The U.S. Congress during the Bill Clinton era approved a handsome budget for the launch of the National Nanotechnology Initiative (NNI). The NNI held a workshop on the still unknown social and economic implications of NT with various experts. The rationale for the workshop was premised on the view that a " ...sober, technically competent research on the interactions between nanotechnology and society will help mute speculative hype and dispel some of the unfounded fears that sometimes accompany dramatic advances in scientific understanding". [1]

Nanotechnology describes the science or technology of 'manipulating and controlling things on a small scale'. Small, implying a billionth of a meter in size, ten to the power of nine (10^{9}). So small that one would need powerful microscopes or instruments to visualize the manipulations being undertaken. Advances in atomic physics make it possible to use electromagnetic waves, or the charged properties of atoms, to change the behaviour of particles so that new kinds of atomic structures and features can be generated. Or nanotechnology 'refers to the ability to design and synthesize materials and devices at the molecular and atomic level.' (Dayrit and Enriquez, 2001)

NT is thought by some to be an important new technology that will revitalize the electronics and biomedicine industries in this century. (Institute for Nanotechnology, undated) The global market for nano-materials is estimated to be about $10 billion per annum. Material scientists have long understood that the properties of materials, i.e. their strength and ability to conduct electricity are tied or dependent on the arrangement, structure and organization of atoms. NT offers the ability to control the molecular structure of matter and hence the very properties and strength of materials, creating a potential explosion of innovative new materials and fabrication processes as a result.

The power of NT was probably first put forward in a path-breaking paper delivered by the physicist, Richard Feynman, in 1959. [1] When Feynman first presented his ideas, he put forward the challenge and feats of NT. He envisaged it possible that 24 volumes of the Encyclopedia Brittanica can be fitted on the head of a pin. Storing information at such a scale should not come as a surprise. The entire human constitution is locked in tiny packets of information called DNA, which is a group of chemical linkages that form a code.

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The Sociological and Environmental Implications of Nanotechnology: The promise of a new ecological utopia

Saliem Fakir, IUCN Policy Think Tank No.16, January 2002

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The speculative promises and possibilities of Nanotechnology, the science or technology of 'manipulating and controlling things on a small scale' are changing the practices of ecology. Consequently, we're seeing the birth of the new science of NanoEcology. Indeed, as Nanotechnology increases the potential spin-offs for NanoEcology it will have social implications and induce dramatic changes. But, argues Saliem Fakir, we should adopt a measured sense of prophecy and foresight. More important, we should guard from the overzealous promises of an accelerated frontier of extreme sciences and a new ecological utopia.

A recent article covering innovations in the microchip industry read: "Reaching a long-sought goal in computing research, scientist have created a computer circuit based on a single molecule, which could lead one day to far smaller and faster computer chips that use less power". (CNN.Com, August 27, 2001) IBM's latest invention may seem insignificant. However, IBM's work is a culmination of a whole new endeavour in condensed matter physics, or what is now part of an evolving field called Nanotechnology (NT). Nanotechnology is the latest rave in the scientific community, which is said to spawn a new revolution in a number of industries, like the Internet was for the information revolution. Predictions abound as to both the perils and promise of NT. Scientists are generally the most optimistic. But as history tells us, humans are the worst predictors of their own creations. Nevertheless, the element of hype is a notoriously important constituent of our emotion-be they peril or promise.

This code is deciphered by cells into various other forms of chemicals such as enzymes, proteins and other chemical structures that are necessary for the vitality of biological organisms. All of our human traits are coded for by information that is located in exceedingly small space, given the complexity of the human biology.

NT draws from a vast array of fields, such as molecular biology, condensed matter physics, engineering and chemistry. NT is about applying the best available knowledge from these fields to create the tiniest of things: anything from carbon nanotubes, cellular canals, atomic structures, nano-robots, etc. In the case of nano-machines or robots, it would not be impossible to imagine, tiny machines, being able to move around in the body, to fix or repair damaged cells or tissues. *If, you really think of it, all of biological life are self-replicating machines.* A good example of this is the catalytic properties of enzymes which are efficient biological machines able to perform complex chemical reactions in living organisms. However, self-replicating and intelligent nano-robots reside still in the minds of nano-theorist and thinkers. A self-replicating robot would possibly resemble something like a virus, but it will have to have the added complexity of communication, and being able to modify the environment in which it lives to its advantage. The current state of knowledge in the field precludes all such possibilities for now. A large part of the hype about 'living' nano-robots, assemblers, gears and motors has to do more with the language itself, than the fundamental laws of physics which will continue to govern what is possible or impossible. However, the notion of self-replication, which shares parallels to biological life, will arouse new fears and challenges for the future.

