Forum for Global Knowledge Sharing

Technology Intensity and Global Competitiveness

# Symbiosis International University, Pune

**November 30 – December 2, 2012**

## Technology intensity and innovations in the next thirty years

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## Abstract and outline

Last century history is full of inventions that never came through or statements that were totally wrong. There have been many dead ends, false trends, premature innovations, or even suppressed discoveries.

Innovations are of three types, step improvements, breakthroughs, changes of paradigm. And the major inventions, those that change life, may not always be understood, just a few years ahead.

Now, in the world we live in, innovations and practical developments can happen all over, in developed as well as in emerging countries, large or small, rich or less rich. Examples abound. Breakthroughs are almost immediately known and appraised everywhere. Interested partners and would-be investors can show up overnight. This is the major change of paradigm with the Internet.

Actually there were far too many sources, foods for thought, to be surveyed, let alone grasped, within this paper. So, the shape of things to come, a vision for 2040, **must be left to personal interpretation.**

Key words: Acceleration, Globalization, Innovations, Future, 2040, 2030, population, GWP.

## Introduction

By definition the future is uncertain, and the most foolhardy enterprise is to try assessing what will happen some decades from present. The history of past efforts is full of false predictions and disappointments. Some of the most impressive technological developments, like the personal computer and the Internet, were not anticipated by anyone. Most forecasts turn out to be too optimistic about the short-term introduction and too conservative about the societal consequences in the long term.

There are an amazing number of today laughable forecasts that were seriously pondered in their time. Just for fun here are a few pieces of anthology:

"*Everything that can be invented has been invented*." - Charles H. Duell, Commissioner, US patent office, 1899

"*Television won't be able to hold on to any market it captures after the first six months. People will soon get tired of staring at a plywood box every night."* Darryl Zanuck, 20th Century Fox, 1946

"*There is no likelihood man can ever tap the power of the atom*".
Robert Millikan, American physicist and Nobel Prize winner, 1923

"*There is not the slightest indication that nuclear energy will ever be obtainable. It would mean that the atom would have to be shattered at will."* Albert Einstein, 1932.

And just the opposite:

"*Nuclear-powered vacuum cleaners will probably be a reality within 10 years."* Alex Lewyt, president of Lewyt vacuum company, 1955.

"*What, would you make a ship sail against the wind and currents by lighting a bonfire under her deck? I have not the time to listen to such nonsense*". Napoleon Bonaparte, when told of Robert Fulton steamboat, 1800s.

"*Fooling around with alternating current is just a waste of time. Nobody will use it, ever*".
Thomas Edison, 1889, and also, "*The phonograph has no commercial value at all*". Thomas Edison, 1880s.

The world of computers as been particularly rich in wrong forecasts:

"*I think there is a world market for maybe five computers*." Thomas Watson, president of IBM, 1943.
Of course, Watson was referring to room-size mega-machines filled with vacuum tubes. But still.

"*The world potential market for copying machines is 5000 at most"*. IBM, to the eventual founders of Xerox, saying the photocopier had no market large enough to justify production, 1959.

"*Everyone's always asking me when Apple will come out with a cell phone. My answer is probably never."* David Pogue, the New York Times, 2006

"*There is no reason anyone would want a computer in their home*.", Ken Olson, president, chairman and founder of Digital Equipment Corp., 1977.

"*Almost all of the many predictions now being made about 1996 hinge on the internet's continuing exponential growth. But I predict the internet will soon go spectacularly supernova and in 1996 catastrophically collapse*." Robert Metcalfe, founder of 3Com, credited with having invented Ethernet, 1995.

"*The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?"* -- David Sarnoff associates in response to his urgings for investment in the radio in the 1920s.

William Thomson, Lord Kelvin, president of the Royal Society in the 1890s, was particularly prolific in disbelieving virtually every scientific discovery. Among a few gems: "*Radio has no future*," "*I have not the smallest molecule of faith in aerial navigation other than ballooning,"* "*X-rays will prove to be a hoax*". "*Heavier-than-air flying machines are impossible"*.

Orville Wright, in 1908 claimed that "*No flying machine will ever fly from New York to Paris*".

Irving Thalberg, MGM movie producer, said in 1927 that "*Novelty is always welcome, but talking pictures are just a fad*."

