INVITED PAPER

SCIENCE, ENGINEERING, INDUSTRY AND MARKETS*

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Abstract

The lecture brings out the distinct aspects of Science, Engineering, Industry and Markets in the contemporary context. It also emphasizes the need to look through their linkages well in advance, if the benefits are to be derived for the economy and society. That in turn will enhance support for science.

It is a great pleasure and honour for me to deliver a lecture at the National College, which is a unique institution. It is associated with many great and eminent persons in India. In fact, many of them are respected globally, as well. For me, an additional happiness is because of Dr. V Krishnamurthy, a doyen of Indian Industry who helped a number of Indian industries to take many bold steps to march towards global excellence, is associated with it and guiding it.

The multi disciplinary space related high tech development in India with which I was associated since 1964, is a remarkable one. However, the story of Indian industrial technologies was different from these. Though post-independent India built up many large industries and a whole set of Science and Technology (S&T) Institutions and IITs and Universities, their linkages with actual engineering and production for the markets were poor. "Science" was in isolation. Some of the early-stage-technology - developments for industrial or operational uses at the national laboratories, remained generally at the lab stages or at best as small pilot plants. Most of them did not even enter the stages of commercial level activities (that is being market worthy) of engineering for limited production and subsequent large size scale up.

So the Indian industries imported all these know how and associated equipment. Their products were in the markets satisfying domestic and (limited) foreign consumers. It was realised that such a stage is not good in the long run. From the stages of being technology laggard and follower-ship stages, India had to become leaders in many sectors of Industries. That was possible only with a well researched technology forecasting and assessment studies taking into account Indian status and global developments, just as Japan had already done (by then) and as S. Korea, China etc., embarked upon later.

Such a set of bridges between Laboratories, Universities, Industries and Markets were to be designed by Technology Information, Forecasting and Assessment Council (TIFAC) which was established in 1988. The later successes of TIFAC were in several fields like Sugar, Fly Ash Utilisation, Advanced Composites, Home Grown Technologies etc., with commercial level successes. Dr. V Krishnamurthy was its first Chairman and I as Chief Executive of TIFAC learnt about Indian Industry and the national laboratories in different fields.

In addition many specific technology road maps linking Indian Industry (as they were then) to domestic and global markets were generated by TIFAC as reports, which were sought after by the industry and labs, and even by foreign companies: they ranged from petro chemicals to steel to textiles to leather to advanced materials. All these efforts paved the way for the later major national two year exercise leading to Technology Vision of India 2020, done during 1994-1995 resulting in 25 documents and later in a book India 2020, by Kalam and Rajan (1998). I describe this background in the context of the topic of todays endowment lecture in order to understand my view point.

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In today's endowment lecture celebrating the Science Day, symbolically associated with the discovery of Raman Effect - a proud heritage of India - I desire to recall the famous statement by Jawaharlal Nehru in 1937 "Future belongs to those who make friends with science".

Nehru's vision was not just a stand alone "Science" but one which spans all walks of economic, social and individual lives. That will require the whole span of activities covered in the title of this lecture. Such a dynamic and growing linkages (or Orchestra!) will also create many more Raman's in the country, as "Science" will be truly sought after. Let us recall the fact that the Raman-effect-based industries are about one billion dollar worth or more! Not in the country of its discovery, where such linkages did not exist.

Even now the linkages are not as strong as is necessary for India to take global leadership position and also to provide decent incomes for ALL Indians. There are many reasons for this state of affairs. One of it is also because the unique talents of persons **in seeing through the whole link well in advance and take actions, well ahead** were not available to the country during the years of planned economy and, during the most crucial post-liberalisation period.

Nation has to march on and the people of the country have to be prosperous. India has to proudly contribute to the world knowledge the way Sir C.V. Raman and a few others did. We will explore some pathways and the crucial elements to be done, so that we can be back in the business of building and sustaining a strong and prosperous India with sustained happiness for Indian People.

Science and Engineering

It is crucial to understand the specific differences and important interdependencies of "Science" and "Engineering" instead of lumping them under a common word "Science" or S&T or as STI (as is currently popular to attach the word Innovation to S&T thus hoping that economic and social relevance will be built up!).