At the scale of atoms-the nano-scale-all fields converge as being one. This unification of all these fields is possible because the basis of all of life and matter is physics. Understanding the laws of physics at the quantum level helps to unite, many of the difficult questions that need answering in chemistry, biology, etc. As Feynman pointed out, operating at the atomic scale means to operate with different laws when working on a large scale. NT can also be described as hi-tech alchemy as many of its visionaries articulate a future that is very akin to what the ancient alchemist first had in mind. Although, one can manipulate atoms, one cannot fundamentally change an element into something other than its natural constituent as first thought by alchemists. Alchemy in the classical definition alludes to the conversion of base metals into gold, or the achievement of the prolongation of health and life.

By now, most of what we know as matter is either sourced through mining, or used as biological material. We can only make do with things that nature has provided in the form it comes. NT offers the 'unbundling' of the very atoms that make up nature's creation, so that they can be re-arranged in forms and features that is to our desire. Having this power at one's disposal, numerous experiments can be performed to answer the question: " What properties would be generated if atoms could be arranged in the way we wanted?" Hence, NT is attracting great interest and power of imagination in the world of science. It is the ultimate dream come true to completely transform the way matter and phenomena occur.

While NT is still in its infancy and exists as a disparate discipline in the US, Europe and Japan, it has still to find a coherent scientific model, and move from simple ideas of promise to actual technological applications. The Foresight Institute in the United Kingdom describes NT as offering a way of 'unbounding the future', and other less cautious optimists think of NT as opening the doors to a new kind of utopia. Nobel Laureates such as Eric Drexler, the director of the Foresight Institute, who wrote the *Engines of Creation* have popularised the promise of NT in utopian language.

Nano and the environment

Nanotechology hype is viewed in some quarters as the technology of doom for all the environmental pessimists and Luddites who are use to presenting gory images of a technological wasteland and ecosystem apocalypse. However, it certainly would find favour with Bjorn Lomborg, the sceptical Danish environmentalist, who smirked at the apocalyptic pretences of the environmental movement in his latest book *The Skeptical Environmentalist*. NT could be the promise that would reinforce optimism against environmental pessimism. Some of the promise of NT may come from the ability to create high quality goods that produce less waste, lower inputs of raw material, and material that does not persist for too long in the environment once the product has been used. This vision has led one author to comment: "With processes based on molecular manufacturing, industries will produce superior goods, and by virtue of the same advance in control, will have no need of burning, oiling, washing with solvents and acids, and flushing noxious chemicals down their drains. Molecular-manufacturing processes will rearrange atoms in controlled ways, and can neatly package unwanted atoms for recycling or return to their source". NT provides a basis for various kinds of interventions in the ecological era, using the basic principles and methods of NT to solve environmental problems. Some of the interesting prospects for different sectors use of NT are highlighted below:

Energy: Experts in the field predict that NT can contribute to reductions in energy by 10% worldwide. Such reductions will lead to savings of a $100 million dollars or so per year. These improvements will come not only in the way energy is produced and supplied, but the way in which energy is consumed by various devices and utilities. Some of the promise is already to be seen in the manufacturing of high-grade nano-lubricants and magnets which reduce the level of friction and resistance leading to improved efficiency and hence the consumption of energy. Some visionaries also conceive of the idea of using the oceans as a resource to grow biomass fuels using nano-biotechnology advances. Ideas for innovations range in almost every sector where there is a human dependency on energy in one form or the other - this even includes engineered photosynthesis. Perhaps the biggest breakthroughs and improvements will come in the area of solar energy, where some degree of promise is already being met in countries where there is a high concentrations of UV, such as South Africa, Australia, the USA etc. In particular the conversion of sunlight to electricity using photovoltaic cells (PV) may no longer be seen as an obstacle-given the current cost structure-as advances in NT will offer cheaper and more precise ways of making PV. Cheaper, efficient, and cleaner forms of energy also hold promises for the reduction of global green gases which is of concern given the problem of global warming.

Water: Cutting edge work can be achieved using NT in the purification of poor quality water, and the development of low energy devices for the desalination of water as a way of creating new sources of water NT based membranes and filters can be used to extract pollutants, and more energy efficient motors and pumps can be used for the desalination of water from the sea. Most, if not all, intelligence and military agencies include water as a "green issue" of focus as conflicts around natural resources has and can lead to global and national insecurity. Water is seen as an area where NT intervention may hold promise as increased conflict is predicted for water as nations and citizens try to secure greater access and control over this resource. Progress in membrane technology has seen significant strides in recent years, and nanoscale membranes that have molecular receptors are seen to be crucial in purifying water from specific types of pollutants. Developments in water resources management are to be seen in quality improvements, production of water from new sources and more efficiency measures in the usage of water by industry, agriculture and other users. In fact, it may be argued that in countries like Rwanda and Burundi, that these conflicts are nothing more than conflicts over natural resources given the high population densities, and insecure land tenure.

