEAVY TOLL on life and property. Time and effort taken to recover from such calamities are often extremely long and debilitating. Prevention, it is said, is better than cure. That adage may not be totally applicable in this case as it has not yet been possible to predict, and hence prevent, natural disasters. However, proactive steps can be taken to minimise, if not avoid, loss of life and property that becomes an unbearable load on national exchequer. Accurate prediction of the course and intensity of cyclones is essential. We should vow that, whenever a natural disaster occurs, deaths would be as close to zero as possible and essential services would be restored within an hour.

Our entire infrastructure would have to be made disaster-proof so that it can withstand the fury of natural disasters, including retrofitting of the existing dilapidated infrastructure and housing. Notwithstanding these proactive measures, should some disaster strike, we would have to have in place a swift decision making system so that rescue and rehabilitation efforts get underway without delay.

The incidence and frequency of natural disasters have increased significantly in recent times. The situation is made worse by avoidable human-made disasters. Leakages of toxic materials from industrial units, landslides arising out of irresponsible commercial activities, emission of dangerous gases in the environment are some examples of this kind. We will have to adopt a zero tolerance policy in this regard by resorting to absolutely safe industrial and construction practices. We would also have to reduce carbon intensity by 50 percent in relation to what it would be under business-as-usual scenario in 2035. Likewise efforts would have to be made to reduce energy intensity.

A number of social and religious festivals take place from time to time

Our entire infrastructure would have to be made disaster proof so that it can withstand the fury of natural disasters, including retrofitting of the existing dilapidated infrastructure and housing.

TABLE 11

	Are readily deployable	Need to be moved rom Lab to Field	Require targeted research	Are still in the imagination
EARLY WARNING FOR NATURAL AND MANMADE DISASTERS		●	●	
EARTHQUAKE PREDICTION		●	●	
CALAMITY RESISTANT STRUCTURES	●	●		
SENSOR NETWORK BASED RESCUE, RECOVERY AND REHABILITATION		●	●	
ALL-TERRAIN INTEGRATED RESCUE EQUIPMENT AND VEHICLES	●	●		
ACCURATE WEATHER FORECAST AT MICRO LEVEL	●	●	●	
CLIMATE SMART AGRICULTURE	●	●	●	
ARTIFICIAL PHOTOSYNTHESIS			●	●
ENERGY EFFICIENT ELECTRICAL EQUIPMENT	●	●	●	
ALTERNATE FUEL VEHICLES	●	●	●	
TECHNOLOGY FOR LANDFILL GAS RECOVERY	●	●	●	
HOMEOSTATIC DIAMOND TREES / ARTIFICIAL TREES				●
WEATHER MODIFICATION TECHNOLOGIES	●	●	●	

Technologies, concepts and approaches relating to disaster and climate resilience that–

- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

resulting in gathering of thousands of people in a relatively small area. These, in turn, become breeding grounds of epidemics caused by contaminated food and water which can spread rapidly due to close contact. These can be prevented by adopting appropriate public hygiene practices. We cannot afford to slacken our vigil and would have to be alert to pandemics caused by newly emerging infectious diseases, often with global vectors and linked to changes in climate systems. Development of potent vaccines and their easy availability can go a long way in preventing such calamitous situations.

Climate change is here to stay. We cannot allow it to impact our agricultural production. In order to ensure that there is no loss whatsoever in per capita agricultural production we would have to develop climate resilient agricultural practices. Achieving these lofty goals is easier said than done. We will have to overcome a series of challenges to reach those targets. First and foremost amongst these are improving efficiency, accuracy and fidelity of the early warning systems. These would have to be coupled with reliable weather forecasts at the micro-level to help farmers take proactive measures to mitigate impact of fickle weather. Developing varieties of crops constituting major food items that are resistant to the stress imposed by adverse weather conditions as well as contra-indicated soil characteristics have to be accorded top priority.

Achieving climate resilience would need futuristic and ground-breaking technology development, such as homeostatic diamond trees. Essentially, these are artificial trees that capture atmospheric carbon and convert it into diamonds which are but another and valued form of carbon. We would need to continuously use technology to better understand the root causes of climate change.

Another dimension is added to the disaster scenario with increasing terrorist activities and asymmetrical warfare. We can think of building structures that resist impact of high strength blasts. However, those indulging in these nefarious activities have demonstrated their ability to make innovative deployment of apparently harmless gadgets and instruments as lethal equipment. In addition, these groups appear to be technology savvy and have shown their penchant for using highly advanced technologies. To meet this threat we would have to take proactive measures and try to remain one step ahead all the time. Intimidating as these challenges are, they are not insurmountable, thanks to a basket of technological solutions as shown in *Table 11*.

ECO-FRIENDLY CONSERVATION OF NATURAL RESOURCES

NATURAL RESOURCES CONSTITUTE THE WEALTH of the country, and are irreplaceable. We therefore need to set strong targets to conserve them. By the year 2035, technology will be the key enabler for ensuring that we account for all our natural resources in terms of location, quality and quantity. We will ensure that all exploration and extraction processes would be eco-friendly. No key species will be facing extinction and all indigenous biota will be protected from bio-piracy and illegal exploitation. All freshwater bodies will be restored to pristine condition. Forest cover would be restored and increased by 20% of what it is today. The biggest challenge for the nation will be the creation of a national registry of our natural resources, including a national genetic database. Monitoring the resources of our ecologically megadiverse nation, particularly in fragile zones and wetlands, will be required. Instituting a system of land development that respects the integrity of land morphology will be essential. We need to revive our aquatic ecosystems and prevent overfishing. Finally, we need to maintain air quality at better than global benchmark levels. To achieve our aspirations, some of the technology enablers that we need to work on are outlined in *Table 12*.

ICT will be the key enabler for creating the national natural resource registry that is owned by all sections of the bureaucracy, at the national

By the year 2035, technology will be the key enabler for ensuring that we account for all our natural resources in terms of location, quality and quantity. The biggest challenge for the nation will be the creation of a national registry of our natural resources, including a national genetic database. ICT will be the key enabler for creating the national natural resource registry.

