TECHNOLOGIES OF THE 21ST CENTURY AND THE ROLE OF UNIVERSITIES

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ABSTRACT

A brief historical survey of technological developments in the last century is given. The factors which drive technological development and the role of science in this development are discussed. New and emerging technologies are pointed out and the role of universities in exploiting them is stressed. Finally, it is pointed out that unconstrained technology may lead to serious social and ethical problems, necessitating creation of ethical codes in science and technology. It is emphasized that, over the years, the science-technology chain has become shorter and shorter, with the result that a scientific discovery becomes utilized more quickly in the shape of technology.

Moreover, our means of information and communication have become increasingly more rapid. Thus, in a human life-time, the world is transformed much more drastically than was the case, say 50 to 60 years ago. As a consequence, jobs will become increasingly more sophisticated and will use new knowledge and an individual would be expected to have more than one career during his life-time. What strategies should universities develop to cope with this challenge? The issues involved are discussed.

TECHNOLOGY IN HISTORICAL PERSPECTIVE

Modern Science is relatively new. Its roots date back to the 17th century. Technology, on the other hand is pre-historic. Our technology has been of two kinds: green and grey. "Civilization began with green technology, with agriculture and animal breeding, ten thousand years ago. Then, beginning about three thousand years ago, grey technology became dominant, with mining, metallurgy and machinery. For the last five hundred years, grey technology has been racing ahead and has given birth to the modern world of cities, factories and supermarkets"[1].

The grey technology has gone through three important phases. The first phase, which took place at the end of 18th century, was mainly created by "handy men" as C.P. Snow calls them. Academic science played very little role in this phase. In the second phase, chemistry played a major role: giant chemical companies were established in Europe and U.S.A. In the third phase, atomic particles like electrons, nuclei, and atoms played an essential role; here the development of physics in the 20th century in universities played a crucial role. There are two remarkable things about the third phase, which resulted in the first place from two conceptual revolutions, relativity and quantum mechanics, which took place in the 20th century: Firstly, investigations that seemed totally irrelevant to any practical objective or practical problem yielded all the modern scientific and technological developments. "Nuclear energy, lasers, x-ray technology, NMR imaging, semiconductors, computer, internet, superconductors only exist because we have relativity and quantum mechanics. To our society and to our understanding of nature, these are all-encompassing"[2]. The second remarkable thing about this third phase of the technological revolution is that it has reversed the old saying "Necessity is the mother of invention": "Invention is now apparently the mother of our necessities. Inventions only later become necessities! Time and again, inventors created things that had to wait many years to be recognised for their practical value. Nobody really needed the aeroplane, the FM radio, television, xerography, lasers, transistor, or the quantum mechanics that led to the transistor"[3].

Thus we have what came to be known as the science - technology chain, which is largely responsible for the great scientific and technological progress of the 20th century. Technology today uses science with a time-delay of order of 10 years; science, in turn, is driven by the new developments in technology; and both progress together. The science - technology chain is becoming shorter and shorter, so that, on one hand, the distinction between basic and applied science is disappearing and, on the other hand, the pace of introduction for new technologies is accelerating [see Figure 1 & 2].

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EMERGING GREY TECHNOLOGIES

Having brought out the role of academic research in modern technology and the interdependence of science and technology, let me now enumerate some emerging grey technologies that are likely to dominate the 21st century:

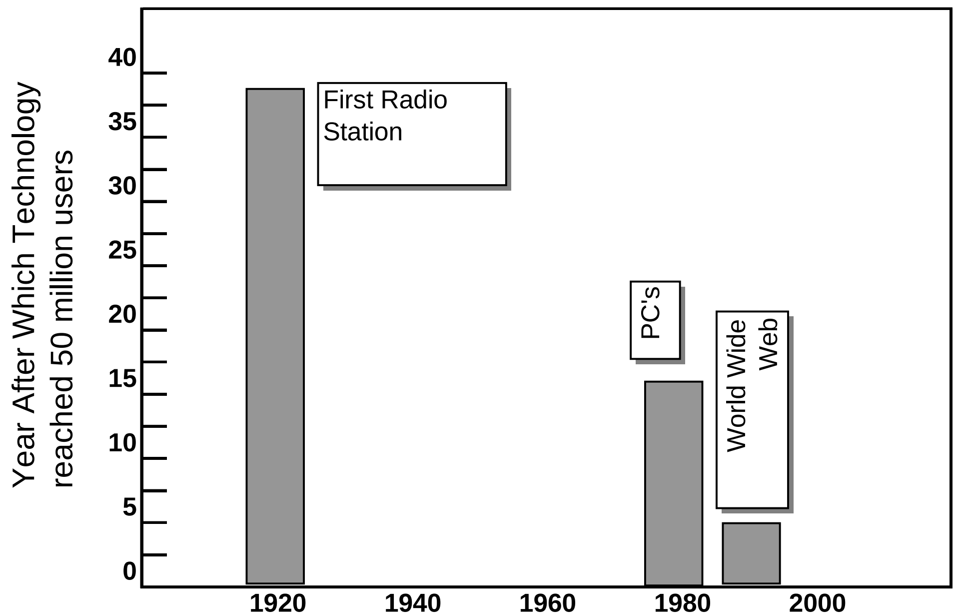

Figure - 1.