Waste Management and pollution: The ability to produce less waste and make it easily disposal in the end are part of the far-reaching promises of NT. The promise extends from ordinary domestic garbage to long-life nuclear waste. Already, there are some breakthroughs in the area of biodegradable products. The issue of persistent pollutants and toxins, which continue to elude environmentalist, may no longer be an issue in the future. NT will provide solutions in the form of the new production methods and enable the remediation of current loads of waste and toxins. Nano-visionaries envisage the future to look like this: "To see how nano-machines could be used to clean up pollution, imagine a device made of smart materials and roughly resembling a tree, once it has been delivered and unfolded. Above ground are solar-collecting panels; below ground, a branching system of rootlike tubes reaches a certain distance into the soil. By extending into a toxic waste dump, these rootlike structures could soak up toxic chemicals, using energy from the solar collectors to convert them into harmless compounds. Rootlike structures extending down into the water table could do the same cleanup job in polluted aquifers". Other areas where NT may have a role is the retrieval of space debris, which clutter outer space, and occasionally sink a hole in satellites, spacecraft or finds their way down a fiery path to earth. As commercialisation of space expands this cleaning up of outer space will be a new and pressing international pollution problem. NT also has potential in creating devices that have 'super sensory' ability that will monitor and detect noxious gases or pollutants with greater degrees of precision and quantification. In the car manufacturing industry, which may become the early adopters of NT, already advances in catalytic[1] converters will greatly reduce emissions from cars and other industrial processes. It is possible that with NT nothing is conceived as waste but raw material that can be transformed into one form of utility or the other. Surplus carbon for instance in the atmosphere may be extracted for the manufacture of carbon based materials.

Agriculture and biodiversity: Breakthroughs are also envisaged in the agricultural sector. NT will most likely provide a basis to meet the growing food demands, and deal with issues of increasing the productive capacity of land and fisheries (freshwater, aquaculture and marine fisheries). NT involves the molecular engineering of biological processes, and allows the creation of biological control devices. In so doing, its application to agriculture can be extended to the monitoring of infestation, pest control, improving soil fertility, soil management and post-harvest preservation of produce (Dayrit and Enriquz, 2001). The reduction of pressures on biodiversity can take place through the restoration of land for production. The problem of biodiversity loss is a result of the land fragmentation and conversion, the introduction of alien species and damage to the ecosystem. Some visionaries believe that the use of insect or microbe size devices called 'ecosystem protectors' could deal with

[1] Catalysts are molecules that cause chemical reactions to occur without themselves being consumed.

pollution and remove non-native species: "these ecosystem protectors could be equally finicky about species they approach, and then, before attacking, could do a DNA analysis to be sure."

Social Impacts of Nanotechnology

Given the relative infancy of the technology, it is difficult to speculate on both the positive and negative impacts. However, as NT has the potential for radical convergence of mechanical, biological and neural technologies, one can only assume that such convergence will lead to new forms of utilities never possible before. The manner in which technology is diffused in society is an important aspect, as it is not value neutral. The effects of diffusion have to be taken into account, as generally, new technologies can have the tendency to displace relations, and shift the balance of power not only of users versus non-users, but also nation-states within the global economy. NT is more than likely to raise new ethical considerations, issues of justice, risk and equity. In general, though there is no doubt and as numerous examples would attest, new technologies have the capacity to introduce major social transformations.

The rate of diffusion of NT is largely dependent on the maturity of the various ranges of technologies that are being developed under the name of NT. Comparative technologies may have to be studied and lessons drawn from the diffusion experiences of these technologies so as to better inform policy and regulation of these technologies. One can only draw lessons from experiences with technologies, most notably from the last century about nuclear, information and genetic technologies. Theorist of technology diffusion, are also increasingly focusing on the role of entrepreneurs as agents of change and diffusion of technology or what the economist Schumpeter termed the "agency of entrepreneurs". Entreprenuership[2] as distinct from the notion of a plain old trader. Entrepreneurship has one additional key feature; i.e. the transformative capacity that they have in offering radical ways in which society changes by the adoption of the new technology. The specific characteristics and resources applied by entrepreneurship in many cases are responsible for the catalytic, rapid diffusion and use of technologies in the market. In turn, their engagement with users provides technology developers with information that enables them to develop the technology and further variations of it by end-user and entrepreneur (distributor) feedback. (Miller and Garnsey, 2000) As NT is likely to have impacts on a range of sectors, entrepreneurship will be stimulated in the areas of defence, environmental engineering, medicine, commerce, agriculture and education.

[2] The entrepreneur is neither to be confused with the inventor. While inventors may be entrepreneurially speaking good businessmen, entrepreneurship is a practical occupation which use and effect are wider than that of the inventor.

In general, as experience has shown elsewhere, that once the basic science and technology is available, it undergoes a second and third wave of innovation where different permutations and uses for the technology are added by the entrepreneurs and users. These can have unintended consequences that may not have been considered when the technology was first developed. It is no longer a question of whether technology does not cause social change, but are there ways in which these social changes can be anticipated to mitigate any negative consequences.

One could categorise social impacts at different dimensions, but let us focus on what I would consider several pertinent areas, where the impact is almost inevitable, and for which some level of anticipatory work needs to be done to minimize the impacts. The dimensions are as follows:

Labour and production

Advances in new technology have certainly changed both the relation of labour to production, and the very content of labour itself. As theorist of business cycles would note, the upswing periods in economies is generally attributed to the emergence of new technological revolutions (or disruptive technologies). During these revolutions, there is a great deal of new venture capital investment and a rise of new areas of entrepreneurship as we have noted in the development of information and communications technologies.