TABLE 12

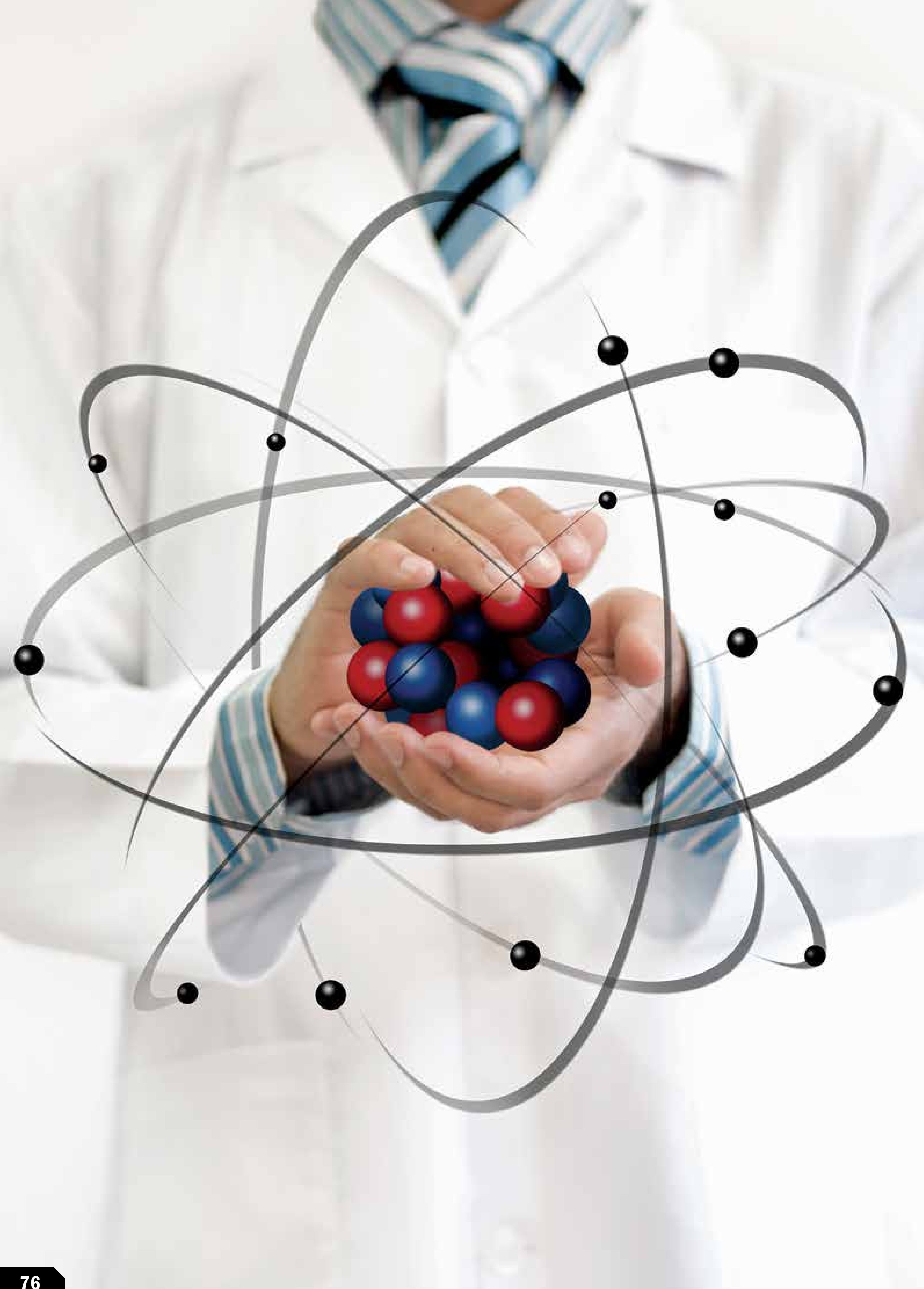
	are readily deployable	needs to be moved rom Lab to Field	require targeted research	are still in the imagination
HIGH CELLULOSE CONTENT AND STRESS TOLERANT FOREST TREE SPECIES		●	●	
USE OF MICROBIAL CONSORTIA FOR ENHANCING BIOMASS PRODUCTION	●	●		
SENSOR-BASED FOREST FIRE MITIGATION		●	●	
IDENTIFICATION OF FORESTRY SPECIES FOR RECLAMATION OF DEGRADED SOIL, WATER LOGGING, OR BIO-DRAINAGE	●	●		
MODELING TREE WATER RELATION HYDROLOGY			●	
NATIONAL LAND MORPHOLOGY MAPPING		●	●	
REGENERATION OF EXTINCT SPECIES FOR REASONS OF BIODIVERSITY		●	●	
IDENTIFYING, CONTROLLING AND ELIMINATING INVASIVE SPECIES			●	
SATELLITE TELEMETRY TO GAIN INFORMATION ABOUT THE SPECIES MOVEMENT, MIGRATION AND DISTRIBUTION	●	●		
SPECIES DISTRIBUTION KNOWLEDGE AND MODELING			●	
STUDY OF POPULATION DYNAMICS OF SPECIES AND THRESHOLD LEVEL	●	●		
TECHNOLOGICAL MEASURES TO MITIGATE MAN-ANIMAL CONFLICT	●	●	●	
USING INDIGENOUS KNOWLEDGE FOR ECOSYSTEM PROTECTION	●	●		
GREEN MINING		●	●	
MICROBIAL ENHANCED OIL RECOVERY	●	●	●	

Technologies, concepts and approaches relating to ecofriendly conservation of natural resources that—

- are readily deployable
- needs to be moved rom Lab to Field
- require targeted research
- are still in the imagination

and state levels. Development of ICT backed systems for monitoring our resources, and working with all strata of our population to prevent further degradation, will be required. Development of our waterways for cost effective use, and parallel development of aquaculture, will need major technology intervention. In the case of agriculture, the movement towards use of hilly terrain is a near term certainty. Technology backed efforts towards mind set change for respecting the integrity of land morphology will be required not only in agriculture but also in transport infrastructure and habitat creation.

ESSENTIAL PREREQUISITES



ESSENTIAL PREREQUISITES

TECHNOLOGIES IN CERTAIN AREAS of national endeavour constitute the underpinning of any developmental effort. In particular, three critical 'transversal' technologies – materials, manufacturing, and information and communication technology (ICT) – provide the foundation upon which all the other technologies depend. Similarly, technologies for infrastructure creation should go in lockstep with technology developments in mining, energy, transport and other areas. Finally, technology development cannot take place in isolation. It has to rely heavily on cutting-edge fundamental research. Hence, the section also highlights the importance of fundamental research in achieving the technology vision.

TRANSVERSAL TECHNOLOGIES

Materials: Our country is fairly well endowed with natural resources which can be tapped to provide materials that would be needed to harness many of the technologies. Nonetheless, we have not been able to convert these resources into utilisable materials most essential for harnessing various technologies. This has been due to lack of entire chain of processing technologies. Further, development of the right material for every important application will be essential for innovation-led growth. Our engineering and research endeavours should be geared towards establishing appropriate ecosystems for this effort. Critical to the 2035 needs will be electronic and energy materials, new metallic materials, polymers and composites, bio- and nano-materials, glasses and ceramics. For the near term, technology indigenisation (for

Manufacturing is the last step of a three step problem resolution process: identifying a problem and deciding to address it, locating the optimum solution to the problem, and executing the solution through design and manufacturing.

electronics and solar applications) will be a major focus for silicon. However, this will have to shift towards silicon replacements like graphene, zinc oxide and organic materials. Energy efficient and environmentally friendly mining and processing techniques for traditional metallic materials is a crying need. Thrust would also have to be on developing non-toxic and biodegradable polymers. Development in biomaterials will need to keep pace with application needs in medical sciences.

Manufacturing: One of the most important prerequisites in 2035 will be our ability to 'make' things that not only meet our own needs but also support an export base where we have a cost and technical advantage. Making things involves a cultural disposition to use our own hands, which we currently lack and for which our education system needs to be fundamentally overhauled. Manufacturing is the last step of a three step problem resolution process, each of which we must master: identifying a problem and deciding to address it, locating the optimum solution to the problem, and executing the solution through design and manufacturing. Precision engineering, consisting of both design and manufacturing, is a current deficiency that must become one of our core strengths. In this regard, indigenisation of machine tool industry to global levels will give a boost to driving innovation in all spheres of activity. There are only a few manufacturing sectors where we have already achieved this, such as leather. In future, manufacturing technology development must be geared towards reduction of environmental impact (including zero discharge), minimise carbon footprint, waterless processes and recycling, dematerialisation, adaptive automation and process intensification. Several other sectors would do well to emulate the success of leather. Our indigenous defence production could also mean a large boost to the manufacturing sector. 3D printing will lead to distributed and customised manufacturing, which could revolutionise manufacturing at the small scale.

Information and Communication Technology: The most important facilitator for meeting all our 2035 needs is ICT. It has the power to impact our lives from cradle to grave. ICT can empower the individual with real time decision making while at the same time provide the government with tools to reach the masses at the individual level. In the telecom sector, India needs to catch up with the development of light weight and energy efficient devices that have already blurred the telecom-internet divide. Development of self-organisation, cognitive radio and interference channels will enable truly distributed and omnipresent, cellular systems. Deployment of very dense cognitive wireless nodes that are energy aware, self configuring, optimising and healing will be a reality. ICT will facilitate integrated decision making in power, transportation, sensor, healthcare, industrial automation and others. ICT will enable persons with disability to lead near-normal lives through effective use of technologies to augment all our senses. ICT will facilitate commercial options for all individual with an ability to do cashless transactions.

India needs to catch up with the development of light weight and energy efficient devices that have already blurred the telecom-internet divide.

INFRASTRUCTURE

TECHNOLOGY DEVELOPMENT will require foundation of networked institutions and infrastructures as a springboard for growth. The first and most essential infrastructure initiative must be the establishment of advanced manufacturing hubs tightly integrated with relevant knowledge institutions. Other infrastructure development, in areas such as airports, ports, highways, railways, pipelines, cold chains and dams, can lend crucial support with all the appropriate connectivities and forward and backward linkages, and are therefore essential. Execution and implementation (inclusive of budgets and timelines) will be the major area of focus. In addition, soft infrastructure elements like skill development and regulatory framework for operation in continuum would be needed.

FUNDAMENTAL RESEARCH

TECHNOLOGY DEVELOPMENT is also guided by advances in fundamental research, by which is implied knowledge creation that is open ended and largely curiosity driven. This trend would gain momentum: recent history has amply demonstrated that the time interval between discovery and its transformation into invention is shrinking rapidly. The first industrial revolution, which heralded the emergence of technology as a vehicle for economic emancipation and social equity, depended largely on fundamental research in physics and chemistry. Technologies based on understanding of the basic principles and processes that govern biological systems provided fodder for the next industrial revolution. Visible on the horizon now are biotechnology and nanotechnology as the lead technologies of the next few decades, ready to impact the planet. Future technologies would have their underpinnings in interdisciplinary research. At the same time, discoveries of newer resources could direct technology development along unanticipated pathways.

