This century is one of those rare times in history when we are in the midst of human society transforming form one type to another. The changes brought about in our physical and economic environment are so profound that parallels are rare in history. In this transition, technology as always is the catalyst. And interestingly, it is a self amplifying one because each enhancement brings about an ever increasing capacity for change. Faster computers design even faster computers!

The remarkable thing about this phase in history is that the pace of change has become almost exponential. For most of human history, people could reasonably expect their grandchildren to grow up in a world much like their own. Planning for the future was easy. Monarchs could start to build temples, cathedrals and monuments which could take centuries to complete. But today, the rate of technological change is such that we cannot even imagine what the world would be like a decade later, let alone half a century later. The world is changing too fast for any such prediction to hold water. To use a mathematical metaphor, we can no longer use a linear scale to plot our progress but need to do so on a logarithmic scale. All this is a result of our being in the midst of a transition. Our imaging the world fifty years later is at the same level as the Neolithic man imagining the life of a settled agriculturist.

There is no aspect of our existence in this century which is untouched by profound technological changes. High yielding varieties, chemical fertilizers and now genetically engineered strains have revolutionized agriculture. The internal combustion engine, the airplane and in the near future, high speed magnetically levitated trains will transform our perceptions of spatial distances. In the field of energy, hydroelectric power, nuclear power and hopefully soon, affordable and clean solar power will offer immense opportunities for increase in economic well being. Of course, some of these technologies have been mixed blessings as is evident from large scale displacement which has accompanied large hydroelectric projects and the rush-hour smog ridden metropolises of today. Nevertheless, that technology has changed our physical environment in an enormous way is incontrovertible.

The change in the technological landscape which we have witnessed in the last few decades will in all likelihood become insignificant compared to what the next millennium will bring. Though it is hard to predict precisely the technological advances which will be seen in the coming decades, one can certainly do some intelligent guesswork and try and extrapolate from present trends the shape of things to come. Of course, the whole exercise is fraught with dangers because of the self amplifying nature of contemporary technologies.

The field of communications will certainly be among those where fundamental changes can be expected. At the moment, more than half the population of the world lives more than two hours of travel time from a telephone! And even for those parts of the world which are connected, the basic telephone service is by and large provided by analog copper wire. Interestingly, this technology is more than a hundred years old and will never be upgraded. On the other hand, the advanced network connections for the information highway require very high information carrying capacities (or bandwidths). This is true for a majority of applications like digital video which would require gigabits capacity. This would lead to the famous last mile problem where the networks themselves will have hundreds of gigabit capacities (with optical fiber) while the final link between the telephone company and your home phone will still be limited by obsolete technology. There will be a lot of optical fiber and fancy electronics, linking countries and telecom companies but the connections between individual users will be through conventional wires. A large fraction of the world will in this scenario have no access to telephone service or have it through low data rate technology. What would be required would be an inexpensive technology which could be compatible with high data transfer rates and mul-

timedia applications. Even in a country like ours, we would need high data transmission capacities for institutions like universities, research laboratories and even hospitals while also providing basic telephony services to the majority of the population living in the rural areas.

The solution to this lies in the development of satellite systems. These systems could serve vast areas and are indifferent to terrain. The terminals can be deployed quickly and the system is not vulnerable to natural calamities like floods or fires. This connectivity could also be a catalyst in stemming the growth of cities where large scale migration of people takes place in search of economic opportunities. In this sense, maybe the information highway may actually be more than a metaphor. Just like in this century, a town near a road or a railway prospered, similarly one could expect a region connected to cyberspace have more opportunities for economic advancement.

Transportation will be another area where one can reasonably expect far reaching changes. This century has been the century of the automobile and of the jet plane. Both these modes of transportation will see further developments in technology. Electric cars will become the preferred mode of transportation for intra city travel, while advanced automobiles running on “smart” highways will be used for inter city transportation. Better, larger and more fuel efficient subsonic jets would take care of long distance travel. There will however be physical limitations on the growth of these modes of transport because of clogging of highways and airports in urban conglomerates. The alternative will be the development of an efficient and fast rail network. Already, in most European countries trains have replaced airplanes as the preferred means of travel for medium distances. Improvements in existing rail technology, though having the advantage of using the infrastructure already in place has limitations of speed and the specter of noise pollution. However, with the development of magnetically levitation trains (maglev), speeds upto 500 kilometers per hour could be easily achievable. Maglev is a family of technologies in which the vehicle is suspended and propelled by magnetic forces. With the development of room temperature superconducting materials, the limitations on the design and size of magnets could also be easily overcome.

In the field of energy generation one is likely to see the growing use of nuclear fusion and solar power. In the time frame of fifty to a hundred years, the reserves of fossil fuels will be reaching critical levels, forcing the changeover to alternative sources of energy. Nuclear fusion, though a distant dream as of now, would have evolved into a safe and cost effective alternative. If the planned International Thermonuclear Experimental Reactor, a giant collaborative effort of the European Union, Russia, Japan and the U.S., is built, it could provide a major impetus to fusion research. Solar energy is another clean source of energy whose use will certainly grow, especially in a tropical country like ours. Though at the moment none of the technologies available are cost effective, except in remote areas where the cost of transmission infrastructure for electricity is huge, the future could change all of this. It is unlikely that any single solar technology will predominate and the mix will be determined by regional variations. However, solar cells and the conversion of sunlight into hydrogen fuel are the two promising approaches. Photovoltaic or Solar cells which convert sunlight directly into electricity are at the moment not efficient because of the limitations of the material used for them. With development of new materials one can envisage an increase in the efficiency and a reduction in the cost. Converting the sunlight directly into hydrogen fuel which can then be used locally or transported to produce electricity, is another area which will grow.

