Foresighting the New Technology Wave – Expert Group

State of the Art Reviews and Related Papers

November 2004

This document is divided into reviews and summaries of related documents from various aspects of the scope of the reviews carried out by the Expert group. The scope of each review relates to specific aspects of the reflection of the Expert group and does not claim to be exhaustive nor complete in each case. Whereever possible, existing sources were used. There are sections dealing with

Thematic Areas
1. Nanotechnology,
2, Biotechnology,
3. Information technology and
4. Cognitive Sciences/Cognition.

Additionally there are sections dealing with
5. US and related Policy analysis
6. Risk Aspects;
7 Ethical, Legal and Societal aspects of Converging technology;

and reviews of
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Voltaire

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Glossary of Nanotechnology
see http://www.nano.org.uk/vocab_terms.htm

Military Nanotechnology: Perspectives and Concerns[1]

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It is predicted that nanotechnology (NT) will bring revolutionary changes in many areas, with the potential for both great benefits and great risks. Developments in the military could entail specific dangers, containment of which will need special analysis and effort. Military research and development in NT is expanding rapidly. Potential future applications span all areas of warfare. Special dangers to arms control and stability may arise from new biological weapons and micro-robots. For humans and society, non-medical body implants – possibly made more acceptable via the military – raise a number of problems concerning human nature. Further research is needed to find the best way to avoid possible dangers. For the near and medium term, several guidelines for limits and restrictions are suggested. As a first step, transparency and international cooperation should be improved.

Keywords: military • nano-science • nano-technology • preventive arms control • technology assessment

NANOTECHNOLOGY (NT[4]) WILL BE THE BACKBONE of the next fundamental technology wave. Science and technology have advanced to a point where structuring matter at the nano-metre scale.

(1nm = 10 -9m, a billionth of a metre) is becoming routine. Scanning-probe microscopes now allow us to image and move single atoms on a surface. In the life sciences, molecular processes within cells are being elucidated, microelectronics are being reduced to below 100nm, and the first cosmetics containing nano-particles are already on the market. Increasingly powerful computers allow ever better modeling of matter at the atomic and molecular scale.

Expecting huge markets in the future, both governments and large and small enterprises have greatly increased their NT research and development (R&D).

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[1] SAGE Publications, www.sagepublications.com Vol. 35(1): 61–79, © 2004 PRIO, www.prio.no, 62 *Security Dialogue* vol. 35, no. 1, March 2004

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[4] NT (which here includes nano-science) deals with structures from 0.1nm (atom) to 100nm (very large molecule) size.

In 2003, government spending alone represents $650–800 million in each of Western Europe, Japan, the USA and the rest of the industrialized countries (Roco, 2003). NT is predicted to produce revolutionary changes, bringing far-reaching consequences in many areas. Expected benefits include stronger, lighter and smart materials, computers that are smaller, consume less power and are far more powerful, diagnostics and therapy at the single- cell level, reduction of resource use and pollution, and miniaturized, highly automated space systems (see, for example, Roco & Bainbridge, 2001: 3–12). Some visions of NT reach farther: to artificial intelligence of human capability and beyond; robotics from nano- to macro- scale; nano-devices within the human body that eradicate illness and ageing or interface with the brain; and universal molecular assemblers capable of self-replication, leading to super-automated production[5].

Whether such visions can be realized has been disputed, particularly with regard to the assembler concept[6]. However, following the precautionary principle, one should take these possibilities seriously as long as they have not been demonstrated to be impossible for fundamental or technical reasons. Some were discussed at a recent workshop sponsored by the US government on improving human performance through the convergence of nano, bio, information and cognitive science and technology (NBIC) – for example, nano-implant devices, slowing down or reversing ageing, direct brain–machine interfaces and 'artificial people'[7].

Yet, while opening up fundamentally new possibilities, NT also poses grave risks, among them environmental pollution, increased inequality, invasion of privacy, displacement of human workers and physical harm. Molecular NT would increase the risks even further – as consequences of automatic production, or through accidents or malevolent use of self-replicating systems, for example[8]. Debate on the general risks posed by NT has already begun. The US National Nanotechnology Initiative/National Science Foundation and the European Commission have explicitly recognised the need to investigate the societal implications of NT (Roco & Bainbridge, 2001; Roco & Tomellini, 2002).

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[5] A universal molecular assembler would be a complex molecular system that would read a program of instructions, take the corresponding atoms or molecules from the surroundings and put them together to form the intended product, in a manner roughly similar to the processes in a living cell but not limited to biological conditions and materials. By varying the program, any structure compatible with the laws of nature could be synthesized, in particular a copy of the assembler itself. For macroscopic useful goods, many generations of self-replication would first produce billions of assemblers, which would then turn to making the intended product. This has been called 'molecular NT' by Drexler (1986); proponents expect that such technology will arrive within decades. In this article, the term 'molecular NT' is used in this sense. Of course, much present NT research deals with molecules but has nothing to do with assemblers.

[6] Refutations of the concept of molecular assemblers argue that they are (nearly) impossible by the laws of nature or will not arrive within a long time (Tolles, 2001; Smalley, 2001; Whitesides, 2001; for countering arguments, see Drexler et al., 2001a,b). Scientific articles in refereed journals are lacking. For peer- reviewed molecular-NT articles, on the other hand, see, for example, Merkle (2000) and references cited therein.
[6]Roco & Bainbridge (2002: 101ff., 179ff., 182ff., 213ff., 244ff., 251ff., 258).
[6]For a list of potential dangers, see CRN (2003).

[7] Roco & Bainbridge (2002: 101ff., 179ff., 182ff., 213ff., 244ff., 251ff., 258).
[8] For a list of potential dangers, see CRN (2003).

However, there is a paucity of ethical, legal and social research (Mnyusiwalla, Daar & Singer, 2003). This is even more the case regarding risks from military uses of NT. The aim of this contribution is to raise awareness of the dangers connected with military NT activities and to offer some preliminary recommendations[9].

After a brief overview of the literature, the article presents a summary of current military R&D on NT in the USA. It then discusses potential military uses of NT before turning, in the subsequent section, to the question of preventive arms control, which leads to a concluding discussion and recommendations. Aspects of molecular NT are discussed in separate paragraphs.

Previous Writing on Military NT

Up until now, there has been practically no scholarly research on military NT. The topic has been discussed mainly in government papers, conferences, military journals and popular media.

Seen from a narrow national-security standpoint, NT provides grand new options for the military. For the year 2030 or after, the UK Ministry of Defence foresees nano-solar cells and nano-robots designed for a range of purposes – including medical robots used internally in humans and micro- platforms for reconnaissance (UK Ministry of Defence, 2001). The US National Nanotechnology Initiative (NNI) has referred to the possibility of information dominance through nano-electronics; virtual reality systems for training; automation and robotics to offset reductions in manpower, reduce risks to troops and improve vehicle performance; higher-performance platforms with diminished failure rates and lower costs; improvements in chemical/biological/nuclear sensing and casualty care; improvements in systems for non-proliferation monitoring; and nano-/micromechanical devices for control of nuclear weapons (Roco & Bainbridge, 2001: 10–11).

The national-security panel of the US NBIC workshop stated that in ‘deterrence, intelligence gathering, and lethal combat . . . it is essential to be technologically as far ahead of potential opponents as possible’ (Asher et al., 2002). Others have looked with a wider angle and have hinted at potential harmful uses of nano-weapons or the potential for controlled distribution of biological and nerve agents (ESANT, 1999; Meyer, 2001; Smith, 2001). Questions have been posed as to killing by robots (Metz, 2000; Crow & Sarewitz, 2001)[10].

Some authors acknowledge that national security will have to be sought in a context of global security (Yonas & Picraux, 2001; Petersen & Egan, 2002). Aside from such hints, discussions of strategy and security have not yet taken up NT in a systematic fashion.

Dangers from military uses of molecular NT were already under discussion when the vision was first described to the general public (Drexler, 1986: 171–202). Destabilizing effects and arms races arising in particular from exponentially growing autonomous production were considered by Gubrud (1997).

[9] This article expands an an earlier presentation (Altmann & Gubrud, 2002) and builds on my study of military applications of micro-systems technology (MST) (Altmann, 2001). Dealing with structures of micro-metre size (a thousand-fold larger than those of NT), MST is already established, though still advancing fast. MST and NT will mutually interact and accelerate each other. A larger study on NT is in preparation.

[10] Note that one US military writer has stated that ‘military systems (including weapons) [are] now on the horizon [that] will be too fast, too small, too numerous, and will create an environment too complex for humans to direct’ (Adams, 2001).

Joy's (2000) warnings about genetics, NT and robotics have become widely known, and have evoked much critical comment. However, this has been mainly directed at general aspects rather than the dangers posed by military/terrorist uses (e.g. Brown & Duguid, 2001; Tolles, 2001; Smith,2001).

Moreover, the little arms-control discussion that exists has mostly addressed molecular NT. Drexler (1986: 171–202) argued in general terms for international agreements, but finally recommended 'active shields': nano-machines that, like the white blood cells of the human immune system, would 'fight dangerous replicators of all sorts'. However, the feasibility of such shields seems even more unclear than that of self-replicating systems themselves. Gubrud (1997) stated that not producing weaponry en masse would be verifiable, calling for a space weapons ban and recommending a single global security regime.

The Foresight Guidelines (Foresight Institute, 2000), suggesting rules to prevent runaway replication, mention the risk of military abuse, but explicitly reject limitations by treaty because 'a 99.99% effective ban would result in development and deployment by the 0.01% that evaded and ignored the ban'. Truly 100% verifiability can of course never be achieved, but a strong verification regime could restrain the technological development of leading states that might otherwise be caught in an accelerating arms race. In order to prevent NT-enabled mass destruction, Howard (2002) has presented two alternative approaches: reserving 'inner (atomic and molecular) space' for peaceful exploitation, or preserving it as a 'sanctuary', forbidding nano-technological exploration and engineering completely[11].

Military R&D of NT in the USA

While other countries are certainly active in military R&D of NT, there can be little doubt that the USA is spending far more than any other country, and maybe more than the rest of the world combined[12]. Military R&D in the USA is much more transparent – not only in comparison to, for example, Russia or China, but also relative to countries such as the UK, France or Germany. Because US military NT activities provide an important precedent, they will be briefly described here.

US military R&D of NT started in the early 1980s with ultra-submicron electronics; later, scanning-probe microscopy became a focus; and in 1996, nano-science was named as one of six strategic research areas for defence with related expenditure of US$70M for FY 1999.

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[11] The author does not discuss historical research, existing applications and definitional problems. Modelling limitation treaties for the very small after the Outer Space Treaty is certainly inappropriate.

[12] Figures on military NT R&D funding in other countries are difficult to obtain. The conjecture is supported by the following: the USA spends about two-thirds of the global military R&D expenditure at large (BICC, 2002); in the field of MST, according to a cautious estimate the US military R&D spending was more than ten times that of Western Europe (Altmann, 2001: 46); conference and internet presentations show an overwhelming preponderance of US work in military NT.

Within the NNI, founded in 2000, 25–30% of the funding goes to the Department of Defense (DoD). Military NNI funds are spent by the R&D agencies of the DoD and the armed services[13]. Much work is done in the laboratories of the services themselves. Basic science and engineering in universities is supported by the Defense University Research Initiative in NT(DURINT). In 2001, 16 grants were awarded for work on nano-scale machines, carbon nano-tubes, quantum computing, magnetic nano-particles, etc. In addition, 17 grants were given for acquisition of NT research equipment (DefenseLink, 2001).

In March 2002, the US Army selected the Massachusetts Institute of Tech- nology (MIT) to be the host for the Institute for Soldier Nanotechnologies[14] (MIT News, 2002; Talbot, 2002)[15].

Here, $50 million is to be spent during the first five years, plus an additional $40 million from industry. Up to 150 people will carry out basic and applied research in seven teams, focusing on materials and sensors for soldier protection (against bullets, directed energy, chemical/biological agents), performance enhancement, and body monitoring and injury intervention. One goal is to reduce the carrying weight of infantry-soldier equipment from 60 kg to 20 kg.

Another guiding vision is the development of a battle suit that dynamically provides protection, communication, mechanical enhancement and thermal management, compresses wounds and administers therapeutic drugs.

Broad national-security goals as guidelines for military R&D in the convergence of NT, biotechnology, information technology and cognitive science were expressed at the NBIC workshop (Asher et al., 2002; see also CIEMN, 2002). These goals include the development of miniature sensors, high-speed processing, wide-bandwidth communication, unmanned combat vehicles, improved virtual-reality training, enhancement of human performance (e.g. modified biochemistry to compensate for sleep deprivation) and applications of a brain–machine interface.

While the military part of the NBIC workshop was more cautious than the other sections with respect to far-reaching concepts of human-body manipulation etc., the US military is open towards such ideas. For example, in 2001 an army workshop mentioned 'artificial systems within the soldier' such as 'neuro-functional implants', 'biological input/output devices', and 'implanted miniature computers'[16]. Whereas some of these concepts would have beneficial medical uses (e.g. in paralysed patients), their general application in soldiers would raise important ethical problems, with consequences already for the research stage[17].

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[13] The DoD share of the NNI has grown from $70 million (of a total $270m) in FY 2000 to $243 million (of $774m) in FY 2003. Of the $201 million originally requested for FY 2003, $96 million were for basic research and $105m for applied research/advanced technology development (Roco, 2002a, 2003).

[14] see http://web.mit.edu/isn/

[15] Further information on the ISN is available at http://web.mit.edu/isn/index.html (24 November 2003).

[16] This was characterized as a 'high-risk, visionary' programme (ARO, 2001). The workshop 'Nano- technology for the Soldier' was part of the preparations for the founding of the Institute for Soldier Nanotechnologies.

[17] Note that the present Brain Machine Interface programme of the Defense Advanced Research Projects Agency (DARPA) intends to derive human–brain signals by non-invasive means (e.g. using multiple sensors on the scalp). However, magnetic particles in the brain are being discussed, and a university specializing in micro-electrode recording of animal brain activity is involved in the research (Wessberg et al., 2000; Nicolelis, 2001; Rudolph, 2001; Duke University, 2002; Nicolelis & Chapin, 2002; see also Hoag,2003).

Potential Military Uses of NT

A wide variety of military NT applications is conceivable as outcomes of R&D (not confined to the US guidelines mentioned above). In the following, several examples are given, excluding molecular NT (Altmann, forth- coming).

-Electronics and computers will become much smaller and at the same time much faster and less power-consuming through the use of NT. Such systems – augmented by new levels of artificial intelligence – will be used throughout the military, even embedded in very small components (rifles, glasses, uniforms, mini- and microrobots, munitions). On the other hand, large battle-management and strategy-planning systems will encompass many layers and a high degree of autonomous decision- making. Together with sensors, wireless communication components and small, lightweight displays, they would form an ubiquitous network not only on the battlefield, but also, for example, in logistics.
-NT allows smaller sensors – principally, down to sizes of micro-metres instead of centimetres[18] – but in many cases signal strength depends on the size of the receiving component, potentially limiting the downsizing of the overall system. A lower-size limit can also derive from the communication antenna or the power supply. Nevertheless, cheap mass production may allow distribution of tens of thousands of sensors in a particular area.
-Lighter, stronger and more heat-resistant materials will provide higher speed and agility for conventional ground, water and air vehicles, but may also allow new types of smaller vehicles, all with more efficient engines. Lighter energy-storage and conversion systems – such as fuel cells using nano-particle-based membranes or hydrogen tanks based on nano-tubes or fullerenes – could make all-electric military vehicles practical, including electromagnetic guns.
For small systems, contracting molecules or deforming materials offer the potential of muscle-like motion. Surfaces with locally variable colour – for example, through the use of mobile pigment particles – can be used for camouflage. Surfaces with tailored absorption properties for electromagnetic radiation can reduce radar and infrared signatures. Nano-structured material can result in stronger light armour, but it is unclear whether it could offer improvements over heavy armour. Nanofibre-based garments can provide better protection against projectiles.
-Soldier-worn systems could sense the state of health of the wearer and react by releasing drugs or, using smart materials, by compressing wounds. Energy for communication could begenerated by normal body movements.
-Employing advances in materials and explosives, conventional guns could shoot to larger ranges at reduced mass. With NT-based guidance systems, targeting accuracy could increase markedly. The same holds for missiles. With respect to penetrating projectiles, it is unclear whether NT-designed materials and structures will transcend the properties of tungsten or (depleted) uranium. Whether NT-based armour will prevail over NT penetrators or viceversa is an open question.
-With NT, the size of autonomous mini- and micro-robots could decrease, principally down to far below 0.1mm. These could move in all media: on the ground, in water and in air, using propulsion principles known from larger technical systems (wheel, track, propeller, wing, jet, rotor) or bio-mimetic ones (using legs, wriggling like a snake, hopping, using flap- ping wings, flagella, etc.). Mini-/micro-robots could be designed for a wide variety of purposes – such as reconnaissance, communication, target designation for larger weapons, actuation on a

[18] A sensor usually converts some property of the surroundings – such as temperature, patterns of light etc.

small scale – or as weapons. Speed and range would be limited, but mobility could be aided – for example, by wind – or they could be transported first by grenades, missiles, etc. Capabilities for sensing, communication and actuation would decrease with shrinking size. Such limitations, however, could be compensated for by close range or mass use. One possible scenario would involve entering into a target object or subject and approaching a central node; there the robot could eavesdrop, manipulate or destroy.
Another possibility would be acting in high numbers, choking air intakes, blocking windows, putting abrasives into mechanics, etc. Biological–technical hybrids, such as insects or small mammals con- trolled by nerve/brain electrodes, could fulfill similar purposes. Thus, they should be classed with mini-/micro-robots.
-For systems implanted into the human body, NT would provide improved possibilities over micro-systems technology (MST). One type of application would monitor the medical and stress status of a soldier, releasing therapeutic drugs, hormones, etc., as necessary. Another would have electrodes connected to sensory organs, sensory nerves, motor nerves or muscles – or to the respective brain-cortex areas. This could, for example, be used to decrease the reaction time for pilots. Communicating complex sensory impressions or thoughts, however, requires fundamental progress in brain research and a reduced barrier against human experiments.
-For military uses of outer space, NT (with MST) will provide many possibilities for markedly smaller satellites, together with smaller launch vehicles. Small satellites could be used in swarms for radar, communication or intelligence. Owing to the large effective antenna size of such a system, the target resolution would be high; however, the total antenna and solar-cell area would determine the strength of received or transmitted signals. Small satellites could damage or destroy other satellites – either by a direct hit with high relative velocity or through manipulations after rendezvous and docking. NT-enabled electromagnetic acceleration could also be used for kinetic-energy space weapons.
-For nuclear weapons, no qualitative change is expected. NT will allow smaller guidance or safety/arming/fusing systems. However these would not change basic weapon properties, mainly the requirement for a critical mass of uranium or plutonium for a fission explosion, leading to a total mass of at least 70 kg. An exception might be hypothetical pure- fusion weapons without a fission primary, where the fusion fuel would be ignited at a micro-spot using MST/NT. The yield could be arbitrarily low, and the size and mass correspondingly small, blurring the distinction with conventional weapons.

In one scenario, a minute amount of antimatter would be kept safely in a micro-trap until released onto lithium deuteride (Gsponer & Hurni, 2000: 130–134; Gsponer, 2002). Such possibilities are speculative at present, but should be followed up systematically.

-With respect to chemical and biological weapons, on the other hand, NT will provide qualitatively new options. One might be capsules that enclose active agents more safely, releasing them only when required. Together with improvements in genetics, NT may enable chemical/biological weapons (the difference becomes fuzzy here) that selectively react to certain gene patterns or proteins. Such weapons could be targeted at certain ethnic groups or even single individuals, or might act against animal breeds or plant varieties. NT could also be used for easier entry into the body or its cells. Mechanisms could be designed that limit or prevent damage to own forces, such as self-destruction after a defined period of time or reliable inoculation. The outcome of all this would be to make biological warfare much more manageable and effective. On the other hand, NT might permit more sensitive sensors for chemical or biological warfare agents.

NT materials with high active surface areas could be used to bind and neutralize agents, or they could be used in protective equipment and for decontamination of affected areas.

Most of these applications will need 10 or 20 years to mature. Not all need turn out to be feasible, effective, cost-efficient and sufficiently robust to counter- measures. Several will be developed in parallel or chiefly in the civilian realm, in particular where a mass market is foreseen. Here, military uses may be driven by civilian technology. On the other hand, the military will continue to lead in many high-risk areas, sometimes paving the way for later civilian uses.
Because of the wide variety of effects, various combat countermeasures that would make massive use of NT themselves are to be expected, of course at the respective technological level available. For countering NT- based weapons, armed forces could make increasing use of autonomous systems, protect own systems passively (encapsulation, molecular-size sieves) or defend actively (reactive surfaces against adhering objects, ‘guard’ micro-/nanorobots). The effectiveness of weapons vs. countermeasures is unclear at present. However, there are no indications of defence dominance, so counter-attack and preventive attack will likely play an important role in armed conflict.
Some military uses of NT would not create concern (e.g. soldier health systems); some would be so close to civilian developments that limitation will be excluded (e.g. improved computers); and some could even contribute positively to protection of civilians and disarmament (e.g. sensors for biological agents). However, a number of applications are likely to bring dangers, as will be discussed in the next section.
The special nature of molecular NT raises particular concerns. As noted, the feasibility of molecular NT is disputed. Should its development become realistic, possibly in a few decades, self-replicating molecular assemblers would at first produce their like, then potentially larger machinery on many size scales.

Finally, at the end of the production process, arbitrary goods could be made (see note 2 above). In such a scenario, fast, indeed exponential, growth in the production of armaments would be made possible, limited only by resources, energy or transport. Thus, by means of molecular NT a state could vastly enlarge its military production within a short time (Gubrud, 1997).

Whereas assemblers could produce weapons and carriers that are similar to traditional guns, tanks or aircraft, the technology would play to its full advantage in the building of new types of systems that make use of proper- ties characteristic of molecular NT, such as smallness, reliance on locally available resources, very high numbers, very high computing power, a wide variety of sensors and actuators, the ability to enter into objects and organisms, self-replication, etc. Explosion, kinetic-energy impact, electrical/chemical/biological interaction, information attack and other methods of causing damage would be used. Because the mobility of very small objects is limited and because important targets will continue to require consider- able energy release for destruction, macroscopic carriers and weapons would not vanish.

The nature of the mixture of macro-/micro-/nanosystems that would evolve from the complex interaction between measures and countermeasures cannot be assessed at present. Principally, one will have to expect damaging systems on all size scales, from specially designed poison molecules via nano-, micro- and mini-robots to large weapon systems. Potential ‘molecular hackers’ and terrorists would add to the complexity.

NT and Preventive Arms Control

When new military technologies are seen in the context of an interacting international system and enlightened national interest, they often increase threats and reduce stability. For preventing or at least reducing such risks, limitations can be agreed upon in advance, before new weapons or technology are deployed, acting mainly at the stages of development and/or testing, and sometimes at the research stage. Precedents for preventive arms control – a variant of qualitative arms control – exist explicitly or implicitly (for example, in the – now defunct – Anti-Ballistic Missile Treaty of 1972, the Biological and Chemical Weapons Conventions of 1972 and 1993, respectively, the nuclear testing treaties of 1963 and 1996, and the Protocol on Blinding Laser Weapons of 1995).

Ideally, preventive arms control consists of four steps:
(1) prospective scientific-technical analysis of the technology in question (properties of weapons, propagation, effect on targets);
(2) prospective analysis of military and operational aspects (probable use, targets, unusual employment forms, collateral effects);
(3) assessment under the criteria of preventive arms control; and
(4) devising possible limits and verification methods that do not impede positive uses and keep costs within reasonable limits.

Studies of the various potential military applications of NT have yet to be carried out. However, significant concerns arise when one considers the three areas of preventive arms-control criteria.

Dangers to Arms-Control Agreements and the International Law of Warfare

Existing arms-control agreements, such as the Biological Weapons Convention, might be undermined by new agents based on NT-enabled progress in biotechnology. (On the other hand, strengthening of the Biological and Chemical Weapons Conventions might be possible through new NT-based sensors or materials for neutralization.).
Also, limits on conventional forces could be circumvented by new weapons types not covered by treaties or outside treaty definitions – for example, by autonomous micro-robots or electromagnetic guns below the 75mm-calibre threshold for tanks under the Treaty on Conventional Armed Forces in Europe.

Moreover, the international law of warfare could be endangered – for example, through the introduction of autonomous fighting systems producing superfluous injury or not reliably recognizing non-combatants or combatants hors de combat.

Dangers to Stability: Attacker Advantage, Arms Races and Proliferation

Destabilization of the military situation between potential opponents is probable with the more efficient, distributed data-processing systems as well as omnipresent sensor nets and smaller weapons that NT will make possible. Pressures to act fast will increase with mini-/micro-robots; these could be sent into an opponent's territory already before hostilities begin, ready to strike on command, heightening uncertainty and nervousness. Other dangers could ensue from the need to delegate more decisions to autonomous systems because waiting for human pondering could lead to clear disadvantages. Unintended action–reaction cycles might evolve between opponents' systems of warning and attack.

Arms races have to be feared in all areas of military NT use. Even though the USA would probably remain in the lead, several potential opponents could follow up with only years of delay. In anticipation, the USA will work on countermeasures at an early stage. Others might react by increased reliance on asymmetric warfare, including attacks against infrastructure or using weapons of mass destruction.

With respect to horizontal proliferation, transfer of technologies, materials and knowledge is to be expected, as are direct exports of complete NT-based military systems.

The problem of proliferation will grow as systems similar to military ones begin to pervade civilian society; examples are micro-sensors and robots, wearable ultra-small personal computing devices, light vehicles, energy storage, implanted systems, etc. The smaller the system, the more difficult it will be to prevent covert exports.

Dangers to Humans, the Environment or Society

Dangers to humans or the environment could ensue from new NT materials, propellants, etc., as well as from exploration of new damage mechanisms for weapons.
However, these effects could largely be contained by civil society regulation, except in cases where military regulation is less strict.

Society could be detrimentally affected in a variety of indirect ways – for example, through diffusion of the technology. One such way might involve state agencies, enterprises, private persons or criminals (singly or organized) eavesdropping through the use of micro-sensors and robots. Another might involve the use of small autonomous systems for criminal attacks – and in particular terrorism – including attacks on critical infrastructures. A third possibility is implanted systems and other forms of body manipulation for 'improving human performance'. Deciding what kinds of body manipulation should be permitted, and under which circumstances is a problem of peacetime civilian life, and should be handled by civilian society.
However, military R&D and deployment of such systems could establish a fait accompli before society is able to carry out a thorough debate on the desirability of particular technological developments.

Preventive Arms-Control Criteria and Molecular NT

In a molecular NT scenario, all of the above problems would exist with much higher urgency (Gubrud, 1997). Military robots with sizes from nanometres to metres would bring threats on an unknown scale[19]. If they could kill, they could constitute new forms of weapons of mass destruction more potent than known biological warfare agents. With non-lethal effects, such as disruption of personality, mass attacks could lead indirectly to the breakdown of a society and the death of a large portion of its members.

[19] In principle, replicating nano-robots could also be released unintentionally, in the worst case consuming all organic material, fast converting the biosphere into 'grey goo'. Freitas (2000) has argued that this is fairly improbable. The Foresight Guidelines on Molecular Nanotechnology (Foresight Institute, 2000) contain the principle that artificial replicators must not be capable of replication in a natural, uncontrolled environment, and they discourage evolution within a self-replicating manufacturing system. Keeping such rules is obviously more difficult if unrestricted military R&D tries to find out what is possible.

Partly as a result of their smallness, but mainly owing to their potential for self-replication and the production of additional weapons on site, nano-robots would create extreme uncertainty. Pre-deployment against an opponent would be easier.

The pressure to act fast and to use automated decision making would grow. Unintended action–reaction cycles could work at all levels, from molecules to large-scale decision making. Motives for preventive attacks would exist for both technologically leading and technologically lagging powers.
Molecular NT would also create unknown arms-race levels as a result of attempts to maintain or increase a technological advantage, or to catch up. The urgency would be greatly increased if one assumes capabilities for fast-growing autonomous military production. In theory, the very first user could achieve a runaway advantage, with ensuing world dominance. This would create massive pressures to proceed as fast as possible if autonomous production draws close. Horizontal proliferation would be nearly unavoidable with small, self-replicating systems – in principle, a single copy would be sufficient for growth in another country or sub-state entity. However, reprogramming of targets etc. might be needed for unauthorized copies, and sophisticated security measures would need to be overcome. Molecular NT used for military purposes could also result in increased dangers to humans, the environment and society. Diffusion of systems and technology to criminals and terrorists could hardly be avoided, opening up new options for crime and manipulation. The consequences of accidental releases of nano-robots could be contained if reproduction capabilities were limited and autonomous evolution reliably prevented.

Conclusions and Recommendations

As discussed above, military NT applications have great potential for dangers and risks, even if molecular NT may remain unrealizable. Thus, there are good reasons to analyse the problems and to think about preventive limits at an early stage. Such studies have yet to be carried out, but already a few considerations suggest themselves.
Because of the fundamental nature of NT, because misuse could occur in both the military and the civilian realms, and because such misuse could come about via military as well as civilian systems, any limits on NT clearly need to encompass both realms simultaneously, even though the rules could differ between both. Thus, national regulations and international controls should be coordinated closely.

Likewise, verification of compliance would be required not only in military institutions, but also in civilian ones. In bio-NT, as well as in the case of specific limits on other micro-/nano-systems, verification would probably have to be at least as intensive as foreseen in the Draft Protocol on Verification negotiated for the Biological Weapons Convention. This protocol – with declarations, laboratory inspections by managed access, etc. – might form a good starting point. It is therefore unfortunate that the USA has stepped out of this important international process.
Parallel regulation in the civilian realm could follow the proposal of a bio-security convention (Tucker, 2003). With respect to other new weapons types having macroscopic sizes, access to test ranges together with notifications on military R&D may suffice.

The potential for mistrust is expected to be particularly high in areas where revolutionary changes are foreseen and the speed of those changes can change rapidly. Thus, transparency about national NT initiatives is of immense value and can significantly contribute to building confidence. Formally agreed confidence- and security-building measures about NT R&D might range from information exchanges on projects and budgets to direct cooperation, including exchanges of scientists and engineers. Such informal and formal measures should be striven for on many levels. However, it is doubtful whether they would suffice without legally binding agreement with stringent verification covering military NT R&D.

Many of the military NT applications could arrive 5 to 15 years from now. Some would mostly serve for defensive protection, including protection against terrorist attacks. Others will arrive inevitably because of parallel civilian developments. Seen from today, the most problematic areas in the medium-term future seem to be new chemical/biological weapons, miniature anti-satellite weapons, autonomous fighting vehicles of all sizes, small robots for various purposes and body implants.

Consequently, the following general recommendations might be given[20]:

Existing arms-control/disarmament treaties and humanitarian inter- national law should be upheld, and the Biological Weapons Convention strengthened.
A comprehensive ban on space weapons should be concluded, possibly with special rules for mini-/micro-satellites and carriers.
Autonomous ‘killer robots’ should be prohibited[21].

For small, mobile artificial systems (including biological–technical hybrid systems), specific restrictions should apply[22].

Body implants that are not directly medically motivated, including mobile micro-/nano-systems for movement/operations within the body, should be subject to a renewable moratorium of, say, ten years’ duration.

To support efforts in these directions in the short term, the technologically leading nations should exercise unilateral and coordinated restraint with respect to military NT activities, in particular de-emphasizing or avoiding those that could lead to offensive uses. NT R&D should be extensively published, in both the civilian and the military realms. In particular, states that are traditionally less open about their military R&D should increase their transparency to avoid creating unnecessary mistrust. The nanotechnology initiatives of various nations should work together to build confidence and to address concerns such as arms control and safety protocols. The various efforts at international outreach and cooperation carried out by the US NNI are to be commended here (Roco, 2001, 2002b).

Future research should study the foreseeable military applications in depth from the viewpoint of preventive arms control. Verification investigations should focus on the detection of small objects/activities by cooperative technical means deployed on site (an interesting area could be such means that are themselves based on NT).

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[20] In part based on my recommendations for MST (Altmann, 2001), expanding on Altmann & Gubrud (2002).
[21] Uninhabited military vehicles/robots with or without combat function need a differentiated analysis; for first considerations, see Altmann (2003). The least one should demand is no autonomous use of deadly force (keep a person in the loop at all times).
[22] One concept of such restrictions would be a ban below a certain size, for example, 0.2–0.5m, with narrowly circumscribed exceptions for important civilian purposes, as proposed for MST (Altmann, 2001).

A specific responsibility of technology assessment, not only in the military realm, is to look scientifically into molecular NT. For responsible decisions, it is indispensable to clarify whether self-replicating nano-robots, universal molecular assemblers, nano-robots that act within the body, etc. can be realised, and, if so, in which time-frame. The widespread impression that these concepts can be safely discarded as pure science fiction is not backed up by serious research, and the proponents' findings have not been decisively refuted. Measures to limit dangers from self-replicating artificial nano-systems would be needed as soon as the feasibility of such systems comes into sight[23].

As in other technology areas, it is probable that the USA will be without a serious technological challenge from a potential military opponent in military NT R&D. This implies that unilateral restraint by the USA would not lead to threats to the USA from NT in the hands of such opponents for quite some time. Theoretically, this could buy sufficient time to agree internationally on appropriate, reliably verifiable limits. This will require the technology leader to understand that restraint is in its own best interest. Such an understanding is not commonly found with the present US government or military. It could grow, however, when it becomes obvious that, through arms competition and proliferation, technologies and systems developed in the USA at high cost could in the future also be used against the USA, be that by terrorists, agents or military opponents[24], with negative consequences for the USA.