Even as the world braces for the molecular age and new technologies disrupt the world, some broad trends that may guide the evolution or shape of future technologies and products are well in sight. Improvement in computing speeds, larger bandwidths and storage capacities have phenomenally improved our capabilities in simulation and modelling. It is possible to create not only virtual worlds at any place but also design products aided by virtual reality. Another major trend visible from the products around us is the smartness or the intelligence built into them. We can already see the convergence of multiple features in gadgets/devices around us. Internet-of-things will result in objects getting wired to the Internet: the convergence of atoms and information. Future technological trends include molecular manufacturing, artificial intelligence, adaptive automation, digital genome, neuromorphic technologies and big data analytics leading to virtualisation, convergence and customisation. These trends will result in technologies and products in next couple of decades, making them relevant to us in the run up to 2035. Some illustrative areas for future research include:

- Manufacturing technologies that are not energy or manpower intensive
- Multi-potent vaccines that can be administered through milk or fruits that are usually imbibed raw thus simultaneously ensuring maintenance of cold chain
- Chemically impregnated stents in drain pipes that clean effluents even before they are presented to purification plants
- Solar panels that mimic photosynthetic pathways releasing hydrogen as a by-product
- Development of easily detectable markers that help advance detection of diseases
- Genomic identification of adult vulnerabilities even in childhood
- Stem cell derived organs for transplantation
- Mind-machine interface

Future technologies would have their underpinnings in interdisciplinary research. At the same time, discoveries of newer resources could direct technology development along unanticipated pathways.

CAPABILITIES AND CONSTRAINTS

CAPABILITIES AND CONSTRAINTS

OUR VISION would have to be realised within the framework of our capabilities as well as constraints placed on them. Unless a rational assessment of these is carried out we would not be in a position to design the blueprint for employing technological solutions to meet various targets. Crucial elements towards this realisation are availability of materials, manufacturing ability and information and communication technology that would play a leading role in almost all walks of life.

At this stage it would be worthwhile to recognise that we need to follow a graded approach to building our national technological capability.

TECHNOLOGY LEADERSHIP

EVERY COUNTRY HAS TO FIND its niche technologies. This depends on core competencies, availability of trained and skilled manpower as well as supportive infrastructure, intellectual environment and traditional knowledgebase. It has then to assume leadership in those areas. India has already proved itself to be amongst the top nations in two or three areas. We have to maintain this lead. In addition, we have to develop other areas where we have the potential.

Nuclear energy is an obvious example in this regard. Due to the worldwide ban imposed on us that prevented us from importing technology and materials even for our civilian nuclear energy programme, we have had to go it alone in continuing these projects. This caused certain delays and cost overruns. Nonetheless, we were successful in establishing and running several nuclear power plants augmenting the share of nuclear power in the overall power generation in the country. This involved indigenous development of technologies in all sectors of nuclear power production as well as nuclear fuel cycle and ancillary facilities. More importantly, fast breeder reactor (FBR) technology was developed during this period. FBRs are able to breed more fissile fuel than they use from non-fissile but fertile material like U238 or more importantly in our context Th232. We have second largest reserves of thorium in the world. We have the capability to use thorium cycle based processes to extract nuclear fuel. This has special significance for us as our abundant thorium reserves has the potential of meeting our power needs for at least 150 years if not more.

India began to develop the **Indigenous Remote Sensing System (IRS) satellite programme** to support national economy in the areas of agriculture, water resources, forestry and ecology, geology, water sheds, marine fisheries and coastal management. Data from IRS satellites is received and disseminated by several countries all over the world. With the advent of high resolution satellites new applications in the area of urban sprawl, infrastructure planning and other large scale applications for mapping have been developed.

With 12 operational satellites, the IRS system is the largest constellation of remote sensing satellites for civilian use in operation today in the world. This unequivocal leadership would have to be maintained with ever more powerful remote sensing capabilities having greater resolutions. This would meet our real needs in a host of areas and also become a major technology export by providing world class data and consultancy at a fraction of the cost. This, in tandem with our satellite launch capabilities and our exploration ventures in the deeper solar system, has given us an acknowledged leadership in all aspects of space technology.

With 12 operational satellites, the IRS system is the largest constellation of remote sensing satellites for civilian use in operation today in the world.

We have already established ourselves today as a leading provider of **IT based solutions** to operational problems encountered in various industries worldwide. Business process outsourcing has been earning sizeable profits for our IT industry and valuable foreign exchange. Most of these are, however, customised applications based on existing platforms provided by others. Without doubt this is remarkable in the sense that no other service provider can match the quality. While continuing to maintain this lead, it will be necessary to expand the horizons and utilise the talent pool and expertise to devise engine drivers of our own either in the form of indigenous platforms or operating systems. As ever-increasing branches of technology become IT driven, India's presence in this sector would yield it significant dividends.

Another area which has been ignored so far is the exploitation of our **traditional knowledgebase.** In particular, there is renewed interest in our Ayurvedic medicinal regimen, which is particularly effective in treating chronic ailments caused by physiological disorders that are the bane of life style diseases. Most of these regimens are based on natural products derived from flora and fauna; thus the possibility of adverse side reactions can be minimal. It must be accepted that little effort has gone into substantiating Ayurveda claims by putting them to stringent tests dictated by modern science. This neglect can prove very costly. There is a crying need for conversion of this knowledgebase into viable technologies by adopting methods of modern science. Now that product patents have become the order of the day, the industry would do well to turn its attention to this traditional knowledgebase and establish leadership in this area.

Technology leadership ultimately transcends technology. It is a critical element in our country's soft power. It demonstrates to the rest of the world that we can do some things as well as, if not better than, any other country. As such, technology leadership is indispensible to comprehensive national power.

Technology leadership ultimately transcends technology. It is a critical element in our country's soft power.

TECHNOLOGY INDEPENDENCE

THERE ARE SEVERAL AREAS wherein we would have to develop technologies on our own. Reasons for these are not far to seek. Some technologies would simply not be available from elsewhere either for love or for money. Strategic technologies needed to maintain our sovereignty may not be obtainable from elsewhere. Defence scenario has been steadily and constantly changing. A paradigm shift is looming large on the horizon. Future conflicts are likely to take place in the cyberspace. Nations are becoming increasingly dependent on information systems to regulate all walks of life. Computerised management of water resources, communication networks, transport systems, energy grids have come to stay. Any interference in these control centres has the potential to wreak havoc and cause much greater destruction than a physical attack with an explosive device. Technological solutions to safeguarding these vital lifelines of our society would have to be developed on our own. While many of these could be acquired from abroad, there would be even greater danger in doing so because it would imply compromising the secrecy of codes governing our management protocols, thereby making us even more vulnerable.

Maintaining integrity of a nation is no longer restricted to securing borders from intrusion. Ensuring food and energy security and also perhaps water management may belong to this group. As we progress towards knowledge based society, considerations of intellectual property rights would assume critical importance. Previously unthought-of non-tariff barriers are being raised not only to deny technology import but also to strangle indigenous technology development. Thus, even manufacture of essential life saving drugs could be hampered due to technology denial.

Certain needs would be specific to our society. Our diet is mostly vegetarian. Protein needs of our society are thus largely met by vegetarian sources such as pulses. This is one component of our diet that is not found, at least not to the same extent, outside the Indian subcontinent. Thus, agricultural technologies targeted at enhancing per acre yields of these crops as also improving their nutritional potential are not given much importance elsewhere. We would have to be on our own in this sector.

History is replete with instances where totally innovative technologies have progressed by leaps and bounds. Therefore, the importance of blue sky research cannot be overemphasised. Informatics, stem cell research, nanotechnology, robotics, biochips, brain-to-brain communications are areas where investment of man, material and money can be expected to pay handsome dividends.

Future conflicts are likely to take place in the cyberspace. Nations are becoming increasingly dependent on information systems to regulate all walks of life.

TECHNOLOGY INNOVATION

OVER THE LAST DECADE, our research output has gone up by 146 per cent, a rate of increase that is 3 times higher than that in the technologically advanced countries. This rise manifests itself in both published research papers in peer reviewed international journals as well as patents granted. The basic research output is most notable in the field of chemistry, followed by agriculture and engineering and technology. On the other hand, a large number of patent applications are based on innovations in the fields of agrochemicals and pharmaceuticals. This capability should constitute the underpinning for technological push to propel the country along a sustainable development path. This would only become possible if the basic research output of our country is converted into commercially viable products and applications. Creating an environment that facilitates tapping the countless innovations taking place at the grassroots would be a crucial condition for national empowerment.

Technologies developed to meet the needs in one particular sector have often found use in totally different sector, thanks to a ground-breaking idea. Computerised Axial Tomography (CAT) scan, which has now become common place as a very useful diagnostic tool, stands out as an example of this kind. Development of crop varieties that defy restrictions imposed by agro-climatic conditions have also become possible due to such innovative thinking.