A modest attempt was done by me (about 50 page write up) and it can be seen in my website www.ysrajan.com under Article section. In this brief talk, I will try to touch upon a few salient aspects, with some examples.

The old explanations or definitions of "Science" are no longer fully valid: observe - experiment measure-analyse data-theorise-arrive at truth (laws) etc., is too simplistic in the current stage of human development. They were more appropriate during 17^{th} and 18^{th} and perhaps even 19^{th} century context. Explosive growth of modern physics during the early 20^{th} century totally changed the picture (and the philosophy of science). Thought experiments, and purely mathematical models predicting about possible laws of nature (which may find experimental evidence or negation years or decades later) became also a part of the accepted corpus of "Scientific Research" that is "Science". As long as a scope exists for falsification through an experiment in a distant future or through subsequent theoretical or other findings, then it is still a part of "Science".

We will in the following, look at the conclusions of some important papers which have attempted to illustrate the processes of science, with examples as to how they get falsified. They also elucidate the difference between correlation and causal connection.

"Science" and "Scientific Research" now face massive "ignorance" (not the usual uninformed ones) as well as the complexities of phenomena. Thus the scientific methodologies when used to life sciences, evolution, medicine, economics, psychology, meteorology, geophysics, astronomy etc., face most difficult challenges. By necessity, many of the plausible multi parameters are kept away and experiments or data collections **revolve around a few select quantifiable parameters**. Complex statistical or mathematical models are used to derive conclusions out of such massive data sets.

There are now many well researched studies which indicate that many such research findings are false (not because of intentional unethical actions by researchers but by the very process itself). Some references are: "Why most published research findings are false?" by John P.A. Ioannidis in PLOS Medicine 2(8): 124, August 30, 2005. The author is himself a famous researcher. He states "Research findings (in that paper) are defined as any relations, informative predictors, risk factors or associations".

His conclusions through detailed studies of many research papers (such a research is now termed as Meta research) are startling. "Well powered epidemiological studies may have only one in five chances of being true...." "the majority of modern biomedical research ....there are no true findings at all to be discovered.......

I have given only a few glimpses of the paper which is full of statistically derived analysis. It is worth reading in full.

In another paper "What do scientific studies show?" by Gary Gutting, in **The Stone** April 25, 2013, this process of research conclusions being often found later false is explained with a perspective. In a sense that is the scientific process which should be understood by all. Some quotes. He starts the paper: "..... popular media report "scientific results" nearly every day. They come delivered in news reports and opinion pieces, and are often used to make a variety of points concerning important matters like health, parenting, education, even spirituality and self-knowledge. How seriously should we take them?"

He answers: "The key feature of empirical testing is not that it's infallible but that it's self-correcting".

He quotes a few examples about the use of Vitamin D which were in 2010 John Hopkins Health Alert, based on "a decade of an explosion of research". A more rigorous study in 2013, places the conclusions into serious questions. Similarly many papers about taking niacin to increase "good cholesterol" have been disproved by more rigorous study.

He poses a few questions after these examples:

"Such reporting have led many readers to question the reliability of science. And given the way the news is often reported they seem to have a point. What use are scientific results if they are so frequently reversed? But the problem is typically not with scientific results but with reporting".

The reasons for the above statement, he explains further: "In both the above examples earlier studies had shown a **correlation but not a causal connection**. They had not shown, for example, taking Vitamin D was **the only relevant** difference between those whose pain is decreased and those whose pain did not decrease..........Typically, the best way to establish a cause rather a correlation is to perform a Randomised Controlled Experiment (RCT), where we know that only one possibly relevant factor distinguishers the two groups. In both Vitamin D and the Niacin cases, there was a RCT that showed that the earlier results had been merely correlations.

"RCT's are often very difficult to set up properly and can take many years to carry out. As a result, most research we read about involves just correlational studies".