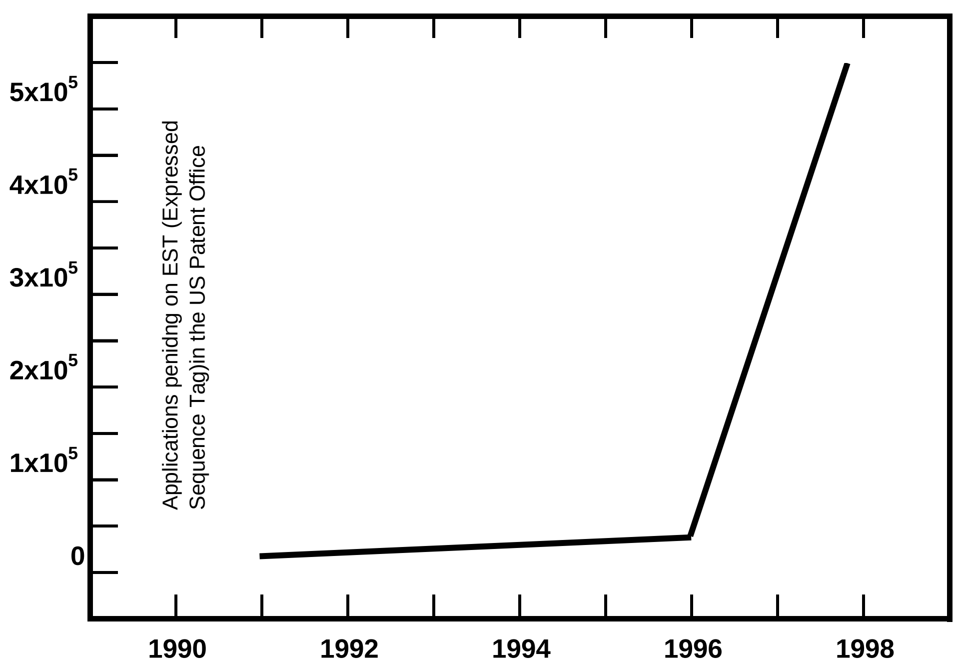

Figure - 2.

1. **New Materials**: High-technology products often depend on "special materials": alloys, composites, doped silicons; ceramics, magnetic materials and polymers. These are special, because of the processing they require and not because the raw material, out of which they are made, is scarce or unevenly distributed.

2. **Nano-technology:** In late 1959, Richard Feynman in a lecture" There is Plenty of Room at the Bottom" proposed that machine-tools could make smaller machine-tools, and that these in turn could make even smaller machine tools, and so on, until the tools were molecular in scale. Such tools, Feynman suggested, might fabricate vast numbers of ultra-small, ultra-fast computers, various micro- and nano-scale robots, and even medical machines that could act as miniature surgeons. Nano-technology may be defined as "the construction and utilization of functional structures and materials, with at least one characteristic dimension at the nanometre scale"[4]. There is a tremendous potential of nano-scale science and technology across a broad spectrum of basic and applied research. "Nano-technology is, to inanimate matter, what biotechnology is to animate matter". It is the logical consequence and ultimate destination of our quest for the control and manipulation of matter[5]". Both the interest of major US institutions and commercial enthusiasm are indicated by the charts shown in Figure 3 & 4.

   In sum, this is a technology with momentum. It will go forward - for good or ill. For those who might think that it is a game for advanced countries, let me remind them of the following words of Dr. Homi Bhabha, who argued, one year prior to Hiroshima: "An Institute is needed as an embryo, from which I hope to build in the course of time a school of physics comparable to the best in the world. When nuclear energy has been successfully applied to power production, in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand".

   Countries like Pakistan missed the transister revolution, it is now trying to enter I.T. when the I.T. bubble has already burst. Let us, therefore, realize the position, so that when the nano-technology revolution would be on us by 2010 ~ 2020, we are ready for it.