Out of the box thinking could pay handsome dividends. For example, solar cells patterned on chlorophyll based photosynthetic pathway, could become a potent source of renewable energy in the future. Such technologies would have to be nourished and provided with adequate funding and infrastructure to prove their viability on commercial scales.

Creating an environment that facilitates tapping the countless innovations taking place at the grassroots would be a crucial condition for national empowerment.

TECHNOLOGY ADOPTION

THERE IS A THIRD OPTION besides technology independence and technology innovation. This would be to obtain technologies from elsewhere either by purchasing them or by collaborative approach.

Biotechnological solutions are being developed all over the world. We would have to take advantage of these even as we underline importance of our own efforts in that direction.

These would then have to be modified to suit our own needs. This would reduce permanent reliance on other sources. Manufacture of essential life-saving drugs whose patents have expired by indigenously developed processes is one example of such an approach.

Growth rate of our population has shown signs of decline: it is expected to plateau out by 2035 before registering a gradual reduction. Yet, there is likely to be a billion and a half mouths to feed. Reduction in land under cultivation would pose a threat to increasing the total food supply even after raising productivity. Our agriculture is still largely dependent on monsoon rains. Even at the best of times monsoon is very unpredictable. Thus, accurate monsoon forecast not just at the macro level but also at the micro level must be emphasised. This would enable farmers to plan their crop management schedules more effectively.

In the years to come, another problem would become even graver. Climate change would cause irreversible and fickle alteration in the agro-climatic conditions. If the contribution of the farm sector to GDP growth has to be maintained then development of crop varieties that resist stress induced by adverse agro-climatic conditions would have to be given highest priority. Biotechnological solutions are being developed all over the world. We would have to take advantage of these even as we underline importance of our own efforts in that direction.

Almost a fifth of our agricultural produce gets lost due to lack of proper storage and preservation facilities. At the same time, processing of excess food to provide ready-to-cook products and also to enhance its shelf life would have to be accorded greater importance. As life styles change in tune with better economic conditions eating habits too would change dramatically. To cater to the altered tastes supply of processed yet nutritious food would be necessary.

Water is another very basic necessity. To have enough potable water for the increased population, steps would have to be taken to clean our water reservoirs. Simultaneously, treatment of waste water to convert it to potable quality would also have to be given importance. Effective rainwater harvesting to make it last through the dry two thirds of the year would go a long way in augmenting our water supply.

Notwithstanding our efforts, financial resources and highly trained manpower, India is likely to remain dependent on technologies developed elsewhere in certain areas. The following reasons are responsible for this situation: infancy (technologies in which India is a late starter and is therefore likely to remain behind the curve); redundancy (technologies that are easily obtainable from abroad); and insignificance (technologies that are not likely to have a significant imprint on India's growth trajectory in the next 20 years).

Several such areas, spanning across a number of sectors, can be identified. As we move inexorably towards knowledge based economy almost all walks of life would get automated and digital. While we can rely on ourselves for developing required software, for hardware including design and manufacture of chips, we would have to be dependent on external sources.

Our waterways have already become polluted almost beyond redemption. The major cause for this is dumping of untreated industrial effluent. To remedy this situation, we would need efficient effluent treatment technologies. We have a large coastal line and vast oceans. Desalination technologies, thus, would have to be pressed into service. Certain other countries have perfected quite a few of these technologies and have proved their efficiency in actual operation. Unless we have a novel approach based on a new paradigm we should obtain them from these providers.

In view of the ever rising number of vehicles on our roads, the quality of air in most urban areas leaves much to be desired. India has started adopting European standards for acceptable emissions from exhausts of these vehicles. To meet these stringent standards, technologies would be needed. These have been developed by others who have established a sizeable lead in the sector. It would be futile to try and catch up.

Other areas of continuing technology dependence include construction technologies for erecting eco-friendly and energy conserving structures that would also resist impact of natural disasters; technologies for harnessing non-conventional energy sources, in particular, solar and wind energy; technologies needed for exploration of our ocean resources, in particular minerals, shale gas and gas hydrates.

While we can rely on ourselves for developing required software, for hardware including design and manufacture of chips, we would have to be dependent on external sources.

Some aspects of biotechnology have posed serious legal and ethical problems in recent years. Cloning, assisted reproduction, stem cells, organ transplants and GM crops have led to situations where extant laws have been found to be inadequate.

TECHNOLOGY CONSTRAINTS

THE USE OF CERTAIN TECHNOLOGIES could be counterproductive. Those that are not eco-friendly, and can thus possibly cause even greater degradation of environment, belong to this category. Likewise, those that are likely to bring about rapid socioeconomic changes would widen the gap between haves and have-nots. This would also have to be given a go by. Some aspects of biotechnology have posed serious legal and ethical problems in recent years. Cloning, assisted reproduction, stem cells, organ transplants and GM crops have led to situations where extant laws have been found to be inadequate. While legal structure would have to be changed to meet the new exigencies, adoption of such technologies would have to be tailored to suit social psyche. In the absence of such strategy irreparable damage to the social fabric would ensue.

India has one of the richest biodiversity in the world with a wide variety of species of both flora and fauna. Introduction of technologies that destroy or even threaten this natural wealth would have to be carried out only if absolutely essential. Even then, their adverse impact would have to be mitigated by suitable modifications.

Certain technologies lead to overexploitation of necessary raw materials. This would not be in the interest of the country. Given the rapid depletion of natural resources, future technologies would try and make use of natural resources not tapped or considered of little importance so far. Thus, innovative utilisation of these neglected resources is likely to drive future technology spurt. At the same time, technologies that would make efficient recycling of existing resources is likely to be accorded greater importance. Employment of technologies currently being used for a limited purpose would be sought for uses in totally unheralded areas.

HOW CAN THE TECHNOLOGY VISION envisaged in this document be actualised? Should we focus more on the principal actors or the key activities? Are there any grand challenges in the technology landscape of our country that we must focus our collective energies on? Most importantly, what are the actual modalities that need to be adopted in order to bring this vision to reality? In this, and succeeding section of the document, we reflect on these important questions.

PRINCIPAL ACTORS

FOR LONG TERM SUSTAINABILITY of India's technological prowess, it is important that our higher technical education institutions engage in advanced research on a large scale and become a part of overall innovation ecosystem of the country along with industry. This is necessary because education is the fountainhead of young human resource and that must be oriented and prepared to be effective in strengthening Indian innovation and technological capability.

Government has been progressively enhancing its financial support to R&D in India. Today this stands at around one percent of GDP. The announced target is to take this figure to 2%. While increased budgetary support is important and welcome, it is important to recognise that we appear to be achieving more with lower levels of investment than other countries. Also, different parts of Team India need to focus on different stages of technology. This would imply not only a significant increase in private investment in R&D but also a private sector focus on technologies that are readily deployable or translatable from lab to field. With expected progressive increase in GDP and the resolve of the Government to enhance share of contribution to S&T, we do expect further increase in the Government investment in research.

The challenge with us is then to increase the number of full time equivalent scientists, bring in greater efficiency in terms of technology and economic returns and most importantly private sector investment in research.

In this context, it is necessary to recognise that the effort, involved in translation of research from the level of newfound knowledge to a technology readiness level at which significant business investments can take place, is large and the framework to facilitate support to such translation needs considerable strengthening in our country. Apart from financial support and risk coverage, a more important factor is to build greater mutual confidence between the research and industry domains. Several progressive low cost confidence building measures such as mutual visits for lectures, idea exchange, teaching and training collaboration, industry sponsorship of student internships and research fellowships with emphasis on real life problems between research and industry communities are therefore necessary to start with. Progressively, an innovation ecosystem, where students, faculty/researchers and entrepreneurs could work together on translation of research to technology product/process, would emerge.

In order to promote R&D in technology areas that are policy priorities, government needs to ensure an ecosystem to incentivise the relevant market players. These could take several forms, including fiscal incentives and disincentives, regulations, technology performance mandates, and public procurement (for large publicly funded programmes). The market players, in their own pecuniary interest, may then be expected to respond to changes in the ecosystem by taking up relevant R&D efforts.

It is necessary to recognise that the effort, involved in translation of research from the level of newfound knowledge to a technology readiness level at which significant business investments can take place

What are the situations in which direct participation in technology development by government R&D institutions may be necessary? Clearly, a pre-existing capability of the concerned public R&D institutes in precompetitive domain that can be accessed by all interested industry players is necessary. Even in India, a collective of private players partnering with public funded efforts would help focus public funded efforts in a manner more consistent with user interests. More importantly, the seeds of mutual confidence between potential partners of a network to carry an innovation forward get sown here. Beyond this, several different modes to reach the stage of deployment in market/society can be adopted. For developing products of interest to a specific entrepreneur, modes like contract research, incubation in co-development mode, technology transfer and consultancy could be adopted. In parallel, there should be facilities for setting standards, product evaluation/certification and shared use of capital intensive equipment. Such facilities could be funded fully or partly through public funds with balance coming from industry collectively. In case of a strong public goods character of the technology areas, industry could be incentivised to develop products to meet a given functional need on a competitive basis. Market entry of such products after due qualification, would need to be facilitated, in a calibrated manner if necessary.