Totally wrong forecasts have also been made in non technical fields:

*"It will be years, not in my time, before a woman will become Prime Minister", Margaret* Thatcher future Prime Minister, 1969.

"*Ours has been the first, and doubtless to be the last, to visit this profitless locality*." Lt. Joseph Ives, after visiting the Grand Canyon in 1861.

"*Stocks have reached what looks like a permanently high plateau*." Irving Fisher, Professor of Economics, Yale University, 1929.

**The problem with the present is that the world is moving so fast that someone saying that it cannot be done is generally interrupted by someone doing it.**

## The recent past

The major innovations of the last century had some common features. They have been universal, widespread and of ready access to large numbers of people, if not all. They have all been created, developed and marketed most successfully by market economics. They continue to be perfectible, and perfected, and their improvements still are the core part of current industries and technology.

All encompassing and horizontal discoveries, affecting the widest range of activities, are, not limitative:

Electricity, grids, energy, appliances, refrigeration, radio, telephone, television, computers, Internet
Transportation, fast trains, automobiles, air planes, city transport
Networks of infrastructures, railroads, long range highways, electrical grids, water distribution
Laser and fiber optics

And, oriented to just one branch of activity:
Agricultural mechanization and/or back to chemical less agriculture
Space flight and exploration
Health technologies
Nuclear technologies
Plastics and high-performance materials
Artificial intelligence and robotics
Preservation of History and Species

The list could probably be longer. A few and not the least were initiated in the century before, but really developed last century, and most are part of the 20$^{th}$ century.

These and many others are all being improved, perfected, with developing stepped innovations. They are part of the present world and of the foreseeable future.

They have many pitfalls too, like pollution and excess. For the last two centuries, technology kept offering the promise of a better world through the elimination of disease and material improvements to standards of living. However, resource extraction, emissions of dangerous materials, and pollution of air, water, and soil have also created catastrophes and caused many irreversible damage. Even the seemingly innocent developments like the Internet, have their dark face. For instance, about 90% of the messages sent through the Internet are spam…

## The most talked about developing innovations

Technological growth includes incremental developments and disruptive technologies.

For instance, an incremental development is an innovation that continues an existing innovation, for instance a bicycle to which a motor, electric or thermal, is added. A disruptive technology is one that enters an entirely new field that did not exist before, such as personal computers.

Among the many lists that have been reviewed, one of the lists seems the most complete and is here given for thought. Of course, like all such lists it is incomplete and open for discussion.

One of the most comprehensive attempts to grasp the full view of innovations to come was presented by Christopher Barnatt. It is more of the kind of popularizing “easy” science, but it is an attempt at synthesizing as well as any. Just for fun and for the curious, they have been left as links.

All these can be excitingly discussed at length, and even some more added.

**Finally, many of the technologies thus highlighted reflect an overarching trend: convergence. Although not a technology in itself, synergistic convergence between different areas of knowledge and expertise will likely dominate emerging technology trends in the next decades.**

In the new twenty-first century there are numerous scientific-technical innovations to revolutionize daily life. The major breakthroughs are all encompassing, and covering many fields. The three most important to be briefly discussed are energy, nanotechnologies and 3D printing and the least hailed and probably of major interest, intermediate technologies.

**Energy**

Energy is a key aspect of sustainable development. It is a prerequisite for all modern living, from daily comfort, to transport, to communications, to solutions for shortages, like desalinization of seawater.

The present energy system is mainly based on fossil fuels. This trend is considered unsustainable for a number of reasons, threats of man-made climate change by greenhouse gas emissions, the rapid depletion of fossil fuels, rising energy prices due to increasing demand, geopolitical uncertainty, and threat of instability in oil-rich countries.

And yet, the fossil energy is far from dead, with the shale oil and gas, and the potential of abiotic oil.

Stepped improvements are made in all energy sources with preferences for the so-called renewable energy with its pitfalls and the support of many dubious interests. Solutions for renewable energies are being explored around, and none really decisive.

Just to name a few, the renewables are based on sun, wind, biomass, tides, geothermal exploitation, and many others.

Hydrogen is an option, but only if it can be efficiently generated by use of renewable energy.