3. **Information Technology:** Higher densities of information, on scaled-down computers, will become a necessity in the near future. As an example, let us consider the computing challenge to be faced in the analysis of data from Compact Muon Silicon Detector (CMS) associated with the Large Hadron Collider (LHC), which will be the world's largest particle-accelerator being developed at CERN, the European Organization for Nuclear Research in Geneva. The data-rate would be 100 MB/sec so that the amount of data to be analysed per year by two thousand users, distributed geographically in various parts of world, will be 1 PB (10^{15}B). To put it in proper perspective, the bench mark for PC (1999) is 15 Spec Int 95 and what would be needed is 25,000 Spec Int 95.

4. **Space Technology:** The exploration of the solar system and the physical environment of the earth, so as to reduce the negative effects of technical change on the environment, in terms of pollution, desertification, environmental degradation, waste management, etc.

EMERGING GREEN TECHNOLOGIES

1. **Biotechnology and Genetic Engineering:** During the last fifty years, we have achieved a fundamental understanding of the processes occurring in living cells. Molecular understanding of the gene-basis of living organisms could lead to new processes and products for agriculture, industry, the environment, and for animal and human health. If used wisely, "one of its major benefits will be to allow us to make great areas of the globe economically productive, without destroying their natural ecology[6]".

2. **Nano-medicine:** "The science of diagnosing, treating and preventing disease, with the use of novel molecular technologies — from "smart drugs" that target specific organs or cells, to miniature robots that can ferry materials into and out of cells, and even enter cell-nuclei to repair damaged genes[7]".

ETHICS

Increase of science and technology by itself is not enough to guarantee genuine progress; they alone

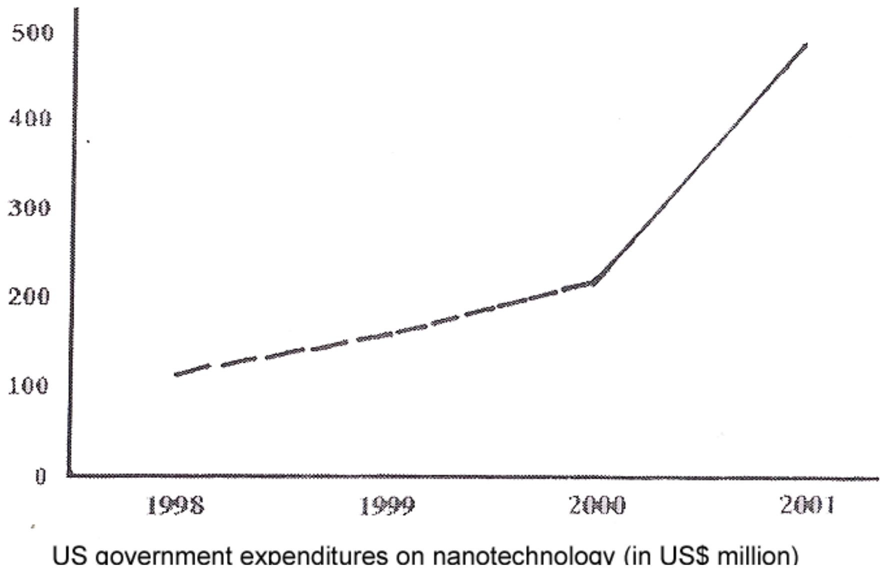

Figure - 3: U.S. Government Expenditures on Nano-Technology (in US$ million)

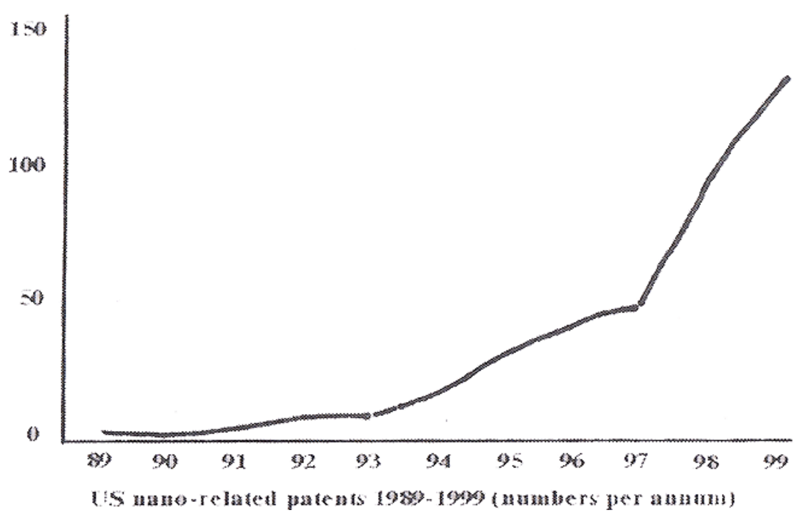

Figure - 4: U.S. Nano-related Patents 1989 – 1999 (number per annum)

cannot bring social justice to human societies. There is an ugly side of technology. The 20th century saw the best, as well as the worst of science and technology. A new nation was born in the last century - a nation that dwells in total silence; a nation that cannot speak. Scottish writer Gil Elliot calls it a nation of dead. He estimates its population to be 110 million, a fully cosmopolitan nation[8]. It was created by man-made weapons. Grey technology brought us nuclear weapons, as well as internet. Similarly, the green technology brought us anthrax bombs as well as antibiotics. Besides the dangers of man-made weapons, technology brings other dangers having nothing to do with weapons. One is the mismatch between the new waves of technology and the basic needs of the poor. The point is that the market-driven technology usually results in the "toys" for the rich, since they are expected to pay more than the poor for new products, thereby resulting in the ever increasing gap in economic well-being between rich and poor. The increasing gap between human needs and technology can only be filled by ethics.