For products of strategic nature, there may be a case for development entirely through public funding on grounds of sensitivity/technology control or inadequate commercial potential. In order to supplement the financial, human, and institutional resources of government, partnerships with market players and/or academia may be of advantage. In the design of such partnerships, it would be necessary to ensure that the respective comparative advantage of the partners is realised, and that the incentives for participation are mutually consistent. In order to ensure that investments remain productive and there is continuity of knowledge, government agencies piloting these activities need to ensure continuity of work for industry engaged in technology build up for the country at least in early phases.

In order to ensure that investments remain productive and there is continuity of knowledge, government agencies piloting these activities need to ensure continuity of work for industry engaged in technology build up for the country at least in early phases.

Yet another mode of technology development relates to building of large technology platforms such as a nuclear power plant, large ships/submarine, rockets, satellites, aircrafts etc. Much of such development has taken place as public funded efforts in critical/strategic areas. While this capability must be nurtured, one can visualise increasing industry initiative with growth in this segment. Special encouragement to such efforts including capability building through progressively increasing responsibilities would be worthwhile. The aspect of protection of investment and knowledge/skills through continuity of orders would be even more important here.

Policies and actions of government agencies would need to be defined with clarity and assured credibility that leads to sufficient confidence among different stakeholders.

KEY ACTIVITIES

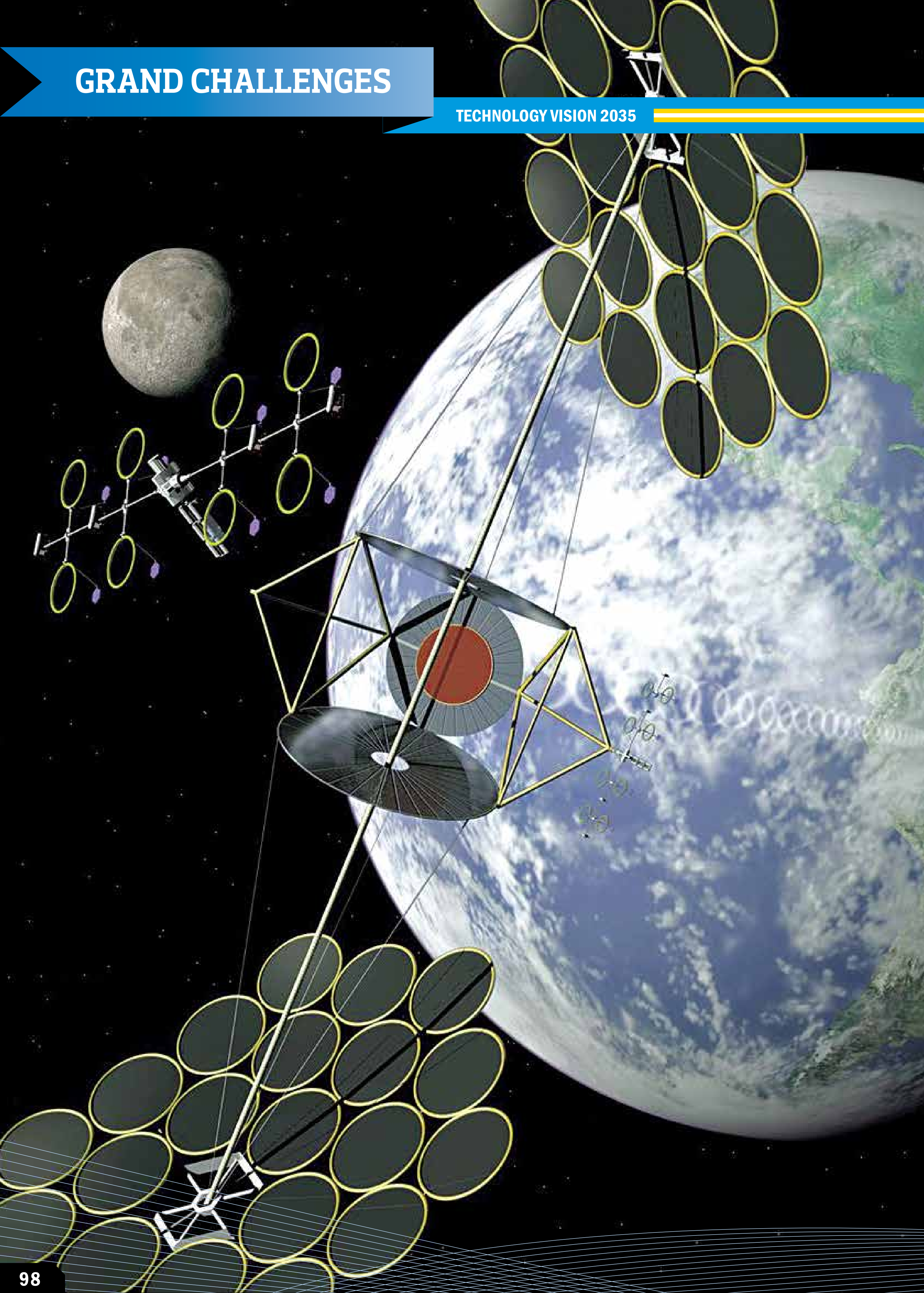
THERE ARE THREE KEY activities that will continuously engage the attention and efforts of all actors in the technology domain. The first of them, and perhaps the most important, is **knowledge creation** which is essential to satisfactorily meet the basic needs of security, prosperity and identity. The world is not only more globalised but also more knowledge intensive. Economic activities will increasingly rely on leveraging knowledge asymmetries; the gap between haves and have-nots will be determined in terms of knowledge disparities. As India and as Indians, we cannot afford to not be in the forefront of the knowledge revolution. As the premium on knowledge increases across the world, the creation of an indigenous knowledge base that is relevant and cutting edge in all disciplines of the natural, social and human sciences becomes essential. The knowledge base could be either applied or pure, i.e. immediately applicable today or a repository for future use.

A second key activity in the technology domain, and one that tends to be neglected and underemphasised, is **ecosystem design for innovation and development.** By ecosystem we mean market conditions, including risk perception; public policies with their resultant laws and regulations; and resource constraints. A critical element in the innovation and developmental ecosystem is the ability to absorb failures and learn useful lessons from failed initiatives; uncertainty is inherent to the research process. Although there are many players in the technology game, the primary responsibility for ecosystem design must necessarily rest with government authorities. Single window approaches to encouraging innovation are essential. The ecosystem covers the entire technology cycle, from ideation to deployment, from knowledge creation to wealth creation. Fundamental ecosystem elements include incentives for innovation and coordination mechanisms to link innovation with entrepreneurship.

A third key activity, and one that we have traditionally neglected in our country, can be characterised as **technology deployment**. Creating knowledge and ensuring an enabling environment would not, by themselves, be enough. We will have to deploy technology to solve real human, social and national problems. Traditionally, for reasons that go deep into our millennial civilization, we have tended to privilege knowledge over skills, 'knowing' over 'doing'. Celebrating our service sector is all very well, but it must not be at the cost of our agricultural and manufacturing sectors.

All technology projects must have well defined goals and targets. Many of these projects would be implemented by public and private players using routine modes and standard operating procedures. However, some technology projects would merit focused attention because of their intrinsic importance, difficulty, complexity and/or impact. For these projects, the most appropriate implementation modality would probably be to launch National Missions. Several specific features distinguish projects suitable for the National Mission approach from other implementation modalities. Firstly, these projects require circumventing bureaucracy and standard operating procedures. Secondly, they also involve specific targets, have a defined timeline, possess a clear inventory of resources and constraints and require only a few (or single) carefully identified players.