Previous examples (the Anti-Ballistic Missile Treaty 1972–2002, the Laser Blinding Weapons Protocol 1995) show that under certain conditions the USA can be receptive to such arguments of enlightened national interest. In the long run, one cannot dismiss the thought that containing the risks of new and powerful technologies such as genetic engineering, pervasive computer networks, micro-systems and nanotechnology may become difficult in a world in which security is built mainly on the threat of military force.

Reliably preventing misuse and adequately ensuring compliance may require far-reaching limits, intensive verification and an effective system for criminal prosecution of transgressors, similar to what has been developed and become accepted within civilian society – for example, in the fields of workplace security, the environment, accounting and law enforcement. Long-term security thus calls for strengthening of law and political institutions at the international level, including international criminal law, while reducing the dependence on national armed forces.

References/Bibliography

Adams, Thomas K., 2001. 'Future Warfare and the Decline of Human Decisionmaking', Parameters 31(4): 57–71; available at http://carlisle-www.army.mil/usawc/Parameters/01winter/adams.htm (16 January 2003).

Altmann, Jürgen, 2001. Military Applications of Microsystem Technologies: Dangers and Preventive Arms Control. Münster: Agenda.

[23] The Guidelines of the Foresight Institute (Foresight Institute, 2000) may serve as a starting point. In particular, their exclusion of agreements on the military sector should be amended.

[24] There should be little doubt that technologically capable countries such as China or Russia that (have to) see themselves as potential opponents of the USA would be able to follow, though with some years' delay and qualitative disadvantage. Nevertheless, with the potential for asymmetric action and exploitation of vulnerabilities, very disturbing threats to the USA would likely ensue.

Altmann, Jürgen, 2003. 'Roboter für den Krieg?' [Robots for War?], Wissenschaft & Frieden, 21(3): 18–22.
Altmann, Jürgen, forthcoming. 'Military Nanotechnology and Preventive Arms Control', in preparation.
Altmann, Jürgen & Mark A. Gubrud, 2002. 'Risks from Military Uses of Nanotechnology: The Need for Technology Assessment and Preventive Control', in Mihail C. Roco & Renzo Tomellini, eds, Nanotechnology: Revolutionary Opportunities and Societal Implica-tions. Luxembourg: European Communities; at http://www.ep3.ruhr-uni-bochum.de/bvp/riskmilnt_lecce.html (21 October 2003).
Army Research Office (ARO), 2001. 'Soldier Status Monitoring, Working Group Result', Workshop on Nanoscience for the Soldier, Army Research Office, 8–9 February; avail- able at http://www.aro.army.mil/phys/Nanoscience/sec4soldier.htm (16 January 2003).
Asher, Robert; Delores M. Etter, Tony Fainberg, Michael Goldblatt, Cliff Lau, James Murday, William M. Tolles & Gerold Yonas, 2002. 'Theme E Summary', in Roco & Bainbridge, 2002 (327–330).
Bonn International Center for Conversion (BICC), 2002. Conversion Survey 2002: Global Disarmament, Demilitarization and Demobilization. Baden-Baden: Nomos.
Brown, John S. & Paul Duguid, 2001. 'Don't Count Society Out: A Response to Bill Joy', in Roco & Bainbridge, 2001 (37–45).
Center for Responsible Nanotechnology (CRN), 2003. 'CRN Research: Current Results – Dangers of Molecular Nanotechnology'; available at http://www.crnano.org/ dangers.html (25 April 2003).
Committee on Implications of Emerging Micro- and Nanotechnologies (CIEMN), 2002. Implications of Emerging Micro- and Nanotechnologies. Washington, DC: National Academies Press.
Crow, Michael M. & Daniel Sarewitz, 2001. 'Nanotechnology and Societal Transformation', in Roco & Bainbridge, 2001 (55–67).
DefenseLink, 2001. 'Nanotechnology Research Rewards Announced'; available at http:// www.defenselink.mil/news/Feb2001/b02232001_bt079-01.html (16 January 2003).
Drexler, K. Eric, 1986. Engines of Creation: The Coming Era of Nanotechnology. New York:Anchor.
Drexler, K. Eric; David Forrest, Robert A. Freitas Jr., J. Storrs Hall, Neil Jacobstein, Tom McKendree, Ralph Merkle & Christine Peterson, 2001a. 'On Physics, Fundamentals, and Nanorobots: A Rebuttal to Smalley's Assertion that Self-Replicating Mechanical Nanorobots Are Simply Not Possible', Foresight Update no. 46: 6–7; available at http:// www.imm.org/SciAmDebate2/smalley.html (15 September 2003).
Drexler, K. Eric, David Forrest, Robert A. Freitas Jr., J. Storrs Hall, Neil Jacobstein, Tom McKendree, Ralph Merkle & Christine Peterson, 2001b. 'Many Future Nanomachines: A Rebuttal to Whiteside's Assertion That Mechanical Molecular Assemblers Are Not Workable and Not A Concern', Foresight Update no. 46: 8–17; available at http:// www.imm.org/SciAmDebate2/whitesides.html (15 September 2003).
Duke University, 2002. 'DARPA to Support Development of Human Brain–Machine, Interfaces' (15 August); available at http://www.pratt.duke.edu/News/Stories/57.html (16 January 2003).
ESANT, 1999. 'Economic and Social Aspects of Nanotechnology', first draft report of Working Group 6 of the Euroconferences on Nanoscience for Nanotechnology; avail- able at http://www.nano.org.uk/ESANT99.htm (16 January 2003).
Foresight Institute, 2000. 'Foresight Guidelines on Molecular Nanotechnology – Revised Draft Version 3.7: June 4, 2000'; available at http://www.foresight.org/guidelines/ current.html (16 January 2003).

Freitas, Robert, 2000. 'Some Limits to Global Ecophagy by Biovorous Nanoreplicators, with Public Policy Recommendations'; available at http://www.foresight.org/NanoRev/Ecophagy.html (16 January 2003).
Gsponer, André, 2002. 'From the Lab to the Battlefield? Nanotechnology and Fourth-Generation Nuclear Weapons', Disarmament Diplomacy 67; available at http://www.acronym.org.uk/dd/dd67/67op1.htm (16 January 2003).
Gsponer, André & Jean-Pierre Hurni, 2000. The Physical Principles of Thermonuclear Explosives, Inertial Confinement Fusion, and the Quest for Fourth Generation Nuclear Weapons, INESAP Technical Report no. 1, 7th edn. Darmstadt: IANUS, Darmstadt University of Technology.
Gubrud, Mark A., 1997. 'Nanotechnology and International Security', paper presented at the Fifth Foresight Conference on Molecular Nanotechnology; available at http://www.foresight.org/Conferences/MNT05/Papers/Gubrud/index.html (16 January 2003).
Hoag, Hannah, 2003. 'Remote Control', Nature 423(6942): 796–798.
Howard, Sean, 2002. 'Nanotechnology and Mass Destruction: The Need for an Inner Space Treaty', Disarmament Diplomacy 65; available at http://www.acronym.org.uk/dd/dd65/65op1.htm (16 January 2003).
Joy, William, 2000. 'Why the Future Doesn't Need Us: Our Most Powerful 21st-Century Technologies – Robotics, Genetic Engineering, and Nanotech – Are Threatening To Make Humans an Endangered Species', Wired 8(04); available at http://www.wired.com/wired/archive/8.04/joy_pr.html (16 January 2003).
Merkle, Ralph C., 2000. 'Molecular Building Blocks and Development Strategies for Molecular Nanotechnology', Nanotechnology 11(2): 89–99.
Metz, Steven, 2000. 'The Next Twist of the RMA', Parameters 30(3): 40–53; available at http://carlisle-www.army.mil/usawc/parameters/00autumn/metz.htm (4 February 2003).
Meyer, Martin, 2001. 'Socio-Economic Research on Nanoscale Science and Technology: A European Overview and Illustration', in Roco & Bainbridge, 2001 (278–311).
MIT News, 2002. 'Army Selects MIT for $50 Million Institute To Use Nanomaterials To Clothe, Equip Soldiers' (13–14 March), news release; available at http://web.mit.edu/newsoffice/nr/2002/isn.html (16 January 2003).
Mnyusiwalla, Anisa; Abdallah S. Daar & Peter A. Singer, 2003. '"Mind the Gap": Science and Ethics in Nanotechnology', Nanotechnology 14(3): R9–R13.
Murday, James S., 1999, 'Science and Technology of Nanostructures in the Department of Defense', Journal of Nanoparticle Research 1(4): 501–505.
Nicolelis, Miguel A. L., 2001. 'Actions from Thoughts', Nature 409(6818): 403–407.
Nicolelis, Miguel A. L. & John K. Chapin, 2002. 'Controlling Robots with the Mind', Scientific American 287(4): 24–31.
Petersen, John L. & Dennis M. Egan, 2002. 'Small Security: Nanotechnology and Future Defense', Defense Horizons 8; available at http://www.ndu.edu/inss/DefHor/DH8/ DH08.pdf (13 December 2002).
Roco, Mihail C., 2001. 'International Strategy for Nanotechnology Research and Development', Journal of Nanoparticle Research 3(5–6): 353–360.
Roco, Mihail C., 2002a. 'National Nanotechnology Investment in the FY 2003 Budget Request by the President'; at http://nano.gov/2003budget.html (16 January 2003).
Roco, Mihail C., 2002b. 'National Nanotechnology Initiative and a Global Perspective', presentation at the 'Small Wonders' Conference, Washington, DC, 19 March; available at http://www.nsf.gov/home/crssprgm/nano/smwonder_slide.pdf (16 January 2003).
Roco, Mihail C., 2003. 'Government Nanotechnology Funding: An International Outlook'; at http://www.nsf.gov/home/crssprgm/nano/intpersp_roco_june30.htm (21 October 2003).

Roco, Mihail C. & William S. Bainbridge, eds., 2001. Societal Implications of Nanoscience and Nanotechnology. Boston, MA: Kluwer; available at http://www.wtec.org/loyola/nano/societalimpact/nanosi.pdf (2 July 2003).

Roco, Mihail C. & William S. Bainbridge, eds., 2002. Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science, report sponsored by NSF/DOC, Arlington, VA; at http://wtec.org/ConvergingTechnologies/Report/NBIC_report.pdf (21 November 2003).

Roco, Mihail C. & Renzo Tomellini, eds, 2002. Nanotechnology: Revolutionary Opportunities and Societal Implications. Luxembourg: European Communities.

Rudolph, Alan, 2001. 'The Brain–Machine Interface'; (16 January 2003).http://www.darpa.mil/dso/thrust/sp/presentations/BioMagnetics_Rudolph.pdf

Smalley, Richard E., 2001. 'Of Chemistry, Love and Nanobots', Scientific American 285(3):76–77.

Smith, Richard H., 2001. 'Social, Ethical, and Legal Implications of Nanotechnology', in Roco & Bainbridge, 2001 (257–271).

Talbot, David, 2002. 'Supersoldiers', Technology Review (October): 44–51.

Tolles, William M., 2001. 'National Security Aspects of Nanotechnology', in Roco & Bainbridge, 2001 (218–237).

Tucker, Jonathan B., 2003. 'Preventing the Misuse of Pathogens: The Need for Global Biosecurity Standards', Arms Control Today 33(5): 3–10.

UK Ministry of Defence, 2001. 'The Future Strategic Context for Defence: A Lesson from History'; at http://www.mod.uk/issues/strategic_context/index.htm (16 January 2003).

Wessberg, Johan; Christopher R. Stambaugh, Jerald D. Kralik, Pamela D. Beck, Mark Laubach, John K. Chapin, Jung Kim, S. James Biggs, Mandayam A. Srinivasan & Miguel A. L. Nicolelis, 2000. 'Real-Time Prediction of Hand Trajectory by Ensembles of Cortical Neurons in Primates', Nature 408(6810): 361–365.

Whitesides, George M., 2001. 'The Once & Future Nanomachine', Scientific American 285(3): 78–83.

Yonas, Gerold & S. Tom Picraux, 2001. 'National Needs Drivers for Nanotechnology', in Roco & Bainbridge, 2001 (46–55).

Nanotechnology: opportunity or threat?

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See also :
Opportunities and threats from nanotechnology

The Lord Sainsbury of Turville, Minister for Science and Innovation, Department of Trade and Industry

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What are Nanosciences and Nanotechnologies, D. Andler

Executive Summary

Although it is now generally admitted that the new technological wave will take advantage of the convergence of four disciplines, Nano, Bio, Info and Cogno; it is also clear that nano-sciences and nano-technologies have probably a prominent role in the development of this convergence. In April 2004, both French Academies of Science and of Technology have jointly published a book entitled “Nanosciences, Nanotechnologies”. This report outlines the opportunities brought by nanotechnologies in chemistry, physics and technologies.

We have taken the opportunity of this document to focus on the nanoworld’s specificities in order to try to get a precise idea of the changes that working at this dimension will bring to science and society. However, unlike the choice made in this report which classified applications by discipline, such as chemistry, physics and technologies, we will consider those changes by field of applications. This choice appears relevant in regards of the prerequisite that represents the collaboration of sciences such as chemistry, physics and biology to reach any real technological achievement at a nanoscale level.

Actually, as we will see in this summary, nanosciences require the expertise of many fields of research, each of them relevant for different knowledge and know-how.

Thus, after a description of the nanoworld’s main theoretical breakthrough, we will focus on the applications in the fields of:

Medical applications
Information technologies
Energy production and storage
Material science
Food, water and environmental
Security

In each case, for the more striking breakthrough, we’ll try to describe more precisely the in an out of the nanosciences in the achievement.

Nanosciences in a nutshell.

The prefix “nano” signifies 10-9, i.e. one billionth (= 0.000000001).
One nanometre (nm) is one billionth of a metre.
The average size of an atom is 10-10 metre. (1 Angström)
So basically, the nano world is composed of molecules that gather between 10 and 100 atoms.

The challenge of working at this specific scale is to control the different interactions and properties of each atom or molecule simultaneously with the ability of assembling them in a structured pattern.

The scientist working at a nano scale is at the crossroad of the supra-micro world and the macro world. This is at this very scale that the carbon will either turn into diamond or wood or any other carbonic composite.

Usually part of those interactions can be neglected when working on a smaller scale or on a bigger one.
But at a nanoscale level all are to be taken into account.

On the other hand, a lot of properties are to be controlled and taken advantage of when working at such a scale.

The scientists and the engineers have to find their ways through an important amount of constraints and opportunities.

The interactions are:

Electrostatic interactions. Each neutral atom has a certain ionization potentials and electron affinities. The building of the molecule partially depends on this ionization potential and the possibility atoms have to combine their electrons. In the building of molecules, those interactions are to be taken into account. Once the molecule created, the distribution of those electrons stands for the polarity of the molecule. This polarity generates interactions between molecules and groups of molecules. They are called “Van de Waals interactions”. The electrostatics interactions are also to be considered at a macro level during the building of patterns of molecules or atoms.

“Van der Waals” interactions. Those interactions are intermolecular attractions due to the polarity of molecules. This polarity depends a lot on the geometrical aspect of the molecule. The control of the geometrical aspect of the same chemical formula atoms can influence the way the molecule will behave in regards of others. The nanosciences will enable some arrangements that weren’t possible without this control.

Depletion interactions. Those interactions are to be considered at a microscale level, based on thermodynamic models. They exist between amounts of molecules and are due to geometrical attractions of different patterns.

Hydration interactions. The patterns of molecules can behave following to hydrodynamic rules and interactions when they are generated in a fluid environment.

Magnetic interactions. The magnetic interactions are to be considered on an atomic level as well as on an electronic scale, with the interactions of spin that plays an important role in the storage of information and quantic electronic design.

The Strong and Weak nuclear forces that are to be considered for the study of the constitution of an atom can be left on the side when working in the nanoworld.

The control of the properties of the atoms at the nanoscale level allows the building of molecules and groups of molecules with very specific and refined properties at a macro level.

The important number of parameters that can be controlled at the same time allows the synthesis of complex molecules and materials with innovative mixture of properties. Those properties are to be chosen between:

Chemical functionalities: the ability of the atoms or molecule to react with each others in order to generate a new component can be combined with some new properties that weren't linked to the chemical aspect. For instance, it is possible to imagine the combination of some antigens or specific catalysers with certain kind of oxides activated by light. The activation of the chemical power of the antigens or catalysers could then be switched on and off by the power of light.

Optical characteristics: This concerns all the properties of the atom or the molecule in regards of light. The light can either activate some properties of the component or the component can generate lights in response to some specific kind of activation. The item can also behave as a "filter" with different response depending on the frequency or orientation of light.
The miniaturization of optical devices would find a direct application in the improvement of screen resolution. The molecular photonic would take advantage of the possibility to create molecules with electrical conduction activated by light (photo-activated). It opens the way to the building of optical circuit of very small size. Nanotechnologies in Photonics highlight recent development in design, fabrication, and characterization of nanostructures as applied to photonic applications including optical data storage, lasers, LEDs (Light-Emitting Diodes), modulators, amplifiers, detectors, and beam forming and control.

Magnetic properties: in this area, the key point is the control of the magnetism of one molecule. It would allow: the storage of information on one molecule and thus a very high storage density; magnetic molecule could also be controlled and manipulated using a magnetic guidance. The writing of the information on the molecule could be performed by light activation if the molecules created have specific optical properties.

Electrical characteristics: some molecule with specific shapes and electrical properties could be used as connections within electronic circuits. Those "uni-molecular wire" could then be gathered with molecules behaving like transistors or other electronic components.
Quantic properties: the molecular electronic circuit could take advantage of the quantic properties of molecules with important values of spins. Today all the calculations performed by computers are based on a large amount of connections being either switch on or off. With the use of the spins, the computation would deal with states not on or off, but being on and off with a certain probability for each event.

Geometrical characteristics: the geometry of a molecule is important for the way it behaves with all the other molecules that will compose its environment. The creation of specific patterns, the linking of different molecules with limited constraints and maximum compatibility, the mechanical properties of the nano, micro or macro objects built with the molecule and the emphasis of other properties are always bound to the shape of the molecules involved.

Commonly discussed nanostructures are buckyballs and carbon nanotubes. Each of these structures is a precisely constructed array of carbon atoms that exhibit a series of unexpected and potentially valuable characteristics such as strength, reactivity, and electrical characteristics. Single-wall carbon nanotubes (SWNTs), also known as buckytubes, are the ultimate engineering polymer, 100 times the strength of steel and less than one-sixth the weight. This cylindrical polymer of pure carbon, said to be the strongest, toughest, stiffest material known, conducts electricity like metals and conducts heat better than diamonds. The control of the shape of the nanocomponents also offers the possibility for guest encapsulation, the improvement of biological compatibility, the control of solubility

To conceive and build nano objects, two main routes are usually considered:

Top down: start from micro-systems and try to miniaturise them with conservation of their properties.
Bottom up: start at atomic and molecular level and synthesize the macro objects from it.

The bottom-up approach allows the synthesis of objects or materials with very specific qualities and behaviours, forecast and created by the scientist and the engineer at a nanoscale level.

The bottom-up approach is in an early development phase but its potential impact is far reaching with a disruptive potential for current production routes.

Far more than just the opening of a new range of miniaturization, the nanotechnologies open the way to the building of complex, specific, animated and even "intelligent" materials or objects in many fields of applications.

The applications

1) Medical applications

By controlling the properties of a synthesised material at the nanoscale level, it is possible to improve their bioactivity and biocompatibility.

It opens the way to two main fields of application:

Intelligent and biocompatible objects :

Miniaturised diagnostics that could be implanted for early diagnostic of illness. Here the nano-object has to be able to register memorized and communicate some specific datas (temperature, sun exposition, concentration of any substance…). The storage of the information can be magnetic, optical, geometrical (the shape of the molecule and its properties can be altered by the event measured). ADN chips could also be used.

Targeted drug deliveries. Recently nanoparticles could be channelled into tumour cells in order to treat them through heating.

Nanometrics pumps, valves, levers controlled by sensors activated by different kind of stimuli (chemical product, electricity, light, magnetic field…)

Tissue engineering and bio mimetic materials :

Improve the compatibility of implant

Long-term potential of synthesising organ replacement.

2) Information technologies

The nano objects open the way to data storage with very high recording densities.

But they also bring innovations in the way the storage or the computing could be conceived:

The storage on flexible plastic and resistant display would become possible, while today the information is stored on silicium at a scale that doesn't allow any mechanical flexibility.
The use of the quantic properties of the nano world could open up spintronics and quantum computing. The binary system used today could be replaced by a quantic formalism.

In this quest for the high density of data storage, the bottom-up (molecular electronic) and top-down (miniaturization) approach both require very specific tools able to deal with one atom or molecule at a time.

Different kinds of microscope are being used such as the STM (Scanning Tunnelling Microscope) which reaches a resolution of one Angström (0.1 nm).

The development of the technologies of visualisation and manipulation of the nano objects are tightly linked to the possible improvement of the nanotechnologies and sciences.

3) Energy production and storage

The impact of the nanotechnologies in this field can be direct or indirect, as new storage solution, or as regulator for the use of existent sources of energies.

Direct :

-Novel fuel cells. The synthesis of nano catalyser could enable the transformation of selected gas to usable fuel.
-Nanosized lithiated titania charge and discharge at rates that are orders of magnitude higher than more conventional material. This ability to deliver energy at such high rates and to recharge in such a short time offers a new and revolutionary tool to battery manufacturers seeking solutions to battery requirements for solar cars, fuel cell drives, hybrid vehicles, and other growing markets for portable power.
-Low-cost photovoltaic solar cells (e.g solar "paint"). The storage and restitution of light power is enabled at a molecular scale, and thus allow the fabrication of paintings that can directly be used on any materials. Today the photovoltaic cells are composed of different layers and thus are to be used between two pieces of glass.
-Electrode materials supporting catalysts in fuel cells: Much of the technology that automobile companies are now using in fuel cell cars involve getting the hydrogen from another source, namely methanol or gasoline, but research is being done so that elemental hydrogen may be stored by itself. Work is also being done to combat the hydrogen storage problem indirectly with the usage of acidic electrolytes to increase the temperature at which the cells run at, thus increasing the productivity of the hydrogen stored. This would mean that less would have to be stored. The methods of direct storage that appear to be the most promising are those of glass microspheres, carbon nanotubes, and graphite nanofibers.

Carbone nanotube : one way carbon can arrange itself is in a sheet pattern like a honeycomb. This is the graphite form of carbon. The sheets are not bound tightly together, but if they are wrapped on top of each other, a very strong carbon nanotube is formed.
Graphite nanofibers : The graphite nanofibers work by using fuel cells combined with hydrogen and oxygen to produce an electric current. The graphite nanofibers are packed closely together. They consist of stacks of graphite platelets and vary from 5 to 100 millimeters in length and from 5 to 100 nanometers in diameter. As a result, 6.2 liters of hydrogen per gram of graphite can be achieved by covering the surface of the graphite crystal in a single layer of hydrogen molecules. Graphite nanofibers can store up to three times their own weight in hydrogen under pressure at room temperature. Hydrogen-powered cars with graphite nanofibers could travel up to 8000 kilometres on a single tank.
-Indirect :
Improved insulation with specific materials (cf. materials science)
Efficient lighting using material with a high level of luminescent response to electrical excitation.

4) Material science

Nanoparticles are already used for reinforcing materials or functionalising cosmetics. Surfaces can be modified using nanostructures to be, for example, scratch-proof, unwettable, clean or sterile.

5) Food, water and environmental

Tools to detect and neutralise the presence of micro organisms or pesticides. The DNA chip represents a real technological gap. This tool requires molecular biology, micro electronic, chemistry, picture analysis and bio computer science. The idea is to recognize targeted cells or organisms based on their DNA sequence. The chip is composed of a small support on which are set tens of thousands DNA sounding system. Those sounding system are able to recognize DNA pattern that are complementary to theirs. The analysis of the chip with laser beam allows the tracing of the hybrids thanks to signal sent by fluorescent molecules. The numeric treatment of this “picture” gives the identity of the organic components.

The origin of imported foods could be traced via novel miniaturised nano-labelling.

The development of nanotechnology based remediation methods (e.g. photo-catalytic techniques) can repair and clean–up environmental damage and pollution (e.g. oil in water or soil).

6) Security

Novel detection systems with a high specificity that provide early warning against biological or chemical agents, ultimately down to the level of single molecules.

Improved protection of property, such as banknotes, could be achieved by nano-tagging.

The development of new cryptographic techniques for data communication is also underway.

Conclusion:

Nanoscience and nanotechnologies offer the possibility to combine mineral and organic components in order to create complex, innovative and specific material.
Bottom-up synthesis stands very close from the creation of biological objects.
Thousands of projects can be considered as “nano projects” with only a far fetched link to the nano world.
Nanosciences carry a lot of hopes but the gold rush has to be controlled.

Nanotechnology & Regulation: Toxic Substance Control Act (TSCA)

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Introduction

A recent Scientific American article on nanotechnology contains the following observation: "If Einstein were a graduate student today probing for a career path, a doctoral adviser would enjoin him to think small: "Nanotech, Albert, nanotech." would be the message conveyed"[25]. Nanotechnology seems to be the next big thing, though a couple of years ago, few people had heard of nanotechnology, and even fewer had contemplated its possible economic and societal impacts.

The Los Alamos National Laboratory described nanotechnology as "the creation of functional materials devices and systems, through control of matter on the nanometer (1 to 100nm) length scale and the exploitation of real properties and phenomena developed at that scale." [26]For reference, a nanometer is about ten times the diameter of an atom, or ten thousand times smaller than the diameter of human hair. There are several reasons for the importance of nano-scale technology and the euphoria of the growing nanotech fan-club. The manipulation of matter on the nano-scale tends to change the properties of chemicals, but not the chemical composition itself. The organization of matter at the nano-scale is key to biological systems, and applications of nanotechnology include medicinal delivery systems.
Nano-scale components have high surface areas that aid a variety of physics-based phenomena. In comparison to macro-scale components, the nano-scale provides for harder, less brittle nano materials. Even optoelectronics has reasons for supporting nanotechnology, because the wavelength scales begin to converge with the size of nano-scale components.
These reasons and many others have scientists and engineers excited about the future for nanotechnology. Examples of nanotechnology applications include commonplace processes like photography, catalysis, and electron tunneling microscopes; however, new nanotechnology applications range from computer hard drives to carbon nanotubes used for handles and frames of tennis rackets or fibers in men's slacks[27].

Along with the promise of nanotechnology, a number of cautionary tales have emerged that deal with thetechnology itself (and potential for self-replication) and the shortcomings of our society and institutionsto place proper controls on technological evolution. Those distrustful of the technology have advocated a cautioned approach to its development and deployment. But what exactly does that mean? An outright ban on technological advance is both unrealistic and counterproductive but valid concerns have been raised about our lack of knowledge of the environmental consequences of nanotechnology and, in general, about our inability to anticipate unintended consequences and spill-over effects associated with rapid

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[25] Gary Stix, "Little Big Science," Scientific American, September 2001, 32
[26] 2Los Alamos National Laboratory, "What is Nanotechnology?" Nanotechnology at Los Alamos NationalLaboratory, 25 June 2002, < http://www.lanl.gov/mst/nano/definition.html> (8 August 2003).
[27] Los Alamos National Laboratory.

technological change. With real nanotech products already in the marketplace, and a deluge to follow, an urgent set of issues revolve around the adequacy of our existing regulatory system to providethe necessary safeguards and early warnings.
We began this paper with a very simple thought exercise, “How would an existing regulatory framework, the Toxic Substances Control Act (TSCA), administered by the Environmental Protection Agency, apply to nanotechnology?” Also, given the fact that nano-based materials such as carbon nanotubes are already being produced and commercially marketed, we were interested in whether TSCA had been applied to these substances and, if so, to what effect, and, if not, why? The paper relies on past research on nanotechnology and environmental regulation and draws conclusion based on synthesizing this information.

Our overarching conclusions are fourfold:° The very nature of nanotechnology – its ability to alter the fundamental properties of substances – is likely to challenge the existing regulatory structure and cause confusion both on the side of industry and the government concerning the role of regulation.° To date, very few people or organizations have addressed the adequacy of our current regulatory system to protect human health and the environment or thought about possible alternatives to existing regulatory regimes (beyond extreme positions such as complete bans on nanotechnology).° A lack of adequate and conclusive research on the health risks of nano-based substances makes the need for a dialogue on regulatory adequacy, inadequacy, or possible alternatives more urgent.° A wrong or ill-conceived approach to regulation could have enormous economic consequences given the revolutionary nature and potential of nanotechnology.

We begin the paper with an overview of the Toxic Substance Control Act, discuss existing research on the health effects of nanotechnology, examine current recommendations concerning regulation, dive into TSCA in more depth, and provide some tentative observations and conclusions.

The Origins of the Toxic Substances Control Act Congress passed the Toxic Substances Control Act in 1976 to fill in the gaps of existing chemical substance regulation. The impetus for passing TSCA came from public concern that had grown from recent incidents involving chemical exposures. These included Kepone contamination in the James River and the news of polychlorinated biphenyls’ (PCBs) potential harmful effect to the environment. The act gave the EPA Administrator the power to regulate chemicals.

The TSCA Chemical Substance Inventory is the list of chemical substances existing in U.S. commerce and it can be accessed at http://msds.pdc.cornell.edu/tscasrch.asp. The review of new chemicals occurs under the pre-manufacture notice (PMN) process. The testing of existing chemicals is provided for by test rules outlined by the EPA to industry. The direct regulation of chemicals means that the EPA has the power to prohibit or limit the manufacture of particular chemicals based on risk assessments. Under TSCA, manufacturers must keep records of potential adverse effects of chemicals, and they must report these to the EPA in the required timeframe, especially during the research and development phase.
The import/export requirements are under the authorization of the Treasury Department as well as TSCA. With all these methods of regulation, the definitions within TSCA are important to understanding its requirements for industry and potential effects. Section 3 of TSCA points out key definitions. The most important definition is that of a chemical substance. It is defined as “any organic or inorganic substance of a particular molecular identity, including any combination of such substance occurring in whole or in part as a result of a chemical reaction or occurring in nature and any element or un-combined radical.”

This definition excludes mixtures, articles, pesticides, tobacco products, nuclear material, food, cosmetics, and drugs. Most of the exclusions are regulated by other agencies of the federal government. A new chemical substance is “any chemical substance which is not included in the chemicals substance list compiled and published under section 2607(b) of this title [TSCA Chemical Substance Inventory].”

Thisdefinition has implications for the international commerce of such chemicals.

It is important to keep in mind that foreign companies that produce their chemicals within the U.S. are nonetheless subject to TSCA regulation. These definitions are important to understand for the in-depth discussion of TSCA’ simplifications on nano-technology. The Chemical Abstracts Service (CAS), which is a division of the American Chemical Society, develops chemical nomenclature and keeps an important database that is crucial to the EPA. This database has significant implications for the emerging nanotechnology industry. The CAS inventories approximately thirty million chemicals that are spotted in technical literature around the world. A majority of these chemicals are not in commercial use, but exist only in labs at universities and research and development divisions of companies. Each chemical is allotted a registry number, or CASRN, plus a corresponding unique chemical name. The relationship between the CAS and TSCA is critical for nano-materials, as will be discussed later.

The issue of whether nanotechnology poses significant environmental and health risks remains a large and looming question requiring the focus of government and industry. Exactly what type of data could be put on the table to satisfy EPA, or larger public, concerns about the potential risks posed by nano-based substances? We will review some of the existing research findings in the nextsection. Does Nanotechnology Pose Health Risks?

There has not been a great deal of research done on the subject of nanotechnology and health risks. The significant research that has been done is reviewed here. Five studies cover the inhalation and dermatological risks associated with carbon nano-tubes and ultra-fine particles. Three of these studies were presented at a recent conference of the American Chemical Society (ACS).

The first series of studies that are reviewed have to do with the toxicity of ultra-fine particles. Dr. Gunter Oberdöster at the University of Rochester has studied the effects of ultra-fine particles (<0.1micrometers in diameter). Nano-scale particles fall clearly into this realm, so the question arises as to whether research on UFP’s may be relevant to understanding the behaviour and toxicity of nano-particles. Oberdöster’s research used ultra-fine carbon particles and found greater lung penetration than with larger particles. His recent paper raised the possibility of ultra-fine particles crossing the blood-brain barrier and impacting the central nervous system. Oberdöster stated, “With the emergence of so many unanswered questions, the health consequences of inhalation of UFP [ultra-fine particles] remain an important area ofinvestigation.” Of those questions, the two most important were the impact of inhalation of ultra-fine particles on the central nervous system and the daily exposure to such particles.

The rest of the studies reviewed here examine carbon nano-tubes specifically. Dr. Chiu-Wing Lam at Wyle Labs of the NASA Johnson Space Center and Robert Hunter at the University of Texas (Houston) studied the impact of carbon nano-tubes on lung tissue by instilling a suspension of nano-tubes directly into the lungs of mice. They found that the nanotubes clumpedtogether into bundles and stimulated an immune response, which left scar tissue in the lungs.