But is the RCT the final answer? Unfortunately, no. Gary Gutting further states based on the studies of John Ioannidis (we have quoted earlier):

"John Ioannidis, in a series of highly regarded analyses, has shown that, in published medical research, 80 percent of non-randomised studies (by far the most common) are later found to be wrong. Even 25 percent of randomised studies and 15 percent of large randomised studies -the best of the best, turn out to be inadequate".

Naturally a question will arise in the minds of non-scientists: "Why, then do scientists even bother with correlational studies, most of which they know will turn out to be wrong? One reason is that such studies are excellent starting points for deciding which hypotheses to evaluate with more vigorous R.C.T's....... contrary to what many non-scientists seem to believe, the key feature of empirical testing is not that it is infallible but that it is self-correcting. As the physicist John Wheeler said.. "our whole problem is to make mistakes as fast as possible". Indeed as Karl Popper built an illuminating philosophy of science on the idea that science progresses precisely by trying as hard as it can to falsify hypothesis".

The above examples are from biomedical research. In all other areas of science where multiple parameters are involved the above process holds good. Most weather and climate studies will fall in this category as also many experimental studies trying to validate one or other hypothesis. In areas of theoretical physics, cosmology, planetary studies etc., where such empirical testing is hard to do, many mathematical models are built with their own predictions, to be tested somewhere in the future or falsified through later new hypothetical models........ A few evidences which may come later, will knock out many of them. We have seen many such examples in particle physics, astronomy, planetary sciences, and cosmology. Many such examples continue to be reported in active Scientific Journals.

Unfortunately, in India the scientific groups and "science policy" leaders do not emphasise and illustrate such processes of "science". On the contrary, they tend to project an image of invincibility of scientists. Worse still they often tend to propagate an idea that more of such work would "automatically" result in new products of technology for Indian society!. They often tend to ignore the word "engineering"!

The situation of "scientific research" in psychology and social sciences has further crucial limitations to apply for day-to-day lives. Gary adds further: "Even the best RCT based conclusions are at best certain only in a particular situation". Those of us, who tend to rush up on reports from USA and Europe on educational pedagogy or economics based on such researches and recommend policies for India, have to be very cautious.

The real situation of modern day scientist or researcher is beautifully brought out in a paper "What science wants to know" by Stuart Firestein (Scientific American March 28, 2012). It is down loadable by goggling. I quote a few extracts: "Most scholars agree that Isaac Newton while formulating the laws of force and gravity and inventing calculus in the late 1600's, probably knew all the science, there was to know at that time. In the ensuing 350 years as estimated 50 million research papers and innumerable books have been published in natural sciences and mathematics. The modern high school student probably now possesses more scientific knowledge than Newton did, yet science to many people seems to be an impenetrable mountain of facts".

So he goes on: "to cope up worth this mountain, scientists become more and more specialised". He says "as a biologist, I wouldn't expect to get past two sentences of a physics paper.....". He says some papers in his own field mystify him. He adds further that scientists mostly ignore many papers.

He goes on further: "Sure, you have to know a lot to be a scientist but knowing a lot is not what makes a scientist. What makes a scientist is ignorance..... for scientists facts are just a starting place. In science every new discovery raises 10 new questions........"

"One crucial outcome of scientific knowledge is to generate new and better ways of being ignorant: not the kind of ignorance that is associated with the lack of curiosity or education but rather a cultivated, high quality ignorance ...."

He suggests further that scientists should communicate with public not the accumulation view of science, which is confusing but with the questions they are posing now to find new answers.

How much we do so in India, we need to ask ourselves!

Technology, Engineering

So far we have looked at "Science" and "Scientific Research" in the modern (2013) context. It is very different in the form and contents than what it was during the times of Newton or Einstein or Sir C.V. Raman. However basic principles remain as illustrated earlier.

Engineering existed earlier. It was not dependent on "Science" and "Scientific Research" per se. Steam engine is a classic example. It led to the Industrial Revolution. The science of thermo dynamics was not known then. It came much later So also the air fights of the Wright brothers took place much before the science of aerodynamics came up systematically. Even now many engineering products reach markets or new engineering processes adopted in factories, not always as a direct outcome of a scientific research or a paper.