GRAND CHALLENGES



IN this technology vision exercise, many of the challenges faced could be readily related to the developmental needs of our country. By identifying twelve prerogatives, we have sought to relate technology to the real needs of the people and the country. However, it is important to recognise that there are some goals that go beyond the prerogatives, in the sense that they address some challenges of enormous magnitude, would come to fruition only in the medium term, and call for concerted and herculean efforts. We suggest that there are some Grand Challenges that face us as a nation. There are a few common features to the Grand Challenges identified here. They all encompass an overarching objective with not one but multiple specific targets. If successfully achieved, the Grand Challenges would have a multiplier impact, i.e. it would lead to positive spinoffs, build virtuous cycles and feed into a number of different sectors. Apart from the impact factor, a Grand Challenge also involves a significant degree of difficulty either in terms of knowledge creation, ecosystem design or technology deployment, or some combination of the three. By the very nature of things, a Grand Challenge cannot be met by a single agency, organisation or group of individuals. It would consist of multiple players and involve multiple technologies. Undoubtedly, the investments that would be required to tackle a Grand Challenge would be enormous, but the payoffs would be just as rewarding. However, we must keep in mind that these are investments for our future generations; in other words, the payoffs are deferred. In assessing whether an endeavour is a Grand Challenge or not, we also need to ask whether it addresses our basic needs of security, prosperity and/or identity. Thus, undertaking a Grand Challenge is a strategic visionary decision for the entire nation, symbolising our collective desire to scale greater heights.

In this spirit, we propose ten Grand Challenges that we should resolve to confront as a nation.

1

GUARANTEEING NUTRITIONAL SECURITY AND ELIMINATING FEMALE AND CHILD ANAEMIA

Nutritional security for all Indians should be our first Grand Challenge, with elimination of anaemia in women and children as our specific target. Unlike other markers of women's health, which have registered significant improvements over the last two decades, the trend for female anaemia in India are showing a worsening trend. Currently over half of all Indian women of reproductive age are chronically anaemic. The price that individuals, families and the nation pay for the high incidence of female anaemia is enormous. Only a combination of targeted public health and nutrition initiatives, involving government, civil society and research institutions, will reverse this morbid trend.

2

ENSURING QUANTITY AND QUALITY OF WATER IN ALL RIVERS AND AQUATIC BODIES

Cleaning our rivers would be an integral part of our second Grand Challenge. The quantity and quality of water in our rivers, inland waterways, water bodies and aquifers has an enormous impact upon the health and quality of life of all Indians. We will need to conceive of our river basins from source to sink as integrated biotic systems, and plan our hydraulic engineering schemes accordingly. Desalination technologies, which would reduce the pressure on our freshwater systems, would be a crucial part of this Grand Challenge, as would the provision of 100% sanitation and sewage to all households.

3

SECURING CRITICAL RESOURCES COMMENSURATE WITH THE SIZE OF OUR COUNTRY

Criticality of resources in the national context would depend on factors like potential constraints on supply, non-availability on Indian landmass and potential for performance enhancement. Economic and security strength of a large country like ours would be dependent on assured access to critical resources. With depleting earth resources, their uneven distribution and increasing global demand, this could eventually become a challenge of unprecedented dimensions. Assured access to required resources thus needs well targeted exploration efforts as well as sustaining diverse supply chains through concerted diplomatic and commercial linkages. The latter has to be a dynamic process alive to the evolving geopolitics. A key strategy in resource security management would be to maximise domestic value addition. This is also important for the economic growth of the country. While accessing critical resources should remain a matter of priority action, we also need to strengthen our technological capabilities to develop alternatives that need less raw material resources or substitute them with more abundantly available alternatives. This calls for a dedicated long term program that encompasses relevant R&D and its translation to commercialisation. Development of fusion energy, fluid hydrocarbon substitutes, functional materials, low cost high technology products that deliver desired objectives more effectively and with minimum use of materials, are some examples of thrust areas that need to be pursued in a concerted manner. A standing framework that monitors and responds to resource security vulnerabilities that could emerge and implements a long term program to make the country self-reliant in terms of critical resources should be established.

4

PROVIDING LEARNER CENTRIC, LANGUAGE NEUTRAL AND HOLISTIC EDUCATION TO ALL

Our fourth Grand Challenge relates to the provision of educational opportunities to all Indians. Technology makes it possible for us to move beyond the bane of predetermined, one-size-fits-all content; we can now provide individualised curriculum that is relevant to the needs, interests and talents of each individual learner. Assimilation of material deemed essential for all learners can be accomplished at different paces and sequences. Language need no longer be a barrier to learning. Education and skilling would then be liberating and empowering, imparting the values to make complete human and social beings while being relevant in terms of life and livelihood possibilities.

5

UNDERSTANDING NATIONAL CLIMATE PATTERNS AND ADAPTING TO THEM

Notwithstanding impressive strides taken as a result of Green Revolution, our agriculture is still principally dependent on the monsoon rains. Even slight alteration in its course or timetable and the agricultural output along with its contribution to the GDP suffers badly. Granting that monsoon is a variable phenomenon making it difficult to chart its progress, we cannot afford to be at the mercy of fickle weather. The problem has been compounded further in recent years with worldwide climate change having disturbed the weather routine to which we have become accustomed for decades. This cannot be allowed to continue as it can harm our development plans disastrously. All efforts would have to be made, therefore, to understand the national weather pattern along with global atmospheric conditions impacting on it, so as to be able to provide reliable forecasts at the micro level. This would require not only modernising our weather forecast machinery but also designing newer models of prediction. We will have to take simultaneous steps to impress on all stakeholders the necessity of adapting to the changed patterns. Grand as this challenge is, it is well within the potential of technological and human resources we have at our disposal.

6

MAKING INDIA NON-FOSSIL FUEL BASED

Presently, energy use at a level commensurate with high Human Development Index poses the twin challenge of energy resource sustainability and threat of climate change. Coal is the mainstay of our electricity supply and may come under severe stress in a few decades. Most of our hydrocarbon needs are presently met through imports. In the business as usual mode, our energy import bill which is already very high is likely to become unmanageable. The Grand Challenge then is to be free from such heavy dependence on fossil energy. Luckily, our energy resource endowment in thorium, renewable energy (primarily solar) and as yet untapped hydro potential is quite favourable to this objective. Since there are a number of India specific challenges that are unlikely to be of priority interest to most other countries, we need focussed indigenous efforts to develop and deploy these technologies. Technologies for production of electricity as well as fluid hydrocarbon substitutes would need to be developed. A comprehensive implementation structure to deal with policies, technology development and rapid large scale deployment of non-fossil energy in the country would have to be put in place.

7

TAKING THE RAILWAY TO LEH AND TAWANG

If the difficult Katra–Banihal stretch is completed by 2017, we would finally have a rail link to the Kashmir valley in our 70th year of independence. Our seventh Grand Challenge would be to push onwards toward Kargil and Leh, tunnelling through the Great Himalayas. On the eastern flank of the Himalayas, we would also need to take the railway line across the Brahmaputra and all the way to Tawang. This Grand Challenge would be an order of magnitude more difficult than tunnelling under the Pir Panjal range to Kashmir. Nevertheless, in strategic terms, there is no Grand Challenge more urgent than building a rail link connecting the rest of India to these important national peripheries.

8

ENSURING LOCATION AND ABILITY INDEPENDENT ELECTORAL AND FINANCIAL EMPOWERMENT

Our eighth Grand Challenge would be to leverage technology to empower all Indians politically and financially irrespective of their location and ability. Holding free and fair election is a mammoth logistical task in our country, requiring massive and sustained contributions from our administrative and security personnel. Unfortunately, millions are not able to exercise their franchise as they are unable to reach a specific location either due to disability or other reasons. Many do not possess even the physical ability to press button or cast votes through paper ballots or other means. Technology can overcome these barriers and would empower each citizen politically and financially in real sense.

9

DEVELOPING COMMERCIALLY VIABLE DECENTRALISED AND DISTRIBUTED ENERGY FOR ALL

To ensure universal availability of quality power to all households and establishments, we will need innovative solutions for generation, transmission and distribution. While the present approach of establishing centralised and large scale power generation facilities is a basic necessity for quickly addressing the energy availability shortfall at the macro level, we will always be in catch up mode for ensuring techno-commercial viability in urban pockets, rural and remote areas. To address this issue, we will require the development and integration of technologies that enable synchronous utilisation of renewable energy sources, micro-generation facilities, smart grids, and extra energy efficient equipment. The Grand Challenge will be execution of the above in a manner that is commercially sustainable, environmentally benign, weather and resource independent, and for all time to come.

10

ENSURING UNIVERSAL ECO-FRIENDLY WASTE MANAGEMENT

Of the several important initiatives that would be integral to our last Grand Challenge, perhaps the most important would be to provide modern sanitation facilities to 100% of our households. By 2035, automotive components and electronic devices would be ubiquitous, so ensuring their 100% recycling would be essential. All biodegradable wastes would be decomposed and converted into energy, thereby eliminating large landfills on the edges of cities. Manufacturing processes would produce minimal waste, which would be inputs into other production cycles. India would be well on the path to becoming a zero waste economy.