Hunter’s message was that “People should really take precautions. Nanotubes can be highly toxic.” Dr. David Warheit at Dupont’s Haskell Labs performed a slightly different experiment. He instilled single-walled carbon nanotube soot mixture into the trachea of rats. For comparative purposes, he also instilled a group with carbonyl iron and quartz, respectively. Fifteen percent of the rats treated with carbon nanotubes suffocated to death within twenty-four hours due to clumping of the nanotubes that obstructed the bronchial passageways. Granulomas and legions formed as a reaction to the foreign substance. The quartz-instilled and carbonyl iron-instilled rats had some toxicity and no toxicity, respectively. The main conclusion was that carbon nano-tubes might be irrespirable.
All three of these researchers recommended inhalation studies as the next step, since these studies involved instillation, not inhalation, into the lungs of animals. A year and a half ago at the University of Warsaw, two studies released at the same time studied the dermatological and inhalation effects of carbon nano-tubes. In the study on dermatological effects, which used rabbits, the researchers “did not [find] any signs of health hazards related to skin irritation and allergic risks.” The study recommended no special precautions with respect to carbon nano-tubes in theworking environment; in fact, the article was titled “Carbon Nano-tubes: Experimental Evidence@

Today, there is no real regulatory policy formulated to deal with nanotechnology. No stakeholder in this arena has taken the initiative to change the status, although some experts believe it is an issue in the immediate future. Null Risk of Skin Irritation and Allergy”. In the next study, “Physiological Testing of Carbon Nano-tubes: Are They Asbestos-Like?” the researchers found that carbon nano-tubes do not exhibit effects similar to asbestos. “Thus working with soot containing CNTs [carbon nano-tubes] is unlikely to be associated with any health risks.”

Two or three papers have explored regulatory opinions, and they are summarized below. The papers reviewed are:• “Regulating Nanotechnology Development” by David Forrest (1989)• “Environmental Regulation of Nanotechnology: Some Preliminary Observations” by Glenn Harlan Reynolds (2001)• “Forward to the Future: Nanotechnology and Regulatory Policy” by Glenn Harlan Reynolds(2002).

The Foresight Institute, a California-based non profit educational organization formed to help prepare society for anticipated advanced technologies, sponsored all three of these papers in some way. At the time of Forrest’s paper, nanotechnology was still in its infancy. The significance of this paper is its brief, subtle mention of TSCA. Forrest states: “Slightly modifying the language of the Toxic Substances Control Act (TSCA) provides a reasonable starting point... Again, using TSCA as a model, anyone wishing to manufacture a new chemical must give prior notice to the EPA for review under the pre-manufacturing notice requirement. In the face of civil and criminal penalties (as in TSCA) most firms and researchers would comply with the notificationrequirements.”

Forrest advocates modest civilian regulation of nanotechnology during its early stage development and envisions a standards-enforcement approach for the field of nanotechnology as it becomes more mature. The major takeaway is his mention of TSCA as a model of future regulation and the advocacy of regulation at some level. In Environmental Law Reporter, Reynolds presents a primer for the upcoming technology and regulation. Nanotechnology is introduced as a promising technology but with potentially dangerous spill-over effects. Reynolds makes three conclusions. The first is that a ban on nanotechnology is impossible and harmful. Environmental groups like The ETC Group have advocated this sort of action.

The second conclusion is that strict government regulation is probably not completely possible, though it may be desirable from a public good standpoint. The third conclusion, and a critical one, is that nanotechnology regulation is a process, not an event. A rush to legislate could be disastrous for a young and rapidly growing industry. About a year later, the Pacific Research Institute released another paper by Reynolds. It examines three possible regulatory futures for nanotechnology: “prohibition, limitation to military applications, and modest regulation with an emphasis on civilian research.” The conclusion is that prohibition is improbable and impossible, exclusive military application might lead to misuse by totalitarian regimes, and modest regulation and civilian research is the best route to the success of nanotechnology.

The thinking in these papers is clouded by the unfortunate tendency to connect nanotechnology(broadly), with molecular nanotechnology (MNT), focused on self-replication, nanobots, and assemblers. A host of regulatory issues will arise long before molecular nanotechnology becomes a reality. Nanotechnology is a body of science and technology, not a specific type. The industry must distinguish between the near and longer-term possibilities of nanotech, or it will suffer a great disadvantage in any dialogue on regulatory schemes. Another assumption affecting the thinking about regulation is the belief that the nano industry is still in its infancy. A few years ago people studying nanotechnology maintained that it would take twenty years for the impact of its industry to be felt on society.

The ongoing estimates of the industry’s maturity are continually decreasing. The time to consider regulation and nanotechnology is now, not five years from now. TSCA and Nanotechnology A Guide for the Perplexed We would now like to take a closer look at TSCA, broken down into its specific steps. We do this from the perspective of a company or someone outside of EPA.

To test TSCA’s applicability, we will examine carbon nano-tubes, which are already commercialized. According to the Nano-Business Alliance, thirty-one percent of nanotechnology companies are involved in materials and manufacturing.

There are sixteen major producers of carbon nano-tubes, and eight of those are in the United States. These companies produce over 2.5 tons of carbon nano-tubes per day. Carbon nano-tubes are being cited for use in applications for semiconductors and metals to hardened materials. In ten to fifteen years, they could replace silicon in computer microprocessors. In PC Magazine’s July 2003 issue, carbon nano-tubes were described as one of “20 Hot Technologies to Watch.” Also, in comparison to other nano-materials, carbon nano-tubes have been studied the most. Even though they may not be crucial for this paper, other products from sunscreens to facial creams to clothing use nano-materials, and each one must be examined individually for its effects on our health or environment. The following is an overview of key steps, especially viewed from an industry perspective.

This is not meant to be a conclusive guide, so companies and other interested parties should consult directly with EPA concerning steps specific to their products and concerns.

Readings

Lynn L. Bergeson, Lisa M. Campbell & Lisa Rothenberg, "TSCA and the Future of Chemical Regulation," EPA Administrative Law Reporter 15, 4 (2000): 4, 19

Chan B. Thanawalla, Complying with TSCA Inventory Requirements, (New York: John Wiley and Sons, 2002), 4.

The Environmental Law Institute and Latham & Watkins, TSCA Deskbook, (Washington, D.C.: Environmental Law Institute, 1999), 7-8.

Günter Oberdöster and Mark J. Utell, "Ultrafine Particles in the Urban Air: To the Respiratory Tract andBeyond?" Environmental Health Perspectives 110, no. 8 (August 2002): A440.

Huczko and H. Lange, "Carbon Nanotubes: Experimental Evidence for a Null Risk of Skin Irritation & Allergy," Fullerene Science & Technology 9,n2 (2001): 247.

Huczko et al., "Physiological Testing of Carbon Nanotubes: Are They Asbestos Like?" Fullerene Science andTechnology 9, no. 2 (2001): 253.

Baron, Paul; Maynard, Andrew; Foley, Michael (2003): "Evaluation of Aerosol Release During the Handling ofUnrefined Single Walled Carbon Nanotube Material," NIOSH DART-02-191, April.

"Nanotech is Not So Scary," Nature, 421 (2003): 299.

David Forrest, "Regulating Nanotechnology Development," 23 Mar 1989, http://www.foresight.org/NanoRev/Forrest1989.html (20 June 2003).

Glenn Harlan Reynolds, "Environmental Regulation of Nanotechnology: Some Preliminary Observations,"Environmental Law Reporter, 31 (2001): 10685.

Glenn Harlan Reynolds, "Forward to the Future: Nanotechnology and Regulatory Policy," (San Francisco:Pacific Research Institute, November 2002), 1.

Reynolds, "Forward …", 12-14; William G. Schulz, "Nanotechnology Under the Scope," Chemical &Engineering News, 9 December 2002,

Ann M. Thayer, "Nanotech Offers Some There, There," Chemical & Engineering News, 26 November 2001, 14.

Kurt Kleiner and Jenny Hogan, "How Safe is Nanotech?" New Scientist, 29 Mar2003, 15.

Cade Metz, "Carbon Nanotubes: Silicon's Likely Successor, and Much More," PC Magazine, July 2003, 83.

National Renewable Energy Laboratory, "MSDS List C," ES&H Reference and Support Materials: ChemicalSafety, 1 November 2001, <http://www.nrel.gov/esh/reference/chemsafe/msds197c.shtml> (16 July 2003).

Shenzhen Nanotech Port Co., Ltd., "Material Safety Data Sheet: MWCNTs," Shenzhen Nanotech Port Co, 2003,<http://seasunnano.com/MSDS1.pdf> (16 July 2003).

Kent Anapolle, <Annapolle.Kent@epa.gov > "Re: CAS Numbers for Carbon Nanotubes," 18 July 2003, personale-mail (18 July 2003).

"Fullerenes by the Ton," Chemical and Engineering News, August 11, 2003.

Nanotechnology Communication COM(2004)338

Communication of the European Commission:
"Towards a European strategy for nanotechnology"

On the 12th May 2004, the Commission adopted the Communication “Towards a European Strategy for Nanotechnology” COM(2004) 338. It seeks to bring the discussion on nano-sciences and nanotechnologies to an institutional level and proposes an integrated and responsible strategy for Europe that takes into account the following issues:

increase investment and coordination of R&D to reinforce the industrial exploitation of nanotechnologies whilst maintaining scientific excellence and competition;

develop world-class competitive R&D infrastructure that take into account the needs of both industry and research organisations;

promote the interdisciplinary education and training of research personnel together with a stronger entrepreneurial mindset;

ensure favourable conditions for technology transfer and innovation to ensure that European R&D excellence is translated into wealth-generating products and processes;

integrate societal considerations into the R&D process at an early stage;

address any potential public health, safety, environmental and consumer risks upfront by generating the data needed for risk assessment, integrating risk assessment into every step of the life cycle of nanotechnology-based products, and adapting existing methodologies and, as necessary, developing novel ones;

Complement the above actions with appropriate cooperation and initiatives at international level.

Full document in multiple languages available from http://www.cordis.lu/nanotechnology/src/communication.htm

Also see Vision 2020 - Nanoelectronics at the centre of change – see http://www.cordis.lu/nanotechnology/src/pressroom.htm#vision

2. Biotechnologies

Biotech to-day, and future trends, M. Morgan

This report is a synthesis of various reports and from my own understanding of the field and further reading. Mt approach has been largely to adopt material from the Canadian Foresight Study which explained "S&T Foresight involves systematic attempts to look into the longer-term future of science and technology, and their potential impacts on society, with a view to identifying the emerging change factors, and the source areas of scientific research and technological development likely to influence change and yield the greatest economic, environmental and social benefits during the next 10-25 years.

I have attempted to identify those developments which might have an especial resonance in Europe and which might be expected to have a significant impact.

1.Background

The HLEG is tasked to identify how the 'converging technologies' of nanotechnology, biotechnology, informatics and cognitive sciences will evolve and how Europe should position itself to benefit from positive technology developments while mitigating any undesirable effects. The objective of this report is to identify developments in biotechnology, which will depend on advances in one or more of the other technologies or contribute to the developments of the other technologies producing new and advanced products. The study is of necessity speculative and does not attempt to identify all possibilities.

The group is aware of the efforts taking place in many departments of the EU, using panels of experts, to identify the scientific developments occurring in many scientific disciplines, which underpin and will impact on the 'converging technologies'. It is the unique remit of this group to attempt the synthesis of the separate technologies and identify synergistic activities and how the EU might ensure that they benefit the European peoples as a whole.

2. Converging Technologies

The term 'converging technologies is used to encompass combinations that might include: the biosciences and especially recent developments in genomics, proteomics, structural biology, integrative biology, the cognitive sciences and basic neuroscience; nanotechnology; information technology including artificial intelligence (AI), advanced computing and networks.
A number of reports have waxed lyrical on how this convergence could lead to remarkable new insights into the structure of matter and provide new tools to enable a mature and rational approach to manipulating materials at the atomic level. This convergence has provoked widespread interest and enthusiasm, described in terms of a "New Renaissance" and "Threshold Technologies". The possible capabilities that could be generated include:

?Exceptionally strong and light new materials, including those specifically designed to be biocompatible
Personalized health profiles
?Tiny bio-sensors that could reside in and monitor events in the human body
?Direct linkages between brain and machine, then brain-to-brain.
?Gene therapy and the general ability to control the genetics of humans, plants and animals

?Highly targeted pharmaceuticals specifically designed for an individual host and released on an as-needed basis to the appropriate body part
?Sustainability priorities for industrial and social practices?
?Bio-remediation and regenerative medicine under various societal scenarios ?
A better understanding of ecological systems (species adaptation, nutrient systems and bio threats)
Some of these promising technologies are very speculative, others have prototypes in labs. The next two decades will ultimately be the only way of knowing how the converging technologies will evolve. What is known is that R&D spending in these areas has accelerated. The US in particular sees these converging technologies as the key to continuing technological superiority and they do not intend to fall back. The convergence of these technologies is not a coincidence. It occurs as result of our expanding ability to observe and understand natural phenomena. The expansion takes place at both ends of the measurement scale, from the very small to the very large.

The standard disciplines (physics, chemistry and biology) occur at what could be called human scale. This is the directly observable world as it would have been observed by everyone and anyone until fairly recently.

Developments in optics opened up the scale of what is observable, with telescopes letting us see larger more distant objects and microscopes letting us observe nature at the cellular level.

We can now observe matter down to the atomic scale. The ability to observe and work with energy and materials at these smaller and smaller scales has resulted in a convergence, and to some extent an integration of sciences. At the nanoscale atoms, circuits, DNA code, neurons and bits become conceptually interchangeable.
New disciplines are emerging that cross traditional boundaries. At the nanoscale level, technologies to build semiconductors can be adapted to build medicine. At the nano level genes, bits, neurons, and atoms all start looking like the same thing.

Developments in combinatorial modeling and artificial intelligence show the way to understanding the behavior of large complex systems by combining the known interaction of their component parts.

Information technology exists on multiple levels, rather than along a continuous scale. At its lowest, material level - circuits and semiconductors - IT integrates directly into the physical world at the nanoscale. Beyond that material level, circuit states are understood in terms of bits, which in turn are manipulated and understood as either data or programs. Discoveries at the nanoscale about how atoms and molecules, DNA and genes, interact open the door to modeling their behaviour at much higher levels of aggregation.

3. Biotechnology

The term encompasses the science and technology that has as its goal the understanding, alteration, and functional modification of cells including humans, plants, animals and microorganisms. It also includes work on non-cellular life forms (e.g. viruses) at which point biotechnology converges with nanotechnology.

Some specific topics are:

?Biosensors
Biomaterials
Cloning? including both therapeutic and reproductive (non-human)
Cosmaceuticals
Environmental technology, including bioremediation
Fuel sources
Gene therapy
Genetically modified organisms (plants, animals and micro-organisms)
Neutraceuticals
Pharmacogenomics and personalized medicine
Predictive medicine?
Proteomics?
Stem cells

4. Technologies and Capabilities

One of the most important observations is that much impressive technical advancement could happen relatively soon. The following lists some technologies that are technologically possible, along with prospective early arrival dates.

(Caveat: The prospective early time frames were made based on information in 2001 – 2002. The key assumptions behind them were: (1) some organisation was pursuing the goal, and (2) it was properly funded. These therefore represent feasible, but not inevitable, technology. Changing economic conditions, or for that matter new regulatory frameworks, could alter the arrival times. Specific details aside, it illustrates that the drumbeat of innovation is fairly quick.)

SOME KEY TECHNOLOGY DRIVERS

Capability to synthesise specific genetic sequences and proteins.
?High level of capability to monitor and measure phenomena at the molecular level and in remote or hostile environments.
?Ability to substitute industrial processes with sustainable agricultural processes.
?Much higher understanding of the specific causes and specific remedies for a wide range of common diseases

The impact of these drivers is extremely dependent on the scale at which they are implemented. It is easy to point to technologies that are possible now, but which have no impact because they are not widely available. It is safe to speculate on some impacts.

?The ability to detect and monitor key illnesses could create a greater reliance on "out-patient" approaches to health care delivery.
New drugs and new procedures, along with predictive capabilities would create an increase in demand for health care products.
?Bio process to replace industrial ones could increase, rather than decrease, environmental stresses as the agricultural sector grows.

Technologies possible in the next 5 years

Biosensors available to monitor and measure in situ bioremediation. They can be applied to pollutants that are difficult to measure or are in hard-to-reach locations.

Gene Chip available that can include markers for all human genes and can test for over 100,000 conditions. Professionals in can use it selected applications.[28]
Many new and older drugs can be prescribed after screening a patient's genetic profile to estimate safety and efficacy. (The UK is already proposing to establish a new born genetic profiling service). New drug prescriptions can include a screening kit.
Therapeutic cloning of embryonic stem cells leads to 'cures' of some cases of organ failure (diabetes, heart failure, some neurological disorders).
Bioengineered microorganisms available as biocatalysts for industrial use. E.g. produce lysine from sugar for use in animal feed.
Design and fabrication of self-healing bio-nano materials
Some deployment of micro-electro mechanical systems (MEMS)
Increasing adoption of 'biological solutions and paradigms' to speed development of nanotechnology
"Green" genetically modified plants using altered genes from the original plant, rather than the introduction of foreign materials.
Early use of genetically modified organisms (GMOs) to remove difficult-to-degrade materials.

Technologies possible in the next 5-10 years

Drugs designed for specific genotypes and phenotypes will begin entering clinical trials.
Pharmacogenomics accelerates both the discovery and the approval process.
Drug economics can shift from the production of 'blockbuster' drugs to specific target drugs.
Comprehensive genetic, behavioral and environmental screening can be capable of predicting degree of disposition to most major chronic diseases.

Gene therapy can be commonly used to treat some genetic diseases.
Stem cells can be matured in cells producing dopamine to treat patients with Parkinson's disease.
GM crops valued at over $20 billion annually are likely.
Global environmental technology worth $2 trillion. Up to 20% is bioremediation.

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[28] **The Hapmap project** The International **HapMap** Project aims to speed the discovery of genes related to common illnesses such as asthma, cancer, diabetes and heart disease. Expected to take three years to complete, the HapMap will chart genetic variation within the human genome and create a tool that will help researchers detect genetic contributions to many diseases. Although any two people are 99.9% identical at the genetic level, the 0.1 percent difference helps explain why one person is more susceptible to a specific disease than another person. By studying the patterns of genetic variation, or genetic differences, researchers expect to identify which differences are related to disease.
Single nucleotide polymorphisms - SNPs - represent by far the most common source of genetic variation. SNPs are single-letter variations in a DNA base sequence. The human genome is thought to contain over 10 million SNPs, about one in every 300 bases.
In theory, researchers could develop a gene-hunting tool using a map that contains all 10 million SNPs. Such an approach is both impractical and prohibitively expensive. Instead the HapMap Project will identify and map the "chunks" into which the genome is organized. Each chunk may contain dozens of SNPs, but researchers will only need to detect a few tag SNPs or markers to identify the unique chunk or block of genome and to know all the SNPs associated with that one piece. This strategy works because individual genetic variation is organized in "DNA neighborhoods" called haplotype blocks. SNP variants that lie close to each other along the DNA molecule form a haplotype block and tend to be inherited together.

Consumer pressure and environmental concerns accelerate transition to environmentally sustainable bio-manufacturing in the chemical, textile, paper, food, and industry sectors.
Bio-fuel represents 5% of automotive fuel in Europe.
Multiple sensors on single chip with integrated logic functionality
Computer model of “virtual plant” can be used to understand plant physiology and selected genetic modifications.
Biomarkers can be used by most individuals with cancer or at risk of getting cancer. They can monitor early development, identify tumour subtype, pinpoint treatments, monitor responses, and estimate prognosis.
First preventative vaccine tested for a specific cancer
Transgenic pig organs that reduce human rejection start to be used for heart, kidney and liver transplants.

All of these technologies have aspects that can require regulation both to prevent harm and to promote the underlying infrastructure needed to capture benefits.

Longer-range technologies with more uncertain horizons for deployment are suggested below. While this may be long-range foresight, it is not that far away in terms of legislative eras and government “lifetimes”. The preparation of new laws, including consultative processes, can easily take five years or more.

Technologies possible in the next 10 to 20 years

50% of all new drugs may be based on genomics. They would be specifically designed for a target subset of the population.
Pharmacogenomic tools can reduce the cost of drug development and approval by 30%.
The time from discovery to regulatory approval can be cut by 50%.
Molecular nanotechnology can be used in the manufacture of molecular compounds for use in bio-engineered medications.
First major chronic disease can be prevented at the molecular level by a genetically engineered drug.
Bio-based economy begins with agriculture producing significant sources of energy and natural resources.
Commercial production of hydrogen from water using genetically modified algae is used for fuel cells producing electricity.
Bio-mimetic material systems
Nano diagnostic products enter commercial marketplace
Noninvasive, imaging diagnostics for cancer and other major diseases
Targeted cancer therapies in routine use
Biochips a practical, clinical tool
Sensory chips – taste, smell, sound
Nanobots are working in labs and being tested, evaluated, and fielded for various specific applications
Nanomedicine may be replacing older forms of medicine such as surgery, traditional pharmaceuticals, rational drug design
Functional mind-machine interface.

Developments relying on converging technologies

Neutraceuticals: nanoemulsions help specific drug absorption while nanodroplets bind drug and enable to to cross cell membrane that otherwise it couldn't.

For example, Phytosterol, a cholesterol lowering naturally occurring drug can be incorporated into foods.

Vaccines delivery less painful by mouth or through the skin.

Biomaterials:

Bone and Tissues
- Artificial skin
- Regeneration of tissue
- Wound healing

Inplants, special coatings
- Tissue engineering – substitutes
- Cell engineering – get cells to form tissue by modifying the extracellular matrix

Medicine and Biotechnology

Nanomagnetic particles: target tumour cells. Under an electric field the particles heat up and kill the cancer cells.

Quantum dots to diagnose cancer and infectious diseases. Changes in proteins at cell surface can be detected.

Drug delivery systems by encapsulating in a variety of nanomaterials.

Biological Detectors

Electronic noses: variety of applications in security, health and Bioterrorism.

Space Medicine

Nanosensors: synthetic polymer with fluorescent tags. Light up when radiation damage and can release e.g. oxygen to help in DNA repair.

Conclusions

By using structure at the nanoscale, it is possible to greatly expand the range of performance of existing chemicals and materials to produce major benefits to biology, medicine and healthcare, i.e., a new generation of chemical and biological sensors, tiny medical probes that will not damage tissues, entirely new drug and gene delivery systems. In the next century, the emerging field of nanotechnology will lead to new biotechnology-based industries and novel approaches in medicine.

There are numerous potential applications of nanoscience in medicine and health, including: Diagnostics and therapeutics using rapid and efficient genome sequencing and intracellular sensors.

A wide range of biological probes and biosensor systems and new imaging technologies that detect emerging disease in the body, which will shift the focus of patient care from disease treatment to early detection and prevention (e.g., of cancer and other diseases).
More effective and less expensive healthcare using remote and in-vivo diagnostics and treatment devices.
New formulations and routes for targeted gene and drug delivery that enormously broaden their therapeutic potential by effecting and targeting delivery (e.g., to cancer cells and organs) of new types of medicine to previously inaccessible sites in the body.
Novel biocompatible materials for more durable, rejection-resistant artificial tissues and organs.
Miniaturised "smart" medical devices that will extend human performance, protect health, and repair cellular/tissue damage minimizing collateral damage of human tissues.

Services Science and Co-evolution

See article on http://www.corante.com/brainwaves/archives/002103.html

Faster than Thought

See article on http://www.corante.com/brainwaves/archives/002099.html

CT and Pharmaceuticals, A. Morato

"Europe is lagging behind (the USA) in its ability to generate, organise and sustain innovative processes that are increasingly expensive and organisationally complex".

Main characteristics of the industry:
Industrial landscape made up of large and SMEs industry.
Highly skilled job profiles required.
Positive contribution to the trade balance in EU.
Contribution to Public Health.
Contribution to the development of environmentally friendly tech.

Weaknesses:
Markets are not competitive enough.
R&D throughout Europe is quite fragmented.
Growth in R&D spends is weak.

<u>1.- Cooperation issues.</u>
What's being made?
Projects under the 6th Framework Programme for Research about telematic strategy:
EudraNet project, to allow efficient and safe exchange of information between competent regulatory authorities.
EudraVigilance project, to support pharmacovigilance activities.
EuroPharm database, to support regulatory activity and to provide a harmonised set of information on all products.
Setting up and strengthen databases on clinical trials.
ERA-NET plan to stimulate and support coordinated programs at a European level.
Creation of the G10 Medicines, a High Level Group on innovation and the provision of medicines. It has been created to take a "fresh look" at the problems facing the pharmaceutical sector and to come up with creative solutions.
Creation of an Advisory Group on Competitiveness in Biotechnology, to identify issues affecting European competitiveness in biotechnology.
Creation of the European Medicines Evaluation Agency (EMEA 1995) so as to make every medicine authorised in the EU available to patients in all Member States. The main objective is to get the single market in the pharmaceutical field.
European Patients Forum (February 2003).
Pharmacovigilance systems, that continuously collect and disseminate information on new drugs placed in the market.

Development of a website with indicators on competitiveness (http://pharmacos.eudra.org) covering four main areas: Supply, demand & regulatory framework, industry outputs, and macroeconomic factors. The Commission will publish annual tables of competitiveness indicators and will undertake work under the Public Health Programme to develop a range of public health indicators.
A European Health Portal is being developed, with links from EC Health Portal to national health sites.
E-health Commission communication on "Quality criteria for health-related websites".

What needs to be done?
To coordinate R&D project, to widespread scientific collaboration at a European level and to coordinate public and private funding in research.
To set up a European Centre for disease Prevention and Control.
To share more information among Member States.
To strengthen and coordinate all pharmacovigilance activities.
Enhance the Europharm database of the EMEA in order to support regulatory activities and provide a harmonised set of information.
To implement virtual institutes of health, connecting all existing competence centres on fundamental and clinical research into a European network of excellence.
To increase the availability of information to patients (mainly via internet) and increase the influence of patients in the decision making process.

Although much effort has been made so far by the European Commission in the pharmaceutical industry, there is a scarcity of initiatives directly related to the converging NBIC technologies. There's an urgent need to coordinate national policies and strategies so as to consolidate and focus European efforts in the fields of the convergence. The main weakness of the EU versus the USA is the lack of coordination and integrated projects. We are in a fragmented area, with agents acting in an isolated way.

By coordinating efforts, the exploitation of knowledge will be more efficient and, by the way innovation will be more effective. It's also important to go on with the integration of society in the decision making process and to gain feed back from it. We cannot forget that in this particular field it's of great importance to have an informed society so as to reduce initial reluctances to the new changes to come.
Finally, it would be necessary to draw the attention to the need of more integrated R&D projects at a European level, including different disciplines, mainly biotechnology and ICTs.

2.- Educational issues.
In order to exploit all the nanotechnologies potential, the UE must have a multidisciplinary community of researchers and engineers capable of generating knowledge of quality and transfer it to the industry sector. Although the need for multidisciplinary has been widely studied by the Commission, it does not seem that they have in deep analysed the particular needs for the pharmaceutical industry.

As a first approach to the educational subject, it could be said that convergence will require specialists working in the pharmaceutical industry to have knowledge in the following disciplines: Pharmacy, Chemistry, Biology (mainly molecular biology), Computers (Bioinformatics), Engineers (from different specialities), Materials, Micro and Nano technologies.

Based on the latest data, the number of researchers in Europe should be increased in 1.2 millions by 2010 (from the Lisbon summit). From this perspective it is of great importance to take measures to attract new people to the field of nanotechnology and to retain those actually working in it.

In a general framework, the Commission has asked the Member States to identify the educational needs in nanotechnology and give solutions to the possible gaps that they find in their educational systems. Universities should make an effort in the interdisciplinary approach. By doing so, the creation of real multidisciplinary research groups within the university should be granted.

Additionally, so as to make possible that already graduate researchers and engineers have access to this new field, postgraduate programs on the new and complementary skills needed for the latest job profiles should be developed. Professionals with an entrepreneurial mind should be formed, and so the technological transfer from research centres to the industry will be sped up.

Finally, there's also a need to create Centres of Excellence at a European Level that coordinate and perform integrated research projects.

3.- Manufacturing processes issues.

"Nanotechnology will offer enterprises valuable ways to innovate, and in order to gain competitive advantage, they will have to do so".

- Modifications on the actual manufacturing processes.

It is important to differentiate between two steps: R+D and manufacturing processes. At the moment, we are at an initial stage, where new developments are being made at a lab/pilot plant scale. Convergence has not completely reached the industrial dimension in such extent. So right now, and in the short and medium term, it is imperative to undertake R&D projects from a convergent point of view better than the manufacturing processes as such.

New advances at a R&D level will require experts in nanotechnology developing novel medications and their appearances, bio-technicians for the development of more personalised medicines, ICTs as basic tools for the whole research process, etc.

In the manufacturing processes, convergence appears to be more in line with the development of new control systems, and subjects related to ICTs. Experts on the field believe that the following advances are possible realities to come with the NBIC convergence.

Factory optimisation using virtual tools will be in widespread use, and most manufacturing operations will be supported by artificial intelligence tools.
In-process monitoring of manufacturing based on sensor data and image processing replaces final inspection in a majority of production sites and processes.
Widespread use of technology for monitoring and maintaining equipment and facilities from outside the factory via information networks (tele-maintenance/remote-control).

These are just examples of what the future might bring to the pharmaceutical industry. No specific actions have been taken by the Commission in order to give support to the change from the old to the new manufacturing processes to come. Although we are at a very early stage, an assessment plan on how to manage change and how to incorporate new technologies should be elaborated by the Commission.

In the biotechnology field, which by the way it's a priority research area in the European pharmaceutical industry; advances have come mainly combining biotechnology and ICTs.

Examples of these developments are:
Miniaturization of diagnosis and testing devices: lab-on-a-chip. The development implies the miniaturization of analytic and complex lab processes.
Integration and analysis of a large amount of data by means of bioinformatics. In this way genomic and proteomic research can be carried out in virtual labs (connected via internet). The advance goes in line with the development of a better data management system to avoid data replication. Virtual labs will help research by offering storage, integration and analysis of data at a European level.
Development of high speed technologies in pharmacogenetics for the molecular characterisation of illnesses, in order to have an optimum therapy, that at the same time reduces side effects (toxicogenomic). Possible applications on the field might be the discovery of new drugs which are active just to the damaged proteins, and not to the intact ones, studies on the drugs activity based on genetic profiles, etc.

Examples of new advances in the biomaterials field are:

Development of new drug release systems for long term treatments which show an intelligent response from the material in use. The systems will be able to react to metabolic changes and also to adapt the drug release in real time. The innovation involves the development of intelligent biocompatible materials by means of nanotechnology.
Development of microelectronic biocompatible systems which allow the use of implantable sensors/actuators. In this line, it is also necessary to advance in the research on the implantation of intelligent electrodes and/or microchips which allow the control of refractory illnesses to chronic medication, such as Parkinson, epilepsy, convulsive diseases and pain.

In most cases, the main barrier for achieving such developments is based in the lack of coordination between microtechnology and biotechnology disciplines, more than in the development as such.

- Enterprise models.

As said before, the industrial landscape in the pharmaceutical field is made up of both big multinationals and SMEs. In order to gain the multidisciplinary required by the technological convergence, a significant level of coordination and cooperation among different enterprises is to be achieved. Not only among enterprises, but also among enterprises and universities, technology institutes, etc. The European Commission should encourage this line of work by supporting research projects involving a mixture of SMEs showing to have synergies for the development.

Finally, once the technology is set companies may also outsource a considerable percentage of manufacturing and support activities. In this way, they can focus their efforts in their core business.

4.- Financial issues.
Even though much effort is made by the Commission in order to support projects related to the NBIC convergence, we should make a call for more public funding (at both European and regional level) if we want to remain competitive. The following data show the precise figures of public investment.

Health research and development in government budget, as percentage of GDP and Euros (2000)

	% GDP	Mn Euros PPP
Austria	0.0142	33.95
Belgium (1999)	0.0080	23.14
Denmark	0.0136	23.98
Finland	0.0681	89.22
France (1999)	0.0528	815.35
Germany	0.0270	603.58
Greece (1999)	0.0139	35.43
Ireland (1999)	0.0084	99.66
Italy (1998)	0.0322	596.09
Netherlands (1999)	0.0294	142.26
Portugal	0.0341	96.04
Spain (1999)	0.0289	304.35
Sweden	0.0101	25.16
United Kingdom (1999)	0.1048	1729.73
Slovak Republic	0.0200	14.28
Japan	0.0253	944.04
Norway	0.0545	83.83
Swtzerland (1998)	0.0026	6.44
United States	0.1885	20988.35

5.- Legal concerns.
The Commission aims the European pharmaceutical industry to focus their efforts in the development of innovative medicines, with special interest in the ones derived from biotechnology. Within this group, there is also room for nanotechnology developments. The Commission wants to provide better access to innovative medicines, by encouraging their development and the speed of access to them. The companies should be able to begin to market as soon as they are authorised, and so the regulatory framework in use should be revised an updated. Even though USA system for accessing the market is faster than in elsewhere, the European pharmaceutical industry remains a powerful sector. But in order not to lose competitiveness, Europe should speed up the process for new products to access the market.

It should be developed a robust European system for protecting pharmaceutical inventions, which is vital if European industry is to continue to thrive. This is being done in the biotechnology field, where eight member states have yet to implement the "Directive on the Legal Protection of Biological Inventions". The Commission should develop a Community patent legislation giving coverage to all areas within the pharmaceutical industry.