The hope for nuclear fusion, creating a child of the sun on earth, has had a bright future for the last fifty years, and it will probably remain so for decades to come.

And many others, bubbling all over, but not considered scientifically correct, just like were the “heavier than air that could not fly” in the late 19th century.

Altogether in spite of the still very energy hungry developing areas, energy demand growth will slow as economies mature, efficiency gains accelerate and population growth moderates. Energy demand in 2040 should be only 30 % higher in 2040, compared to 2010, according to ExxonMobil, *The Outlook for Energy: A View to 2040*, 2012.

**Nanotechnology**

Nanotechnology is the design of technology at the molecular level. Nanotech has been a dominant emerging technology over the last ten years.

But nanotechnology is really just convenient shorthand for many emerging technologies that have in common an engineered structure of a scale between 1 and 100 nanometers. Thus, rather than focusing on nanotech as such, it is better to look at specific technologies which will make a significant impact.

The most important current applications, as measured by the number of patents, are in micro-electronics, such as massive storage devices, flat panel displays, electronic paper, extended semiconductor approaches, and information processing, transmission.

Some current and near-future applications of nanomaterials include catalysts, dry lubrication, coatings, clothing, and materials.

Beyond this, there are more far-reaching ideas about “DNA-computing” and computational self-assembly. The main drivers for these developments are computing, telecommunications, consumer electronics, and military applications. In chemistry and pharmaceuticals, nanotechnology promises new forms of drug development and delivery, medical diagnosis, and disease treatment.

One of the most evocative possible applications could be “nanobots” or robots on a nanoscale, which could be introduced into the bloodstream to clean unwanted substances from blood cells.

Nanotechnology, in combination with biotechnology, promises advances in genomics, combinatorial chemistry, high throughput robotic screening, drug discovery, gene sequencing, and bioinformatics and their applications.

Nanotechnology could reduce the energy demand for lighting. In photovoltaics, nanotechnology could raise efficiency and lower costs. In the military sector, nanotechnology may contribute to surveillance, sensors and barrier systems, small anti-tank weapons, and smart munitions.

Nanotechnology may also contribute to virtual reality systems, automation and robotics, chemical, biological, and nuclear sensing, and aerospace, food processing, and construction industries.

Among the best known examples of nanomaterials there are “buckyballs”, or fullerenes, and “buck tubes”, or nanotubes, which are curved carbon-carbon surfaces wrapped into a sphere or a tube, respectively, with remarkable properties, especially for absorption and lubrication.

**Graphenes** belong to nanotechnologies in a broad way. They are made of pure carbon, with atoms arranged in a regular hexagonal pattern similar to graphite, but in a one-atom thick sheet. Carbon atoms are densely packed in a honeycomb crystal lattice. Graphene can be visualized as an atomic

scale chicken wire made of carbon atoms and their bonds. The crystalline or "flake" form of graphite consists of many graphene sheets stacked together. The short term use could be to replace silicon.

The Nobel Prize in physics for 2010 was awarded to Andre Geim and Konstantin Novoselov at the University of Manchester "*for groundbreaking experiments regarding the two-dimensional material graphene*".

There obviously are environmental and health concerns about nanotechnologies such as the effects of infiltration in humans, the possible attachment of high concentrations of toxic substances, the effects on living systems, the possibility of slipping past the immune system, the potential damage to lungs by nanotubes.

Even more frightening potential dangers are runaway self-replication in nature and a nanotech arms race.

**3D printing**

This is a process of making three dimensional solid objects from a digital model. 3D printing is achieved using additive processes, where an object is created by laying down successive layers of material. In this way, 3D printing is the opposite of traditional machining techniques, or subtractive processes, which rely on the removal of material by drilling, cutting etc.

3-D technology now has many names, additive fabrication, additive processes, additive techniques, additive layer manufacturing, freeform fabrication.

The use of additive manufacturing takes virtual designs from computer aided design, to transform them into thin, virtual, horizontal cross-sections and then creates successive layers until the model is complete.

3-D printing is one of the most exciting technological innovations in recent years, and fast advancing. Now it moves from the sophisticated early adopters to people who just want to print something. In the next few years, with economies of scale, a 3-D printer may cost as little as $100.