Sir David Davies in an address at the Annual Function of the Indian National Academy of Engineering (INAE) held on 3rd December 1998 defines Engineering as: "Engineering is about innovation, design, and the construction of new products and new capabilities. We must take care not to define it solely in terms of physical products since engineering can also often offer new services often without the need for additional hardware".

"However whatever the form of the new innovation its design is inevitably a compromise between many different parameters. The success of the products is therefore bound up with the efficiency of the design process which has the role of matching the design to the requirements in as efficient a way as possible......"

He goes on further to define engineering innovation. In the recent times, the word "technology" has overpowered the word "engineering" especially during the later half of 20th century, almost displacing that word. Any practical application is given the word "technology".

In India the word "engineer" is almost reduced to the last mile supervisor of a project. Organisations like ISRO have still maintained the word "engineer" in a respected manner in its description of all its scientific and engineering personnel described as Scientist/Engineer without differentiation as a joint designation. However space technology is the word that is used to describe the engineering of rockets, satellites and its application products.

But when a successful launch takes place popular description is to give credit to ISRO or Indian scientists!

In USA, in popular speech/writing, any thing that is difficult yet a great achievement is compared to "rocket science".

Information Technology (IT) persons have captured the word technology for themselves as if every engineering that does not have a component of IT is not technology!. **Even the routine repetitive work of IT business is presented as superior technology; but complex automobile engineering does not receive a respectable level!**. Worse still is the situation for Coal or Iron mining or metallurgy of many advanced materials or regular electricity related engineering!

But very well meaning policy researchers have included all aspects of engineering into the word technology. I like a definition of technology by Lewis Branscomb (Empowering technology: implementing a U.S. Strategy edit by Lewis M Branscomb 1993, MIT Press).

"A Technology is the aggregation of capabilities, facilities, skills, knowledge and organisation required to successfully create a useful service or product. Technology policy concerns the public means for nurturing those capabilities and optimising their applications in the service of national goals and the public interest".

Reduced to the basics, technology and engineering are the same. They aim at delivering useful products and services to the consumers (people). We use the two words as same in this paper. Without engineering or technology, the knowledge and skills will remain bookish, buried in papers or patents or books. Actually "engineered" products or services turn out to be the public face of "Science". Lay persons attribute all such achievements of engineering/technology (items which were considered as magic decades or centuries before) as the result of "Science".

But there is no direct correlation between engineered products services and "scientific research", as we have explained before. Indian "science policy" makers and powers-that-be were/are more-or-less blissfully unaware of (or wilfully neglecting) this important distinction between "Engineering" and "Science", thus reducing the importance of engineering in terms of govt support. That is the reason why India lags behind industrially/economically in most spheres. Practical applications suffer a great deal, thus depriving the benefits of science and engineering to the Indian people.

With the huge growth of science and engineering (technology), these two are now no longer completely self-dependent. Many new scientific discoveries in every field have come about because of availability of new engineered products for observation: be it telescopes, microscopes, satellites, biomedical engineering equipments like ultra sounds, MRI's, lab equipments, positron emission tomography (PET) etc., Nano sciences are products of immense capabilities of observation at nano levels through engineered products like Scanning Tunnelling Microscope. Even the "God particle" experiments at CERN, are possible due to multi-disciplinary engineered products.

Similarly many new engineered products of micro electronics, photonics, low emission engines, new materials like surface engineered products, genetically modified crops etc., to name a few, are the results of new scientific researches/discoveries. The new knowledge bases are used to engineer new products.

This process of intertwined existence of science and engineering is the reality of modern knowledge society. These complexities are systemised and understood better, by Mathematics. That is the reason why US emphasizes on STEM (Science, Technology, Engineering and Mathematics).

It is also necessary to touch upon the limitations of engineering (or technology). Intuitive engineering as was done for steam engine when it was invented is no longer a preferred method. Modern engineering has developed a lot of knowledge bases. And many of the new understanding of engineering process have been strengthened by newer discoveries in "science". In addition a discipline called broadly as "engineering sciences" has also developed many theories and models. Identification of causal connections within many engineering processes have graduated engineering from the mere level of how to do methods to "know-how", "know-why" also. These knowledge bases allow engineers to "predict" new possibilities - be it for new structure or a new alloy or a chemical engineering processes or a new pharma product. Intuition still works but in a totally different level.