We hold these freedoms to be self-evident…

Do you want to block traumatic memories from scarring your mind? Perhaps you do, but would you be happy if someone else did it for you? Or how about receiving marketing messages beamed directly at you in hypersonic waves? Mind control is getting smarter by the minute, says Richard Glen Boire, co-founder of the Center for Cognitive Liberty and Ethics in California. And, as he told Liz Else, we ain't seen nothing yet...see http://www.november.org/stayinfo/breaking2/Scientist.html

3.Information Technologies

ICT and AI in View of CT
W Bibel

SoA contribution is in pdf format, see external document
Bibel-IT.pdf, Under Appendixes

Summary of the State of the art of NBIC convergence in ITC I.Pearson, BT May 2004

Introduction

NBIC convergence as a whole obviously intersects with developments across the whole field of information technology, which, by virtue of artificial intelligence and artificial life activities, already intersects with cognition technology. We are now beginning to see intersections of IT with nanotech, as chips move into that domain and as sensors develop, and an intersection with biotech as electronic biomedical implants become commonplace. This document outlines just some of the typical areas where IT is already converging with the N,B and C fields. It is not a complete list by any means, and can only give a crude indication of the scope. The list of advances is necessarily diverse so is presented mostly as a list where there is no common story line.

IN

Most transmission today makes extensive use of components and mechanisms that depend on quantum effects. This has been the case for many years, and it is hard to do much in optical communications without some basic quantum theory knowledge. This applies to design of optical fibre, couplers, switches, amplifiers, filters, and of course lasers. To that extent, nanotechnology is already interwoven with telecomms. A typical example is the use of quantum wells in lasers. Quantum dot technology is also developing rapidly, and will allow single photon emission. It simply is not possible to run a high speed network today without using a range of quantum effects. So telecomms has been a nanotech industry for many years.

Carbon nanotubes have been demonstrated in use as a communications wire, and are expected to be widely used for purposes such as on-chip interconnect in the future. This development will require bottom up assembly rather than lithography or vapour deposition technology used commonly today.

Photonic crystal fibre is a relatively new type of optical fibre with multiple holes that guides light along it using quite different principles at the quantum level than conventional transmission.

Soliton transmission depends on non-linear quantum effects in fibre and is a widespread tool for long distance high speed optical communications.

A device called the passive picocell uses an electron absorption modulator to provide wireless communication via radio linked directly to an optical signal on a fibre. This is a single electronic component that relies totally on quantum effects. It has significant potential to revolutionise wireless communication as optical networks are deployed further into the local loop.

Quantum cryptography can be used on point to point optical links and depends on the fact that a signal thus encoded cannot be intercepted without the intended recipient becoming instantly aware.

Tiny holes in an aluminium sheet just a few nanometres across have been shown to increase light coupling, which will have uses in optical switching. These use quantum effects to 'pull' far more light through the holes than their diameter would intuitively suggest.

IB

Optical fibre is found in lobsters' eyes so there is some natural convergence of modern information technology with biology. And of course we may consider the whole of the biological nervous and sensory system to be an IT system that is broadly equivalent to a sensor network.

The concepts of evolution, self organisation, robustness that exist so widely in nature have been extensively used as inspiration in a large field called biomimetics. For example, the principles governing the spacing of hairs on a fruit fly's abdomen have been used as the basis for tools for mobile network design.
Ditto cell differentiation. Evolution principles are already used in limited areas of software and hardware design, and a company called Evolved Networks uses computers to 'evolve' network architectures. Most of these techniques fall under the label of genetic algorithms, though some techniques that we are developing are significantly different in style from organic evolution.

Ants and other insect colonies exhibit behaviours that have stimulated a wide range of network management tools. BT still has many engineers looking at nature for biomimetic inspiration. MIT have followed this work and are in ongoing development of ANT based management.

Future networks may well have built-in immune systems using many of the same principles found in nature.

A number of telemedical implants and wearables exist that allow remote supervision of patients. Video systems have been developed that are safe to swallow, that can show video all the way through the human digestive tract.

IC

There are a few areas here that are very different. One is links between organic systems such as the human body to electronic systems. Another is the field of artificial intelligence in its various forms, including artificial life, expert systems, artificial neural networks, software etc. Another field that is probably much more significant in our timeframe is that of cyberspace, which is the are where human concepts and ideas meet IT system infrastructure, and is essentially another universe domain that exists inside the network. This is fundamentally different from the natural world, and it really should be separated out as another convergent technology in its own right - NBICC.

Bio-IT links

Some biomedical implants use IT to gather and process information, converting it into signals that can be passed into the human nervous system. Examples are the cochlea implant, of which millions are now deployed, and more recently, retinal implants that can provide crude vision to otherwise blind people by directly stimulating retinal cells.
Although the field is still in its infancy, growing nerve fibres straight onto chip surfaces is progressing and is used in limited trials to permit patients to control prosthetic limbs.
Thought recognition is moving on steadily. MLE for example has a range of computer games that are driven by thoughts, and some driven by emotional state. I believe current resolution is still only about a dozen words. Direct implants onto the brain surface improve the quality of recognition somewhat but the devices are still only useful as an aide for severely disabled people and are no match for normal ability.

Sensory translation is possible and is used for some blind people. A visual scene can be encoded as an audio input that the blind person can learn to interpret. For example, ultrasound or radar can be used to survey the environment and different tones indicate location of nearby objects. GPS positioning and navigation systems are now also being used as inputs to these aids.

Haptics is the technology of touch at a distance and developing quickly, along with limited multisensory environments. A range of data gloves and body suits allows a degree of sensory involvement in distant environments and virtual environments. Haptics already makes use of simple thought recognition.

A new field called active skin is progressing and addresses the range of potentials as electronics becomes both smaller, printable on a skin-like surface, and uses less bio-hostile materials. Silicone based electronics is a major step forward in the field, as is organic transistors and organic LEDs, which should allow processing, sensor and display technology to be integrated into our bodies, at least at the skin surface level. This will allow a wide range of applications such as sensory translation, sensory recording, emotion detection and control of local IT systems by bodily or mental signals. Importantly, it allows the user to be fully integrated into future virtual and augmented reality environments at cognitive and sensory level.

Artificial Intelligence

IC Convergence has been under way now for decades, though progress has been both patchy and to many people, frustratingly slow. We are still far from a truly conscious or intelligent machine, and opinion is still divided as to whether a machine ever could be conscious, or have human level intelligence. However, some of us are sure that this is possible and that the timescales may not be too far away. I personally believe a conscious machine with human equivalent intelligence will be achieved between 2015 and 2020 and design of the concepts on which this might be realised is one of my research projects. Sadly, mine is a minority viewpoint and most people in the field would put the date significantly later, some never.

Expert systems are already in widespread use in the medical environment.

Psychiatric tools can already be used for net based therapy, and are very good at emulating humans. Many people find it easier to talk to a machine than to people, especially when the content is sensitive, so IT systems can be used to improve medical diagnosis by capturing more relevant and more truthful data from the patient.

Artificial intelligence is progressing in many other areas too, many of which are not digital. Many researchers around the world are looking at strong AI and even artificial life for many years now. Although we are still far from human level cognition in machines, they outperform humans in many niche tasks. Artificial neural networks can grade and sort items on production lines much faster, cheaper and more reliably than people, and neural networks are used extensively in other non-manufacturing fields such as traffic management, retailing, travel and so on.

Direct response allows relatively simple electronic circuits at the interface to allow machines to react more rapidly and appropriately to external stimuli. So for example, instead of a robot doing all of its sensory analysis and response decisions in a central processor, faculties such as touch and balance are better implemented by using systems at the periphery to make local decisions. Balance is achieved by making a signal to the appropriate actuators directly as a result of a specific sensory input without going via central control. A robotic insect might use only a few transistors at each foot to achieve such goals.

Work at MIT on a system called COG (for several years now) uses artificial intelligence in a way that the robot develops its own understanding and experience of the world around it rather than having it programmed by human engineers.
This is increasingly the approach taken by roboticists. It is also my own approach in the OB1 concept, and I believe it will eventually lead to true cognition and awareness in machines.

Cyberspace

I believe that in the now to 2020 timeframe, the most lucrative part of IC convergence is in cyberspace, which exists already as a major global business platform, and is developing at n accelerating rate. Rather than including a long section about cyberspace here, I have attached a lengthy paper on the subject as appendix 1. It was published in the BT Engineering Journal in 1999.

IS

Society is not an official letter in the NBIC acronym, but since it is an obvious concern, I have also listed some of the new areas where IT will have a direct impact on society, IS convergence. Obviously there is already a large social impact today from IT in society.

Increasing globalisation caused by need for scale, and enabled by IT causes feeling of disenfranchisement amongst affected populations.

The use of IT by government to police crime is becoming a major privacy and freedom issue, and is quite likely to be a major precipitant of anti-tech backlash, which is likely around 2010.

Electronic implants into the human body are already eroding the boundaries between people and machines. This has been tolerated so far because they are still uncommon or don't obviously represent a threat (e.g. hearing aids) but this cannot be assumed to stay so as the technology becomes increasingly powerful, pervasive and intrusive.

IT increases the gap between rich and poor and so therefore may contribute to worsening security globally. This hopefully is a short to medium term problem, as falling costs will eventually make such technology available to everyone.

IT impacts on free time and pace of life, especially mobile phones and email. This is causing a growth of downshifting, and also the growth of a relatively new phenomenon called the search for authenticity, where people seek out a more 'real' lifestyle in rejection of today's superficial world.

A rapidly changing technology environment such as that in IT threatens people's personal feelings of security and increases personal uncertainty about the future, and thence undermines the foundations of happiness levels.

Entertainment is becoming ever more readily available over the net, and cultural competition between regions is increasing. This threatens the livelihoods of less attractive cultural outlets such as regional theatres by giving people access via the net to more interesting stuff elsewhere.

Information pollution is becoming a problem. It is increasingly difficult to find what you want on-line because of the sheer volumes of marketing materials that get in the way. Search tools bring up thousands of marketing sites before the one you need most of the time.

Potential increased unemployment due to AI could cause increased friction for immigrant populations as jobs become scarcer. This could threaten the benefits of diversity.
IT diversity is required for security reasons but people want to run the same software for ease of compliance and compatibility. That means we will see more frequent security problems, which undermines the potential benefits.

There is a reducing correlation between the influence a group can wield and the group size. This reduces the quality of democracy and makes those powerful who can use the IT best.

Network based attacks on the economy are becoming ever more feasible and likely. This is coupled to vulnerability asymmetry - they can attack us but they have little that they can attack. The problem will increase over the next decade.

There will be an asymmetric impact of IT on men and women, young and old. This could cause resentment and conflict between social groups.

Electronic voting is likely to increase in the short term, but levels of trust in the system might undermine it in the longer term unless backed up by paper systems.

Community networks give a higher feeling of involvement in decision making, and are particularly suited to those people who are house bound such as the old and frail.

Biometrics is in increasing use as a security tool for personal authentication. There is a danger of an anti-Big Brother backlash with this technology.

Information overload is affecting many of us already and is worsening. We will need new management practices to protect people from corresponding stress overload.

Improved productivity by using IT implies that fewer workers are needed for any give role in a company. This implies redundancies and retraining on a frequent basis for many people who will feel less content as a result.

There is strong evidence that centralisation in companies reduces efficiency, as does misuse of IT to over-manage staff and processes. We may see significant drops in output as new business tools become widely available if they are misused.

The use of network communities as a political platform should be assessed as it competes with geographic government and we have few techniques to deal with such power types.

Gaps, problems and markets

There are 11 areas of overlap between N,B,I and C. For each of these, I have listed a small subset of technology gaps, potential problems and market opportunities. I have highlighted the opportunities in italic.

NB

DNA manipulation is still embryonic
Proteomics many years from maturity
Unable yet to design new bases and protein systems
Lack of knowledge of impact of nanoparticles on organisms and environment
Hostile public
Concerns about weaponry use
Lack of design knowledge for synthetic nanotech based organism colonies
Organic customisation
Synthetic nanotech based organism colonies
Extremely small organisms
DNA Compression (reduction of redundancy)
Synthetic viruses for DNA enhancement

NI

Most engineers locked into digital and silicon mindset, few could address use of DNA computing for example
Lack of quantum engineering capability
Lack of bottom up manufacturing capability
Markets for high speed computing well established
Cost and size reductions enabling pervasive ICT and AmI visions to be realised

NC

Difficult to link N & C conventionally except via I due to lack of knowledge of non-electronic processing systems
Sensory augmentation via nanotech particles or structures
Mechanical intelligence via MEMS and NEMS?
Intelligence via basic physics and chemistry using emergence from small-scale interactions (Stephen Wolfram)

BI

Lack of electronic materials that are safe in the body
Room temperature printable electronics needed to reduce cost
DNA based in-body processing for synthetic immune systems and cancer control
Telecare & Bioinformatics already are large fields
Flexible displays will be ideal for body monitoring purposes
Active skin
Emotional jewellery
Emotion monitoring

BC

Little understanding of biological computation methods
Only biological intelligence mechanism is neural based
Positive feedback loop is strong between B&C
Use of stem cells in brain regeneration after stroke or accident
Biological sensors often superior to man-made, so could be used to enhance engineering systems

IC

Concepts of cyberspace are still very immature, so we don't know how artificially intelligent entities could progress
Persistent lack of understanding of consciousness
Little understanding of what makes life
Strong AI researchers seen by many as cranks
Lack of legal framework for independent inorganic artificial life or conscious machines
No understanding how we might manage hybrid life forms that exist both in cyberspace and physical world
Use of cyberspace linked to augment objects in physical world
Smart responsive environments, AmI & PICT
Obvious commercial advantages from high levels of AI
Conscious computers can handle extra kinds of tasks
Affective computing
Human-free companies
Autonomous systems

NBI

NB+BI+NI+…
Can't even do BI links well at large scales
Advanced bio-monitoring
Advanced telecare systems
Precision drug targeting
Cancer cell detection and destruction

NBC

NB+NC+BC+…
Biological intelligence augmentation
Artificial brain cells
MEMS-based and NEMS-based intelligence, sensing, actuation that can be linked to biological systems

NIC

NI+NC+IC+…
Bottom up assembly of highly advanced IC systems

BIC

BI+BC+IC+…
Early stages of chip-nerve links, hard to mix silicon with biology
Disagreements between neuroscientists on nature and mechanisms of consciousness
No understanding how we might manage hybrid life forms that exist both in cyberspace and physical world
Little understanding of effects on neurons of trying to make direct brain linkages via nanotech contacts
Enhancement of intelligence and sensory capabilities
Remote sensory monitoring, recording and stimulation

NBIC

Powerful technology combination attractive to weapon use - policing difficult
Sensors & Sensor nets
Hybrid systems
Biological customisation
Smart bacteria
Full direct brain link
Mental immortality

Summary

There are many areas where there is already convergence between information technologies and BNC technologies, but many new areas will develop over the coming years. Nanotechnology is already important in IT today and as feature sizes on the latest chips are in the nanotech domain, this will continue. However, bottom-up assembly of IT systems is far from achievable at nanotech sizes except in very small-scale laboratory demonstrations.

The strongest IT convergence is with the cognition field, in three areas. Convergence with biological IT systems is already under way and is one of the main focal points of NBIC activity in the far future too. However, non-human cognition is likely to prove an even bigger field in due course, with machine intelligence potentially developing to superhuman levels in the next two decades. This will obviously have a very deep impact on the whole of human culture when it happens. There is a great deal of disagreement among computer scientists on the feasibility and timescales of superhuman machine intelligence, but it would be unwise to ignore the possibility. And finally, cyberspace is a hugely significant socio-economic technology that will change human culture significantly as we learn to use networked platforms for business, politics, communication and leisure. The whole of the impact of the internet so far is just a small part of the ultimate potential of cyberspace.

Cyberspace , I.Pearson et al

This is a paper about cyberspace. It is an overview of the main concepts and how they relate to the human and machine worlds, as well as the business and social significance.

CYBERSPACE - FROM ORDER TO CHAOS AND BACK

by
Ian Pearson, Michael Lyons, David Greenop

Abstract

Cyberspace is a new domain, overlaying the physical world with a bypass network that allows us to reconstruct many aspects of human activity without respect to geography. It is much more than just web sites and discussion rooms. It has a multitude of dimensions and trillions of potential variants. Because it allows us to do things in new ways, it will profoundly affect our business and social lives.

Companies and other institutions will be decomposed and recomposed, with new power structures. Many current institutions may not even exist when the re-composition is complete. Specialist roles will survive and thrive, while departments evaporate. Virtual companies will evolve through several distinct stages until many of them disappear into cyberspace completely. The new order will be more volatile, and empires will come and go with increasing regularity. New roles such as guides, facilitators and interfacers will be powerful components of the value chain, but today's value chain will be barely recognisable in the future.

There are many opportunities in cyberspace to make money, such as running knowledge guilds or organising people's lives. But enabling these opportunities will require a much faster network. ADSL will not suffice for long.

Businesses in the future that understand cyberspace well will co-ordinate and control much of the activity in the real world, and be able to reap high rewards. Their volatility will necessitate quickly capitalising on this before someone else with better insight or vision comes along.

Cyberspace will enable a much more efficient economy, but at the cost of us having to get used to very rapid change. Stability is not a characteristic that can be easily associated with the cyberspace world.

Introduction

Many people mistake the Internet for Cyberspace, whereas it is simply a network linking computers together. Cyberspace is actually that notional ‘space’ where transactions on the Internet take place. Cyberspace is a dynamic, developing concept. This article offers some introductory views of its current state and some indications of its future potential. Life experiences today are increasingly divided between the physical here and now and a ‘someplace else’ immanent in a virtual electronic space. The social, economic, and political lifelines of the world are now evolving almost exclusively within this electronic space. Here, for example, large corporate alliances busily co-ordinate their quest to balance efficiency, flexibility, and economies of scale. Here, data about consumer demand, production flows and finance is managed and shaped. Here is where our savings reside in bit form so that large banks and investment firms can fundamentally mould our lives. Here also is where the new activists reside, hidden from media view, in their invisible communities they plan and organise until their presence explodes into the physical world. This virtual world is thus a place in which we already live.

A telephone call can be thought of as simply a virtual meeting in Cyberspace. Likewise, virtual reality environments are commonly considered as Cyberspace. But Cyberspace is composed of far more than the much-hyped Internet or new virtual worlds. It is the total communications space that saturates our lives. It all adds up to an existential sprawl so vast and ubiquitous as to seem unmistakably ‘real’. Cyberspace is the information space of modern society. It pulses with blasts from the sophisticated production studios, satellite uplinks, digital delivery systems, and receivers of the global media. It is the society of the spectacular. The irony, of course, is that the more ‘wired’ we become as a society, the more dependent we grow on the mediating technology. Despite the steady hyperbole about how networked virtual worlds will render the mental landscape of our electronic culture uniquely visible, the essential point about the Internet is precisely its growing invisibility.

But its roots go deeper. Cyberspace refers to the emulation of physical space in electronic environments. As the Internet continues to grow, electronically mediated environments will expand and ‘physical place’ will become less important. Mathematicians use the term ‘space’ to describe complex systems.

In very complex systems, spaces acquire their own unique dynamics, as they require extremely high dimensions to be described.
Many complexity theorists describe Cyberspace as an emergent phenomenon whose properties transcend the sum of its component parts. Cyberspace is therefore a place outside physical space.

Part 1 - An introduction to cyberspace

In the beginning there was the physical universe. When intelligent life originated with the capability to internalize a representation of the physical universe, mental space came into existence,. When it became possible to electrically link together devices that were physically separated, cyberspace came into existence, the notional space where some kind of electronic transaction takes place. A telephone call is a meeting in cyberspace. Strict definitions might demand that some representation of the notional space must exist in the machines at either end, such as a VR environment, but this definition is unduly limiting when considering the potential of this new domain.

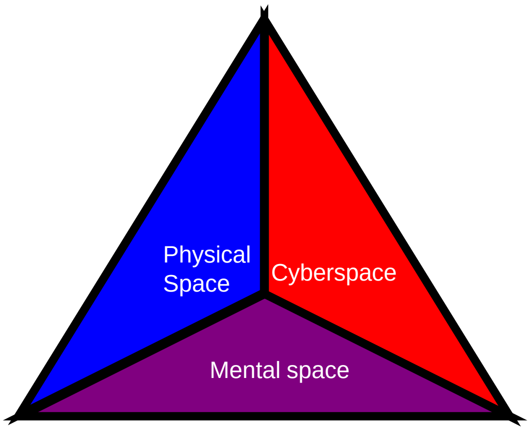

Figure 1 - Space domains

Much of the brain is dedicated to imaging the outside world, and then internalizing the information from those images. Our thinking is dominated by visual analogies, so cyberspace can introduce us to new ways of thinking in a networked world. But we only explore the tip of the iceberg in applying spatial analogies to networked systems. We will find many more opportunities when we can think outside the box.

In the physical world, geography dominates. In cyberspace, time and connectivity dominate. Geography has little importance in cyberspace.

Physical space

Of these spaces, we only understand physical space very well. It is governed by laws of physics and is highly geographical or time constrained. Shops and distribution outlets rely for their existence on the geographical limitations in the physical world. The inconvenience of distance makes direct buying from manufacturers difficult and creates a wholesale industry. Similarly, the physics of displaying many diverse products, in easy to compare ways, creates a retailing industry.

Mental space

We understand our own mental space quite well, but there is much we don't understand since our attention is normally outwardly directed. Understanding and trying to manipulate the minds of other people has been addressed by billions of person lifetimes of effort, still with limited success. However, there are of course many areas where we all agree. Human knowledge and culture are full of shared concepts. We agree on what to call a red ball, and share the concept of a filing cabinet. From time to time, a new concept is created by someone and spreads to other people's minds to become part of their mental space too. They take a lot of time to spread and often the original concepts are modified substantially as they spread, so that many people have slightly different views of the same space. This helps creativity and new ideas, in the same way as mutations spur on evolution, but interferes with and degrades the quality of communication.

Physical - mental mappings

Because of the significance of physical space, we each hold a mental picture of the geographic world, its various structures and behaviours. However, although our models need to be sufficiently similar to those of other people to allow exchange of information, they don't have to be identical. I might not have noticed a building or feature that forms a central part of someone else's model of a particular street.

We also conceptualize fictional entities. We imagine structures, and make them. Mental space includes many imaginary items. We use shared mechanisms for storing abstract knowledge, and build on these abstractions to develop and share more abstractions, such as higher mathematics or works of art. The foundations for human mental space growth are thus being continuously laid, but still mostly based on geographic thinking. But there are other limitations to inventiveness.

No one could have imagined most of today's technologies in the 10th century because even the basic building blocks for the concepts didn't exist then. Mental space grows from existing seeds, from recombining or modifying existing concepts or transferring and applying concepts from one area in a different area. Since today's historic institutions are designed for the geographic world, and because our minds are designed to cope with it, we find it very hard indeed to think freely about a world where geography doesn't have the same significance.

Cyberspace

Today's cyberspace is founded on physical and mental spaces. We already have cyberspace emulations of the physical world: shopping arcades, chat rooms, tourism, virtual cities, libraries, banks, magazines, newspapers. We have complex virtual environments where we can meet others. Our web sites are our little patch or place in cyberspace. Some of it is very physically oriented. We don't care that this information is in Australia, this picture in Sweden, and this chat room in the US. But in our imaginary meeting areas, it is as if we were still limited by real world physics. Spatial relationships are preserved and objects largely behave in everyday ways.

But the net also echoes our mental world. We see advertising, security and encryption, which have little physical world root. Also language translation, information processing, and a few abstract information representations or interfaces. But we are just beginning to scratch the surface. Just as we can have whole fields of human knowledge and culture that do not explicitly have any mapping onto the physical world, so we can have infinitely more in the cyberspace domain than mappings from physical space and from mental space.

Most of today's companies think the net means they just have to put up a decent web site, install an e-commerce capability and then continue as they are . They don't appreciate its full potential for change. The infinite potential of cyberspace will mostly have to wait for us to catch up. Nonetheless, in due course, machine intelligence will invent many of its own concepts and execute those, sharing with us or keeping them within the machine world. This is already happening with computer-based design, evolving software, artificial life and so on, but this is just the beginning of the flood. For now, we mostly map existing concepts, hoping for occasional flashes of inspiration and cross-fertilisation from other fields. Computer based intelligence and creativity is still too much in its infancy to contribute significantly. Cyber-creatures and other forms of computer generated life will come later.

Until we start the cyberspace reconstruction of our world in earnest, it is in the mapping of existing physical and mental entities and processes that much of the rewards will lie. Since cyberspace is relatively new, this mapping process is still in its early stages, and it is requiring a great deal of experimentation to discover which mappings are worth making and in exactly which form.

Characteristics of cyberspace?

Cyberspace is not just the computer's 'mental space', although this is certainly a large component of it. Some parts of cyberspace can still exist when the computer is off. It is a higher level construction, of which human and computer mental space are two important types of building blocks, but not the only ones.

It is spatially and temporally disjointed. When someone plays in a virtual world on an isolated machine, that virtual world is certainly part of cyberspace, but is not connected to any other part. By contrast, no part of the physical universe is completely isolated. Some parts of cyberspace spring in and out of existence when machines are switched on and off, or programmes activated or closed down. Links in time can be backwards or forwards. Normal physical laws of causality need not be observed, and processes need not be played out in physical time.
It is asymmetric. When the network is reconnected to the above machine, that part may be connected to the rest of cyberspace either uni or bidirectionally, so that the user may be able to see out with no one permitted to see in, or vice versa. Also, a select group of people may be able to see in, perhaps to different degrees. This is no different conceptually from someone allowing a group of people a key to their front door, or being able to go outside while not permitting anyone entry.

Appearances are not fixed. While we all might agree that a ball is red, a cyberspace entity might present itself differently to different viewers, in different conditions, or at different times. A virtual shopping arcade might be a cosmic landscape with floating shops staffed by weird aliens to one user, while being a conventional 1980s mall to someone else. Both could buy the same products, though perhaps in very different ways.

Physics is optional and customisable. There are no God-given rules as to how things should behave or interact, and there is no absolute requirement for consistency of behaviour. Imagination and skill are the only limits and variability of behaviour may be a desirable option.

The roles of time and space are reversed relative to the physical world. While space and distance are dominant in the physical world, time and delay are dominant in cyberspace, while space is irrelevant.

World	Physics	Presentation	Time Consistency	Blend	Immersion
Real	Real	Universal	Stable	Pure	Screen 2d
Rearranged	Textbook	Personal	Dynamic	Overlay	Screen 3d
Recorded	Customised	Group dependent	Cyclical	Substitution	Partial immersion
Customised	Sanitised	Role dependent	Variable	Mixed	Full immersion
Sanitised	Synthetic	Position dependent	Random		Full sensory immersion
Synthetic	Imaginary	Mixed	Mixed		Mixed
Representational	Variable				
Imaginary	Random				
Mixed	Mixed				

Navigation	Access	Control	Instance	Appearance	Driver	etc
Fly to	Closed	Read	Whole self	Realistic	Self	
Paths	Open	Write	Role	Substitutional	Proxy	
Regional	Hierarchical	Modify	Multiple	Cartoon	Agent	
Free	One way	Move	Lurker	Symbolic	Recorded	
Guided	Duplex	Add/Delete	Viewer dependent	Invisible	Learned	
Mixed	Mixed	Mixed	Variable	Multiple	Mixed	
			Mixed	Viewer dependent		
		Owner		Variable		
		Presenter		Mixed		
		Viewer				

Figure 2 - Cyberspace dimensions

Figure 2 shows the many degrees of freedom in cyberspace in many dimensions. Although this figure is by no means exhaustive, the numbers of permutations is already in the trillions. Most of these options will never be explored, even once, by anyone.

What use is it?

The main advantages of cyberspace are the absence or real world restrictions such as time and space, its potentially infinite extent, and the resultant scope for facilitating physical and mental business, social and personal processes that would otherwise be impossible because of the constraints of these two domains.

Cyberspace allows people to share a meeting even though they are geographically dispersed. It allows a limited form of telepresence, where a user can see or do things as if he were in a remote location. The only real limitation is that of course it doesn't allow for direct manipulation or transfer of atoms so the user has to rely on signalling to persons or machines to do this for him.

It allows conceptual entities and processes to interact freely independent of their physical location or manifestation. This is tremendously important as it means we are unconstrained by today's business and social structures. Companies that have evolved in the physical world may have no reason to exist in a cyberspace dominant world, and certainly we should challenge every aspect of our familiar world to see if there is a better way of achieving our goals.

Cyberspace - physical feedback

Although cyberspace is not directly linked to physical geography or building design, the behavioural characteristics of cyberspace may often be affected by the delay in the physical world, which is linked at least in part to geography.

Parts of cyberspace that have a larger delay between them will generally have a reduced range of capability. The large part of the increase in computer power so far has come from decreasing component size, resulting in decreasing path length, hence faster clock rates and execution of instructions. Increasing distances between components of a process, however it is caused, will reduce performance again. Obviously, networks have to cover large distances and nothing can yet be done to reduce transmission delay below that given by the speed of light, but even this limits the range over which applications can be usefully implemented. For some applications, anything other than execution on the same chip will introduce a significant drop in performance, whereas others will remain tolerant of delays in the regions of seconds or even minutes. Wherever we draw the line, there will be some markets to which we will not have access.

While there is much talk of increased teleworking for people, the latency problem may ensure that some processes remain in the office, and offices remain in the city. For stock market applications, information decreases in value extremely quickly, and just a microsecond difference will soon be significant. There would thus be a premium on gaining a site as close to the centre of information as possible. Possible approaches to this include charging for guaranteed rapid delivery, or charging for simultaneous delivery, or to own the best centre of information.

Part 2 - Institutional evolution in cyberspace

So cyberspace is different to the geographic world, and need not be constrained by geographic world thinking. Over the next decade or two we will see a massive deconstruction and reconstruction project as we make use of cyberspace to get the most out of our world. Existing companies put up web sites, and even today's entrepreneurs are often crippled by having been taught old world thinking, over the next few years, we will see a new generation leaving college with little prejudice about how systems should be organised. Having been brought up in an IT dominated world, they will look first to IT based solutions. They will be native cyberspace thinkers. They will have seen the turbulence caused by the internet and will not assume that the best way to build a system is in any way related to today's. While today we mainly see ongoing automation and some disintermediation, tomorrow we will see very different structures.

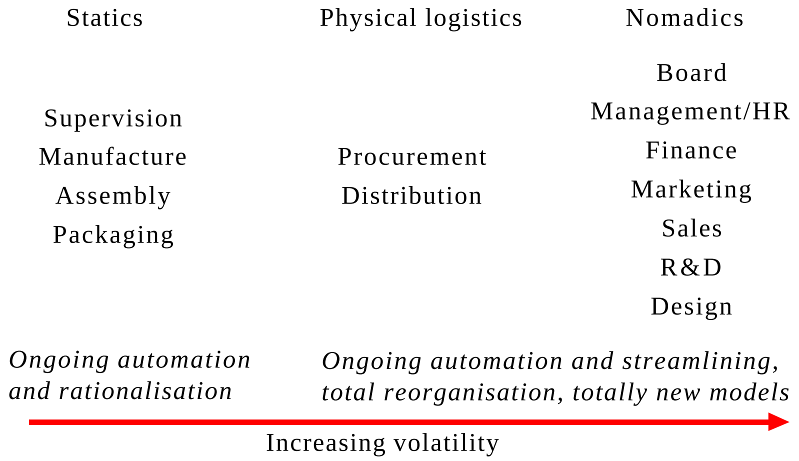

Figure 3 - Decomposition

So begins the decomposition phase of the internet. If we look at most companies today, we see a mixture of functions. Some of these have to take place in a particular factory or building or place. These are the statics. They are fairly immune to the impact of the net, since they cannot easily be uprooted and moved elsewhere. They will change slowly, as they do today. The actual manufacturing processes in an industrial company is a good example. However, the organisation of this, right down to organising the date for the machine tools, is not static. If we look at other functions such as procurement and distribution, they certainly have a geographic element, but they can be organised from anywhere. A truck has to drive along a road, but might get its route information from anywhere. The other processes in a company such as finance, personnel management, sales, R&D and so on, could be based anywhere. Decomposition will allow a complete disassembly of the functionality right across our business and society.

From now on, there is no reason for all these processes to exist in the same location. Outsourcing was the beginning of this process. The net will allow processes to be combined in optimal ways regardless of historic business structures.

Decomposition is of course accompanied by recomposition. We will still need most if the functionality of today's systems, it's just that they will be organised differently. It is likely that statics will remain mainly as they are today, though we will of course see more of the ongoing processes of automation and collaborative manufacturing.

The logistics side of businesses will be revolutionised. With a mature and ubiquitous e-commerce/e-business infrastructure, organisational units and processes will mostly have standard interfaces. Super-efficient logistics companies will organise processes on a global scale for millions of businesses. They will be the best of class, and we won't need very many of them. Wholesaling and retailing exist today because most manufacturers don't have the means to organise delivery to the individual customer. In a cyberspace world, this will be organised by a remote logistics company. Customers will decide what they want and the logistics company will find or organise its manufacture, collection and delivery.

This will rely on many physical distribution and storage providers, but their selection and co-ordination can reside anywhere.