*“Digital fabrication also takes the expensive parts of traditional manufacturing and makes them cheap. In mass production, the more complicated a product is and the more changes you make, the more it costs. But with digital fabrication, it’s the reverse: The traits that are expensive in traditional manufacturing become free.*
*Variety is free: It costs no more to make every product different than to make them all the same.*
*Complexity is free: A minutely detailed product, with many fiddly little components, can be 3-D printed as cheaply as a plain block of plastic.*
*Flexibility is free: Changing a product after production has started means just changing the instruction code”.* Chris Anderson writing in Wired.com:

*“3D printing technologies have come a long way since their earliest incarnations as rapid product prototype makers. It’s now shaping up as the next disruptive technology and in medical science, 3D printing has huge potential. The latest advance comes from University of California, San Diego Nano engineering Professor Shaochen Chen, whose group has demonstrated the ability to print three-dimensional blood vessels in seconds. If the technique proves scalable, it could revolutionize regenerative medicine: For instance, it would mean being able to recover from a heart attack by replacing a faulty aortic valve with a brand new one, made of same own cells”*. Doug Hendrie in Gizmag.com

3D printing is usually performed by a materials printer using digital technology. Since 2000, there have been developing sales of these machines, and their price dropped substantially. This technology can be used in the fields of jewelry, footwear, industrial design, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education, geographic information systems, civil engineering, and many others.

3-D printing makes it as cheap to create single items as it is to produce thousands and thus frees from economies of scale.

According to The Economist February 10 2011, "*It may have as profound an impact on the world as the coming of the factory did....Just as nobody could have predicted the impact of the steam engine in 1750, or the printing press in 1450, or the transistor in 1950, it is impossible to foresee the long-term impact of 3D printing. But the technology is coming, and it is likely to disrupt every field it touches*".

Industrial 3D printers have existed since the early 1980s, and have been used extensively for rapid prototyping and research purposes. They generally are larger machines that use proprietary powdered metals, casting media like sand, plastics or cartridges, and are used for many rapid prototyping uses by universities and commercial companies. Industrial 3D printers are made by companies such as ExOne, Objet Geometries, Stratasys, 3D Systems, EOS GmbH, and Z Corporation.

Rapid prototyping permits to quickly fabricate a scale model of a physical part or assembly using 3-D CAD data. The first techniques for rapid prototyping became available in the late 1980s and were used to produce models and prototype parts. Today, they are even used to make production-quality parts in relatively small numbers.

Advances in rapid prototyping technology have brought about the ability to use materials that are appropriate for final manufacture. These advances in material use have brought about the prospects of directly manufacturing finished components. The advantages of 3D printing in rapid manufacturing come from the relatively inexpensive production of small numbers of parts.

Forecasts for the future of commercial manufacturing indicate that this development may change the nature of commerce and globalization, because end users will be able to do much of their own manufacturing rather than engaging in trade to buy products sometimes from far away.

*"To really let this robotic evolutionary process reach its full potential*," says Lipson, a Cornell University computer and engineering professor, "*we need a machine that can fabricate anything, not just complex geometry, but also wires and motors and sensors and actuators*." Lipson developed a low-cost, open-source fabricating system, Fab at Home. There are reports of printing with everything from food, cheese, chocolate, to epoxy, to metal-powder-impregnated silicone to make conductive wires.

A Fab at Home kit costs around $2400. Lipson compares it to early kit computers such as the MITS Altair 8800, which democratized computer technology in the 1970s. At-home fabrication, Lipson says, "*is a revolution waiting to happen*."

As 3D printing will permit the direct digital manufacture of a wide variety of plastic and metal items, there might be more to come.

**Bioprinters** are another potential revolution. Bioprinters are bound to artificially construct living tissue by outputting layer-upon-layer of living cells. Currently all bioprinters are experimental.

Yet, in the future, bioprinters could revolutionize medical practice. "*Bioprinters may be constructed in various configurations. However, all bioprinters output cells from a bioprint head that moves left and right, back and forth, and up and down, in order to place the cells exactly where required. Over a period of several hours, this permits an organic object to be built up in a great many very thin layers".*

Several experimental bioprinters have already been built. For example, in 2002 Professor Makoto Nakamura realized that the droplets of ink in a standard inkjet printer are about the same size as human cells. He decided to adapt the technology, and by 2008 he had created a working bioprinter that can print out biotubing similar to a blood vessel. In time, Professor Nakamura hopes to be able to print entire replacement human organs ready for transplant.