The shift away from analog to digital systems of production automation has increased the human-machine interface, to such an extent that there is a mutually dependent relation. From the side of production advances may have led to enhanced features, or completely replaced old methods of production for new. With greater human-machine interface devices, such as the computer, older streams of production that were both spatially and temporally located away from each other, are now combined within the same space (workstations) and time. Factors of increased efficiency, time-cost improvements, the need for more intellectual capital and inputs have changed the nature and speed with which work is being done. This even extends to what was once thought of as highly labour intensive forms of production such as agriculture.

Such dislocations or advancements have generated a new class of labour called: knowledge workers.
As Peter Drucker points out:

"This new knowledge economy will rely heavily on knowledge workers. At present, this term is widely used to describe people with considerable theoretical knowledge and learning: doctors, lawyers, teachers, accountants, and chemical engineers. But, the most striking growth will be in the "knowledge technologist": computer technicians, software designers, analysts in clinical labs, manufacturing technologist, paralegals. These people are as much manual workers as knowledge workers...But, their manual work is based on substantial amount of theoretical knowledge which can be acquired only through formal education, not through an apprenticeship". (*The Economist*, November 3rd, 2001)

Knowledge workers are the new elite that in societies where the human-machine interface is predominant and highly dependent their labour content has been an essential component of processes of production. NT certainly falls within the category of knowledge work and production methods. The shift from raw labour to a new class of intellectual labour is an important feature of the new economy. The new class is not tied to or dependent on the material means of production such as land or other equipment, as their knowledge is mobile and can easily be relocated to other sites of production. The more the human-machine interface increases the more raw labour will get marginalized and be made peripheral to the knowledge economy-they are the *proletariat* of the new economy.

Often disruptive technologies are left to their own fetters, without the state playing the important role of putting in place social programmes, where it is needed, to accommodate for any form of displacement that is likely to occur. A pertinent example of the impacts of technology comes from the invention of the mechanical cotton picker. When the picker was introduced in the American south, suddenly, millions of Afro-American share-croppers were obsolete, leading to the massive migrations from the American South to the cities of the North. Other larger scale displacements have occurred for instance in the sugar plantations of the former colonies with the introduction of artificial sugar such as High Fructose Corn Syrup (HFCS) produced from traditional biotech or fermentation processes. HFCS competes with normal sugar as a constituent of soft drinks and confectionaries. Large quantities of HFCS is now produced in Canada, USA, and Japan, which has limited the market for sugar, causing considerable hardship for countries dependent on the export of sugar. (Mehta and Gair, 2001)

The range at which social impacts are likely to be visible are potentially large. There is no doubt that labour will be transformed, as there is more integration of cyber-human knowledge interfaces, both humans and technology will be transformed in the process.

Political control

If society were apolitical, then technology would have no political dimension. However, inherent in all societies is that technology - and perhaps the contradictory feature of democratic societies – has the ability to secure political domination, but at the same time democratic participation. In all respects, technology is interwoven within the fabric of society such as the governance system and its institutions. It should be no surprise then that many of the technological uses we find within the realm of the public domain and commerce have had their first origins as military and surveillance utilities, if one thinks of satellite, internet and mobile phone technologies.

The release of new technologies into the broader society is always political and has a double-edged sword. For as much as they become handy devices for achieving economic, cultural and social uses, they are also ready-made tools for potential subversion of the existing political order, or instruments by which more economically privileged groups are able to advance their interest further. In so doing, they can also increase the level of disenfranchisement and disparity, which manifest today at the national and at the global level. And, as sociologist would show greater economic well-being increases manifold the opportunities for political participation at the national and international levels by groups that are able to take advantage of technology. As such, they are also capable of controlling the decisions and political views of those excluded from the dominant economy. New technologies provide different avenues and possibilities never thought of before in the enterprise of domination or acts of rebellion.

For example, some of the anti-establishment movements seen in the last few years are able to mobilize widely because of the Internet. The power with which they are able to demonstrate the use of the technology has led decision makers both in the State and the private sector to find ways to control what is described as the 'Internet commons'. The role of the Internet to undermine the hegemony of certain ideological tendencies is very similar to the way in which the invention of the Gutenberg press allowed widespread dissemination of written material against the Church in Europe. The Gutenberg press was prescient in that its timing coincided with the Renaissance. It allowed the liberal ideas of Renaissance thinkers to spread widely through Europe. In so doing, it undermined the hegemony of the Church in politics and culture.