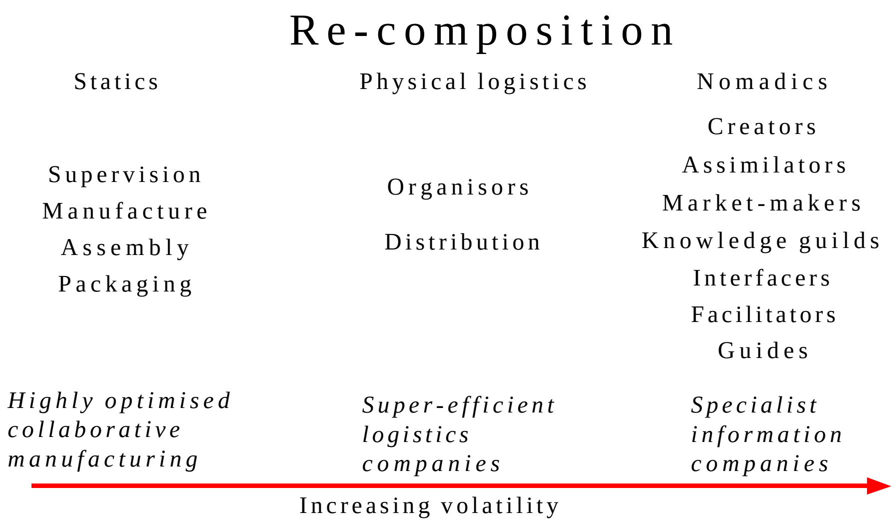

Figure 4 - Recomposition

But most of the departments in today's companies might just disappear into history, or change beyond recognition. Many of the administrators just aren't needed in a cyberspace dominated world with masses of machine intelligence in the background. E-commerce will produce easily traceable audit trails, and statistics by the database-load. It will be able to arrange and record most things automatically. We will need very few accountants or auditors, very few managers and very few clerks. Almost of all of their roles can be automated. Most sales will be arranged between agents, and the organisation of the system needs far fewer points of sale in any case. Managing personnel in such a world can be very lightweight too. Not because they will be any more pliant, but because most of us will work on short term contracts on particular projects, freelance. People with appropriate skills will log them in e-commerce databases, and they will be contracted when an appropriate job needs to be done for which they are suited. Of course, their 'suitability' includes a host of factors. Even the board is not guaranteed survival. People will lend money on the net according to various parameters. Loss adjusters, risk assessors and so on will help this process. Virtual companies will spring up using this capital pool, and managers will be employed on the same virtual company basis as any other staff to implement or oversee the implementation of the system.

So the virtual company, or virtual co-operative has no need for a department of permanent accountants. If and when the virtual company needs some finance function that can't be fulfilled automatically, an accountant will be contracted to provide it.
We might of course have some companies that specialise in those particular skills, and they may link to many virtual companies. We could see specialist marketing companies, assimilators, interfacers and so on. Even functions such as R&D may be more commonly arranged as separate entities than being full time parts of a specific company. It is very rare indeed that the fruits of research are appropriate to only one company, and the net allows the results to be marketed for maximum reward.

But we might see an alternative structure - the knowledge guild. The guild simply guarantees the quality of the workmanship of its members. Members get work. These might evolve from today's guilds and professional institutions, but will be much more powerful, because they will be global, with all the advantages of a network community (see future power structures). Apart from the guilds, we will see a great many genuine individuals, whose specific skills or attributes guarantee them a privileged position in the new order. The guilds will be for the new middle classes, while the elite will be those with rare or unique skills.

Volatility

As we move from statics to nomadics, we see increasing volatility. The share prices we see today for many internet companies are much too high because they are very volatile. Yahoo may be doing very well today, but if a trendier site appears tomorrow, they could lose market share very quickly indeed. Their company is probably worth a tiny fraction of its current valuation, and the same could be said of many others. They are only as good as their next front-end revamp. The real value is in creating an appropriate market image and keeping up with fashion. Their existence depends also on the nature of the browser. If it were replaced by a cyberspace browser with a 3D mall style interface, they might disappear in to oblivion if they couldn't adapt fast enough. Their volatility is very high. The cyberspace world will be very dynamic. Empires will rise and fall with great regularity.

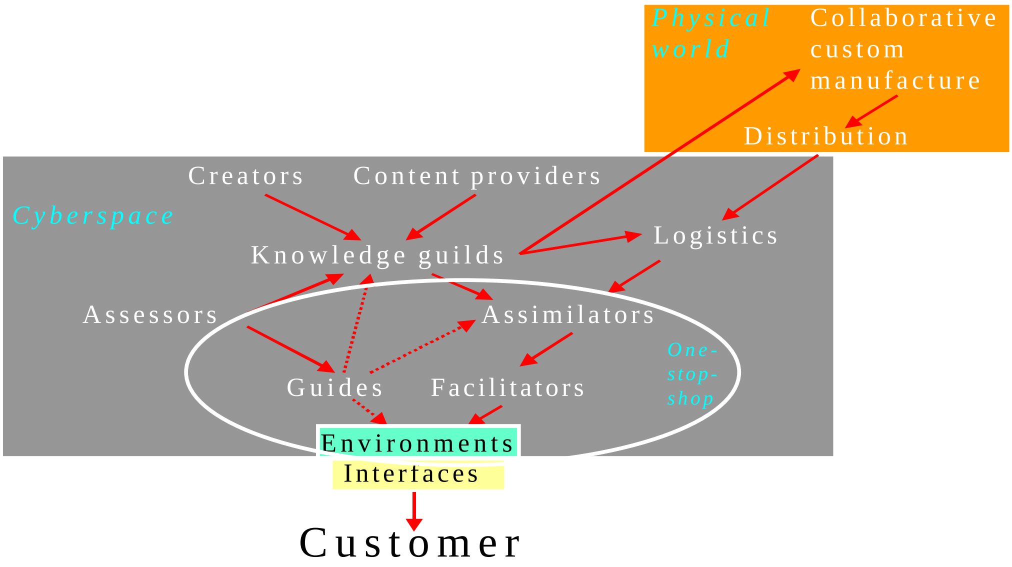

Figure 5 - Cyberspace value chain

The value chain in cyberspace will evolve too. Customers will have a wide choice of interfaces through which they enter cyberspace - whether mobile communicator, 3D booth, interactive TV or a computer screen or whatever. Providing a wide range of usable interfaces to cyberspace functionality will be big business. The interface will take the user into some sort of personal cyberspace environment, which could be anything from a simple list on a cellphone to a fully 3D virtual reality space. Translating a multiplicity of forms of internet data into a wide variety of personalised interfaces will keep interfacers very busy indeed.

The internet already has a huge amount of functionality and it is rarely obvious which is the best site to go to or the best product to pick. Guides will therefore play a very important role, as will facilitators, who will help users do what they want.

Assimilators will bring together the functionality that the user wants. Today we have portals that do some of this, but really, with increasing complexity in everyday life, users will want a one stop shop that offers to unload from them all the hassle of organising their everyday lives. Quite simply, the one stop shop will manage just about everything for the user - diary, appointments, social life, business life, home management, contacts, finance, shopping around, buying, booking, getting information, news and providing chat, entertainment, travel, hiring - the list goes on and on. This will be the future of the portals. But they will look nothing like Portals or the personalised services we have today.

Outside of this customised personal cyberspace, knowledge creators, guilds and quality assessors will provide service to the one-stop-shop. Logistics providers will organise acquisition of goods and services that the user buys, including of course collaborative custom manufacturing and its distribution.

What we won't need

It is clear that many of today's institutions are unnecessary in such a world, where an almost optimal system will provide our every need at minimum cost. Shops may become try-on outlets as people go there simply to try clothes on before buying direct from a customised manufacturer in exactly their size. Even today's e-tailers are just old world shops in new world clothing, as are the vast majority of corporate web sites, trying to keep obsolete companies hanging on in a world that doesn't need them. Most will vanish as cyberspace thinking makes them redundant. We won't need banks, building societies or insurance companies, just the risk assessment and loss adjustment that they provide. With digitised cash that can be stored in secure databases enabled only by digital signatures, our computers can manage our cash easily, buying and selling it, calling in appropriate services as necessary.

And best of all, we won't need mountains of admin. With globally standardised processes and interfaces, and with all our data electronic, almost all of it will be automated.

Part 3 - Personal cyberspace

Most people will have their own little patch of cyberspace, even if it amounts to no more than an answerphone message. Usually, they will interface with the rest of the net via their own area. They may maintain many zones with a variety of privacy attributes, echoing the range of different roles that the personal plays. Some will be completely personal and secure, other shared with family or with close friends, others with business colleagues or members of a club. Users will be shielded from the cacophony of information noise by a multiplicity of smart filters and translators.

But people like to talk more than to listen and we can expect people to want to make their mark by transmitting into cyberspace as well as receiving from it. This ego-echo will challenge the assumption that lines to people's homes should be asymmetric with more data travelling to the home than from it. It may be the other way round!

Their personal area would appear differently to other people depending on who they are, where they are, and when they are looking, as well as on that viewer's personal interface characteristics.

Personal cybespaces will interact with each other and of course we will have group cyberspaces too.

Remaining opportunities
In spite of the large number of internet start-ups hitting the headlines every week, there are still many opportunities left. Here are just a few:

? Some of those identified above - the one stop shop, guides, facilitators, organisers and assimilators are largely untapped today.
? Knowledge guilds exist but are using the wrong models so far
? Historic quality guarantors exist but aren't well developed on the net, yet the net can never achieve its full potential as a reliable information source without them.
? Lifestyle management is completely green field today but will be an essential component of our lives in a decade.
? Competent proactive search engines have been on the horizon for years but still haven't happened. Push technology is a failed attempt in this direction.
? Providing interfaces that maximise what can be achieved through a thin medium such as portable communicators will be very lucrative
? Building and renting visual cyberspace environments exists and is developing well. However, there are huge associated markets in tools and assistance
? Putting customers in touch with the best customised manufacturers is an obvious application, but is almost invisible. Today's net models are still almost all minor adaptations of conventional retailing
? Provision of standard business procedures and interfaces is developing but there is still no easy way of automatically linking existing resources and facilities together into virtual businesses. There will be.
? Supporting this will be huge resource databases, again almost non-existent today
? Identifying niches could be done almost on the fly by the e-commerce environment. It would be fairly easy to spot areas where local distribution is a problem for instance
? Telework centres, where people can work for virtual companies from a nearby hot desk instead of trying to work from home. They barely exist, and the few that do often use the wrong models
? Trust based distribution - someone has to provide the function of delivering at a convenient time, instead of expecting householders to stay at home waiting for delivery.

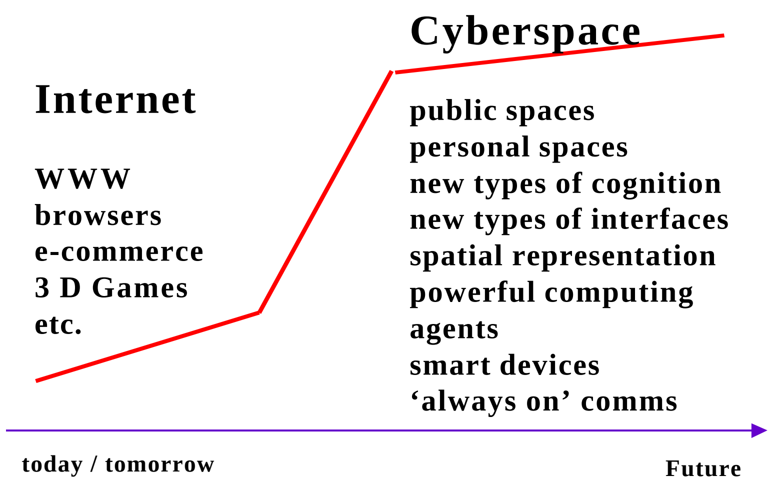

Figure 6 - Evolving opportunities

Part 4 - Engineering cyberspace

The internet is not a global superhighway. It is a machete-hacked footpath through the information rain forest. The following table explains part of the reason, based on a user with a high end PC, using the highest speed domestic access.

	1981	1986	1991	1996	2001
RAM	32 k	500 k	8 M	64 M	640 M
computer speed	0.1 MIPS	0.5 MIPS	8 MIPS	200 MIPS	3000 MIPS
aggregate file volume	256 k	2 M	80 M	2 G	100 - 200 G
terminal access rate	-	10 Mbit/s	10 Mbit/s	10 Mbit/s	32 Mbit/s
file volume / LAN speed	-	1.6 s	64 s	0.44 hr	13.9 hr
Telco line rate	-	2.4 kb/s	9.6 kb/s	28.8 kb/s	1 Mb/s
file volume / access rate	-	1.8 hr	18 hr	154 hr	444 hr

Table 1 - Relative network bottleneck

The bottom line clearly shows that computer performance is racing ahead of network capability, so the network is getting relatively worse. Although the technology to transmit tens of megabits per second to the home over optical fibre has existed for a decade, the access network of tomorrow will be even more of a bottleneck than it is today. While we continue to delay the deployment of fibre to the home, with low cost and high bandwidth, cyberspace and its boundless potential will remain embryonic. Simple substitution arguments would suggest that not only is a high speed fibre based network economic, but would pay for itself in a very short time. Meanwhile, huge revenue opportunities remain unexploited.

Today, people access the net via an internet service provider. Tomorrow, the network will be IP based so any computer or communicator will be able to access the internet directly. ISPs will have no reason to exist. Some may survive as portals or one-stop-shops.

Asymmetry might be the reverse of the assumption underlying ADSL. People running their own cyberspace presence from home may need more upstream bandwidth than downstream. The network will have to cope with this.

Privacy and security will be important factors. We cannot expect each individual to be an IT expert, so the infrastructure will need to provide simple means of guaranteeing these hygiene factors.

Finally, mobility will be important. UMTS will allow people to access the internet at relatively high rates within a few years. As people become accustomed to always being in touch with the internet, they will depend more and more on it. Being in an area with a poor signal today is annoying, tomorrow it will be intolerable. Providing truly ubiquitous access will be an essential characteristic for mobile networks that wish to survive.

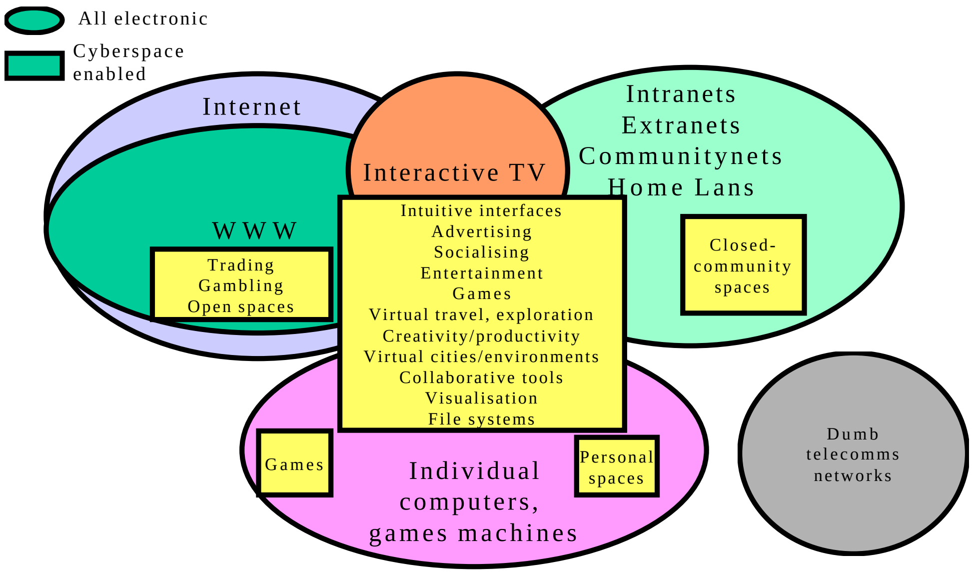

Figure 7 - Cyberspace markets

Colonising Cyberspace - developing a new economy

In a companion paper in this issue[29] an economic view of the information economy was presented. In this section, a more speculative view is taken, which draws on biological metaphors. In contrast to mainstream economics which sees the world essentially at equilibrium, biological metaphors see the economy as a system far from equilibrium and in constant change. A static view of economic and commercial systems is transformed into one which is characterised by evolution.

The two themes of this section are:

Commercial change is driven by the interplay of new business opportunities with the physical, mental and cyber spaces.

[29] M H Lyons, *Information, Networks and Economics*

Cyberspace is relatively undeveloped compared with physical and mental space, and can be pictured as a new territory to be colonised by new species. At present it is empty; over time it will develop a rich 'ecology' of novel organisations and institutions which will interact to form a cybereconomy.

Commercial change

Although assumed almost a right, the causes of economic growth are far from understood. Growth in labour and capital are only responsible for a small fraction of total economic growth. Technological progress is a key factor, but is estimated to be responsible for only 20-50% of total growth. The economist Paul Romer suggests that 'Economic growth occurs whenever people take resources and rearrange them in ways that are more valuable.'[30]
He points out that number of ways resources can be arranged are multiplicative, not additive. Thus, in a simple model where there are N resource, each of which may be used or not to from a new economic good, the number of possible combinations is 2N. Of course, not all combinations will make commercial sense, and there is more to a product than simply 'mixing ingredients', but the message is clear: the more technology develops, the greater the number of goods which can be combined with existing goods to provide an explosion of new possibilities.

Marketeers emphasise the need to meet customer needs. But customer needs are not a constant. True, there are some basic needs: food, water, shelter etc. which must be met. But the vast majority of goods and services offered in the marketplace have little to do with meeting these basic needs. There is a constant interplay between the products and services which are created and marketed in the physical space and the needs they meet in the mental space. New products create new needs. For example, the Sony Walkman is a classic example of a new product which created an unrecognised (and probably non-existent) 'need'. In the future, Rolf Jensen has suggested we will live in a 'Dream Society' in which successful products are those which appeal to people's emotional needs and aspirations[31].

We have, therefore, two spaces - physical and mental, in which products and wants are co-evolving. Cyberspace opens up a third space which can interact with the others. Cyberspace changes the way we interact with each other, and the way we can interact with the physical world. As new ideas are developed in cyberspace, they can create new consumer wants in the mental space, and also interact with the physical space to create a vast new range of possible hybrid products and services, which in turn create new needs in consumers and yet more product ideas. Because the possibilities are so vast, it is impossible to predict all the products which may be developed, or which will be successful. All we can be certain of is that the range of possibilities is increasing all the time.

In the long run, the stream of new product opportunities will ensure continuing economic growth. But cyberspace may also increase the rate of growth. Because there is no geography, a new product can be marketed world wide in seconds. Ideas spread more rapidly and as more people are connected to cyberspace, both the number of ideas for new products will increase, and the rate at which these are generated.

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[30] P M Romer *Economic Growth.* The Fortune Encyclopedia of Economics, David R. Henderson (ed.) Copyright, Warner Books.
[31] R Jensen (1999) *The Dream Society.*

Developing the CyberEconomy

Isolated volcanic islands, such as Hawaii or the Galapagos Island, started as barren rocks, yet they now support rich ecological systems, with many unique plants and animals. In the beginning, animals and plants arrived by chance from other, existing ecologies. But over time these species evolved in their own unique way, to form species found nowhere else.

Such a picture is an analogy to what is happening in cyberspace. At present, ideas and concepts are being migrated from our existing physical and mental spaces, to cyberspace. Many of the ideas being tried out in cyberspace are deliberately modelled on physical space equivalents. Thus we have seen cyberspace 'shopping malls' and electronic chat 'rooms'. Many of the new business developed on the internet are exploiting the possibilities of cyberspace to reduce transaction costs, in order to market and distribute goods in the physical world. In other words, the initial businesses in cyberspace are derived from and supported by the physical space or 'real' economy. Some parts of this economy have, in reality, already moved to cyberspace.
Money is no longer a physical commodity (such as gold) but information stored in computers around the world. Similarly, the trade in stocks and shares is primarily one which occurs in cyberspace. And as more people become involved in cyberspace, so direct trading in these instruments ceases to be the preserve of specialists, but open to everyone.

At present, the activities which generate money are largely supported by activities in the physical world. By and large money flows through cyberspace, but is not generated in cyberspace. But as more cyber-businesses are created, then increasingly money will be generated by economic activity occurring solely within cyberspace. These businesses will explore more of the commercial possibilities offered by cyberspace. In addition, the development of these businesses will change peoples desires and expectations. These changes will in turn alter the commercial environment of individual businesses. A new business will start and grow by serving a niche market. As it grows it will change its commercial environment: some firms will continue to do good business in a specific niche. Others will grow to dominate particular sectors, but many will decline and fail.

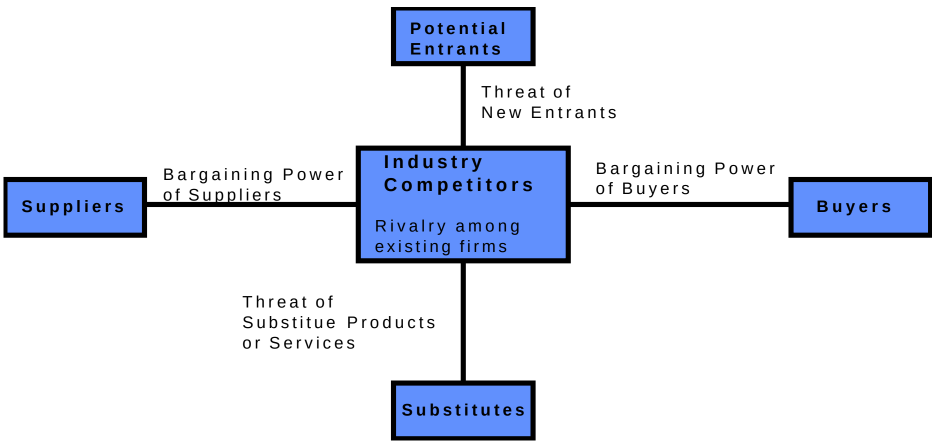

Figure 8 - Porter Five Forces Model

Change is characteristic of all life. But in the natural world, evolution does not occur at a constant rate. There are periods when the ecology is relatively stable, and evolutionary change is slow. At other times, evolution is very rapid, with many species developing and declining over a short period of time. In many cases, these burst of activity have occurred after a mass extinction event, when many new niches suddenly become open and are waiting to be filled. The emergence of cyberspace is a new business world in which many new forms of business may evolve. Some, if not all of these, will also affect the way businesses in the physical world operate. Fig. 8 shows Michael Porter's model of the strategic forces which can affect a company's growth and which have to be taken into account in developing a strategy. Underpinning this strategic approach is the assumption that the forces do not change too rapidly. If the substitute products arise, buyers needs and power change, or new entrants can emerge at a faster rate than strategies can be implemented, then strategic planning no longer has meaning. In cyberspace, the strategic landscape is changing all the time. New players and new business ideas will be emerging constantly. Rather than thinking of corporations planning for the future, it is better to think of new business ideas as a search mechanism, where the search is for a viable business niche. But because so many new ideas are being developed and will be developed in the near future, no company can be certain of its commercial environment, even in the short-term. If companies are to succeed in the long-term they will need to be constantly innovating. As the cyber-economy becomes larger, some areas will start to stabilize. At present, all cyberspace is frontier. But eventually, more permanent business forms will emerge and the frontier will move to new areas of human and business need. As the environment becomes more stable, the focus of companies will alter. Instead of a focus on change and constant innovation, there will be greater emphasis on efficiency and cost reduction.

However, change is always a threat. Even in the physical world the average life of a company is around 25 years. As de Guess[32] points out, those companies which have histories of a hundred years or more have survived by radically changing their core business over time. They often set up small subsidiaries in new business areas. Some will fail, some will be sold off, but one or two may grow to become the company's new core business. In cyberspace, change will always occur more rapidly, as there are no fixed assets which have to be depreciated or sold off. All businesses will have to develop structures which will not only enable and encourage innovation, but also nurture that innovation to the stage where it is a viable business.

Because there are no physical assets in cyberspace, it is easy and quick to set up new businesses. This fact, coupled with the primacy of innovation in maintaining competitive advantage, means there will a shift in power away from owners of physical capital, towards those who possess the intellectual capital. The trend, especially in the US, towards paying people by stock options may, at present, be driven by financial considerations but in the long term it is reflecting the reality that the true owners of a cyber-company are its employees.

[32] Arie de Guess (1997) *The Living Company.* Harvard Business School Press, Boston, Mass.

If one source of power is the intellectual capabilities of individuals, another source derives from the ability or inability of individuals to navigate through cyberspace. Although there is no geography in cyberspace, in the sense that there are no fixed relationships between entities, all who inhabit cyberspace will need to navigate within it, to access information, services and other inhabitants. Because there are no fixed relationships, each inhabitant will develop their own geography. In one sense, this gives considerable freedom to individuals. Because there will be so many routes to any entity (piece of information, service etc) it will be impossible for a government, or even a single cyberspace authority, to control what is accessed. If it's in cyberspace, then anyone can access, duplicate and publish it.

However, if access is uncontrollable, search isn't. The very size of cyberspace means that a considerable power will reside in the portals and search engines people will use to explore. Already, marketeers are recognizing that in the future, the key problem will not be getting you message across, but gaining enough attention form people to even tell them your message. And as more information is thrust at people, so they become more adept at ignoring that which does not grab their attention. For a new and struggling company, then, the most difficult problem will be highlighting your existence to your potential customers. Those who control the portals have the ability to determine whether or not most of your potential customers will ever know of your existence, and in the rapidly evolving cybereconomy 'word of mouth' will, in most cases, just be too slow. In this world, branding will also be important. A brand won't be a product, but an assurance of quality for a wide range of products and services (rather as Virgin is attempting to be). But brands may not just be owned by large corporations. Groups of small companies could group together under a common brand (rather like Best Western in the hotel industry). Such groupings would not just guarantee quality and possibly provide navigating/portal facilities to potential customers, but would provide also actively market their members and provide a route for new entrepreneurs, once they had satisified the membership requirements, to enter into the cybereconomy. Here we have the economic equivalent of the herd.

As the cybereconomy develops, change will become ever faster. In this world, the way in which many present businesses currently work can only lead to failure. There will be no time for business cases. Businesses will be forced to recognize that the only advantage is first-mover advantage. They will constantly launch new products, and be forced to accept that only a few will succeed (rather like a film studio or publisher). Successful companies will be those who can manage the innovation process – exploiting the successful ideas, and controlling the costs of the failed projects. There will not be time to plan – since the world will change too rapidly. A company like 3M, which has a policy that 30% of its revenues should come from products less than 4 years old, will be the norm. Indeed, the 4-year timescale will seem hopelessly pedestrian. Truly, in this world 'In delay there lies no plenty'. Where only the innovative survive, companies will be forced to recognise that those who can develop and implement new ideas, or can sense what consumers will want next, are not just their most important assets, but their only assets.

At present, our pictures of cyberspace are heavily influenced by the physical world. However, as we spend more time in cyberspace, so will our mental constructs evolve and in time influence the way we think about our mental world and the physical world around us.

Conclusions

Unlike the natural world, humans devised Cyberspace. Whereas nature is found, Cyberspace and its properties are constructed for human use. Therefore we have to think in terms of 'engineering' Cyberspace in the same way we engineer other complex human artefacts.
Until recently Cyberspace has been devoted to the relay of text, numerical information, graphics and simple video. But electronic spatial environments themselves will increasingly become subjects for design. A fundamental feature of Cyberspace is its inter-disciplinary nature. Cyberspace is particularly rich in artistic content and in many ways has more affinity with media subjects than engineering ones.
The development of portals serves as a good example of this feature. Portals may be conceptualised as environments within Cyberspace. If portals were merely text-driven spaces then their popularity would be limited. They are, in fact, becoming multimedia-rich design zones. We have to re-think our design parameters for such environments and the ways in which we link them to the underlying software and communication architectures.
In Cyberspace nothing is given. The spatial experience is a conscious choice and requires an investment of effort and resources. The strategies for these spaces require us to determine their content as well as their containing spaces in much the same way as architects are aware of the ergonomics of people and movement when designing terrestrial buildings.
Cyberspace offers designers no such certainties. Users may occupy several spaces simultaneously. Many alternatives are available to users of these spaces, and designers must anticipate each choice, constructing the experience for consistency and grace. Furthermore, this design must be coherent from one space to the next and from one state to another. This might require designers to think like the director of a film, unifying content, movement and transition through careful design. Similarly, the architecture of Cyberspace is more like the space of our dreams, where our environment is complicit with us anticipating our actions and responding to our states of mind.
Conventional architecture of the physical world can only provide passive amenities. Architecture of Cyberspace is a dynamic, changing environment that if well conceived attends us in everything we do. Cyberspace has to reflect the intrinsically human quality of space, its role in thought, communication and identity. Through its perceptual and cognitive realms Cyberspace extends us beyond ourselves to others. This is the potential strength of Cyberspace - that it will allow us to integrate within a single architecture personal, social, economic and political considerations as well as technical ones.

About the Authors

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Ian joined BT Laboratories in 1985, and has worked in a number of diverse areas since. Since 1992, he has worked on mapping the progress of new developments throughout information technology, considering both their technological and social implications. Ian currently works as BT's futurologist in C2G, BT's new Communications Consultancy Group. He was awarded the Best Paper award at the 1993 FITCE Conference for his first externally published paper and has since received six other awards for published papers, including the IEEE Benefactors Premium in 1994 and the IBTE Journal Best Paper Award in 1996 .
http://www.labs.bt.com/people/pearsonid
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Michael currently leads ACE's Business Modelling Group working on economic and business models of the future telecommunications industry. The group's work includes research into regulatory issues, industry structure and future service demand, as well as the development of computer simulation techniques. Michael has also worked on a number of strategic studies for EURESCOM, looking at the future development of the Information Society, and has a particular interest in the new economic and business models which are emerging. Michael Lyons has over 20 years experience of telecommunications research, which has included device development for optical communications systems, and studies in the areas of display technologies and the environmental impact of telecommunications.

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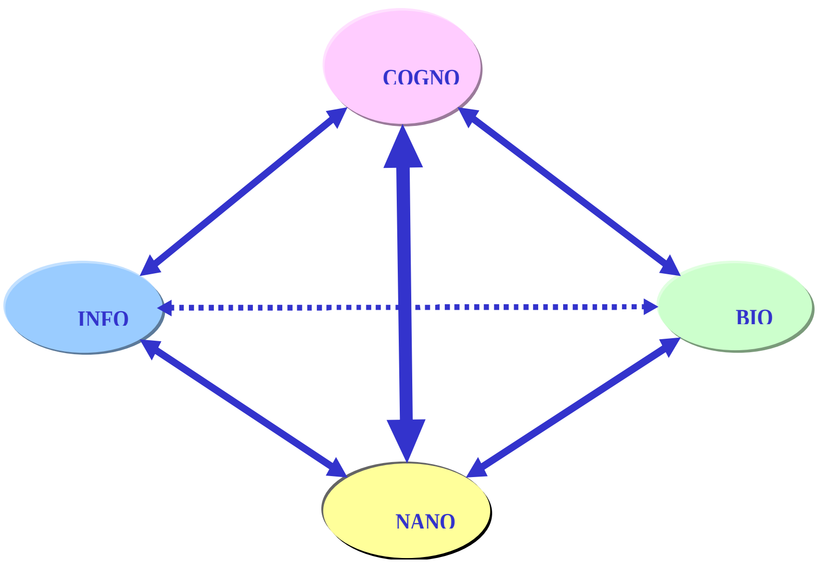
David recently left BT after working for a number of years on a wide range of strategic and technical issues. Within BT he helped develop BTs future network and technology visions. He has made contributions to many other organisations including carrying out forward-looking studies at EURESCOM. He is now an independent consultant and is a Senior Research Fellow with the Telecommunication Department at University College London. He has special interests in the future developments of human centred communications and the multidisciplinary development of cyberspace.

AMBI and the NBIC Tetrahedron NBIC Tetrahedron

Arguably, the workshop organised on 1-2 December has been missing inputs from science and technology. It is difficult to build the higher floors of the building: social concerns, ethics…, without having built first solid foundation and anchorage with the foresight of what could really become feasible in converging technologies within a 10-20 year time horizon, and what could not. For instance as was explained by one participant, the US "21st Century Nanotechnology Bill" assumes that self-replicating nano-scale machines and devices are already feasible, whereas the UK Royal Society Report on nanotechnologies strongly disagrees with this statement.

The definition of nanotechnologies itself is not clear enough. Specifying that they are structures on a nano-meter scale is not enough; a relation with complex system theory or self-organization is needed.

Therefore, it might be interesting as a mind-clarifying tool to represent what the applications of the converging technologies might be in a "NBIC tetrahedron". This tool was suggested in the NSF report page 2 [Roco Bainbridge 2002].



An element on a summit would include technologies from one technological field (info, bio, nano, cogno), on a line from two fields, on a face from three and in the volume from the four.

As an illustration, "e-health" or "bio-informatics" could be on the line [INFO – BIO].
All the developments of nano-optoelectronics leading to an increase in computing performances would be on the line [INFO – NANO].
On the line [INFO – COGNO] one could find:
Artificial Intelligence (neuronal networks, genetics computing) [Bibel 2004];
Ambient Intelligence (intelligence and intuitive interfaces, [Friedewald Da Costa 2003];
Models of the brain processes;
Brain / machines interfaces;
On the line [BIO – NANO] would be the self-building or self-replicating artefacts.
On the line [BIO – COGNO] would be the new drugs modifying the brain processes or the progresses towards understanding the brain functioning.
The surface [INFO – BIO – NANO] would include the nano-robots for diagnosis and chirurgical applications.
The surface [INFO – BIO – COGNO] would include "Ambient Healthcare" defined as the convergence between Ambient Intelligence [INFO – COGNO] and e-health [INFO – BIO] see [e-health 2003].

Ambient Intelligence

"Ambient Intelligence" (AmI) refers to a vision of the future information society stemming from the convergence of ubiquitous computing, ubiquitous communication and intelligent user-friendly interfaces as envisaged in the ISTAG-Scenarios of Ambient Intelligence in 2010 [Ducatel 2001] [Friedewald, Da Costa 2003]. It puts the emphasis on user-friendliness, user-empowerment and support for human interactions.