TECHNOLOGY: COMPREHENSIVE NATIONAL POWER

TECHNOLOGY: COMPREHENSIVE NATIONAL POWER

IN THIS DOCUMENT we have taken a needs-based approach to technology. We have articulated a technology vision that emphasises Indians rather than India, on the assumption that the technologies that are beneficial to the vast majority of Indians would necessarily be advantageous to India as well. Nevertheless, our analysis has not been at the micro level but has taken on a macro perspective, for the simple reason that the impact of technology is felt not just at the individual level but aggregates across the entire society.

Just as technology is empowering for individual citizens, it is empowering for the country as well. India, like so many other countries in Asia, Africa and Latin America, was dragged into modernity by the technological prowess and superiority of Europe. As the colonial period reminds us, the consequence of technological underdevelopment can be the loss of our freedom and autonomy. Since Independence, India has sought to maintain its strategic autonomy at all costs; the foreign policy of non-alignment has long exemplified our country's basic approach to the external world. The world powers forced India to pay a price for its strategic autonomy by setting up extensive global technology denial regimes. However, technology denial by foreign governments and multilateral treaties is yesterday's story: the game will now be played by multinational corporations and patent offices. To counter technology denial in the future, India will have to become a

To counter technology denial in the future, India will have to become a major player in the technology production game and suitably leverage its market attractiveness.

Technology is a fundamental element in comprehensive national power. Accessing, producing and leveraging technology will remain a core national interest with strong external linkages. Only revolutionary changes in our country's education system will make our country technologically competitive.

major player in the technology production game and suitably leverage its market attractiveness.

In a globalised world, technology cannot germinate in any single country in isolation. It is now in the interest of India and the world that our country participates actively in international projects involving large-scale, heavily funded scientific experiments, often involving basic research. Given the high costs and number of personnel involved, international collaboration by India in these experiments makes a lot of sense.

As a country it is important that we gain confidence in our own technological capabilities. Sometimes, taking the first step is the most important achievement. As long as there is a willingness, desire and hunger for technological advance, it should not matter if the first step appears to be a modest one. For example, in the pharmaceutical sector Indian technological planners and workers have gained increasing self-confidence and have advanced in a few decades from clinical trials to drug discovery. This success can be replicated in other sectors, given the same technological and entrepreneurial prowess. Large Indian corporations have the capabilities to invest in technology at the global scale. With this in mind, TIFAC has taken the lead in building capacities in technology foresight for Indian industry. A model of public-private partnership in basic research in which the government takes on a large proportion of risks would make Indian public and private companies more research oriented and willing to play the technology creation game.

In this context, the building of Indian technology brands is essential, whether in biotechnology, information technology, alternate energy or any other area. Since technology is a fundamental element in comprehensive national power, accessing, producing and leveraging technology will remain a core national interest with strong external linkages. Education that promotes innovation and creativity is a key element. Revolutionary changes in our country's education system will make our country technologically competitive. This technology vision is a modest attempt to galvanise our youth, catalyse our technology workers and institutions, and motivate all stakeholders to participate in the quest for technology leadership.

APPENDIX

3D PRINTING

Process of making 3D solid objects from a digital model and is achieved using additive processes, where an object is created by laying down successive layers of material. It can reduce the material wastage and create complex objects.

ARTIFICIAL INTELLIGENCE (AI)

The capability of a machine to imitate intelligent human behaviour, such as visual perception, speech recognition, decision making, translation and other tasks.

ARTIFICIAL PHOTOSYNTHESIS

Artificial photosynthesis is mimicking the natural process of photosynthesis whereby sunlight, water and carbon dioxide are used to convert into carbohydrates and oxygen. The term is commonly used to refer to any scheme for capturing and storing the energy from sunlight in the chemical bonds of a fuel (a solar fuel). Photocatalytic water splitting converts water into protons (and eventually hydrogen) and oxygen, and is a main research area in artificial photosynthesis.

BIG DATA ANALYTICS

Process of examining big data to decipher hidden patterns/trends, unknown correlations and other useful information for better decision making. With big data analytics, one can analyse huge volumes of data that conventional analytics cannot touch.

BIO-CONCRETE

Bio-concrete is a self-healing concrete in which bacteria mediate the production of minerals which rapidly seal freshly formed cracks, a process that concomitantly decreases concrete permeability, and thus better protects embedded steel reinforcement from corrosion. Bio-concrete is a material, which can successfully remediate cracks in concrete.

BIO-FORTIFICATION

Bio-fortification is the process by which the nutritional quality of food crops is improved through conventional plant breeding and/or use of biotechnology. For example, iron bio-fortification of rice, beans, sweet potato, cassava and legumes; zinc bio-fortification of wheat, rice, beans, sweet potato and maize.

BIOLUMINESCENCE

Bioluminescence is the production and emission of light by a living organism as the result of a chemical reaction during which chemical energy is converted to light energy.

BIOMIMETICS

Bio-mimetic refers to human-made models, processes, substances, devices, or systems that imitate nature. The emerging field of biomimetics could give rise to new technologies created from biologically inspired products at both the macro scale and nanoscale levels with properties such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self-assembly and harnessing solar energy.

BIOTRACEABILITY

Bio-traceability is the ability to use downstream information to point to materials, processes or actions within a particular food chain that can be identified as the source of undesirable agents.

BRAIN-COMPUTER INTERFACE (BCI)

BCI, also called a direct neural interface (DNI), synthetic telepathy interface (STI) or a brain–machine interface (BMI) , is a system that allows a person to control a computer or other electronic device using only his or her brainwaves, with no movement required. It can be used for communication, computer access, or control of devices such as a wheelchair or prosthetic arm, among other applications.

C3 TO C4 CONVERSION

Plants use two principal carbon fixation cycles, the C3 and C4 cycles, during photosynthesis. C4 plants (notably tropical grasses) exhibit greater efficiency than C3 plants (such as trees, shrubs and cool-climate grasses) with respect to water, light, and nitrogen use and better yields due to differences in photosynthetic activity, whereas C3 plants like rice and wheat yields are source limited. The probable solution to establish an efficient, higher capacity photosynthetic mechanism in C3 plants is C4 photosynthetic pathway.

CLIMATE-SMART AGRICULTURE (CSA)

CSA contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars i.e. sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change and reducing and/or removing greenhouse gases emissions, where possible.

COGNITIVE SCIENCE

Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics and anthropology.

COMPUTATIONAL PHOTOGRAPHY

Computational photography refers to computational image capture, processing and manipulation techniques that enhance or extend the capabilities of digital photography. It is an emerging new field created by the convergence of computer graphics, computer vision and photography.

DEEP PACKET INSPECTION (DPI) TECHNOLOGIES

DPI, also called complete packet inspection and Information eXtraction (IX) is a form of computer network packet filtering that examines the data part for viruses, spam, intrusion or defined criteria to decide whether the packet may pass or if it needs to be routed to a different destination.

DESALINATION TECHNOLOGY

Desalination can be defined as any process that separates saline water into two parts - one that has a low concentration of salt (treated water or product water), and the other with a much higher concentration than the original feed water, usually referred to as brine concentrate or simply as 'concentrate'. The two major types of technologies that are used around the world for desalination i.e. thermal and membrane. Both technologies need energy to operate and produce fresh water.

FILLER SLAB ROOFING

The filler slab roof is essentially a normal RCC slab roofing where the bottom half (tension) concrete portions are replaced by filler materials such as bricks, tiles, cellular concrete blocks, etc. These filler materials are so placed as not to compromise the structural strength, resulting in replacing unwanted and non-functional tension concrete, thus reducing total economic cost. Filler slabs are safe, sound and provide aesthetically pleasing pattern ceilings without a need for plaster.

FORECASTING

Forecasting is an approach to envisage the future. It is predicting that an event will happen, to a defined extent, and sometimes with a defined probability. It is by definition normative and aims at predicting future developments on the basis of the extrapolation of perceptible trends.

FORESIGHT

Foresight is a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilising joint actions. Foresight involves systematic attempts to look into the future of science, technology, society and the economy, and their interactions, in order to promote social, economic and environmental benefit.

GAS HYDRATE

Gas hydrate is a cage-like lattice of ice / water inside of which are trapped molecules of methane, the chief constituent of natural gas. If gas hydrate is either warmed or depressurised, it will revert back to water and natural gas.

GENOMICS

Study of genes and their functions, and related techniques.

HOLOGRAPHY

Holography is a technique which enables three-dimensional images (holograms) to be made. It involves the use of a laser, interference, diffraction, light intensity recording and suitable illumination of the recording. The image changes as the position and orientation of the viewing system changes in exactly the same way as if the object were still present, thus making the image appear three-dimensional.