The idea of a technological commons is a not a new one, and is debated vigorously around issues of technology transfer and intellectual property rights. Conflicts regarding the 'communal access' weigh heavily on the question of rights of access that lead to the politicisation of science and technology. After all, technological development is tied with issues of power and economy where different strains of interest are competing or in conflict with each other over hegemony. Lawrence Lessig, professor of Law at Stanford University in California and a proponent of the idea of an internet commons, recently pointed out in Foreign Policy (December 2001) that the very flourishing of innovation and use of the Internet is attributed to the lack of ownership and control of the virtual space. The idea of a commons is a key feature of the Internet architecture, which stands to be turned on its head by those opposed to the Internet revolution, as an exclusive and paid for medium of political and legal expressions.

As Lessig notes: "…the Internet was born at a time when a different philosophy was taking shape within computer science. This philosophy ranked humility above omniscience and anticipated that network designers would have no clear idea about all the ways the network could be used. It therefore counseled a design that built little into the network itself, leaving the network free to develop as the ends (the applications) wanted." One of the best examples of consequences of the free Internet is the development of the World Wide Web in 1990 by a Geneva based scientist Tim-Berners Lee. As Lessig's thesis shows, there is a contrast with other industries such as the telephone industry, where innovations are strickly controlled by the use of the backbone of the network. There are both commercial and political reasons as to why the major Internet owners want to fence off the Internet commons. The shift to a state and private control of the Internet will usher in a new era in social programming and control.

Towards a new Techno-Ethics

A range of new technologies in the 21st Century such as cloning, genetic engineering (GE) and others raise a host of ethical issues. In general, social responses to the emergence of these technologies have been retrospective rather than pro-active. Part of the reason lay with the fact that public awareness of the technology is only engaged when the technology is ready to be launched or whenever accidents occur. Technological developments also emanate from the state, the private sector and civic individuals or bodies. The constituencies have different regimes of governance and discourse determining both the rationale and objectives of the technology. In other words, the ethical landscape is fragmented between different agencies and institutions of control, which may or may not act in a synchronic manner. In so doing, a comprehensive ethical jurisdiction doesn't exist, and one very much doubts that it is possible to attain such a goal. An additional dimension is that technology is not fixed to any domestic setting nor to the ethic that informs its context. The transnational spread of technology poses new challenges for culture, human rights, ecology and political dominance. In other words while national oversight is one dimension, oversight across the globe is even a much taller order. What are the possibilities of structuring an ethical road map for the future? While NT has positive contributions to make to the development of Nano-Ecology, it nonetheless needs to be governed by a framework of techno-ethics, that illuminates the possible manner by which it is used as an intervention both in the social and ecological sphere.

It is possible to envisage ethical responsibility to be located at three levels:

Individual ethics**:** Can scientists absolve themselves totally from baring any sort of responsibility that may arise from their work whether the consequences be direct or indirect? Hitherto, such individualisation of responsibility is seen as an inconvenience, and often rationalised by scientists as being anti-science. Scientists are more likely to bare individual responsibility if the very institutions and their culture embody the ethos of individual responsibility. Recently, there has been a flurry of media coverage on public awareness of science and the individual responsibility that scientists need to be bare for their work. The actions of individuals is both determined by the adoption of an ethical conscious by the individual as well as the institution under whose auspices work is being carried out needs to establish a code of ethic that would inform such an ethic. Many university based research institutions already have one form of ethics committee or the other. In some industries there are already practices in place, which are part voluntary and part as a response to regulations being enforced by authorities. The question of individual conscious is a prickly issue with many scientist and industries especially as regards new developments in the biological sciences. But, can the public cry foul when its own preferences, interests and conscious encourage the development and consumption of technologies that legitimate the work of scientists and industries that produce 'negative technologies'-technologies with negative impacts. It is debatable whether all of these fulfil the criteria of necessity given the range of technologies at the disposal of society. It means that without these technologies, humans would suffer great pain and loss or worse slow death.

The individualisation of ethics should encapsulate the desire to do away with all possible forms of material consumption that are aimed at the purposes of exuberance and social status rather than the needs. Conspicuous consumption of goods in most if not all societies often forms part of an intricate ritual of identity formation. "Material goods have been an important markers of social position in all human societies and have rendered visible social groups and hierarchies. In the earlier days of industrial societies, including the first breakthrough of mass consumption, the individual could demonstrate his place in the social hierarchy by the display of status goods." (Ropke, 2001) In the last century, we have seen the rise of what anthropologist have called 'abundance economies". Where the production of goods has exceeded needs. Perhaps this is the moment for a drastic revision of the definition of needs.