Information and Communication Technologies-based artefacts and computers would fade into the background. People would be surrounded by intelligent and intuitive interfaces embedded in all kinds of objects. The environment would recognise individuals and their needs and wants, as well as changes in the individuals, needs, wants, or environment. It would respond in a seamless, unobtrusive and often invisible way, nevertheless remaining under the control of humans. Intelligent agents would eventually make decisions that automatically serve a person or notify a person of a need to make a decision or to carry out an action.

In short, computers would conform to and serve the needs of humans rather than require people to conform to computers by learning specific skills and performing lengthy tasks. Interactions between humans and computers would become relaxing and enjoyable without steep learning curves.

The vision of "Ambient Intelligence" as being developed in the ISTAG report is far-reaching and assumes a paradigm shift in computing from machine-centred towards human-centred computing. It argues for placing the user at the centre of future development. Technologies should be designed for people rather than making people adapt to technologies.

Arguably, the AmI vision encompasses the convergence between ICT and cognition. Making the technological artefacts easier to use require a deep understanding of how human interact with them.

References

Bibel, W., “IT and AI in View of Convergent Technology”, draft version 0.1, January 2004.
e-health in 2010: “Meeting the Lisbon objectives with Ambient Intelligence Technologies?”, workshop organised by the IPTS ICT Unit in collaboration with the IPTS SERA Unit, 1-2 December 2003.
Friedewald, M., Da Costa, O., (eds), (2003), “AmI@Life – Science and Technology Roadmapping Ambient Intelligence in Everyday Life, Working Document”, http://esto.jrc.es/docs/AmIReportFinal.pdf
M.C. Roco, W.S. Sims Bainbridge (eds), “Converging Technologies for Improving Human Performance, Nano-, Bio-, Info- Technology and Cognitive Science”, National Science Foundation, 2002.

ICT and Enlargement

Context

On the 1st of May 2004, 10 Eastern and Mediterranean countries will join the European Union. To prepare this major event, the Enlargement Project has been running in the Institute for Prospective Technological Studies (European Commission, DG Joint Research Centre) since 1999. It has being aiming at improving the level of information about the Candidate Countries in the European Commission and to strengthen co-operative activities between the EU Member States and the Candidate Countries as well as among themselves. One line of work was to examine the situation regarding new ICT within these countries. A summary report will be available within the next two months and will be transmitted to the members of the group who express their interest. An international conference will take place later in 2004. In advance, Marc Bogdanowicz (M.Bogdanowicz@jrc.es) kindly agreed to summarize some of the main issues. I have also drawn information from a draft document written by Prof. Pal Gaspar (ICEG EC – Hungary).

Present Situation

One important fact to take into account is that advanced technologies have been considered in most of these countries more as a joker than as a priority. More striking urgencies, such as the legacies of agriculture, mines, steel industry, as well as vast structural reforms related to the transition and/or the Accession have been calling for the attention of the policy makers. Some of these countries suffer from political and/or economic instabilities: high foreign debts, large budget deficits, high vulnerabilities to the situation in Russia or in the Balkans. For instance, essential shares of the three Baltic country exports as well as some important sectors of their economy still rely on trade with Russia (Lithuanian refined oil products are indirectly under the control of a Russian major oil company).

Moreover, it may be argued that the dedication of the governments to support research, development and manufacturing in the ICT field during the last decade has been irregular. For instance, the e-Europe and e-Europe+ plans have quickly been adopted but have only been slowly implemented.
As a result one can argue that research on ICT in acceding and candidate countries is marginal; manufacturing of ICT remains weak, whereas the use of ICT is increasing.

Manufacturing

ICT manufacturing is mostly realized by large multinational companies such as IBM, Siemens, Philips, Mitsubishi or Elcotec (strongly linked to Nokia). Most of the manufacturing is relatively low-added value, such as consumer electronics, mobile phone or flat screen assembling. Poland, Rumania and Turkey have manufacturing capabilities which are important in absolute value, but remain low in relative term. Hungary, the Czech Republic, Estonia, Slovenia and Malta have succeeded in attracting consequent manufacturing capabilities comparing to their total industrial output by providing extremely interesting economic incentives during the late 1990s.

The competitiveness of the acceding countries is without doubt largely based on their lower wages and their relatively highly-skilled workforce. Such wage-based competition might not be sustainable in the long term, as one of the main expectations of the accession to the EU is precisely to increase the standard of living (convergence effect). For instance, after important investments in Hungary, Czech Republic and Estonia in the late 1990s, companies such as IBM, Philips, Mitsubishi or Elcotec have recently delocalised important parts of their manufacturing capabilities in China.

Use

Concerning the use of ICT, the Foreign Direct Investments (FDI) have also been playing an important role in accompanying the very rapid growth of services in all the 13 acceding and candidate countries. Multinational companies have bought privatized companies or created local subsidiaries. The sectors of telecommunication, banking, wholesale and retail selling represent an important share of ICT use. It is interesting to note that recent macroeconomic studies seem to confirm that ICT use in non-ICT production sectors has a much stronger impact on growth in these developing economies than in advanced ones. Such results are an essential encouragement for those defending the benefits of the Information Society for development.

Within the private households, the use of ICT follows the growth of the household incomes. One has to keep in mind that the average GDP per capita in the 10 acceding countries is about 40% the average GDP per capita of the 15 Member States, and that the use of ICT is lower in a similar proportion.

Future Perspectives

The open question is whether the acceding countries will be able to catch with EU 15 in terms of ICT production and use.
Now that the most difficult phase of the transition to the market economy is completed and that the accession to EU is secure, the upcoming competitive pressure raises the government awareness in these countries about the importance of innovation, investment in R&D and the necessity to further modernise their economies.

Manufacturing

The medium-term future of ICT manufacturing in acceding countries seems to be relatively predictable, save major disturbing events, and is likely to resemble the linear extrapolation from the present situation.
The accession to EU should consolidate the political and legal stability, thereby rising the attractiveness of these countries for global production facilities, if they could at least partially maintain their advantages in terms of lower wages, rapidly-growing productivity (from a much mower level than that of advanced economies) and therefore much higher return on investments than compared in the current Member States.

The accession will enable a more vivid flow of work force and capital to circulate, not only between the large multinational companies, but also at the level of the small and medium-size enterprises. Even if important flux of FDI has already been incorporated during the privatization process, full membership in the Single Market is expected to be an important driver for the continuous growth of FDI in ICT manufacturing and services within these countries. FDI in manufacturing could broaden the base of ICT industries so as to target the regional and domestic growing markets.

According to already-observable structural trends, important consolidation moves and significant concentration should take place in some countries. The geographical location of the country, the incentives offered for foreign investors and the inherited supply side factors (public and private capital, Human skills) will play a role. This integration of corporate sector may be a very important source of positive synergies stemming from the consolidation and restructuring of the ICT sector.

Various trends might emerge from this restructuring.

A handful of countries might consolidate their existing ICT manufacturing capabilities, within the limits of a well-managed transformation from wage-based to knowledge-based competitiveness. Country by country assessments tend to indicate that the countries that succeeded in positioning themselves better in the late 1990s and have today a rather strong position in ICT manufacturing are likely to keep this position during the next few years. Facilities reallocation within Europe should at least partially compensate further delocalisation due to the Asian competitive pressure.
Some other countries (Bulgaria, Romania) might find new niche products eager to compete on international markets, more likely in the development of software than in the manufacturing of hardware. Finally larger countries will benefit from the size of their domestic market to support important domestic manufacturing capabilities, which will serve as a buffer during downturns of the global markets. However, it will be difficult for a country to reproduce Ireland's miracle.

Use

Likewise, the use of ICT should continue to grow as a function of the GDP per capita. However, on the contrary to the case of manufacturing, governments have some room of manoeuvre and ambitious public policies could speed up ICT diffusion within companies and private households: subvention to hardware equipment, encouragements of e-education, e-health, e-transport, e-administration and e-government. However, considering the structural problems remaining in these countries, public to private investment may be more efficient than public to public one.

(This and the previous article were contributed by O Da Cost of the IPTS, an Observer to the Expert group).

4. Cognition

What does the 'C' stand for in the NBIC Acronym?, D Andler

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The purpose of this note is to define a couple of possible confusions regarding the 'cogno' dimension of the converging technologies paradigm.

(1) Cognitive science is not (or not only) the science of knowledge processing. The salience of the 'knowledge society' in the foresight and planning literature tends to give the 'C' part of the convergence a role which doesn't quite fit its avowed goals, which are at once considerably broader and in some ways narrower. Contrary to an arbitrary etymological construal, unfortunately buttressed on occasion by the pronouncements of some aged members of the cogsci community, cognitive science is not primarily in the business of accounting for the accumulation, storage, retrieval and transmission of knowledge.

Insofar as knowledge figures among its chief topics, the questions it poses are, "what is knowledge, that a man may possess it, and What is man, that he may possess knowledge? (a paraphrase of the title of a famous paper, now 55 years old, by Warren McCulloch, a founding father of cybernetics). In other words, while the 'knowledge society' literature pretty much takes for granted the nature of knowledge, and focuses (with good reason) on the consequences of the prominence of knowledge in the private, socio-economic and military spheres, cognitive science investigates the conditions under which an agent can acquire, grasp, lose, retrieve, transform, communicate ,... knowledge, or rather, a broader class of skills and representations of which knowledge, in its hard, encapsulated, propositional form is but the emerging tip. Due to this fundamental character of its research programme, cognitive science is not therefore the science of knowledge in the usual sense (nor does such a science exist, as far as I know, under any name whatsoever), but it is in a position to promote durable development of theoretical and technological progress involving knowledge, in collaboration with the social sciences and informatics.

On the other hand, the scope of cognitive science is not restricted to the matter of belief, knowledge and the like, but covers, pretty much, the entire agenda of scientific psychology and its corresponding parts in philosophy, logic and the sciences of man. The centrality of psychology as a subject matter cannot be overemphasised. While psychology has long ceased to be a unified field, cognitive science, by considerably broadening its toolbox, has transformed its ill-formed initial ambitions into a sheaf of connected research programmes covering not only the traditional topics of memory, problem-solving, categorisation and the like, but also emotions, social cognition, linguistic competence, perception, action, consciousness etc.

This reminder serves as an antidote against the notion that, within NBIC, 'cogno' means, roughly, AI (thus interacting with 'info') plus neuroscience (thus interacting with 'bio'). 'Cogno' means what may be relevant, in the converging technologies, about the mind, not only about its machine simulations nor only about its biological realisations. The force and relevance of cognitive science entirely rests on the proper understanding and deployment of an integrated investigation of the mind/brain, with due consideration of machine and formal models, as well as the profound and rich bodies of knowledge accumulated by centuries of research on language, perception and the other major faculties, in linguistics, in philosophical and scientific psychology, in philosophy, logic, anthropology, economics etc. Beyond the proper synergy, what an overly restrictive info+bio view of cognitive science misses the essential role of this accumulated and evolving knowledge. The failures of early IA and neurobiology have no other source, and we should try and avoid repeating such errors.

This is emphatically not to forget that NBIC is nothing like the simple addition of the basic contributing disciplines: it does not aim, in particular, at absorbing cognitive science. We are considering an interaction of technologies. What I am pleading for is the active and continued presence of psychologists, linguists, anthropologists and philosophers in the planning and implementing of programmes in NBIC.
As an added benefit, I believe that they would help us sort the grain from the chaff in the US and other reports. Another added benefit, this time for cognitive science, is to strengthen its plea for increased support in the EC: as is well known, no technology nowadays fares well in the international competition without a vigorous fundamental science to drive it, and cognitive science cannot thrive on computer scientists and neuroscientists alone – it requires support as an integrated programme.

(2) The societal dimension of the converging technologies is not only a matter of weighing the preconditions and consequences of their emergence and eventual diffusion, an exercise which would be a simple analogue of the classic studies of the long-term socio-economico-ethical effects of, say biotechnologies or satellite communications or numerical TV. NBIC touches on the most intimate and crucial mechanisms of the relation between individual and society in an environment enriched by the presence of machines of all sorts, and deeply modified by networks and other vectors of globalisation, with disrupting effects, in particular, on the structures of authority, power and information.

Now society is the business of the social sciences, and individual that of the cognitive sciences. It turns out that both groups of disciplines depend on one another to thrive and be in a position to contribute to the converging technologies. This interaction, again, should occur at the fundamental level, where the technologies are developed and not only where they are deployed and diffused. In particular, a renaissance of social psychology through a long-term interaction with cognitive science, should be a priority.

Finally, it may be argued that, due to their relative novelty, and to their continued contact with the 'hard' sciences, the cognitive sciences have, at the outset at least, a larger share of the responsibility: it requires some practice of 'hardness' to develop a vocabulary commensurate with the language of technology. Also, of course, the cognitive sciences have long established a direct association with the 'bio' and 'info' components (hence the very idea of NBIC).

Seriously connecting cognition & society,D. Andler

0. Connecting…

Some recent trends in cognitive science
Some recent trends in social science
Inevitable encounters
Minding pitfalls
Enhancing our chances
Looking ahead: evolving self-images of self, community and society. (i) The facts
Self-understanding of self and society. (ii) Some of the questions
Over-arching themes for consideration
.Europe as experimental ground and as end

1. Some recent trends in cognitive science

Situated cognition
Domain-specificity and naïve 'theories'
Social cognition, cognitive ethology: (i) cognitive basis of individual social skills; (ii) social cognitive processes and states
Evolutionary approaches
The hidden face of the mind: emotion, motivation, decision (birth of the 'affective sciences')
Neural extremism and its antidote
The return of Vygotsky and other actionistic approaches
The call for a new paradigm: Evolutionary psychology as the proper basis for scientific social science

2. Some recent trends in social science

Mainstream resistance
Experimental economics
Culture and cultural evolution: the timid beginnings of cognitive anthropology
Minimalist cognitivism
The rebirth and neurocognitive turn of social psychology; cognitive sociology

3. Inevitable encounters

Formal models and experimental approaches of socio-economic evolution
Neural, neuropsychological and philosophical approaches of social psychology
Neodarwinian cognitive accounts of culture and society
Evolutionary formal models of emergence and diffusion of innovation
Deep computational social semantics (web-driven)

4. Minding pitfalls

Babelization
Pseudo cognition
Pseudo social science
Low quality
Tunnel vision
War of paradigms, science war
Meta gap
Political blindness
Over domestication

5. Enhancing our chances

Content: topic selection
Method: principles, experiments, search for plausible mechanisms; ‘natural philosophers’ (fundamental scientists) part and parcel of the technological enterprise
Form: true interdisciplinarity + intradisciplinarity; aim for maximal cumulativity; market AND public follow-up
Strategy: start with proven paradigms in cognitive science and aim for broader view
Tactics: start with a small number of large projects where strongest chances of true interdisciplinary selective advantage.

6. Looking ahead: evolving self-understanding of self, community and society. (i) The situation

a. Scientific assaults on the self:
- the ‘new unconscious’ (neuro/cognitive)
- situationism and ‘lack of character’
- genetic determinism
- self as a node in a swarm
- machine intelligence and robots dwarfing humans

b. Technological transformations of self (nano…: cf. Jürgen’s presentation; also nano-chemo, nano-neuro) and society (info…: cf. Wolfgang’s presentation)

c. The opaqueness of society and the communitarian response

7. Self-understanding of self and society. (ii) Some of the questions

How will the self-understanding of self evolve as the scientific image of self evolves towards quasi-elimination?
To what extent will the converging technologies provide a new intelligibility of society and social processes?
In this new context, what will the range of possible attitudes be towards the Kantian questions: What can I hope for? What ought I to do?

8. Over-arching themes for consideration

Universal constraints and variation
« We »: constraints and range of models
Shared / partial knowledge
Action / individual and joint
Naïve theories of self, norm, knowledge…; constraints, range of models, looping effects

9. Europe as experimental ground and as end

Ground for testing universality/variation hypotheses
Ground for studying the meshing of traditions and paradigms, partial yet genuine understanding across languages and cultures, due to historical alignment of values, ways and skills
Europe as orderly diversity, equally distant from chaos and epilepsy
Enabling, not tyrannical, technologies.

Neuro-scientific aspects of Foresighting the NTW, JP Tassin

Numerous disciplines, such as biology and biomedicine (including genetic engineering, proteomics and metabolomics), nanoscience and nanotechnology; information technology (including artificial intelligence, advanced computing and networks), cognitive sciences (including the neurosciences) and the integrative system sciences are currently converging and overlapping in ways that are producing significant synergies. The aim of this short review is to try to emphasize any synergy which could specifically occur between neurosciences and nanotechnology.

Brain Imaging

It is generally thought that it is the ability to scan the living brain, using techniques such as positron emission tomography (PET) or functional resonance imaging (fMRI), that has shaped the development of neuroscience. Although the development of brain imaging was a huge improvement for clinicians, the trigger role of these techniques in neuroscience is somewhat a “cliché”.

The first images were anatomical, separating white from gray matter, but the techniques have been evolving ever since. It has become possible to distinguish between oxygenated and deoxygenated blood (an index of which brain areas are working hardest), allowing to study disease and, in principle, cognition in the “living, thinking, human” brain. The main interest of the method is that it is non-invasive and can be repeated on an individual subject many times. However, the typical resolutions in human studies are 1-3 mm x 1-3 mm x 1-3 mm, and the temporal resolution is in the order of seconds.

Researchers are just now starting to use fMRI techniques to work out how various networks of brain areas are functionally connected and how they coordinate their activities. FMRI should also allow to directly study human cortical plasticity (how the brain changes with experience).
And studies on animals have begun to bridge the gap between the huge body of cellular work and the images from the brain scanners, revealing for the first time what the scans really mean at a cellular level. Meanwhile techniques such as electroencephalography and magnetoencephalography, which reveal the timing of the brain activity but do not say so much about anatomy, are being combined with fMRI, which is strong on anatomy.

Up to now, imaging techniques were especially useful to clinicians and notable examples include the study and treatment of deficits following localized brain-injury (e.g. caused by stroke, tumour or accident), neuronal pathology such as Alzheimer’s disease, eventually the success or failure of brain implants, surgery or stimulation to the functional networks found to be differentially activated. However, this technology still gives only few information about psychiatric disorders (e.g. schizophrenia, depression, anxiety..). Main improvements would be to build new machines working faster in order to obtain a better definition. It is clear that improvements will come from physical sciences and from computational neuroanatomy but the role of nanotechnology in these improvements is beyond my expertise (and should probably be discussed with the group).

Neurons recording (listening to neurons at work)

While non-invasive functional brain imaging has made remarkable progress, it is clear that they provide indirect measurements of brain activity, such as hemodynamic signals. This is not the case when recording from the neurons themselves. However, recording of neurons has, up to now, been essentially done in anaesthetized animals and more accurate information deserves recording in awaked (ideally freely-moving) animals.

Single neurons are the computational elements of the brain. They transmit information to other neurons by sending "all-or-none" action potentials along axons to other neurons. Recording the activity of many neurons simultaneously in the awaked animal (or even human) would enable to answer questions such as

(i) to what types of input do different neurons respond by altering their spiking activity ?

(ii) At what time do neurons start to respond after a stimulus and how long do they respond ? and

(iii) How much information is in the number of spikes emitted by each neuron, and how much by synchronization ? Finally

(iv) How much information is encoded by populations with different numbers of neurons, i.e. how information increases as more neurons are added to the ensemble ?

New methods for recording spiking activity are available but they consist of a maximum of 240 independently movable electrodes which is a lot but not sufficient if one considers the billions of cells that constitute the brain. It is very likely that nanotechnologies will greatly improve recording from neurons. It may be proposed that carbon nanotubes will be used to obtain multi-electrodes : A carbon nanotube consists of a graphitic sheet rolled over itself, forming a single graphene cylinder exclusively made of carbon atoms.

Its extremities may be closed by two half fullerens (carbon balls). Each nanotube is a single molecule made up of a hexagonal array of covalently bonded carbon atoms, the strongest existing liaison. Carbon nanotubes come in two species : single walled and multi-walled. Single Wall nanotubes (SWNT) consist of one cylinder, whereas Multi Wall nanotubes (MWNT) comprise several (7 to 20 usually) concentric graphene cylinders. They show quantum conductance, the highest tensile strength, the highest surface area for a carbon system and a very large aspect ratio. Nanotubes can be grown at desired places, by pre-patterning of a catalyst. The diameter of MWNTs can be controlled by the size of the catalyst dot. The direction of growth can be aided by applying an electric field. Because nanotubes have the highest tensile strength of any solid, along their axis, they could be used to reinforce polymer composites. The strength or elastic modulus of the composite should vary linearly with the nanotube loading. Finally, their huge aspect ratio or sharpness makes them good field emitters, they are better than other forms of carbon because they conduct well.

Brain (i.e. neurons) stimulation

Recording neurons in the living (awaked) brain will certainly bring a lot of information on how the brain works but brain stimulation has already brought clinical improvements. The most spectacular success was obtained by a french team which has already implanted many hundred of patients suffering from Parkinson's disease. Successes have also been obtained for essential tremor and chronic pain.

Parkinson's disease is believed to be due to the neuronal degeneration of dopaminergic neurons located in a mesencephalic structure, the substantia nigra. Different studies have indicated that an additional lesion of another cerebral structure, the subthalamic nucleus, could "reverse" some parkinsonian symptoms. In 1990, it was found that the stimulation of this cerebral structure with a high frequency current (around 130 Hz) could reversibly induce same improvements than those previously obtained with lesion. When compared with lesions, high frequency stimulation offers many important advantages : First, it is reversible. This means that in case of unwanted effects, electrodes can be removed without any drawback for the patient.
Secondly, it is possible to modulate therapeutic effects with a modification of the stimulation parameters (an action that can be done from outside the body) or even on the site localization because of the placement of "multi-plots" electrodes. However, this technology is expensive (30.000,00 Euros /patient) and invasive (electrode diameter is about 1 mm). There again, the development of new type of electrodes, possibly with nanotubes, will undoubtedly modify this technology in order to make it less invasive.

Along with the treatment of Parkinsonian patients, it was found that some patients, who suffered from obsessive compulsive disorder (OCD), were improved in their behavioural disease by electrical stimulation. Same observations were done for the Gilles De La Tourette's syndrom. The mechanism responsible for these improvements is still debated, one possibility being that high frequency stimulation blocks the response of neurons by "hyperdepolarization". The next step would therefore be to stimulate neurons with parameters as similar as possible than physiological ones (with a frequency from 1 to 4 Hz, for example). This has been tried with few success, probably because effective stimulations have to fit both with physical parameters and precise sites that recordings did not yet establish with a sufficient accuracy.

Altogether, it is easy to anticipate that human brain stimulation has a very promising future, especially if electrodes are modified and become less invasive. Moreover, it will gain a lot from the information gathered by neuronal recordings.

Brain stimulation in animals is an old technology which was used experimentally in rats since the 50's when Olds and Milner showed that when an electrode is positioned in a precise mesencephalic structure, rats can learn to press a lever to obtain an electrical stimulation at the tip of the electrode. When rats have the choice between two levers delivering either a food pellet or electrical current in their brain, depending on the location of the electrode, they prefer to receive electrical stimulation and starve to death. It is known now that the mesencephalic area where the tip of the electrode has to be positioned to induce this behaviour is the ventral tegmental area where dopaminergic cell bodies lie. These dopaminergic neurons regulate the "reward system", a group of brain structures that exist in all mammalians and which constantly define physical and mental states of an individual.

Actually, this regulatory role of the dopaminergic neurons on the "reward system" may explain why some individuals take drugs of abuse and become addicted. Indeed, the satisfaction induced by almost all drugs of abuse (amphetamine, cocaine, morphine, heroin, cannabis, alcohol…) seems linked with an increased dopamine release. Development of addiction would be due to the modification, by drugs of abuse, of the kinetic and the amplitude of dopamine release.

Such a dysregulation induces the addict to artificially memorize any anticipatory signal linked to the product consumption and to become dependent on its obtaining. Electrical stimulation experiments of the ventral tegmental area in humans have yet not been performed (for obvious reasons of safety) but it is almost certain that it would work the same way as in animals, i.e. stimulation would act as drugs of abuse do, and modify mood and motivation. The main difference with drugs of abuse, however, is that electrical stimulation would be precisely controlled from outside. It cannot therefore be excluded that this technology could present therapeutic interests, especially for psychiatric diseases such as severe depressions resistant to pharmacological therapy.

At the interface between recording and stimulation, is the possibility to "repair" nerve injury, particularly at the level of the spinal cord when axons have been physically disconnected from their neuronal target. Up to now, most experiments have tried to drive afferent injured axons to the target neuron using different types of artificial guides. It can be proposed that the electric message arriving at the extremity of the injured axon could be recorded by micro-(or nano)-electrodes and sent to a chip (or micro-electrodes) located on the target neuron that would trigger the muscular response. Two possibilities should exist to transfer the message from the axon to the receiving neuron, either by electrical circuitry or by high frequency radio signalling. The main problem with the radio transmission is the necessity of an antenna which may limit the miniaturization. The same problem exists for stimulation of deep brain structures; radio transmission would avoid the length of the electrode but would necessitate an antenna.

<u>Visualization, Transport, Delivery and Detection of one single molecule in one single cell</u>

In living cells, the ability to selectively detect one molecule (or a small number of molecules) is a powerful way to understand the dynamics of cellular organization. So far, access to single-molecule properties in living cells has been restricted by either the size of the probe (40-nm gold nanoparticles or 500-nm latex spheres) or the photobleaching (disappearance of luminescence) of the small (1- to 4-nm) fluorescent labels. Metal and semiconductor nanoparticles in the 2–6 nm size range are of considerable current interest, not only because of their unique size-dependent properties but also because of their dimensional similarities with biological macromolecules (e.g. nucleic acids and proteins). Advances in nanomaterials have produced a new class of fluorescent labels by conjugating semiconductor quantum dots with biorecognition molecules.

Quantum dots are nanocrystals often composed of atoms from groups II-VI or III-V elements in the periodic table, and are defined as particles with physical dimensions smaller than the exciton Bohr radius.

For spherical CdSe particles, this occurs when the particle diameter is less than ~10 nm. The effect of quantum confinement gives rise to unique optical and electronic properties that are not available in either discrete atoms or in bulk solids. Extensive research in the past 20 years has focused on the photophysics of nanostructures and their applications in microelectronics and optoelectronics; however, recent developments indicate that the first practical applications of Quantum dots are occurring in biology and medicine. Indeed, these nanometer-sized conjugates are water-soluble and biocompatible, and provide important advantages over organic dyes and lanthanide probes. In particular, the emission wavelength of quantum-dot nanocrystals can be continuously tuned by changing the particle size, and a single light source can be used for simultaneous excitation of all different-sized dots.

As previously mentioned, high-quality dots are also highly stable against photo-bleaching and have narrow, symmetric emission spectra. These novel optical properties render quantum dots ideal fluorophores for ultrasensitive, multicolor, and multiplexing applications in molecular biotechnology and bioengineering.

The volume of a single cell of 10 µm diameter is 1 picoliter. It weights, mainly because of its water content, 1 nanog. It contains 10 picog of DNA, 50 picog of total RNA, 1 picog of messenger RNA or around 1 million of copies of messenger RNA molecules. The protein content of a single cell is around 100 picog. A protein representing 1% of the total proteins corresponds to 1 picog or 50 attomoles if the molecular weight of the proteins are 20000. In a neurocrine cell, the cytoplasmic content in neurotransmitter is between 1 and 10 femtomoles, second messengers are much less abundant at a maximum concentration of 1µM or 1 attomole per cell.

The method to study cellular diversity at the single cell level is the single cell RT-PCR after patch clamp. In brief, after electrophysiological recordings of a cell, the cytoplasm of the cell is aspirated in the recording pipette and the content analyzed for the presence of few different messenger RNA species. Experimental data (quantitative PCR) showed that a relatively well expressed neuronal gene is represented by 1000 copies of messenger RNA per cell. The messenger RNAs are first transformed in cDNA by the enzyme reverse transcriptase (RT) and the cDNA materials is amplified by the Polymerase Chain Reaction (PCR).

By PCR amplification one copy of a 2000 bases Messenger RNA weighing 1 attog will become 32 nanog after 35 cycles (35 cycles 235 or 32 x 109 or 32 nanog).

Now the expression of 100 different genes can be monitored simultaneously and it can be anticipated that this may increase up to 10 to 100-fold and may be more. By the ongoing work with DNA microarrays chips it is expected that most of the transcription program of single cell could be analyzed in the future. In addition, Mass Spectrometry can be used in order to identify proteins, peptides, neurotransmitters, second messengers and products of the cellular metabolism in a single cell. These transcriptome, proteome and metabolome analysis at the single cell level represent a new frontier in biology and are essential to deciphering the heterogeneity and the function of the neuronal network of the brain. For example, neocortical interneurons are a class of neurons known to control brain excitability. It has been found that they are highly heterogeneous not only in their anatomy but also in their pattern of gene expression.

This diversity at the gene expression level is probably associated with different functional properties. Some interneurons behave like coincidence detectors and are thus important to control synchrony of brain electrical waves. Other interneurons control brain metabolism and blood perfusion making these neurons good candidates as targets for the development of new drugs in neuropsychopharmacology.

Nanoparticles and nanospheres have also considerable utility as controlled drug delivery systems. This is particularly true for sites located in the central nervous system because of the blood brain barrier. Indeed, the brain is protected from the periphery by a kind of filter which selects entering molecules in function of their sizes, their hydrophilic characteristics and their chemical moieties. When suitably encapsulated, a pharmaceutical can be delivered to the appropriate site, its concentration can be maintained at proper levels for long periods of time, and it can be prevented from undergoing premature degradation, a property particularly interesting for neuropeptides which act as neurotransmitters but are extremely instable in vivo.

These technologies will deliver drugs or other molecules that are hard to dissolve and may even deliver them directly to their site of action (e.g. brain) or specific tissues (e.g. tumor). Indeed, most drugs are delivered throughout the body, rather than to the specific area where they are meant to have an effect. As a result, side effects on other tissues are unavoidable.

By directing drugs primarily to their desired sites of action, lower overall doses of drugs will be given because these will concentrate where they are needed and exposure of other body tissues to the drugs will be reduced.

It must be emphasized that one of the most crucial problems associated with the use of nanoparticles as drug carriers is their short blood circulation. Uncoated nanoparticles are removed when administered intravenously into the host defence system of the body, i.e., the mononuclear phagocyte system. In order to enhance the circulation duration in biological milieu, several strategies have been followed, the most successful of which is “pegylation”, i.e., coating the surface of the nanoparticles with polyethyleneoxide moieties.

The ability to manipulate cells and integrate them with complex inorganic devices and probes will permit to perform a new class of experiments and ask new questions about basic cell functions. In order to achieve these, fundamental research will be needed in the areas of attachment of biomolecules to surfaces, novel bio-patterning techniques (for DNA, proteins, agonists or antagonists to receptors, etc..) and processing of novel nano-phase material for improved biocompatibility. As an example, nanoparticles carrying DNA fragments could be used to incorporate specific genes into target cells and allow gene therapy.
Finally, non-invasive molecular imaging technologies could be developed using luminescent Quantum dots. This should allow viral particles to be followed in vivo, drug molecules to be analyzed in biological systems, and tumor cells to be tracked in real time. In Psychiatry, dysregulations of neural systems are believed to precede clinical symptoms; detection of increased or decreased release of specific neurotransmitters may allow to anticipate pathological episodes of depression or mania.

Last but not least, nanotechnologies have developed micro-machines or MEMS (Micro-Electro-Mechanical Systems) (Micromachines as tools for nanotechnology Ed. By H. Fujita Pub. By Springer-Verlag (2003) Heidelberg, Germany) which can, among others, seize cells such as neurons. This could be exploited to select specific neural cells to be grafted.

In summary,

There are numerous potential applications and convergences between nanoscience, medicine, health and neuroscience. Besides improvements in computers, which may increase the resolution of fMRI and PET imaging machines, one can hope to obtain exceptionally light, strong and small materials which may allow almost non-invasive recording of neurons and brain stimulation. These novel biocompatible materials will be more durable and rejection-resistant artificial tissues and organs. A wide range of tiny bio-sensors that could reside in and monitor the human body, and new imaging technologies that detect emerging disease in the body, will shift the focus of patient care from disease treatment to early detection and prevention.
New routes for targeted gene and drug delivery will enormously broaden their therapeutic potential by effecting and targeting delivery of new types of medicine to previously difficult to access sites in the body such as brain. The final question being whether it will be possible, one day, to link brain to machine and brain to brain.

Murder in mind - Brain Fingerprinting

Could reading the thoughts of criminals help free the innocent?[33]
See http://psychology.designerz.com/psychology-forensics-law-brain-fingerprinting.php

[33] Thursday March 25, 2004, The (UK) Guardian , Clint Witchall

5. National Policy/Market Analysis

Summary of the US Report on: "Converging Technologies for Improving Human Performance"

Released by the National Science Foundation (NSF) and Department of Commerce, July 2002, authored by WTEC

Introduction

Converging Technologies (CT) refers to the "synergistic combination of four major ""NBIC"" (nano-bio-info-cogno) provinces of sciences and technology, each of which is currently progressing at a rapid rate: (a) nanoscience and nanotechnology; (b) biotechnology and biomedicine, including genetic engineering; (c) information technology, including advanced computing and communications; and, (d) cognitive science, including cognitive neuroscience."

The report address the implications of converging technologies, what needs to be done to achieve the best outcome, the visions and ideas that could guide research, how education and research needs to be transformed, and the national (US) strategy that needs to be adopted. It is based on "exploratory research already initiated in representative research organisations", and on the "opinions of leading scientists and engineers using research data". The conclusion is that, given the right push, a convergence of the four technologies nano, bio, info and cogno (NBIC) will take place, built up from nanoscale building blocks.