Advent of powerful computers help to do complex calculations required for the design of a bridge or a rocket propulsion system or a new machine. Years of experience with empirical data available through continual testing during the development of a product and domain knowledge from engineering sciences, can be transferred to a computer simulation model. So much so the entire Boeing 777 aircraft was completely computer designed **without any hard ware model done before its development** (which used to be the earlier practice).

The huge and in depth experience of the developed countries with nuclear bomb allow them to venture into new designs for direct deployment without having to do the ground qualification testing.

Reliability and quality of engineered products have increased many folds due to these multiples of accumulated and new knowledge bases, simulation and periodic (almost automated) testing in the production lines. Mean-time-between-failure (MTBF) of many engineered products are much larger than the guarantee period or even product obsolescence (which is because products with better performance and price range arrive in the market, and not because the earlier product is not functioning).

So much so, the Sony Chairman had a dictum that Sony should make its own products obsolete before competitors do so! The engineering research and development (R&D) drives this process: which is called now "innovation" we will address it later.

All these developments may lead to a feeling of "invincibility" about the modern engineering or technology. Every engineered product or service, howsoever excellent it is, has some limitations of "ignorance" as it is in the case of "science" explained earlier. In addition, cost compulsions and competitive pressures also place limitations as to how much one can accumulate data for empirical validation of some of the models and assumptions made during the design and production phases. Six sigma promises a few errors in a million. But cumulatively the totality of the system may have problems, worse than six sigma.

The problems in the Dreamliner Boeing 787, have important indications of some of the limitations of engineering processes. It is more to do with Systems Engineering where multiple-discipline-products/subsystems are involved; as also the judgements about the operational situations. Some of the limitations of engineering may be due to the then available scientific and engineering knowledge bases. Metal fatigue was understood much later after a few accidents in best engineered products. It led to a whole series of new scientific researches and testing methodologies such as use of acoustic emission devices.

In addition, engineered products may fail in markets though they are perfectly engineered because of poor understanding of markets and business competition. Thus continual feedback from businesses and markets also are important for engineering. Thus engineering is not also invincible and progresses through trial-and-corrected errors. It is an inevitable process of progress of humanity. In addition, as science super specialities grow, engineering, agricultural and medical super specialities also grow in number and depth. **Hence integrating multiple knowledge bases into a product is a great challenge of modern engineering**.

Imagine for yourself an implant of heart pacemaker for global markets or a pollution control system within an active community of people and industries.

Security and privacy in the cyber world, which is a part of modern civilised (engineered) lifestyle, is yet another continuing challenge!

We can go on with many examples. **But it should not give an impression that modern science and engineering are at the end of the roads**. They are growing rapidly with many drastic changes within a generation as against the slow century-long changes in the past. Such a pace is also due to the impact of Businesses and Markets.

Business (Industry) and Markets

So much for "science", "technology", "engineering" etc., No doubt they have done wonders for the humanity especially during the twentieth century and are continuing during the 21st century within a generation. So many changes have taken place and are taking place at a very rapid pace: be it for transport, communication, water supply, agriculture, food, entertainment, medicare or warfare.

But the flow of these knowledge, skills and capabilities for actual end users (consumers who really form the markets) would have been impossible without modern Industries/Businesses. It is the Organised Business that makes the difference. In the earlier centuries (from 10,000 years ago when Agricultural Revolution took place till Industrial Revolution) the human ingenuity and skills to produce new products/services even for war, depended on individual artisan skills.