As Organovo have demonstrated, using their bio ink printing process "*it is not necessary to print all of the details of an organ with a bioprinter, as once the relevant cells are placed in roughly the right place Nature completes the job. The cells contained in a bio ink spheroid are capable of rearranging themselves after printing. For example, experimental blood vessels have been bioprinted using bio ink spheroids comprised of an aggregate mix of endothelial, smooth muscle and fibroblast cells. Once*

*placed in position by the bioprint head, and with no technological intervention, the endothelial cells migrate to the inside of the bioprinted blood vessel, the smooth muscle cells move to the middle, and the fibroblasts migrate to the outside*".

In more complex bioprinted materials, intricate capillaries and other internal structures also naturally form after printing has taken place. The process may sound almost magical. However, as Professor Forgacs explains, "*it is no different to the cells in an embryo knowing how to configure into complicated organs. Nature has been evolving this amazing capability for millions of years. Once in the right places, appropriate cell types somehow just know what to do".*

A team lead by Jeremy Mao at Columbia University is working on the application of bio printing to dental and bone repairs. Already, a bioprinted, mesh-like 3D scaffold in the shape of an incisor has been implanted into the jaw bone of a rat. This featured tiny, interconnecting micro channels that contained "stem cell-recruiting substances". In just nine weeks after implantation, these triggered the growth of fresh periodontal ligaments and newly formed alveolar bone. In time, this research may enable people to be fitted with living, bioprinted teeth, or else scaffolds that will cause the body to grow new teeth all by itself.

In another experiment, Mao's team implanted bioprinted scaffolds in the place of the hip bones of several rabbits. Again these were infused with growth factors. Over a four month period the rabbits all grew new and fully-functional joints around the mesh. Sometime next decade, human patients may therefore be fitted with bioprinted scaffolds that will trigger the growth of replacement hip and other bones.

In Situ Bioprinting will eventually permit organs to be bioprinted in a lab from a culture of a patient's own cells. Such developments could trigger a huge medical revolution, fast damage repair, wounds and burns, replacing organs, growing new limbs, fully regenerating aging skin.

**Intermediate technologies**

To stay on a better-known plane, and in contrast to the areas of so-called high-tech innovation and development, there is a very different strand of technologies, often called intermediate (Schumacher, 1973) or appropriate technologies. Appropriate technology is small scale, energy efficient, environmentally sound, labor intensive, and controlled by the local community.

The breadth of the paradigm of appropriate technology is suggested by the many terms used to describe it: intermediate, progressive, alternative, light-capital, labor-intensive, indigenous, low-cost, community, soft, radical, liberatory, and convivial (Akubue, 2000). Schumacher envisioned a technology for the third world that was midway between, for example, a hand hoe and a tractor.

A very important development of lower, or different, technology would be to prefer the manufacture of more durable goods. There is no reason consumer goods should be made obsolete in a matter of few years and even months, before they are used or even paid for. Other designs are conceivable to allow integrating eventual worthwhile technical improvements. However, this would suppose such a huge change of paradigm that it is even more difficult to fathom than the most fiction-esque discoveries.

One major question is whether the limits of the human brain are in sight, rather than the limit of technology. Now, for the first time in history, people receive much more information than they can process, and these many random messages may not increase the rate of innovation. On the other hand, there are so many more bright and educated minds that innovations are to continue in an exponential fashion.

A key development for the future, to insure a continuing increase of innovation, would be to find processes to filter and prioritize information.

**The Internet must now be used to interconnect the intelligence of many into a single mind.**

## The world in 2040

### The basic environment, population, income, gross world product GWP growth

Just to summarize from many other forecasts:

World population passed the 7 billion mark in 2011, and might be 9 billions in 2040 (<1% per annum).

World gross product, GWP, to rise from $ 70 000 billions in 2012 to $ 184 000 billions in 2040 (3.5%)

World economies will continue to grow, at varying rates:
OECD economies will expand by 2 % a year at most. Non OECD economies will grow faster, 4.5%
World global growth will be powered by emerging economies, rather than held back by them

Some of the major questions that may be raised:

### Slowing down or accelerating?

This is an almost endless question. There seem to as many worries and questioning as there are observers.