The report describes the current situation as "standing on the threshold of a new renaissance" in S&T, pointing out that "the sciences have reached a watershed at which they must combine in order to advance more rapidly", and that possibilities are now open to adopt a holistic view and unite different sciences instead of increasing the specialisation we have seen so far. If the right encouragement is given and the right strategies adopted, the report goes as far as saying that the "twenty-first century could end in world peace, universal prosperity, and evolution to a higher level of compassion and accomplishment. It is hard to find the right metaphor to see a century into the future, but it may be that humanity would become like a single, distributed and interconnected "brain" based in new core pathways of society. This will be an enhancement to the productivity and independence of individuals, giving them greater opportunities to achieve personal goals."

Key principles of Converging technology:

Material unity at the nanoscale; i.e., an understanding about how atoms combine to form complex molecules, and in turn aggregate to form organic and inorganic structures. Natural processes can be harnessed to engineer new materials, bio-products, machines, etc from the nanoscale up to metres and complex microsystems, such as neurones, and macrosystems, such as the human metabolism, can be controlled.
NBIC transforming tools (NBIC-based technologies), based on revolutionary advances at the interfaces between the fields.

Understanding the world in terms of complex hierarchical systems, with a holistic awareness of opportunities for integration.
Improvement of human mental, physical and social performance by better understanding of the human body and development of tools for direct human-machine interaction.

Implications

The long-term implications in key areas of human activity could include:
Societal productivity (well being and economic growth);
Security from man and nature generated disasters;
Individual and group performance and communication
Life-long learning and, graceful ageing, and healthy life;
Coherent technological developments and their integration with human activities;
Human individual and cultural evolution.

The visions

CT promise to increase significantly our level of understanding, transform human sensory and physical capabilities, and improve interactions between mind and tool, individual and team. The report lists 20 ways CT could benefit mankind in 20 years:
Direct broadband interfaces between the human brain and machines, transforming work in factories, controlling automobiles, ensuring military superiority, and enabling new sports, art forms and modes of interaction between people.
Wearable sensors and computers enhancing individuals' awareness of health condition, environment, chemical pollutants, potential hazards, etc.
Robots and software agents useful for human beings, operating on principles compatible with human goals, awareness, and personality.
Individual learning more reliable and quickly.
Communication and co-operation possible across traditional barriers of culture, language, distance, and professional specialisation, increasing effectiveness of groups, organisations, and multinational partnerships.
A human body more durable, healthy, energetic, easier to repair, and resistant to many kinds of stress, biological threats, and ageing processes.
Machines and structures constructed of materials with desired properties, with ability to adapt to changing situations, high-energy efficiency, and environmental friendliness.

Combinations of technologies and treatments compensating for physical and mental disabilities.
National security strengthened by lightweight, information-rich war fighting systems, uninhabited combat vehicles, adaptable smart materials, invulnerable data networks, superior intelligence-gathering systems, and effective measures against biological, chemical, radiological, and nuclear attacks, as well as instantaneous access to tailored information.
Expanded creative abilities for engineers, artists, and architects by a variety of tools and improved understanding of the wellsprings of human creativity.
Human welfare benefiting from the ability to control the genetics of humans, animals, and agricultural plants; widespread consensus about ethical, legal, and moral issues will be build in the process.
Outer space and the Moon, Mars, and near-Earth asteroids will exploited by means of efficient launch vehicles, robotic construction of extraterrestrial bases.

New organisational structures and management principles based on fast, reliable and relevant communication and information increasing the effectiveness of administrations.
Individuals will have improved awareness of the cognitive, social, and biological forces operating their lives.
Factories will be organised around CT and increased human-machine capabilities ("intelligent environments") achieving maximum benefits of both mass production and custom design.
Increased yields and reduce spoilage through networks of cheap, smart sensors monitoring the condition and needs of plants, animals, and farm products.
Safe, cheap, and fast transportation thanks to ubiquitous real-time information systems, high-efficiency vehicle designs, and use of synthetic materials and machines fabricated from the nanoscale.
The work of scientists will be revolutionised by importing approaches pioneered in other sciences.
A transformation of formal education by a unified but diverse curriculum based on a comprehensive, hierarchical intellectual paradigm for understanding the architecture of the physical world from the nanoscale through the cosmic scale.

Strategies for the future

The report also sets educational and transformational goals, and recommends a national R&D priority area on converging technologies focused on enhancing human performance. The report presents the following general strategies to achieve the desired convergence:

Key organisations and social activities should be prepared for the envisioned changes made possible by converging technologies.
Activities must be enhanced that accelerate convergence of technologies for improving human performance, including focused research, development, and design; increasing synergy from the nanoscale; developing interfaces among sciences and technologies; and taking a holistic approach to monitor the resultant societal evolution. A research and development program for exploring the long-term potential is needed.
Education and training at all levels should use converging technologies as well as prepare people to take advantage of them.
Experimentation with innovative ideas is needed to focus and motivate needed multidisciplinary developments.
Concentrated multidisciplinary research thrusts to achieve results, with the establishment of networks of research centres dedicated to each goal, funded by coalitions of government agencies and operated by consortia of universities and corporations.
NBIC scientists and engineers will need a variety of multi-user, multi-use research and information facilities, such as data infrastructure archives, serving a wide range of clients, including government agencies, industrial designers, and university laboratories.
Integration of the sciences requires a shared culture across existing fields and a new technical language based on the mathematics of complex systems, the physics of structures at the nanoscale, and the hierarchical logic of intelligence.
Ethical, legal, and moral concerns, must be addressed throughout the process of research, development, and deployment of convergent technologies, requiring new mechanisms to ensure representation of the public interest in all major NBIC projects, incorporation of ethical and social-scientific education in the training of scientists and engineers, and ensuring that policy makers are thoroughly aware of the scientific and engineering implications of the issues they face.

An acceleration of developments in medical technology and healthcare to obtain maximum benefit from converging technologies.

<u>Actors</u>

The report also addressed the roles different actors should play in the CT priority area:

Scientists and engineers at every career level should gain skills in at least one NBIC area and in neighbouring disciplines, collaborate with colleagues in other fields, and take risks in launching innovative projects that could advance technology convergence for enhancing human performance.

Educational institutions at all levels should undertake major curricular and organisational reforms to restructure the teaching of science and engineering so that previously separate disciplines can converge around common principles to train the technical labour force for the future.

Manufacturing, biotechnology, and information service corporations will need to develop partnerships of unparalleled scope to exploit the opportunities from technological convergence.

A national research and development priority area should be established that focuses on CT:s enhancing human performance. Governments should provide support for education and training of future NBIC workers and prepare society for major systemic changes. Ethical, legal, moral economic, environmental, workforce development, and other societal implications must be addressed from the beginning, involving leading NBIC scientists and engineers, social scientists and a broad coalition of professional and civic organisations. Research on societal implications must be funded, and the risk of potential undesirable secondary effect monitored by government organisations.

The scientific community should create new means of interdisciplinary training and communication, reducing barriers that inhibit working across disciplines.

NGOs representing potential user groups should contribute to the design and testing of convergent technologies and recommend NBIC priorities. Private research foundations should invest in NBIC research in those areas that are consistent with their particular missions. The public media should increase high-quality coverage of science and technology, on the basis of the new convergent paradigm, to inform citizens so they can participate wisely in debates about ethical issues such as unexpected effects on social equality, policies concerning diversity, and the implications of transforming human nature.

The contributors to the report argues that "without special [governmental] efforts for co-ordination and integration, the path of science might not lead to the fundamental unification envisioned here. Technology will increasingly dominate the world, as population, resource exploitation, and potential social conflict grow. "The success of this convergent technologies priority area is essential to the future of humanity."

The whole report is available on http://wtec.org/ConvergingTechnologies/ for downloading as an Acrobat file.

Assumptions & Values of NSF Report , JP Dupuy

Converging Technologies for Human Performance, Mihail C. Roco & William S. Bainbridge (eds.), June 2002, analysed by Jean-Pierre Dupuy, February 2004

Technology is viewed as a means to an end; i.e. the approach is purely utilitarian. As a means technology is the major driver. It is seen as inevitable, almost as fate, but a fate that it is up to us to choose or to refuse. Science and technology follow an autonomous development, a progression that we can slow down or accelerate depending on our decisions and efforts. The ends are glorious, like to "achieve an age of innovation and prosperity that would be a turning point in the evolution of human society." Thanks to the NBIC convergence, "the 21st century could end in world peace, universal prosperity, and evolution to a higher level of compassion and accomplishment." What adds to the utilitarian frame is the resolute individualistic bias: "The right of each individual to use new knowledge and technologies in order to achieve personal goals, as well as the right to privacy and choice, are at the core of the envisioned developments."

The benefits to be expected are plenty: improving work efficiency and learning; enhancing individual sensory and cognitive capabilities; revolutionary changes in health care; improving individual and group creativity; perfecting human-machine interfaces; sustainable and intelligent environments; ameliorating the decline common to the ageing mind; etc. As regards potential threats, there is only one mention thereof in the whole report – a warning by M. Roco himself about the risk of wild self-replication of nanobots, immediately followed by the usual caveat, "we all agree that while all possible risks should be considered, the need for economic and technological progress must be counted in the balance."

The major impediment is ethics, that is, our current ethics, conservative and overcautious. The report looks forward to a possible radical change in ethics, akin to a transformation of civilisation, thanks to which "the acceptance of brain implants, the role of robots in human society, and the ambiguity of death" will conform to new principles.

The socio-economic analysis is of an incredible poverty. There are no social dynamics or forces, only individual behaviour that can be predicted and corrected if need be – for instance, disruptive behaviour, terrorist acts, etc. The inflow of dollars is the only driver. The role of the government is to set the conditions for private initiatives to flourish while ensuring public acceptance.
The worldview is global, or rather universal, to the extent that the American way of life – and of thinking - is implicitly taken to be the only one worthy of consideration, and the "end of history".

Interestingly, there are lapses in the report that do not fit squarely in the general frame. For instance, the admission that the NBIC convergence partakes in a radical transformation of our conceptions of nature, life, and the mind – a sea change that it reveals at the same time that it brings it about. The change is welcome in that it gives us a much higher control over the world. Also, the admission that the whole enterprise is primarily a matter of not lagging behind in a world race: "While American science and technology benefit the entire world [sic!], it is vital to recognize that technological superiority is the fundamental basis of the economic prosperity and national security of the US. [...]

We must move forward if we are not to fall behind." Occasionally, doubts are expressed about the feasibility of the initiative: "There are limits on the complexity of achievable design."

Analysis and Summary of NBIC by Shaping Actors, Driving Forces

Introduction

Converging Technologies (CT) refers to the "synergistic combination of four major ""NBIC"" (nano-bio-info-cogno) sciences and technology, each of which is currently progressing at a rapid rate. The report address the implications of converging technologies, what needs to be done to achieve the best outcome, the visions and ideas that could guide research, how education and research needs to be transformed, and the US national strategy that needs to be adopted. It is based on "exploratory research already initiated in representative research organisations", and (probably somewhat more) on the "opinions of leading scientists and engineers using research data". The conclusion is that a convergence of the four technologies nano, bio, info and cogno (NBIC) will take place, built up from nanoscale building blocks, can and will take place with profound impacts.
The report describes the current situation as "standing on the threshold of a new renaissance" in S&T, pointing out that "the sciences have reached a watershed at which they must combine in order to advance more rapidly", and that possibilities are now open to adopt a holistic view and unite different sciences instead of increasing the specialisation we have seen so far. If the right encouragement is given and the right strategies adopted, the report goes as far as saying that the "twenty-first century could end in world peace, universal prosperity, and evolution to a higher level of compassion and accomplishment. It is hard to find the right metaphor to see a century into the future, but it may be that humanity would become like a single, distributed and interconnected "brain" based in new core pathways of society. This will be an enhancement to the productivity and independence of individuals, giving them greater opportunities to achieve personal goals."

Key principles of Converging technology:

Material unity at the nanoscale; i.e., an understanding about how atoms combine to form complex molecules, and in turn aggregate to form organic and inorganic structures. (Self assembly)
Natural processes can be harnessed to engineer new materials, bio-products, machines, etc from the nanoscale up to metres and complex microsystems, such as neurones, and macro-systems, such as the human metabolism, can be controlled.
NBIC transforming tools (NBIC-based technologies), based on revolutionary advances at the interfaces between the fields.
Understanding the world in terms of complex hierarchical systems, with a holistic awareness of opportunities for integration.
Improvement of human mental, physical and social performance by better understanding of the human body and development of tools for direct human-machine interaction. (and augmentation).

Implications

The long-term implications in key areas of human activity include:
Societal productivity, well being and economic growth;
Security from man and nature generated disasters;
Individual and group performance and communication
Life-long learning and graceful ageing and healthy life;
Coherent technological developments and their integration with human activities;
Human individual and cultural evolution, beyond the self?.

The visions

CT promise to increase significantly our level of understanding, transform human sensory and physical capabilities, and improve interactions between mind and tool, individual and team. The report lists 20 ways CT could benefit mankind in 20 years:
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Robots and software agents useful for human beings, operating on principles compatible with human goals, awareness, and personality.
Individual learning more reliable and quickly.
Communication and co-operation possible across traditional barriers of culture, language, distance, and professional specialisation, increasing effectiveness of groups, organisations, and multinational partnerships.
A human body more durable, healthy, energetic, easier to repair, and resistant to many kinds of stress, biological threats, and ageing processes.
Machines and structures constructed of materials with desired properties, with ability to adapt to changing situations, high-energy efficiency, and environmental friendliness.
Combinations of technologies and treatments compensating for physical and mental disabilities.
National security strengthened by lightweight, information-rich war fighting systems, uninhabited combat vehicles, adaptable smart materials, invulnerable data networks, superior intelligence-gathering systems, and effective measures against biological, chemical, radiological, and nuclear attacks, as well as instantaneous access to tailored information.
Expanded creative abilities for engineers, artists, and architects by a variety of tools and improved understanding of the wellsprings of human creativity.
Human welfare benefiting from the ability to control the genetics of humans, animals, and agricultural plants; widespread consensus about ethical, legal, and moral issues will be build in the process.
Outer space and the Moon, Mars, and near-Earth asteroids will exploited by means of efficient launch vehicles, robotic construction of extraterrestrial bases.
New organisational structures and management principles based on fast, reliable and relevant communication and information increasing the effectiveness of administrations.
Individuals will have improved awareness of the cognitive, social, and biological forces operating their lives.

Factories will be organised around CT and increased human-machine capabilities ("intelligent environments") achieving maximum benefits of both mass production and custom design.
Increased yields and reduce spoilage through networks of cheap, smart sensors monitoring the condition and needs of plants, animals, and farm products.
Safe, cheap, and fast transportation thanks to ubiquitous real-time information systems, high-efficiency vehicle designs, and use of synthetic materials and machines fabricated from the nanoscale.
The work of scientists will be revolutionised by importing approaches pioneered in other sciences.
A transformation of formal education by a unified but diverse curriculum based on a comprehensive, hierarchical intellectual paradigm for understanding the architecture of the physical world from the nanoscale through the cosmic scale.

Strategies for the future

The report also sets educational and transformational goals, and recommends a national R&D priority area on converging technologies focused on enhancing human performance. The report presents the following general strategies to achieve the desired convergence:

Key organisations and social activities should be prepared for the envisioned changes made possible by converging technologies.
Activities must be enhanced that accelerate convergence of technologies for improving human performance, including focused research, development, and design; increasing synergy from the nanoscale; developing interfaces among sciences and technologies; and taking a holistic approach to monitor the resultant societal evolution. A research and development program for exploring the long-term potential is needed.
Education and training at all levels should use converging technologies as well as prepare people to take advantage of them.
Experimentation with innovative ideas is needed to focus and motivate needed multidisciplinary developments.
Concentrated multidisciplinary research thrusts to achieve results, with the establishment of networks of research centres dedicated to each goal, funded by coalitions of government agencies and operated by consortia of universities and corporations.
NBIC scientists and engineers will need a variety of multi-user, multi-use research and information facilities, such as data infrastructure archives, serving a wide range of clients, including government agencies, industrial designers, and university laboratories.
Integration of the sciences requires a shared culture across existing fields and a new technical language based on the mathematics of complex systems, the physics of structures at the nanoscale, and the hierarchical logic of intelligence.
Ethical, legal, and moral concerns, must be addressed throughout the process of research, development, and deployment of convergent technologies, requiring new mechanisms to ensure representation of the public interest in all major NBIC projects, incorporation of ethical and social-scientific education in the training of scientists and engineers, and ensuring that policy makers are thoroughly aware of the scientific and engineering implications of the issues they face.
An acceleration of developments in medical technology and healthcare to obtain maximum benefit from converging technologies.

Actors

The report also addressed the roles different actors should play in the CT priority area:

Scientists and engineers at every career level should gain skills in at least one NBIC area and in neighbouring disciplines, collaborate with colleagues in other fields, and take risks in launching innovative projects that could advance technology convergence for enhancing human performance.
Educational institutions at all levels should undertake major curricular and organisational reforms to restructure the teaching of science and engineering so that previously separate disciplines can converge around common principles to train the technical labour force for the future.
Manufacturing, biotechnology, and information service corporations will need to develop partnerships of unparalleled scope to exploit the opportunities from technological convergence.

A national research and development priority area should be established that focuses on CT:s enhancing human performance. Governments should provide support for education and training of future NBIC workers and prepare society for major systemic changes. Ethical, legal, moral economic, environmental, workforce development, and other societal implications must be addressed from the beginning, involving leading NBIC scientists and engineers, social scientists and a broad coalition of professional and civic organisations. Research on societal implications must be funded, and the risk of potential undesirable secondary effect monitored by government organisations.
The scientific community should create new means of interdisciplinary training and communication, reducing barriers that inhibit working across disciplines.
NGOs representing potential user groups should contribute to the design and testing of convergent technologies and recommend NBIC priorities. Private research foundations should invest in NBIC research in those areas that are consistent with their particular missions. The public media should increase high-quality coverage of science and technology, on the basis of the new convergent paradigm, to inform citizens so they can participate wisely in debates about ethical issues such as unexpected effects on social equality, policies concerning diversity, and the implications of transforming human nature.
The contributors to the report argue that technology will increasingly dominate the world, as population, resource exploitation, and potential social conflict grow. "The success of this convergent technologies priority area is essential to the future of humanity."

OECD and 21st Century Technologies , E. Fontela

The OECD is the international organization that has shown, in recent years, the greatest interest on the study of the economic effects of new technologies. (The OECD is an organization of the advanced industrial countries). The all embracing Technology / Economy Programme (TEP), run between 1987 and 1990 played a key role in raising the level of awareness of Governments to the contribution of new technologies to economic growth. Between 1997 and 2000 the OECD Forum for the Future organised a series of from conferences around the theme of “People, Nature and Technology: Sustainable Societies in the 21st Century”. The contents of these conferences have been published. Of particular relevance for the HLEG are two of these publications: 21st. Century Technologies (OECD 1998) and the Future of the Global Economy (OECD 1999).

In the First Report opportunities and risks are detected for advances in the performance and use of digital and genetic information. It is noted that most dramatic breakthroughs are expected to be achieved through combinations of various scientific disciplines. Two developments associated to these technological changes appear to be especially relevant for our task:

“once liberated from some of the cost, time, and space constraints of traditional education, it might even be possible to get beyond the socialisation methods of industrial era schooling to create a system that encourages individual creativity”
“the quantum leap in genetic knowledge, information, diagnosis, prevention and therapy would mean more personal control over health and more possibilities for self- treatment”

The main opportunities for positive structural change associated to NBIC convergence are therefore to be found in education and health, two “superior services” where at present there are very different national views as to the role of public and private initiative.

In this context, the report contemplates two scenarios, a “market” scenario with mainly private education and health (the government is a “night watchman”), and a “new society” scenario with public driven innovations is these areas. It is felt that both socio-technical dynamism and social tensions will be higher in the “market” scenario (higher economic growth with greater social disparities disrupting existing patterns of assuring societal cohesion).

The “new society” scenario, if it is to avoid economic stagnation, implies a continuous process of creative combinations of public and private, local and global, innovative and traditional approaches, as the conditions for socio-technical dynamism are likely to be continuously evolving.

The full title of the Second Report is: the Future of the Global Economy: Towards as Long Boom? Indeed at this conference the participants concluded that the world is on the threshold of a tantalising opportunity: the possibility of a sustained long boom over the first decades of the new millennium.

In his contribution to this report, Richard Lipsey refers to radical innovations for general purpose technology (GPT), and the existing knowledge on future GPTs associated to NBIC convergence anticipates a set of these radical innovations that could support the long boom idea (provided that there is a perfect matching of GPTs with the institutional framework).

The report includes three geopolitical scenarios: the USA as a growth leader; a global shift of growth towards the Pacific; and a set of growth clusters (cities, regions, all over the world).

In general, OECD transmits an institutional message that a sound application of market economics should stimulate growth and that technological change is the basis of this growth. Optimism on the long term is de rigueur. The market is expected to make the right decisions.

Is the market able to foresee the long term planetary interests? The conventional OECD view answers yes, and public policies are therefore mostly to be oriented towards avoiding market failures with the advent of new technologies.

There is little recognition of the fact that NBICs are likely to have a great impact on human activities (education, health) with considerable distributional effects, and therefore requiring more active public policies.

The Coming NanoBioEconomy and Its Implications for Transatlantic Relations

Notes on a
Symposium Organised by the Centre for Transatlantic Relations, 30 Sep 2003, Brussels

The subject was to review the new world which is dawning fast, where the skills, infrastructure, and systems of the Information Age are fused with the complex, natural world of biology – a world where the developing sciences of miniaturisation, genome research and nano-technology may set the scene for the creation of whole new genres of life: crops, drugs, synthetic materials. The build up was impressive, the afternoon session which I attended was less so – many speakers were substituted. The objectives was to gauge opinions outside the formal EC-US Dialogue.

This emerging “NanoBioEconomy” is rapidly becoming a major economic driver at local, national and international levels and is expected to be an expanding force over the next 20-30 years. It spans multiple industries and influences all who participate or invest in them. It is likely to drive significant social change across the Atlantic and around the world. It raises profound ethical and political issues. It is developing fastest in the United States and Europe, where scientists and entrepreneurs are innovating on the frontiers of human discovery – a realm where global rules are unclear or nonexistent, where even the right questions have yet to be formulated.

Agriculture, food, pharmaceuticals and health care are already being affected, but the changes are likely to affect most economic activities, even such areas as banking, entertainment, retail and travel. For example, nanotechnology, -- the manipulation, placement, measurement, and modeling of matter at the level of atoms and molecules -- is central to new developments in defense and aerospace, materials and manufacturing, life sciences and healthcare, IT and electronics, and nearly every other sector of the global economy. Governments and corporations world-wide, led by the United States and Europe, ploughed over $4 billion into nanotechnology in the last year alone.

These innovations promise major benefits and pose significant dilemmas. Is it ethical to move life around this way, playing mix-and-match with bits from different animals and species? Should we create entirely new kinds of life from the molecule up? Would it be wrong to build a bacterial life form that depended on a machine for survival?

Or is that no more problematic than executing billions of little yeast molecules to make a barrel of beer or a loaf of bread? Do we stand on the doorstep of an agrarian revolution that promises to alleviate hunger in a world afflicted by poverty, disease and famine? Or do we stand poised to release mutant strains that could cause untold damage to human health and the environment? What is different about this that Physics are not already doing on a smaller scale, now what biology is doing all the time? Consumer advocates point out the individual perceives risks differently – personal and group risks are evaluated differently and the new technology must convince that it offers individual benefits first before any sort of personal risk assessment is made. G2 phones vs G3 were an example quoted – mobility was a benefit, accessing the internet while driving or walking not so much.

Few contemporary issues have as much power to stir emotion as genetic engineering and the modification of foodstuffs. Transatlantic differences in this area alone could lead to a WTO case, jeopardise more than $16 billion annually in US-European agricultural trade, endanger efforts to liberalise world trade, and further U.S.-EU relations. Stem Cells also are emotiove but as soon as they are seen to cure, the perception will change from “won’t do” to “can do” – only sourcing is an issue.
Such issues could be but a foretaste of the host of challenges and opportunities yet to come in the new NanoBioEconomy. Many agreed that the agenda has already been hijacked by retrogressive pressure groups who can motivate inaccurate science to be used by the media in ranks of prominence that are enviable. There is no quick riposte, just slow education and persuasion. Small is beautiful will not work this time.

How will the transatlantic community address the coming NanoBioEconomy? What are the implications of the new NanoBioeconomy for the US and European economies of today? Are the factories of tomorrow likely to be inside test tubes or on top of laboratory workbenches? What are the opportunities and what are the barriers? What regimes will shape this new economy? Who will benefit? Who should and who will ask the moral and social questions and who will set the regulations that will shape or stifle innovation?
These questions found much resonance but few answers. One point of agreement was the need for the educational system to deliver multi-skilled graduates by more complex degree structures, not by faster turnover. Equally, business does not yet demand these skills in numbers- but when they do the lag time will be higher than usual.

Could transatlantic norms in this field contribute to global approaches to the intersection of biology, technology, and commerce? Or are Europeans and Americans likely to diverge on their approaches to nanobioeconomic issues?

The designate S&T advisor to Colin Powell (who asked not to be attributed on anything) spoke forcefully and openly on the need for societal dialogue and education, and opened the doors to international collaboration in difficult technical areas (i.e. if the foreign postgrads don’t come to the US anymore, the US has to go to them).

These few questions alone underscore that one of the most pressing issues facing those on the vanguard of the NanoBioEconomy is to communicate with the non-scientific community. Thus a professional dialogue is suggested in order to increase public knowledge, involve public and convince the public at large so that they might become beneficiaries and consumers of the technology (both the under-resourced and the well off).

The European and American public have the right to know that scientists, governments and corporations have examined and addressed the potential risks associated with scientific breakthroughs and new technologies. Citizens want a say in making individual choices and the societal trade-offs related to the application of new technology and science. But are they well placed to have that say? Probably not. Science will be done, money will be invested at the right places by the industrial sector. They're looking for concrete measures aimed at building public confidence in 21st century progress. Decades of speculation and science fiction stories have made it difficult for the general public, political leaders, the media, business or financial communities to understand this fundamental shift in the way we interact with the natural world.

A US speaker emphasised the intention to reshape the world and to push the (Nano-) Biotechnology revolution. He sees Europe missing this revolution, e.g. when hesitating to use and explore GMO. Another European expert pointed out later that this attitude towards GMO still influences some African states due to historical cultural heritage – not to the “benefit” of the poor.
As to nano-bio-economy and the have-nots US and Europe have to come up with a common strategy to encourage private organisations to initiate and strengthen RTD and production (esp. of seed and food) in (non)developed countries (there is no further public money available).

A further step to generally strengthen US –EU relations - having different cultures - could be an exchange of (non-scientists) personal responsible for (executive) RTD etc. in parallel to the existing “task forces” on the legal level (Congress and EU-Parliament), which of course could also be reinforced.

A most useful point was made – the fear factor is in Nanotechnology, the application of nano-science. We still have to do LOTS of nano-science, which is far less contentious. If we can use the timelags of nano-science to educate and inform society then the process of involvement in the roll out of technology - whenever it comes - will be richer for all parties.

The US Keynote speaker ignored military issue and the lack of mechanisms in the NNI to address these issues, even though he is on the Board of the NNI. Somewhat surprisingly they had not met the CEO of the Foresight Institute either, who have been at the forefront of the US push for several years now.

Nanotechnology booming in Australia [34]

Nanotechnology is a national research priority of Australian and an investment attraction priority for Invest Australia. The Australian federal and state governments jointly support fundamental research, R&D and commercialization with $100m (AUD) annually

Over 30 new start-up companies have formed in the last few years. More than 70 research institutions across the country are working on nanotechnology. Australia's national scientific and industrial research organization, CSIRO, possesses major strengths in nano-composite materials and diagnostic devices, while also focusing on biomimetics, interfaces, environmentally significant separations and ambient sensing technologies. According to USA journal Science Watch, CSIRO is ranked third in the world for the frequency of citations for its publications on environmental science and fourth in the field of agricultural research. CSIRO has around 8 different nanotechnology IP platform technologies, ranging from sensors to sunscreens, on the market. A further 76 are undergoing commercial-in-confidence final field trials.

The Australian Nuclear Science & Technology Organization ANSTO has one of the few nuclear reactors in the world that is publicly available for research purposes. The materials company VSPC has facilities to produce 60 tonnes of nanoscale complex metal oxides for a variety of applications including emissions control and electronics. The company Micronisers has developed nanoscale nucleating agents for polypropylene and additives for use in sunscreens, cosmetics and coatings. These and other start up companies are open to discussion with potential international partners and Invest Australia is able to facilitate such relationships.

More information at:
http://www.investaustralia.gov.au/media/Nano% [..]
http://www.investaustralia.gov.au

[34] In an interview with the NanoBusiness Alliance, the Chief Executive Officer of Invest Australia, Garry Drafflin, gave information on Australia's status quo in nanotechnology.

Nanotechnology Markets ,O. Saxl, IoN[35] Nanotechnology in Asia Pacific 2004

There have been significant changes in the Science and Technology Policies of Asia Pacific countries since the announcement of the US National Nanotechnology Initiative in January 2000. Nanotechnology is now one of the main S&T priority areas for Asia Pacific governments. Budgets for nanotechnology R&D have been increased substantially and more strategically allocated. Total spending for Asia Pacific countries has exceeded US$1billion for the past 2 years and will continue to increase.

Japan has been investing in nano-science since the 1980s and after the USA is the heaviest nanotechnology R&D spender worldwide, and along with China, South Korea and Taiwan has increased its budget substantially since 2001. Australia is currently formulating a national strategy, but already has considerable infrastructure and funding in place. Thailand, India and Vietnam have also identified nanotechnology as a priority area and are taking steps to implement the proper framework.

This report gives a comprehensive overview of nanotechnology activity in the Asia Pacific Region. Countries covered include Japan, China, South Korea, Taiwan, Thailand, India, Singapore, Australia and Vietnam.
Nanotechnology in North America 2004

The National Nanotechnology Initiative was unveiled by President Clinton in a speech that he gave on science and technology policy in January 2000. In its 2001 budget submission to Congress, the Clinton administration raised nanotechnology to the level of a federal initiative. The National Nanotechnology Initiative is built around five funding themes distributed among the agencies currently funding nanoscale science and technology research and funding has increased year-by-year to over $800million in 2004. As well as federal funding, the individual states are also dedicating considerable funds to nanotechnology and there are over 250 companies in the US heavily involved in nanoscale R&D.

There is also a significant nanotechnology effort underway in Canada, though no National Initiative. There is strong support for R&D and a commitment from the various provincial governments. As well as the National Institute for Nanotechnology there is also Nano-Quebec: a nanotechnology initiative of the government of Quebec, a nanotechnology laboratory within the Quebec National Institute for Scientific Research, and Nano Innovation Platform under the Natural Sciences and Engineering Research Council (NSWRC).

Canada's core nanotechnology research is in the laboratories of the National Research Council and the major Canadian research universities.

This report gives a comprehensive overview of nanotechnology activity in North America. The report includes all major initiatives, government bodies, programmes, research institutes, universities, networks and companies, with contact details and is up-to-date to January 2004. Over 290 companies are profiled.

[35] Each section is an abstract of an extensive report issued by the IoN (see http://www.nano.org.uk/reports.htm)

Nanotechnology in UK 2004

The UK has excellent research credentials in nanotechnology, with world leading research at universities such as Glasgow, Oxford and Cambridge. Oxford and Cambridge lead the way in terms of nanotechnology research and spinning out companies, but there are a number of other significant centres and universities, with over 1500 researchers UK wide.

In the past couple of years there has been a significant increase in government support for nanotechnology research in universities, including the new University Innovation Centre in microsystems and nanotechnology at the Universities of Newcastle and Durham, and the Interdisciplinary Research Collaborations (IRCs). £18million is split between the two IRCs. Institute of Nanotechnology January 2004.

In 2003 the UK government announced it would be injecting £90 million over the next six years towards nanotechnology R&D and commercialisation. The investment will support collaborative research and a new network of micro and nanotechnology facilities. The government expects the investment will also secure additional industry and regional spending anticipated to exceed £200 million.
Nanotechnology in Europe 2004

Today, most industrialised European countries have Government supported major nanotechnology research and development initiatives. The most active EU country in nanotechnology is Germany at the moment, where the federal government has fostered a number of competence centres and provided over 110 million euros funding in 2003. The French government has also set up a similar structure where they attempt to centralise funding for micro and nanotechnology research. Of course, the initiatives are different due to differing national funding policies. Smaller dedicated programmes also exist in Austria, Finland and Sweden.

Germany is at the forefront with the Nanonet competence networks in which public research institutes, industries and SMEs collaborate on relatively application oriented research topics. The Swiss national programme TOPNano21 is similar. In the UK, the Netherlands and Flanders, governments have been ramping up their support for nanotechnology research.
Government Policy and Initiatives in Nanotechnology 2004
Governments and research bodies worldwide are strongly supporting both the research and development of nanotechnology, with over 30 countries initiating national initiatives. The United States leads the way and will be allocating over $800million in funding to the 2004 National Nanotechnolgy Initiative (NNI). The House of Representatives has also approved a bill that plans to allocate $2.36 billion to nanotechnology programmes over the next three years, not to mention the substantial state funding programmes.