Later with the limited automation of Industrial revolution (which was triggered by engineering), business transcended beyond traditional trade. Modern Business organisations, with the connectivity of IT as well as complex engineering processes in manufacturing or agricultural or services , encompass most of human economic and social activities. Even during 1960s Businesses started with such a role and around 1980s their rapid growth pushed GLOBALISATION. The political and intellectual India was slow to understand these trends, especially the economists and Indian administrators. "Scientists" were in their "cocoons" of the govt supported laboratories and academic institutions, obtaining their share of budgets from the tax-payers money and a periodically telling about the benefits of science to remove Indias poverty, drawing upon Nehru's 1937 statement that future belongs to those who make friends with science and the later "Scientific Policy Resolution" (SPR) in 1958 made by Nehru in the Indian parliament. (We use the words Industry/Business synonymously).

Modern organised businesses have a structure of their own; rationale and dynamics of their own. They are neither govt nor a scientific establishment. They need engineering strengths focussed strongly on production to reach markets in a profitable manner. The profits and return-on-investment (ROI) are the crucial parameters to judge their performance and in fact **their very existence and survivability**. In fact, this is true of Public (i.e. govt funded) Businesses as well, though the Govt (political master/administrator) controlled regime did not allow the public sector enterprises (PSE's) to come of their own.

Post-1991, Indian businesses had much better breathing space, though not enough to fully unleash the full economic and human resource potential of India and the Indians. Even so, Indian economy grew much faster, but not touching the dream of double digit growth, which China enjoyed during the period.

One of the main reason post-1991 was that the focus was more around IT business which grew on the outsourcing from USA and later Europe. Though limited, considering the totality of Indian potential, high paying (compared to the usual Indian standards then) jobs absorbed a huge stream of human resources (young men and women). Their earnings in turn spurred other related businesses-retail chains, processed food, beverages, and above all manufacturing of automobiles and construction sector for housing and malls.

Yet manufacturing per se and agriculture as a source of large business opportunities for India were not recognised to the extent required. India Vision 2020 exercises with 25 documents and the resultant book Indian Vision 2020 pointed out an excellent mix of many sectors, with a road map. But the governance systems, Indian policy and the intellectual class were not paying enough attention to the actions towards realising the full potential of India and Indians, being happy with the "large" money being generated due to liberalisation. This was a clear lack of foresight by the Indian business and governance systems. This process is described as shallow globalisation, by scholars.

Even then, liberalisation of telecom sector though with start-stop processes, launching of major high way projects etc., created further spurt beyond IT sector and associated manufacturing in automobile sector and in construction.

It was very late when the National Manufacturing Council started its tasks for coming up with a clear road map. Instead of full thrust of implementation of that road map, the focus of the Govt. shifted to welfare measures being guided by "developmental economists" and welfare activists.

The basic principle of Businesses was missed. It is to generate wealth using natural resources and human resources, tapping the markets (generated by the workers and their families as well as the global demands for good and services). Only the pull of the markets and the businesses create jobs and incomes. That is the best of the strengths which are needed for Indian people. Social security has to be built around jobs and incomes and the taxes realised from the growth of businesses (not merely by taxing them more!!). During the past five years, the momentum gained by the earlier decade has been lost!

In addition to govt policies and the support systems provided by such policies and corresponding procedures, **there is another source for the growth of business: that is through innovations pushed into the markets by science, technology and engineering**. Post war growth of USA was due to such a growth: new businesses. Look at the use of spin-off technologies derived from the space exploration programme. The most popular one being "teflon" entering into many walks of life. Also the direct use of space led the fast growth of communications and TV and global positioning services.

In India the direct use of space programme grew well. However the power expected of atomic energy was slow to come even after decades. So was the defence based industry, growing from defence research. Spin-off from them was naturally limited as they were by and large cut off from business and markets, as was the case for most of the national S&T Laboratories and Academic Institutions. **If this hiatus did not exist, there would have been many "technology-innovation-pushed" businesses in India, based on technologies from Indian institutions by themselves or in combination with Intellectual Properties (IP) bought from foreign entities**. The IP produced by Indian Science and Technology (Engineering) systems supported by the funds mostly given by Govt, was (is) negligible to flow into Indian or Foreign businesses. Similarly the Indian businesses which were controlled pre 1991 and not fully liberalised even now are slow to demand our own IPs or to generate their own IP's. They are satisfied with technology licenses and foreign consultancies. This is one of the major reasons for Indias Current Account Deficit (CAD). **It reflects the Technology Deficit of Indian industries (businesses)**.