Social ethic**:** Is it possible for citizens as a whole to inform and influence the development and dissemination of technology? If so, what are the most feasible mechanisms that would allow such a process of democratisation? The heart of the issue is about governance. In most instances, these processes are likely to find greater favour and assimilation as a cultural trait in countries with vibrant democracies and a literate civic. Democracy is often spoken of in many countries in a purely normative manner. But, in the arena of realpolitik democracy, it is about active engagement of different interest groups. And, in countries where there are strong democratic institutions and a level of public maturity conflict is seen as an essential ingredient of democracy. Democracy as much as it is about an idea about freedom, it is more alive if it is active, and not the exclusive preserve of a few people. In multi-cultural societies and where income disparity is high, there are considerable challenges in involving the citizenry in discussions and policy regarding issues of technology and science. These challenges include overcoming barriers such as language, levels of education and different ethical worldviews. Some pioneering work has already been done to ensure greater civic participation in issues of science and technology. In Brazil, the idea of a Citizens Jury has been experimented with in order to ensure that different members of Brazilian society are adequately informed and are able to make informed choices on the issue of GMOs. (Toni, 2001)

Ulrich Beck, in his seminal work *Risk Society*, provides a useful discourse and analysis of how the public realm has been excluded from scientific decision-making as much of the policy on risk is managed by experts. His work provides a useful sociological analysis and foundation to examine ways of creating democratic practice in science and technology. The three important insights in Beck's work are (i) that with the advent of modernity and the accompanying rise of industrialization new and unknown risks have emerged that are both apparent and latent. These risks are no longer individualized or isolated but are global. As Beck notes, "Along with the growing capacity of technical options, grows the incalculability of their consequences"; (ii) the distribution of risk follows the general pattern of inequality in society that is a result of class divisions. At the top of the pyramid, more affluent individuals and societies are least likely to be affected, while those at the bottom because of their poverty are likely to be more vulnerable. The wealthier one is the more one is in a position to mitigate risk. Beck also presents the flipside of risk, where its effects over time are likely to affect all spectrums of society. He argues, "Risks of modernisation sooner or later also strike those who produce or profit from them. They contain a boomerang effect, which breaks up the pattern of class and national society"; (iii) inevitably experts who in most instances occupy a monopoly and authority over the interpretation of data and the manner in which it is presented mediate the measure of risk and pronouncements about acceptable levels of risk. The organisation of opinion on risks always follows a trajectory of binary tensions. On the one, there are the experts and regulatory authority and on the other, the public as perceivers of risk. In this relationship, the experts sit at the to of the pyramid hierarchy, ready to dish out technical advice and information so that the perceivers become more knowledgeable. In the opinion of scientific authority, the handiness of this public awareness approach is based on the assumption and prejudice that the public is ignorant. Worse, the public fears can only be allayed by a more efficient distribution of basic information to quell the uncertainties and re-boost confidence in the experts.

As Beck shows, this is rather naïve, as the very basis of risk, given the unequal manner in which it is distributed and the possibility of political manipulation of scientific interpretation, makes the whole process very much political and sociological in scope. It is therefore not one of the passive exchange of information from the experts to the non-experts. Beck points out that the determination of risk is never absent without some ethical vantage point or interest that one takes into account when doing a risk estimate - it is always at the back of one's mind. Beck says: "…one must assume an ethical point of view in order to discuss risks meaningfully at all. Risk determinations are based on mathematical possibilities and social interests, if they are presented with technical certainty. In dealing with civilization's risks, the sciences have always abandoned their foundation of experimental logic and made a polygamous association with business, politics and ethics - or more precisely, a sort of 'permanent marriage without license'." The fact remains that as institutions of knowledge and interpretation, for which in some cases they have a virtual monopoly, wield an invidious source of influence on the decisions on how risk is determined and managed in the end. The need for a techno-ethics gains greater impetus, if we consider Beck's conceptual frame as regards the management of risk. The ethical framework needs to be informed by the nature of risk. Risk, as articulated by Beck, knows no boundaries, and its impacts is differentiated, following the contours of class differences and inequalities, level of political participation and access by different groups, and bias within systems of authority for particular modes of opinion.

Transnational ethics**:** Technological expansion is not limited today to the confines of national geography. It is truly transnational. Scientific research,

research and development (R&D) investment and Intellectual Property Rights (IPRs) are concentrated in the hands of a few developed countries. According to a recent UNDP report, the OECD which has 19% of the world's population owns 91% of technology patents by 1998 figures. This disproportionate concentration implies that the majority of the world is at the receiving end of new technologies and hence having different degrees of absorptive capacities, needs and possible utilities. Technological introductions as often paraded by their promoters display a sense of cultural, historical and political neutrality- but at face value.

This seeming feature of universal utility of technology is a key attribute of modernity that it is embedded in the thinking of western science and rationality. It is also modelled or shaped by western traditions of governance, economic interests and tenets. Nonetheless, instead of bemoaning western and industrial domination, one suspects that without alternatives there is little to do to change the status quo. The dominant tradition will continue to prevail. This is neither to suggest that where there is a lack of research, capital, entrepreneurial and institutional capacities, nothing of value or interest. Technological innovations are embedded in all societies in one form or the other be it for reasons of necessity, aesthetics or culture. It just that certain technologies have gained a greater authority, and penetration than others. The reasons are diverse, complex and not necessarily limited to issues of political economy.