It might be that human-initiated innovation, like energy consumption and population growth, naturally saturates with rising global income levels and technological intelligence.

Shell International's 2001 report http://www.s-e-i.org/reports/shell2050.pdf summarizes IMF and British Petroleum data which note that in every economy where per capita GDP goes above $15,000/year, for instance the U.S., Europe, Japan, Australia, growth in energy use per capita, after rapidly increasing at lower income levels, begins to slow dramatically and then effectively stops.

"*This saturation may be due to a number of causes, such as the increasingly service intensive, information intensive, and virtual nature of developed economies, the sharply fixed basic needs (transportation, housing, etc.), the increasing sustainability politics of affluent nations, and perhaps most importantly, the rapidly advancing energy efficiencies of replicating machines".*

*At a GDP per capita of $25,000/year, energy growth per capita becomes so slow that it is effectively saturated. Americans saturate at 350 Gigajoules/capita, while Europeans saturate at 150.*

*In conclusion, the rate of innovation reached a peak over a hundred years ago and is now in decline. This decline is most likely due to an economic limit of technology or a limit of the human brain that we are approaching. We are now approximately 85% of the way to this limit, and the pace of technological development will diminish with each passing year".*

These conclusions are controversial, but there are profound implications if they are true.

### Tapering off by accumulating and shortages, a devastating combination

Population follows a similar saturation with global economic and technological development.

Total population sizes, after immigration is deducted, are on the decline in every first world country.

Several independent estimates now project total world population to hit a maximum about 2050, followed by an accelerating decline thereafter, a time when even emerging nations will begin to show the technological contraceptive effect now seen in the most advanced countries, below the replacement level. This is a step when the human interest in reproduction begins to conflict with rapidly improving social, economic, and technological choices for personal and child advancement.

With the rapid pace of globalization today, the world as a whole will soon reach the lower levels of technological development and consumer comforts within this century.

*“As technological progress increasingly satisfies current human needs, it is likely that individuals become less concerned with technological development and turn more toward personal growth, unique experiences, and other activities which, while equally creative on an individual level, are less obvious examples of innovation in a technological sense”.*

On one hand, there are more and smarter people on earth, living longer than ever before, so total human innovation would be higher than ever before. On the other hand, the need might become less acute, with some level of content saturation.

One major questioning that has been raised ever since the 1970s and the Club of Rome, is its never-ending pursuit of constant economic growth. Today, economists, politicians and media organizations worldwide have become obsessed with economic growth, with a flat or shrinking economy considered a very bad thing.

Regardless of what governments and even their populations are willing to accept, the finite resources of the Earth mean that economic growth will have to come to an end. For decades, mankind has only been able to achieve constant economic expansion by systematically destroying the planetary ecosystem that keeps it alive. Or as biologist David Suzuki has argued, “*We have somehow raised the welfare of the global economy above the survival of the biosphere. And this is nothing short of suicidal”.*

For example, the Centre for the Advancement of a Steady State Economy (CASSE) has published a document called Enough is Enough, to describe policy initiatives, tools, and reforms "*that would result in a zero-growth economy focused not on making more, but simply "enough".*

### Failing Globalization

There is the beginning of a trend to get factories and production units back nearer the consuming areas. This can already be seen in the US, and to a lesser extent in Europe.

A "global sustainability advocacy group" called the Zeitgeist Movement is proposing a transition to a "resource based economy". This would be governed by the application of the best scientific knowledge, rather than by monetary or political principles.

Jeff Rubin, author of the book “Why your world is about to get a whole lot smaller” discusses the foreseeable depletion of the world natural resources and how this will affect the global economy.

For the last 100 years at least, economics have been based on short-term thinking. As John Maynard Keynes said "*in the long run we are all dead*", there is now a new awareness raising. While we may be dead, children and their children will still be alive and cursing our folly. The selfish, debt-driven mass consumption of the Baby Boom generation has already bankrupted the youth of today. But this inter-generational crime is as nothing compared to the implications of us continuing to run the world according to economic principles that are increasingly wasting the future of billions.

For human civilization to survive, we need to start valuing the future as well as the present.

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