But by far the most important advances are going to be in the fields of biotechnology and information technology. These will have far reaching impacts either directly or indirectly on the lives of a large fraction of humanity. Recombinant biotechnology will revolutionize the fields of agriculture and health care. Treatment of hitherto intractable diseases and the development of pest resistant strains of seeds will be commonplace. And who

knows, may be one would even see the development of a strain which increases the efficiency of the plant to convert solar energy into food by photosynthesis by a small amount.

The proliferation of Information technology (IT) in the last few years has been unparalleled in history. From washing machines to electronic fuel injection, from digital communication networks to the Internet, there is hardly any aspect of modern urban life which is untouched by IT. It is almost certain that the improvements in the hardware and software will continue at least at the same rate (if not faster) as we have witnessed in the past decade. In this case, it is hard to predict exactly what form the developments will take, but some broad trends are already clear.

By 2047, we would see a worldwide very high-bandwidth network which is based on fiber-optics, cables, satellite and general wireless systems. The Internet will continue to grow and almost all of the cumulative knowledge of our species which can be digitized would be available on line. In the field of hardware, one would see the development of single chip supercomputers and essentially unlimited RAM (Random Access Memory). In addition, data storage would become inexpensive, fast and effectively limitless. This could be in the form of optical disks. One is likely to see highly developed hardware and software for human-machine interface. Speech and gesture could replace or supplement the mouse and the keyboard.

These changes in the hardware and software would bring about a radical change in the way we interact with computers. However the most important step in integrating computers completely into our lives would be natural language interface. If we could carry out a two way “conversation” with the machine in our natural language, ask it to perform certain desired functions (like mailing, retrieving information etc.) and get responses in from the machine, it will be an improvement of far reaching consequences. This would require not only a vast improvement in speech recognition software from today, but also the solution to the more difficult problem of contextualising the words. Nevertheless, it is certainly a possibility with the vast resources of the Internet and powerful search algorithms.

Personal information agents are another possibility. These agents (called software robots or bots) are computer programs that roam the Internet on behalf of their owners and perform functions like information retrieval and search on the Net.(In this, they are very similar to their malevolent relatives, computer viruses) Several such agents are already available and will certainly be vastly more efficient and commonplace in the coming years. These, coupled with natural language processing will make the Internet a potentially far more powerful tool than today.

Even with all these improvements in IT, it is clear that though all pervasive, IT will have a partial or marginal contribution to the real problems facing the world. For instance, with faster computers, one could improve weather prediction and develop better strains with biological research, thus hoping for increased global food production. But the political factors (like the agricultural policies of China , the power of the farm lobby in the U.S. among others) will be far more crucial.

And this brings us to the heart of the problem. Technology could play the role of a catalyst and have a potentially enabling role for our own country. But it is ultimately the socio-political domain which will determine the shape of things to come. There exists in India today broadly two categories of people: one which has access to the latest technology and uses that technology effortlessly. Then there is the vast majority of the population which has only marginal contact with high technology (claims of hundreds of millions of wrist watches sold notwithstanding). The technological haves, will continue to reap the benefits of the improvements in lifestyles which technology brings with it. They are not particularly concerned about the infrastructural bottlenecks because they have the

wherewithal to create an alternative infrastructure wherever the existing one is nonfunctional. No water leads to tubewells, no power can be solved with diesel generators, poor telephone services by cellular technology and now the Internet, transportation problems with the Cielos and the Shatabdis and poor health care with superspeciality hospitals equipped with the latest diagnostic tools.

The majority of the population has neither the access nor the means to reap the benefits of technology. It can be argued that they have been denied access to the basic human amenities and thus it is futile to talk of their use of fancy high technology. Yet, there is a lesson to be learnt from the growth and proliferation of STD booths in the remote areas. People will rapidly adapt and use a technology that fulfills a genuine need, if access is easy and affordable. For instance, one can envisage remote corners of the country using inexpensive satellite dishes, powered by solar panels and hooking up computers to the Internet. With natural language processing and speech recognition equipped computers, illiteracy would not be a barrier to the use of the information resources of the Internet. This does not mean that eradicating illiteracy is not a desirable goal. It is just that given the present situation, the prognosis for that goal being achievable is remote even in 2047. Even the formal education system, if it continues the way it is , would almost certainly have collapsed in all but its form.

The India of our grandchildren thus looks not very different in substance to the one which we inhabit. It will have its Laloos and Gujrals presiding over the destinies of a populace which will remain divided into the haves and the have nots. The haves will continue to compete with the their brethren in San Francisco in their fascination with the latest technologies. The others, will have to be content with unsafe drinking water and the marvel of Ganesh drinking milk.