Another problem of ethics, more serious than the handling of weapons of mass destruction, which humanity is going to face is from the convergence of genetic engineering, nano-technology and computer technology. "The ultimate danger comes from technology's power to change the nature of human beings by the application of genetic engineering to human embryos. If we allow a free market in human genes, wealthy parents will be able to buy what they consider superior genes for their babies. This could cause a splitting of humanity into hereditary castes. Within a few generations, the children of rich and poor could become separate species. Humanity would then have regressed all the way back to a society of masters and slaves. The free market must not extend to human genes[1]". Only through proper ethics can we assert control. But ethics, like science, has to be general. Here "scientists and religious believers, physicians and lawyers must come together with mutual respect, to achieve a consensus and to decide where the line should be drawn[1]". We cannot constrain technology - it will go forward, but perhaps we can constrain ourselves.

ROLE OF UNIVERSITIES

The basic issues which a university has to address are:

- Derivative science and technologies involving many disciplines are becoming important.
- Green technology will be moving ahead, faster than grey technology, and will dominate over the latter.
- Over the years, the science - technology chain has become shorter and shorter, with the result that a scientific discovery becomes faster utilized in to technology. Moreover, our means of information and transportation have become increasingly more rapid. Thus, in a human life-time, the world is transformed much more drastically than it was the case, say fifty to sixty years ago. As a consequence, the jobs will become increasingly more sophisticated and will use new knowledge, and so an individual would be expected to have more than one career during his lifetime. This requires that education must be increasingly broad, aiming at developing potential for further and continuous learning, rather than rote learning and premature specialization. To be sure, it does not mean that "vocational" training and professional education are not needed. These are needed for the current job-market, but such people can be trained in existing institutions, and universities which specialize in Engineering, Business Administration, Commerce, Agriculture and Medical Education. But this, now outdated concept, must not continue for new universities. A university has to be a flexible institution so that, within one institution, one has the full range of knowledge; from science to engineering to management and economics, even to public policy, law and social analysis. A modern university must have faculties of humanities (which include social sciences), basic sciences, engineering, agriculture and medical, at one campus, so as to provide an integrated form of education. Existing general universities must re-orient themselves, with added new faculties, where needed, to future trends in education, outlined above, and prepare people and society for a lifetime of learning, with balanced curricula in a multidisciplinary environment.

The following goals and actions are needed on the part of a University:

- Provide a dynamic programme, aiming to develop a potential for a lifetime learning, since in the conditions of modern life of rapid change, an individual can be expected to have more than one career during his/her lifetime.
- Develop total competence in people that require balanced curricula.
- Make use of new information and communication-technologies, which will facilitate access to higher education for groups that would otherwise lack such opportunities, this would provide for the advancement and continuous development of work force.
- Adopt quality-concepts in education, so as to attract and retain a high-calibre faculty, build research groups around a creative faculty, ensure greater mobility of faculty, through international contacts, and attract talented and gifted students.
- Strive for a linkage with government and industry, thereby seeking and acquiring funding for contractual research from external sources.
- Strive for international collaboration with big centres of research, like CERN in Geneva, which is a fine example, in which high technology and pure science reinforce each other and which is open to

every body.

- Of course, a University cannot flourish without basic research, which is needed to expand the frontiers of our knowledge, to further our social, economic and scientific insights, to build new technological applications of our scientific insights, and above all, to produce new generations of researchers. Basic research needs patronage and financial support. For advanced countries, this support finds many channels: governments, industry and endowments created by philanthropists. In the state of Texas alone, there are 42 endowed chairs and 72 endowed fellowships. Creation of endowments for education and research has not yet entered our culture. But this culture has to come if we have to make progress.
- Finally the universities within the country must go through globalisation among themselves, establishing microwave links among themselves, in order to reduce the science and technology gap among ourselves. This is all the more necessary, since we may face in our universities a serious problem of critical size of research groups. Thus, to begin with, it may be more feasible to distribute Centres of Excellence, one or two in each of the new technological and scientific disciplines mentioned above, among the various universities in the country or even in the region.

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