HOMEOSTATIC DIAMOND TREES / ARTIFICIAL TREES

Artificial trees are one of the notable examples of an atmospheric scrubbing process. This concept is used to remove ambient CO_2 and can suck up to 1,000 times more CO_2 from the air than real trees can at a rate of about one ton of carbon per day if it is approximately the size of an actual tree. The removed CO_2 would be captured in a filter and then removed from the filter and stored.

IMMERSIVE VIRTUAL REALITY

Immersive virtual reality is a system in which people feel as if they are truly inside a virtual environment and become detached from the real physical world. In theory, this would involve stimulating all of the normal senses in response to actions taken in a virtual world. More practically, the term can be applied to an experience that involves placing a person in a three-dimensional (3D) environment attempting to create an experience that is fully engrossing, although largely visual. This can be achieved by using either the technologies of Head-Mounted Display (HMD) or multiple projections.

INTERACTIVE FOODS / SMART FOODS

Building on the concept of 'on-demand' food, the idea of interactive food is to allow consumers to modify food depending on their own nutritional needs or tastes. The concept is that thousands of nanocapsules containing flavour or colour enhancers, or added nutritional elements (such as vitamins), would remain dormant in the food and only be released when triggered by the consumer.

LAB-ON-CHIP

Lab-on-chip is a class of device that integrates and automates multiple laborartory techniques into system that fits on a chip upto a maximum of few cm^2 of size.

MAGNETIC LEVITATION – MAGLEV

The Maglev is a method of propulsion that moves between two electro-magnetic fields without physically touching the rail track (magnets are used instead of wheels, axel), a repulsive force and an attractive force induced between the magnets (electromagnetic field) are used to propel the forward motion.

NANOBOTS

A very small autonomous robot, typically the size of a biological cell, designed to work alone or in large numbers to achieve some task. It can manipulate nanoscale objects with great precision.

NUCLEAR FUSION

Nuclear fusion is one of the most promising options for generating large amounts of carbon-free energy. Fusion is the process that heats the Sun and all other stars, where atomic nuclei collide together and release energy (in the form of neutrons). The country needs new, cleaner ways to supply increasing energy demand, as concerns grow over climate change and declining supplies of fossil fuels.

OPTOGENETICS

Combination of genetics and optics to control well-defined events within specific cells of living tissue and also includes the discovery and insertion into cells of genes that confer light responsiveness..

REAL-TIME TRANSLATION

Highly intelligent and interactive system that will allow seamless translation of languages autonomously with reasonable time delay.

ROBOTICS

Robotics is a science that combines a range of fields like Mechanical Engineering, Electrical Engineering, Electronics and Computer Science. Robotics has potential in empowering human being to work efficiently in many areas, for example, home automation, industrial automation, health care, defense, space, surveillance etc. It enables to perform labor intensive jobs very safely and accurately which are otherwise very difficult to do.

SCENARIO

A scenario is a 'story' illustrating visions of possible future or aspects of possible future. It is perhaps the most emblematic foresight or future studies method. Scenarios are not predictions about the future but rather similar to simulations of some possible futures. They are used both as an exploratory method and as a tool for decision-making, mainly to highlight the discontinuities from the present and to reveal the choices available and their potential consequences.

STEALTH VEHICLE TECHNOLOGY

Stealth technology also termed LO technology (low observable technology) is a sub-discipline of military tactics and passive electronic countermeasures, which cover a range of techniques used with personnel, aircraft, ships, submarines, missiles and satellites to make them less visible (ideally invisible) to radar, infrared, sonar and other detection methods. It corresponds to camouflage for these parts of the electromagnetic spectrum.

SYNCHROTRON RADIATION TECHNOLOGY

In a synchrotron, electrons are accelerated to extremely high energy and made to change direction periodically. The resulting X-rays are emitted as dozens of thin beams. This technology is used in art conservation at molecular level.

TELEMEDICINE

Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve a patient's clinical health status. Telemedicine includes a growing variety of applications and services using two-way video, email, smart phones, wireless tools and other forms of telecommunications technology.

TIGHT GAS

Tight gas is natural gas produced from reservoir rocks with such low permeability that massive hydraulic fracturing is necessary to produce the well at economic rates. Tight gas reservoirs are generally defined as having less than 0.1 millidarcy (mD) matrix permeability and less than ten percent matrix porosity. Although shales have low permeability and low effective porosity, shale gas is usually considered separate from tight gas, which is contained most commonly in sandstone, but sometimes in limestone. Tight gas is considered an unconventional source of natural gas.

TRANSGENICS

Transgenics is the study and practice of introducing foreign genetic material into an organism's DNA. Transgenic plants or animals show traits that are normally impossible for their species.

VOLUMETRIC DISPLAY DEVICE

A volumetric display device is a graphic display device that forms a visual representation of an object in three physical dimensions, as opposed to the planar image of traditional screens that simulate depth through a number of different visual effects. One definition offered by pioneers in the field is that volumetric displays create 3-D imagery via the emission, scattering, or relaying of illumination from well-defined regions in (x,y,z) space.

ZOONOTIC DISEASES

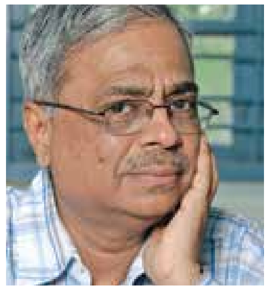
Zoonotic diseases are those diseases and infections which are naturally transmitted between vertebrate animals and man. A zoonotic agent may be a bacterium, virus, fungus, parasite, or other communicable agent.

CHAIRMAN, NATIONAL APEX COMMITTEE & MENTOR

DR. ANIL KAKODKAR
DAE – Homi Bhabha Chair Professor, BARC Mumbai

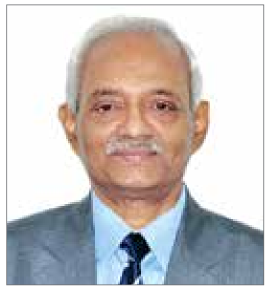
NATIONAL APEX COMMITTEE MEMBERS

DR. PRABHAT RANJAN
Executive Director TIFAC, New Delhi

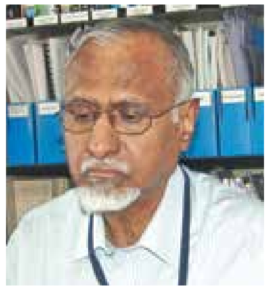


PROF. A. JHUNJHUNWALA
IIT Madras, Chennai

PROF. VARUN SAHNI
JNU, New Delhi



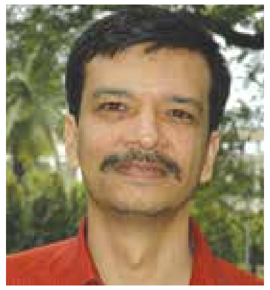
DR. W. SELVAMURTHY
Formerly CCR&D, DRDO, New Delhi



DR. P. GHOSH
Former Secretary, MoEF, New Delhi

PROF. PANJAB SINGH
Former DG, ICAR, New Delhi

DR. GURBACHAN SINGH
Chairman, ASRB, New Delhi



DR. RANGAN BANERJEE
IIT Bombay, Mumbai

DR. SHRIKANT MARATHE
Former Director, ARAI, Pune

DR. L. PUGAZHENTHY
Executive Director, ILZDA, New Delhi

DR. P. RADHAKRISHNAN
Director, PSGIAS, Coimbatore

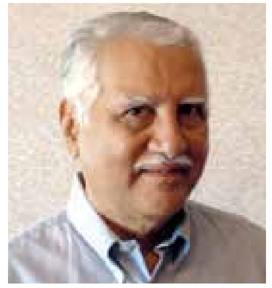
SH. D.P. GUPTA
Former DG-Roads, MoRTH, New Delhi

PROF. S.K. BHATTACHARYA
Director CSIR-CBRI, Roorkee

DR. SIBAJI RAHA
Director, Bose Institute, Kolkata

DR. GAUTAM GOSWAMI
Head, TV 2035 Programme, TIFAC

AUTHORS



DR. G.P. PHONDKE
Former Director NISCAIR, New Delhi

PROF. VARUN SAHNI
JNU, New Delhi

SH. H. SANTHANAM
Former VP (R&D), Mahindra & Mahindra, Chennai

TIFAC TEAM

DR. NEERAJ SAXENA
Scientist E

MS. JANCY. A
Scientist E

DR. T. CHAKRADHAR
Scientist C

MS. MUKTI PRASAD
Scientist C

MS. SWATI SHARMA
Scientist B

MR. MANISH KUMAR
Scientist B

SPECIAL ACKNOWLEDGEMENT

DR. T. RAMASAMI
Former Secretary, Department of Science and Technology, New Delhi

TIFAC

TECHNOLOGY INFORMATION, FORECASTING AND ASSESSMENT COUNCIL (TIFAC)