The ethical dimension comes at the juncture as to whether all technology that originates from their centres of origin (countries which have a dominance over the production of particular kinds of technologies or introduction of techniques) are always appropriate and applicable to the specific nuisances of different cultures, religions, and political economies. This perhaps is as much a question to the producer as it is to the user. Sentiments of a transnational ethic are beginning to manifest in trade talks, and to an extent one could argue that the inclusion of precautionary measures in Multinational Environmental Agreements (MEAs) such as the Biosafety protocol are responses by vulnerable countries to find international mechanisms of control because the introduction of new technologies is so transnational in nature. An additional dimension we may add is that the development of technology – given the commercial interest at stake - is tailored to meeting the requirements of specific patterns of lifestyle and economic forms of production and ownership. They therefore do not always fulfil, especially in poor and developing countries, all the social and development needs of these countries. The relocation of manufacturing from more developed economies to developing and emerging economies and the concomitant transfer of technology is largely based on financial rather than developmental interests. It is in most instance meant to feed the consumerist appetites of middle class constituencies. Technology development driven by the centres of origin is primarily aimed at expanding markets and maximizing profits and not necessarily the needs of the poor. It is therefore possible to envisage because of this bias that the NT solutions proposed, and the Nanoecology interventions will be in favour of the interest of dominant economies and constituencies.

Technology and development:

We must pose a fundamental question as to whether all of technology leads to development and social welfare? If so, according to whose frame of mind and values? This line of argument is pursued for instance around the question of R&D spend at the centres. Or what *The Economist* in its November survey (2001) of technology and development termed the Viagra vs Vaccine debate. While there is considerable public and private sector involvement in technology research, much of this technology is focused on priorities that are demanded by consumers of the developed world, or constituencies in developing countries who have similar lifestyles patterns and habits as those who live in developed countries. R&D investment in pharmaceuticals is a case in point. Of the 1223 drugs introduced between 1975-1996, only 13 were aimed at tropical diseases. Of the $70 billion spent on health research globally in 1998, about $100m was dedicated to malaria research. (*The Economist Survey*, November 2001)

But, given world inequality and unfair mediation, it is more than likely that the role of science and technology will continue to reflect a dominant interest and constituencies. This is also more likely as basic science and educational training in the developing world is on the decline (there are numerous reasons for this) as educational provision becomes globally more competitive. The ability to retain scientific capacity is intrinsically tied to levels of economic development, the nature of state intervention to direct strategic research and sufficient incentive for the educational institutions and experts to continue to retain the capacity and grow new fields of knowledge. International experience shows that the pattern of scientific and technological development and capacity follows a full-loop: running from having a threshold of intellectual resources, facilities, capital investment, organisation and entrepreneurship to transform basic science into useful products demanded by society.

As much as the technology development debate is about a certain kind of morality that should govern its production and use, it is also a reflection of the variant nuisances of power that informs the framework of investment and ultimate utility to which science and technology is put to. In the public parlance, blurted out by public agencies and the private sector, one is led to belief that technology is for all. We are promised a utopia, but this is a utopia for a few as continued inequality and disproportionate benefits from the diffusion of technology continue to prevail in the global community. It is therefore not intriguing to find that technology easily finds a home amongst those who can afford it, or shall we say that the affordability of technology is designed in such a manner that it only finds its home amongst certain constituencies.

A good example of how technologies breakthroughs can lead to underdevelopment is to be extracted from lessons and experiences that developing countries have had in engaging the use of outer space. As global economies become transnational in scope and resource utilisation is transnational in nature – given the transfer of raw material and other resources from one national boundary to the other - the importance of space technology and the control of outer space as an hemisphere for maintaining vast interests and empires of production cannot be missed upon us. Remote sensing technology is now widely used by large mining, oil gas and other companies for identifying new deposits and aiding in planning the use of these deposits putting at their disposal a powerful tool.

For developing countries the power of remote sensing and satellite technologies can help them leapfrog the technological gap and catalyse development in their own countries by assisting them in undertaking better planning and allocation of limited resources. However, both the data and the capacity to interpret this data is located in the hands of a few developed countries and transnational firms. One can only presume that the lack of access to these technologies and data hinders development and possibly contributes to the continued underdevelopment of these countries. It is therefore no wonder that some developing countries like India and Cuba have lobbied the UN Assembly to find international mechanisms for ensuring that as outer space is still deemed to be a global commons the information gathered should come with the requirement that it be done on the basis of prior consent. In this way, hoping to exercise some form of control over proprietorship, use of such information and enable countries to secure a degree of technology transfer.