At this point it may be useful to recall the speech of Sir David Davies at INAE annual function, and the part on innovation after he defined "Science" and "Engineering": "In terms of an engineering product or service an innovation enables it to offer some new advantage in capability or performance (including cost) ...... that there is a strong coupling between engineering and science but it does not necessarily mean that the engineering innovation derives directly from the latest improvements or understanding in scientific theories........."

Innovation thus is much strongly oriented towards markets and businesses, with continual improvements, either based on business/market feedback information and/or new ideas based on experience and imagination.

As for markets, it is a pity that 1.2 billion Indian people, though stratified in terms of purchasing power (Bulky base of poor about 700 million; middle and lower middle 200 million; upper middle 200 million; rich and super rich 100 million), are not fully tapped yet. The irony is that only growth of businesses will provide employment and lift the Bulky Base into middle classes. If one squeezes the wealth generating businesses beyond a point for non-productive welfare measures for other segments of society, then vicious cycle of low growth, low employment rates etc., will set in. Already the country is in such a vicious cycle.

Way Forward

Though there are a number of problems facing the country, it is not the time to lose hope. When I say this, many persons of my generation and even those who are one decade or two younger, may say: "Have we not heard so before?!"

Yes, indeed! Post 1947 hope through the planned economy and even the green revolution of 1960's was very high. Through 1970's much of hope in the economic sectors became elusive. Post 1991 after the initial liberalisation, hope restarted, going very high during the turn of the century. Now it is going down, not yet shattered because there is a lot of energy left with the youth who are born around 1970-'s and lots of hope in the post 1990-born. That is the strength of India.

What needs to be done is well known. **But they are all to be done together and not piecemeal**. Probably a last chance for the Indian people!

- Restore faith in business community and investors. Invite private / foreign investors. Liberate (public sector enterprises (PSE's) from excessive govt controls. Let them do competitive business and grow, guided by their Boards.
- Celebrate wealth generation through modern methods of business. The C.Subramaniams formula should be put to work: "Productive work; and reproductive wealth"
- Tune the policies and make the procedures hassle free to stimulate MSME's, manufacturing, value added mining, metallurgy etc.,
- Liberate Agriculture from excessive controls and enable many of those currently "depend" on marginal/subsistence agriculture to move out of it to better earning jobs nearby.
- In order to trigger "Innovative New Start-Ups" in a large scale, make attractive policies (including allowing of foreign funds) and hassle free procedures. Govts at all levels have to pump a lot of venture capital funds to be managed by professionals. Let us also learn from Israel, Singapore, Taiwan, and USA in this connection.
- Let India have congestion free roads, ports, airports and uninterrupted quality power and water.
- - Make the current hiatus between S &T system and business to reduce drastically. Mandate S & T institu-

tions to contribute to economy, business, agriculture (including animal industry, birds, fisheries etc.,)

- - Make it necessary for S & T institutions, IIT's etc., to help MSME's to take up the massive task of offset production as we import lots of defence equipment (top in the world) and other high tech equipment. Foreign investors, exporters will like it too.
- Liberate "Education" from the licence permit - quota - inspector - raj still prevailing in many vicious forms.
- Skill bulk of the youth of India in all forms of economic trades (some 5000 or more) on a continual basis, so that they earn better.
- With the economy unleashed with above steps, create a robust health sector and also to uplift socially deprived persons and specially challenged persons.

Create massive environmental movement starting from local cleanliness, waste management, protection of lakes and water bodies etc., from schools to all levels. Let the messages be positive instead of pitting environment/nature against modern businesses.

How to achieve all the above simultaneously? It is possible. There is a wealth of knowledge and knowledgeable/experienced persons.

We all have to remember the title "Science-Engineering-Industry-Markets". They have to work together and create a great VIRTUOUS CYCLE for Indian people, living now, yet to be born. That is the key.

It then means truly making "Friends with Science".