The promotion of technology is pervaded by the paradigm of a free market. The notion of free market is couched in the language of 'objective economics', and is in fact presented in that manner. But, what it certainly obfuscates is that in the political arena, notions such as these have less to do with the science of economics, but more to do with putting forward political positions in the name of 'objective economics'. It is for this reason that often the debate on economics is not seen for what it is-ideology and nothing more. Ironically, the very economist who first propounded the idea of free markets: Adam Smith[3], has seen the selective appropriation of his ideas by conservative economist to legitimise and authorise their positions. New scholarship shows that in fact Smith was very cautious of absolutist principles of free marketeering and in fact Smith was concerned more about advocating for political and economic equality. This has led intellectuals like Noam Chomsky to remark:" It's quite remarkable to trace the evolution of values from a pre-capitalist thinker like Adam Smith, with his stress on sympathy and the goal of perfect equality and the basic human right to creative work, to contrast that and move on to the present to those who laud the new spirit of the age, sometimes shameless invoking Adam Smith's name". (National Post on-line, December 3, 2001) Smith's compassionate side emanates from the fact that he was a moral philosopher, and his theory of compassion is a central focus in another of his major works: the "Theory of Moral Sentiments". (Himmelfrab, 2001) This sentiment is carried forth in his *Wealth of Nations* (a classical thesis on economics), leading Smith in various segments of the book to denounce greed, or what he defined as 'mean rapacity', and forms of trade that led to greater suffering of the poor. Smith also warned: "No Society can surely be flourishing and happy, of which the far greater part of the members are poor and miserable. It is but equity, besides, that they who feed, clothe and lodge the whole body of the people should have such a share of the produce of their own labour as to be themselves tolerably well fed, clothed and lodged".

Given the increase of global inequity, the hard rules of capitalism may have to give way for more pragmatic economic interventionism if not for the ethic than it least for the sake of Capitalism's own long-term self-preservation. The issue of technology transfer and development is tied up with debates about intellectual property rights currently being engaged under trade-related aspects of intellectual property rights (TRIPS) at the World Trade Organisation and other forums. They symbolically and de facto, represent the demise of public notions of knowledge sharing and use or what is also referred to as public goods or the commons. (The notion of a commons these days following Garrett Hardin's critical thesis has attained pejorative sense and connotations by mainstream economist). Perhaps the manner in which one needs to look at public goods or the idea of the commons is rather in the form of pragmatic equity. Pragmatic equity implies that not everything is about profit or need to be driven by market forces. There is a need for a healthy mix of private-public

[3] Adam Smith is also regarded as the founder of modern economics. Recent scholarship includes the work of Emma Rothschild's Economic Sentiments: Adam Smitth, Condorcet, and the Enlightenment. (Harvard 2001)

and communal forms of technology development that allows the best to emerge from all three forms of association and proprietorship. For, the absence of this will lead to greater social instability if it has not already.

However, in many developing countries the idea of the commons, and access to the commons, whether it takes a material or immaterial form, is pivotal to the pursuance of economic stability and self-development. The notion of a public good is regarded as a taboo where the major economies have pushed for policies that encourage greater privatisation both in terms of material and immaterial goods. One can easily argue that technologies are essential for development, and where access is restricted or denied to individuals or countries, greater impoverishment and suffering occur. In such circumstances it is no longer an issue of markets, but a basic right. Technology transfer is now elevated to the level of a human right. Casting tech-transfer issues within the ambit of a human rights discourse found some favour at the recent WTO trade round in Doha, Qatar, where it was in principle accepted that essential medicines need to be made more freely available to countries suffering from major epidemics or pandemics such as HIV. This new trade agreement with a human rights face is a concept and discourse still in its infancy and may warrant some further exploration and debate.

The contribution of technology to human well-being is perhaps best encapsulated in the similar manner in which debates about the purpose of economic policy and planning should be. The Nobel Laureate, Amartya Sen argues that economic policy and planning is less about freeing up the markets or the spread of goods, but about how it will affect the poor and their ability to fend for themselves. Sen appeals to a poor-centric approach to economic policy, and therefore turns the question and purpose of economic policy on its head by asking the fundamental question: "How does it lead to improvements in poverty?" This question is also relevant to the issue of science and technology. In the overall scheme of things, in what manner does technology development lead to less suffering and general well being of the populace?

Concluding Remarks

Nanotechnology like space exploration is the unknown frontier. Much of it remains exploratory and speculative. NT is not yet fully brought into the ambit of the discussion of environmentalist. Or maybe we deliberately neglect to look at a possibility of positive future with new technological developments. A dismal state is a convenient state to be in when talking about the future. A fearful future is the bedrock of all problem solvers, or how else can they justify their own existence and their pursuits. In the end, Bjorn Lomborg, the sceptical Danish environmentalist, may gloat or sink in his own conclusions if the promises of NT and nano-ecology turn out to be false.

However, NT has some promising areas. It will open new avenues to deal with future environmental problems. Nevertheless, its utopian pre-conclusions need to be viewed somewhat with suspicion. The scenarios for blissful purgatory or negative consequences are speculative and their conclusions are too early in the making. However, the interwoven social ramifications of the technology into society are hard to ignore, whether positive or negative. Undoubtedly, processes need to be put in place to allow for some democratic input and oversight. Developments in NT will inevitably bring into considerations issues of political economy, ethics and whether they serve the purpose of humanity in the end. Hopefully, NT will address some of the major ecological issues. But more importantly and unlike the ICT revolution, it will become the new promise to the poor centric approach that is essential to contribute to the developmental agenda facing us in the 21st century. Responsibility over the use and outcomes of new technology revolutions needs to be the business of everybody, not a few technology visionaries and futurists.

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