Japan is next up, with almost $750millon in funding in 2002 and the European Union has assigned nanotechnology special status in the Sixth Framework Programme. Germany and Switzerland are leading the way in Europe, closely followed by the UK. The NNI stimulated worldwide interest and most developed countries now have fully-fledged nanotechnology initiatives.

6. Risk Aspects

Complexity and Uncertainty[36], JP Dupuy[37] January 2004

Summary: We have become capable of tampering with, and triggering off, complex phenomena. As a consequence we have to confront a new kind of uncertainty. The "Precautionary Principle" is of little help in that task. Anticipating the consequences of our technological choices is at the same time more important and more difficult than ever. What is desperately required is a novel science of the future.

The debate about molecular manufacturing

Eric Drexler, the inventor of the notion of nanotechnology, and Christine Peterson, the President of the Foresight Institute, are notoriously keen to make the distinction between "near-term nanotechnology" and "advanced nanotechnology". The former refers to any technology smaller than microtechnology, e.g. nanoparticles; the latter to " complete control of the physical structure of matter, all the way down to the atomic level.[38] " It is of course advanced nanotechnology, also known as molecular manufacturing, that will have major societal impact and possibly entail major risks, provided that ... it will see the light of day.

As is well known, controversy is still raging about the physical, technical, industrial, economical feasibility of molecular manufacturing. As Peterson puts it, "Until this issue has been put to rest, neither a funded molecular manufacturing R&D project nor effective study of societal implications can be carried out. [...] We urgently need a basic feasibility review in which molecular manufacturing's proponents and critics can present their technical cases to a group of unbiased physicists for analysis[39]."

In July 2003, the UK Economic and Social Research Council published a report entitled "The Social and Economic Challenges of Nanotechnology". It pointed to the current debate "about whether the radical view of nanotechnology, leading to molecular manufacturing, is feasible or practical, whether by the route sketched out by Drexler or some other means.

Those who consider this radical view of nanotechnology to be feasible are divided as to whether it will lead to a positive or negative outcome for society. This debate takes for granted that nanotechnology will have a revolutionary effect on society, and the contrasting visions are correspondingly utopian or dystopian."

On 18 November 2003, the US Senate passed the 21st Century Nanotechnology Research and Development Act, "to authorize appropriations for nanoscience, nanoengineering and nanotechnology research, and for other purposes". It called for a one-time study on the responsible development of nanotechnology "including, but not limited to, self-replicating nanoscale machines or devices; the release of such machines in natural environments; encryption; the development of defensive technologies; the use of nanotechnology in the enhancement of human intelligence; and the use of nanotechnology in developing AI.[40] "

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[36] A contribution to the work in progress of the "Foresighting the New Technology Wave" High-Level Expert Group, European Commission, Brussels, February 2nd, 2004.
[37] Ecole Polytechnique, Paris, and Stanford University
[38] Christine Peterson, a testimony given before the U.S. House of Representatives Committee on Science, April 9, 2003.
[39] Ibid.
[40] My emphasis.

Many have interpreted this as an opportunity and a challenge to those who support Drexler's vision of molecular manufacturing to make their case, or even as an endorsement of the feasibility of that program. In contrast, the studies performed by the UK's Royal Society/Royal Academy of Engineering are still wondering what nanotechnology is all about, without the least mention of molecular manufacturing.

Richard Smalley, the Nobel laureate in chemistry who was one of the discoverers of the fullerene (C 60), has been challenging Eric Drexler on the possibility of molecular manufacturing. Recently the former accused the latter of scaring children with stories of self-replicating nanobots going haywire, and the latter replied by saying, "U.S. progress in molecular manufacturing has been impeded by the dangerous illusion that it is infeasible. [...]Building with atomic precision will dramatically extend the range of potential products and decrease environmental impact as well.
The resulting abilities will be so powerful that, in a competitive world, failure to develop molecular manufacturing would be equivalent to unilateral disarmament.[41] "

The debate between the two men has also been quite technical, and it is all about the limitations of chemistry. Smalley asserts that atoms cannot simply be pushed together to make them react as desired, in the manner fancied by Drexler, but that their chemical environment must be controlled in great detail, through a many-dimensional hyperspace, and that this cannot be achieved with simple robotics. Drexler rejoins that such components of cells as enzymes or ribosomes are able to do precise and reliable chemistry.

Smalley agrees but adds that this can occur only under water. Drexler replies that his proposal does assert that chemistry in dry surfaces and a vacuum ("machine-phase chemistry") can be quite flexible and efficient, since holding a molecule in one place can have a strong catalytic effect. Drexler ends his statements by calling for further research, beginning with an independent scientific review of molecular manufacturing concepts.

An advocate of Drexler's program recently wrote:

Failure to anticipate the development of molecular manufacturing could have serious consequences. Simple physics theories, conservatively applied, predict that the technology will be dangerously powerful. A working molecular nanotechnology will likely require the design and enforcement of policies to control the use of compact advanced manufacturing systems and their products. But panicked last-minute policy will be bad policy—simultaneously oppressive and ineffective. The military implications are even more perilous.

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[41] Nanotechnology. Drexler and Smalley make the case for and against 'molecular assemblers'", *Chemical & Engineering News*, December 1, 2003. See http://pubs.acs.org/cen/coverstory/8148/8148counterpoint.html.

Molecular manufacturing systems are expected to be able to produce weapons as powerful as nuclear bombs, but much more selective, easier to manufacture, and easier to use. If a powerful nation suddenly realizes that molecular manufacturing is possible, and discovers that rival nations are already making material progress, they may react violently, or may enter into an arms race that will probably be unstable and thus may result in war with weapons of unprecedented power.

On the positive side, molecular manufacturing may be able to mitigate many of the world's humanitarian and environmental crises. Advancing its development by even a year or two could alleviate untold suffering, raising standards of living worldwide while sharply reducing our environmental footprint. However, rapid and effective humanitarian use may also depend on sound policy developed well in advance[42].

My opinion on this is the following. The Smalley – Drexler debate is a red herring, and we should refrain from taking a position about it, even if we had the scientific and technological expertise to do so. There is no doubt that molecular manufacturing is feasible once we regard molecular biology itself as a form of it. The issue is not one of essence but of point of view. As soon as we construe the cell as natural machinery, the possibility of tampering with it becomes a forgone conclusion. If the feasibility of molecular self-assembly is beyond question, it is because we have developed a view of nature and the living system that is akin to our own artefacts

<u>Complexity and Self-organization</u>

It is often asserted that the starting point of nanotechnology was the classic talk given by Feynman in 1959[43], in which he said: "The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. [...] It would be, in principle, possible (I think) for a physicist to synthesize any chemical substance that the chemist writes down. Give the orders and the physicist synthesizes it. How? Put the atoms down where the chemist says, and so you make the substance." Today's champions of nanotech add: "We need to apply at the molecular scale the concept that has demonstrated its effectiveness at the macroscopic scale: making parts go where we want by putting them where we want![44] "

I tend to disagree. If such were the essence of (advanced) nanotechnology, the worries that it raises would rest on sheer ignorance. As Nature science writer Philip Ball puts it in his excellent essay, "2003: nanotechnology in the firing line"[45]:

In March [2003], the Royal Institution (RI) in London hosted a day-long seminar on nanotech called “Atom by atom”, which I personally found useful for hearing a broad cross-section of opinions on what has become known as nanoethics. [...] First, the worry was raised that what is qualitatively new about nanotech is that it allows, for the first time, the manipulation of matter at the atomic scale. This may be a common view, and it must force us to ask: how can

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[42] Chris Phoenix, "Of Chemistry, Nanobots, and Policy", Center for Responsible Nanotechnology, December 2003. http://crnano.org/Debate.htm.

[43] "There's Plenty of Room At the Bottom".
[44] See http://www.zyvex.com/nano/
[45] Nanotechweb.org, 23 December 2003. http://www.nanotechweb.org/articles/society/2/12/1/1

it be that we live in a society where it is not generally appreciated that this is what chemistry has done in a rational and informed way for the past two centuries and more? How have we let that happen? It is becoming increasingly clear that the debate about the ultimate scope and possibilities of nanotech revolve around questions of basic chemistry [...]. The knowledge vacuum in which much public debate of nanotech is taking place exists because we have little public understanding of chemistry: what it is, what it does, and what it can do.

Writing about nanoethics, Ball goes on to say:

Questions about safety, equity, military involvement and openness are ones that pertain to many other areas of science and technology. It would be a grave and possibly dangerous distortion if nanotechnology were to come to be seen as a discipline that raises unprecedented ethical and moral issues. In this respect, I think it genuinely does differ from some aspects of biotechnological research, which broach entirely new moral questions. Yet it is perhaps the first major field of science, applied science or technology - call it what you will - to have emerged in a social climate that is sensitized in advance to the need for ethical debate in emerging technologies.

[...]Yet the pragmatic truth is that if nanotechnology does not acknowledge some kind of ethical dimension, it will be forced upon it in any case. Those working in the field know that nanotech is not really a discipline at all, that it has no coherent aims and is not the sole concern of any one industrial sector. But even funding agencies speak of it as though this were not so. To the public mind, organizations such as the US National Nanotechnology Initiative surely suggest by their very existence that nanotech has some unity, and it is therefore quite proper that people will want to be reassured that its ethical aspects are being considered.

Here I cannot follow Philip Ball. I believe him to be wrong on two major accounts. I believe there is indeed some kind of unity behind the nanotech enterprise and even behind the NBIC convergence; but that this unity lies at the level of the metaphysical research program that underpins such convergence. I also believe that the ethical issues raised by it are to a large extent novel and that they find their source in the very ideas that govern the field.

In order to substantiate those two claims, I suggest that the origin of the new field is to be sought in another classic conference, the one John von Neumann gave at Caltech in 1948 on complexity and self-reproducing automata.

Turing's and Church's theses were very influential at the time, and they had been supplemented by cyberneticians Warren McCulloch and Walter Pitts' major finding on the properties of neural networks. Cybernetics' Credo was then: every behavior that is unambiguously describable in a finite number of words is computable by a network of formal neurons---a remarkable statement, as John von Neumann recognized.

However, he put forward the following objection: is it reasonable to assume as a practical matter that our most complex behaviours are describable in their totality, without ambiguity, using a finite number of words? In specific cases it is always possible: our capacity, for example, to recognize the same triangular form in two empirical triangles displaying differences in line, size, and position can be so described.

But would this be possible if it were a matter of globally characterizing our capacity for establishing "visual analogies"? In that case, von Neumann conjectured, it may be that the simplest way to describe a behaviour is to describe the structure that generates it.
It is meaningless, under these circumstances, to "discover" that such a behaviour can be embodied in a neural network since it is not possible to define the behaviour other than by describing the network itself.

Von Neumann thus posed the question of complexity, foreseeing that it would become the great question for science in the future. Complexity implied for him in this case the futility of the constructive approach of McCulloch and Pitts, which reduced a function to a structure---leaving unanswered the question of what a complex structure is capable[46].

It was of course in the course of his work on automata theory that von Neumann was to refine this notion of complexity. Assuming a magnitude of a thermodynamical type, he conjectured that below a certain threshold it would be degenerative, meaning that the degree of organization could only decrease, but that above this threshold an increase in complexity became possible. Now this threshold of complexity, he supposed, is also the point at which the structure of an object becomes simpler than the description of its properties. Soon, JVN prophesied, the builder of automata would find himself as helpless before his creation as we feel ourselves to be in the presence of complex natural phenomena.[47]

At any rate, JVN was thus founding the so-called bottom-up approach aka reverse engineering. In keeping with that philosophy, the engineers of the future will not be any more the ones who devise and design a structure capable of fulfilling a function that has been assigned to them. The engineers of the future will be the ones who know they are successful when they are surprised by their own creations. If one of your goals is to reproduce life, to fabricate life, you have to be able to simulate one of its most essential properties, namely the capacity to complexify itself always more.

Admittedly, not all of nanotech falls under the category of complexity. However, the scope covered by it, especially in the case of the NBIC convergence, is much wider and relevant than the implications of a possible Drexler-type molecular manufacturing.

Even more importantly, the novel kind of uncertainty that is brought about by those new technologies is intimately linked with their being able to set off complex phenomena in the Neumannian sense.

Unchaining Complexity

It would be a mistake to think that, although novel, our current situation before the consequences of our technological choices is not the outcome of a long historical process. Discontinuities and ruptures must always be analyzed against the background of continuous dynamics. In her masterly study of the frailties of human action, Human Condition[48], Hannah

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[46] Here as elsewhere, the irony of intellectual history is great. Marvin Minsky, who wrote his doctoral thesis under von Neumann, regarded his teacher's attack on McCulloch's approach as an aberration, an admission of weakness, a lack of faith in what he himself, John von Neumann, had managed to accomplish. Now, as is well known, Eric Drexler wrote his dissertation on nanotech under Minsky's supervision!
[47] On all that, see my *The Mechanization of the Mind*, Princeton University Press, 2000.
[48] The University of Chicago Press, 1958.

Arendt brought out the fundamental paradox of our time: as human powers increase through technological progress, we are less and less equipped to control the consequences of our actions. A long excerpt is worth quoting here, as its relevance for our topic cannot be overstated – and we should keep in mind that this was written in 1958:

[...] the attempt to eliminate action because of its uncertainty and to save human affairs from their frailty by dealing with them as though they were or could become the planned products of human making has first of all resulted in channeling the human capacity for action, for beginning new and spontaneous processes which without men never would come into existence, into an attitude toward nature which up to the latest stage of the modern age had been one of exploring natural laws and fabricating objects out of natural material. To what extent we have begun to act into nature, in the literal sense of the word, is perhaps best illustrated by a recent casual remark of a scientist who quite seriously suggested that "basic research is when I am doing what I don't know what I am doing." [Wernher von Braun, December 1957].

This started harmlessly enough with the experiment in which men were no longer content to observe, to register, and contemplate whatever nature was willing to yield in her own appearance, but began to prescribe conditions and to provoke natural processes.

What then developed into an ever-increasing skill in unchaining elemental processes, which, without the interference of men, would have lain dormant and perhaps never have come to pass, has finally ended in a veritable art of 'making' nature, that is, of creating 'natural' processes which without men would never exist and which earthly nature by herself seems incapable of accomplishing [...].

The very fact that natural sciences have become exclusively sciences of process and, in their last stage, sciences of potentially irreversible, irremediable 'processes of no return' is a clear indication that, whatever the brain power necessary to start them, the actual underlying human capacity which alone could bring about this development is no 'theoretical' capacity, neither contemplation nor reason, but the human ability to act – to start new unprecedented processes whose outcome remains uncertain and unpredictable whether they are let loose in the human or the natural realm.

In this aspect of action [...] processes are started whose outcome is unpredictable, so that uncertainty rather than frailty becomes the decisive character of human affairs[49].

No doubt that with an incredible prescience this analysis applies perfectly well to the NBIC convergence, in particular on two scores. Firstly, the ambition to (re-) make nature is an important dimension of what I called the metaphysical underpinnings of the field. If the NBIC converging technologies purport to take over Nature's and Life's job and become the engineers of evolution, it is because they have redefined Nature and Life in terms that belong to the realm of artifacts. See how one of their most vocal champions, Damien Broderick, rewrites the history of life, or, as he puts it, of "living replicators":
Genetic algorithms in planetary numbers lurched about on the surface of the earth and under the sea, and indeed as we now know deep within it, for billions of years, replicating and mutating and being winnowed via the success of their expressions – that is, the bodies they

[49] P. 230-232. My emphasis.

manufactured, competing for survival in the macro world. At last, the entire living ecology of the planet has accumulated, and represents a colossal quantity of compressed, schematic information.[50]

Once life has thus been transmogrified into an artifact, the next step is to ask oneself whether the human mind couldn't do better. The same author asks rhetorically, "Is it likely that nanosystems, designed by human minds, will bypass all this ¨Darwinian wandering, and leap straight to design success?[51] "

Secondly, as explained before, it will be an inevitable temptation, not to say a task or a duty, for the nanotechnologists of the future to set off processes upon which they have no control. The sorcerer's apprentice myth must be updated: it is neither by error nor by terror that Man will be dispossessed of his own creations but by design.

There is no need for Drexlerian self-assemblers to come into existence for this to happen. The paradigm of complex, self-organizing systems envisioned by von Neumann is stepping ahead at an accelerated pace, both in science and in technology. It is in the process of shoving away and replacing the old metaphors inherited from the cybernetic paradigm, like the ones that treat the mind or the genome as computer programs. In science, the central dogmas of molecular biology received a severe blow on two occasions recently. First, with the discovery that the genome of an adult, differentiated cell can be "reprogrammed" with the cooperation of maternal cytoplasm – hence the technologies of nucleus transfer, including therapeutic and reproductive cloning. Secondly, with the discovery of prions, which showed that self-replication does not require DNA. As a result, the sequencing of the human genome appears to be not the end of the road but its timid beginning. Proteinomics and Complexity are becoming the catchwords in biology, relegating Genomics to the realm of passé ideas.

In technology, new feats are being flaunted every passing week. Again, the time has not come – and may never come – when we manufacture self-replicating machinery that mimics the self-replication of living materials. However, we are taking more and more control of living materials and their capacity for self-organization and we use them to mimic smart machinery or perform mechanical functions.

Examples are plenty. To name just a few: in December 2003, IBM managed to create silicon memory chips using a template provided by a plastic polymer that organizes itself naturally. One application of the technology could be to design flash memory chips with cells roughly 1/100th the size of the cells currently required to store a piece of data.

More broadly, IBM said, "the successful research suggests that polymer-based self-assembly techniques could be used to build other kinds of microchips in the future, when more features shrink to such small scales that current production techniques become impractical[52]". On the same month, scientists from DuPont, the University of Illinois at Urbana-Champaign and the MIT used the self-assembly of DNA to sort carbon nanotubes according to their diameter and electronic properties. DuPont said, “spontaneous self-assembly of nucleic acid bases occurs

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[50] Damien Broderick, *The Spike*, Forge, New York, 2001, p. 116. My emphasis.
[51] Ibid., p. 118.
[52] See Barnaby Feder, "I.B.M. set to unveil chip-making advance", *New York Times*, December 8, 2003: http://www.siliconinvestor.com/stocktalk/msg.gsp?msgid=19572729.

on a variety of inorganic surfaces. This phenomenon, considered as an important prebiotic process relevant to the origin of life, has led us to seek a new function for nucleic acids in the manipulation of inorganic nanomaterials, where interfacial interactions dominate."

The feat will have momentous applications, since "the separation of carbon nanotubes is the single greatest impediment to their technological application.[53]" Last November, scientists in Israel built transistors out of carbon nanotubes using DNA as a template. A Technion-Israel scientist said, "What we've done is to bring biology to self-assemble an electronic device in a test tube [...]The DNA serves as a scaffold, a template that will determine where the carbon nanotubes will sit. That's the beauty of using biology.[54] " Etc. etc.

<u>A new kind of uncertainty and the irrelevance of the Precautionary Principle</u>

Our tampering with, and setting off complex processes, in the technical, Neumannian sense of the word "complex", brings about a kind of uncertainty that is radically novel. In particular, it is completely alien to the distinctions upon which rests the Precautionary Principle.

The precautionary principle introduces what initially appears to be an interesting distinction between two types of risks: "known" risks and "potential" risks. It is on this distinction that the difference between prevention and precaution is made to rest: precaution would be to potential risks what prevention is to known risks.

A closer look reveals 1) that the expression "potential risk" is poorly chosen, and that what it designates is not a risk waiting to be realized, but a hypothetical risk, one that is only a matter of conjecture;
2) that the distinction between known risks and hypothetical risks (the term I will adopt here) corresponds to an old standby of economic thought, the distinction that John Maynard Keynes and Frank Knight independently proposed in 1921 between risk and uncertainty. A risk can in principle be quantified in terms of objective probabilities based on observable frequencies; when such quantification is not possible, one enters the realm of uncertainty.

The problem is that economic thought and the decision theory underlying it were destined to abandon this distinction as of the 1950s in the wake of the exploit successfully performed by Leonard Savage with the introduction of the concept of subjective probability and the corresponding philosophy of choice under conditions of uncertainty: Bayesianism. In Savage's axiomatics, probabilities no longer correspond to any sort of regularity found in nature, but simply to the coherence displayed by a given agent's choices. In philosophical language, every uncertainty is treated as an epistemic uncertainty, meaning an uncertainty associated with the agent's state of knowledge. It is easy to see that the introduction of subjective probabilities erases the distinction between uncertainty and risk, between risk and the risk of risk, between precaution and prevention. If a probability is unknown, a probability distribution is assigned to it "subjectively". Then the probabilities are composed following the computation rules of the same name. No difference remains compared to the case where objective probabilities are available from the outset. Uncertainty owing to lack of knowledge

[53] Liz Kalaugher, "DNA sorts out nanotubes", *Nanotechweb.org*,, 3 December 2003: http://www.nanotechweb.org/articles/news/2/12/1/1.
[54] Kenneth Chang, " Smaller Computer Chips Built Using DNA as Template", *New York Times*, November 21, 2003:
http://www.nytimes.com/2003/11/21/science/21DNA.html?ex=1075525200&en=67948bd27029a142&ei=5070.

is brought down to the same plane as intrinsic uncertainty due to the random nature of the event under consideration. A risk economist and an insurance theorist do not see and cannot see any essential difference between prevention and precaution and, indeed, reduce the latter to the former. In truth, one observes that applications of the "precautionary principle" generally boil down to little more than a glorified version of "cost-benefit" analysis.
Against the prevailing economism, I believe it is urgent to safeguard the idea that all is not epistemic uncertainty. One could however argue from a philosophical standpoint that such is really the case. The fall of a die is what supplied most of our languages with the words for chance or accident. Now, the fall of a die is a physical phenomenon that is viewed today as a low-stability deterministic system, sensitive to initial conditions, and therefore unpredictable — a "deterministic chaos," in current parlance. But an omniscient being — the God of whom Laplace did not judge it necessary to postulate the existence — would be able to predict on which side the die is going to fall. Could one not then say that what is uncertain for us, but not for this mathematician-God, is uncertain only because of lack of knowledge on our part? And therefore that this uncertainty, too, is epistemic and subjective?

The correct conclusion is a different one. If a random occurrence is unpredictable for us, this is not because of a lack of knowledge that could be overcome by more extensive research; it is because only an infinite calculator could predict a future which, given our finiteness, we will forever be unable to anticipate. Our finiteness obviously cannot be placed on the same level as the state of our knowledge. The former is an unalterable aspect of the human condition; the latter, a contingent fact, which could at any moment be different from what it is. We are therefore right to treat the random event's uncertainty for us as an objective uncertainty, even though this uncertainty would vanish for an infinite observer.

Now, our situation with respect to the complex phenomena we are about to unleash is also one of objective, and not epistemic, uncertainty. The novel feature this time is that we are not dealing with a random occurrence either. Neither random, nor epistemically uncertain, the type of "risk" that we are confronting is a monster from the standpoint of classic distinctions. Indeed, it merits a special treatment, which the precautionary principle is incapable of giving it.

We know today that what makes a complex system, (e. g. a network of molecules connected by chemical reactions or a trophic system) robust is exactly what makes it exceedingly vulnerable if and when certain circumstances are met. As Albert-László Barabási puts it, this "coexistence of robustness and vulnerability plays a key role in understanding the behavior of most complex systems. [...] topology, robustness, and vulnerability cannot be fully separated from one another.
All complex systems have their Achilles' heel.[55] " Complexity gives those systems an extraordinary stability and a no less remarkable resilience. They can hold their own against all sorts of aggressions and find ways of adapting to maintain their stability. This is only true up to a certain point, however. Beyond certain tipping points, they veer over abruptly into something different, in the fashion of phase changes of matter, collapsing completely or else forming other types of systems that can have properties highly undesirable for people. In mathematics, such discontinuities are called catastrophes. This sudden loss of resilience gives complex systems a particularity which no engineer could transpose into an artificial system

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[55] *Linked. The New Science of Networks*, Perseus Publishing, Cambridge (Mass.), 2002, p. 118 and 121-122.

without being immediately fired from his job: the alarm signals go off only when it is too late. And in most cases we do not even know where these tipping points are located. Our uncertainty regarding the behavior of complex systems has thus nothing to do with a temporary insufficiency of our knowledge, it has everything to do with objective, structural properties of complex systems.

On the other hand, this uncertainty is not random, as it is not amenable to the concept of probability. The key notion here is that of informational incompressibility, which is a form of essential unpredictability. In keeping with von Neumann's intuitions on complexity, a complex process is defined today as one for which the simplest model is the process itself. The only way to determine the future of the system is to run it: there are no shortcuts. This is a radical uncertainty: in contrast with a deterministic chaos – the source of randomness –, perfect knowledge of the initial conditions would not be enough to predict the future states of the system. Its unpredictability is irremediable.

When the precautionary principle states that the "absence of certainties, given the current state of scientific and technical knowledge, must not delay the adoption of effective and proportionate preventive measures aimed at forestalling a risk of grave and irreversible damage to the environment at an economically acceptable cost", it is clear that it places itself from the outset within the framework of epistemic uncertainty. The presupposition is that we know we are in a situation of uncertainty. It is an axiom of epistemic logic that if I do not know p, then I know that I do not know p. Yet, as soon as we depart from this framework, we must entertain the possibility that we do not know that we do not know something.
An analogous situation obtains in the realm of perception with the blind spot, that area of the retina unserved by the optic nerve. At the very center of our field of vision, we do not see, but our brain behaves in such a way that we do not see that we do not see. In cases where the uncertainty is such that it entails that the uncertainty itself is uncertain, it is impossible to know whether or not the conditions for the application of the precautionary principle have been met. If we apply the principle to itself, it will invalidate itself before our eyes.

Moreover, "given the current state of scientific and technical knowledge" implies that a scientific research effort could overcome the uncertainty in question, whose existence is viewed as purely contingent. It is a safe bet that a "precautionary policy" will inevitably include the edict that research efforts must be pursued — as if the gap between what is known and what needs to be known could be filled by a supplementary effort on the part of the knowing subject. But it is not uncommon to encounter cases in which the progress of knowledge comports an increase in uncertainty for the decision-maker, something which is inconceivable within the framework of epistemic uncertainty. Sometimes, to learn more is to discover hidden complexities that make us realize that the mastery we thought we had over phenomena was in part illusory.

Technology Assessment of NanoTechnology, A. Rip

1. Approach

Summary: The focus is on processes (of co-evolution of nanotechnoloy and society) and how to improve them. Three main components:
mapping and analysing ongoing dynamics of technological development, the actors and networks involved, and the further (and possibly conflictual) embedding in society, with particular attention to emerging patterns
articulating, on that basis, socio-technical scenarios about further developments and possible impacts, and stimulating reflection.
search for early signals about impact (as such, and in terms of concerns that can be articulated).

Nanotechnology is at an early stage of development. Promises about new technological options abound, but little definitive can be said about their eventual realization, let alone impacts on society. Thus, an impact assessment of nanotechnology would be speculation; one could call it science fiction (about future nanotechnology) combined with social science fiction (about the world in which future nanotechnology would have impacts). Still, it is important to create visions of possible futures, so as to stimulate reflection and broaden the scope of strategic choices about nanotechnology and more generally.

Within the range of approaches to technology assessment, one can see future visioning as one extreme. The other extreme is how firms and R&D institutions compare existing technological options in order to select the promising ones. In other words, an attempt to pick the winners, even if it the question which will in the end be the winners is still open. Within the range of approaches between these two extremes, new methodologies have been developed and piloted over the last ten years, under the label of Constructive Technology Assessment. This approach is called ‘constructive’ because it attempts to contribute to the actual construction of new technologies and how these get more or less embedded in society, rather than wait for this to happen and only then try to map possible impacts. It is this approach which will be followed in the project. Other methodologies and techniques, and contributions from further disciplines, will be included when appropriate.

The approach of Constructive Technology Assessment has been pioneered by Rip and his group at the University of Twente, and is now attracting attention worldwide.

A. Rip, Th. Misa, J.W. Schot (eds.), Managing Technology in Society. The Approach of Constructive Technology Assessment (London: Pinter Publishers, 1995).
Johan Schot and Arie Rip, 'The Past and Future of Constructive Technology Assessment,' Technological Forecasting and Social Change, 54 (1997) 251-268.
Arie Rip, ‘Assessing the Impacts of Innovation: New Developments in Technology Assessment,’ in OECD Proceedings, Social Sciences and Innovation, Paris: OECD, 2001, pp. 197-213.
Arie Rip, Challenges for Technology Foresight/Assessment and Governance, Enschede: University of Twente, 2002. A report commissioned by the Commission of the European

Union, contributing to the STRATA program area ‘Sustainability: R&D policy, the precautionary principle and new governance models’.
The overall perspective is one of co-evolution of technological developments and societal changes, in which patterns emerge (including preferred technological paths and so-called dominant designs) which will shape further co-evolution. Concretely, the approach combines

mapping and analysing ongoing dynamics of technological development, the actors and networks involved, and the further (and possibly conflictual) embedding in society, with particular attention to emerging patterns
articulating, on that basis, socio-technical scenarios about further developments and possible impacts, and stimulating reflection more broadly..

There is an element of speculation, but it is controlled speculation. It will help technologists and other relevant actors to reflect on their strategies and choices, making these more socially robust. Compared with customary technological roadmapping, this analysis is broader, and builds on analysis of ongoing dynamics rather than reasoning back from goals to be achieved in x years, and identification of what needs to be done to overcome barriers. The 2002 conference on Nanotechnology Business Roadmap for Industry in Chicago indicated the importance of focusing on dynamics. The scenarios which are developed in this project are open-ended, and serve to identify ‘forks’ in the development so that key choices can be made.

Nanotechnology is still at an early stage, which implies that it lives on promises rather than actual performances. In addition, the promises of nanotechnology have to be realized through their uptake in other products and services (from better analysis to sunscreeners to drug delivery). Its impact depends on what happens there, and is in that sense co-produced, even if one might consider that is nanotechnology which has made the difference. (Thus, the well-known problem of attribution of impacts to earlier actions.)

The analysis must therefore focus on expectations and how these evolve and set an agenda, and on the parallel emergence of alliances and networks and how these support particular directions of development. In the NanoNed programme itself one sees such agenda building and links with other researchers and with a variety of interested firms. The combination of evolving agendas and emergent structures, and the irreversibilities that arise, sets the patterns for further developments. Constructive TA reconstructs these dynamics and extrapolates them in socio-technical scenarios.

This approach to assessment of a technology at an early stage can build on a number of relevant methodologies and some pilots (including SocRobust, an EU-FP5 project recently concluded), as well on recent advances in relevant disciplines, in particular innovation studies, sociology of technology, and industrial economics. It also raises challenges for these disciplines, viz. to analyze processes in real time rather than in retrospect, and to do so in interdisciplinary collaborations. There are examples already, but for technologies at a later stage, like fuel-cell technologies.

Avadikyan et al. (2003) emphasize, in their analysis, how networks of firms, laboratories and policy-makers create ‘collective visions’ (or at least, shared agendas) and allow sharing of knowledge, aspects usually neglected by economists. Studies by sociologists of technology show how such networks themselves emerge because of expectations about the new technology and attempts to learn about its potential.

Schaeffer, Gerrit Jan, Fuel Cells for the Future. A Contribution to Technology Forecasting from a Technology Dynamics Perspective, PhD Thesis, University of Twente, 1998
Hoogma, Remco, Exploiting Technological Niches. Strategies for Experimental Introduction of Electric Vehicles. PhD Thesis, University of Twente, 2000.
A. Avadikyan. P. Cohendet, J.-A. Heraud (eds.), The Economic Dynamics of Fuel Cell Technologies (Berlin: Springer Verlag, forthcoming 2003)

Clearly, TA studies of nanotechnology can learn from the analysis of what happened with fuel-cell technologies, provided one takes into account the even more open-ended nature of developments in nanotechnology.

The other dimension on which we can learn from what happened with other technologies is about their possibly conflictual embedding in society. While it is too early to expect actual conflicts about nanotechnology, concerns are being articulated, for example about uncontrolled spread of nano-particles. What happened and is happening in this respect with biotechnology and genomics can be taken as a learning experience, even if the technologies are different. Genomics stimulation programmes now have an ELSA component: Ethical, Legal and Social Aspects of the new technology.

To include TA studies in the NanoNed program is a similar pro-active response to possible societal concerns (the US National Nanotechnology Initiative responds to recent concerns by saying they are working on them already). In nanotechnology, however, it will be more difficult than in genomics to identify such aspects directly, because nanotechnology's impacts will depend on how various technological options are taken up in sectors closer to eventual users.

What is possible, and this is the third main component of the project:

search for early signals about impact (as such, and in terms of concerns that can be articulated).

The challenge is the assessment of the significance of the signals. Customary quality checks cannot be used (the impacts are not yet there) while, as case studies of early warning show, early signals start out as tentative, often diffuse and not yet convincing. Still, there might be something in them. To address this dilemma, two approaches will be used. First, insight in the dynamics of early warning. In particular, recent work in risk assessment has shown the role that 'story lines', say of escape of a new device from its confinement, play in the articulation and assessment of concerns (and not only because novels are written with such a plot). Second, the possibility of quality control of the process of interaction and articulation, rather than the signals themselves. This idea is now pursued more widely, and a few interesting experiments with interactive TA can be a further input into understanding the quality of the processes and improving them.

In general, TA of new technologies faces the problem that the technology, let alone the impacts, are not yet there (so controlled speculation is necessary). In addition, the technology that is the object of a TA study may well change along the way, as such and as to intended functionalities; or it may be left because other options appear to be more attractive.

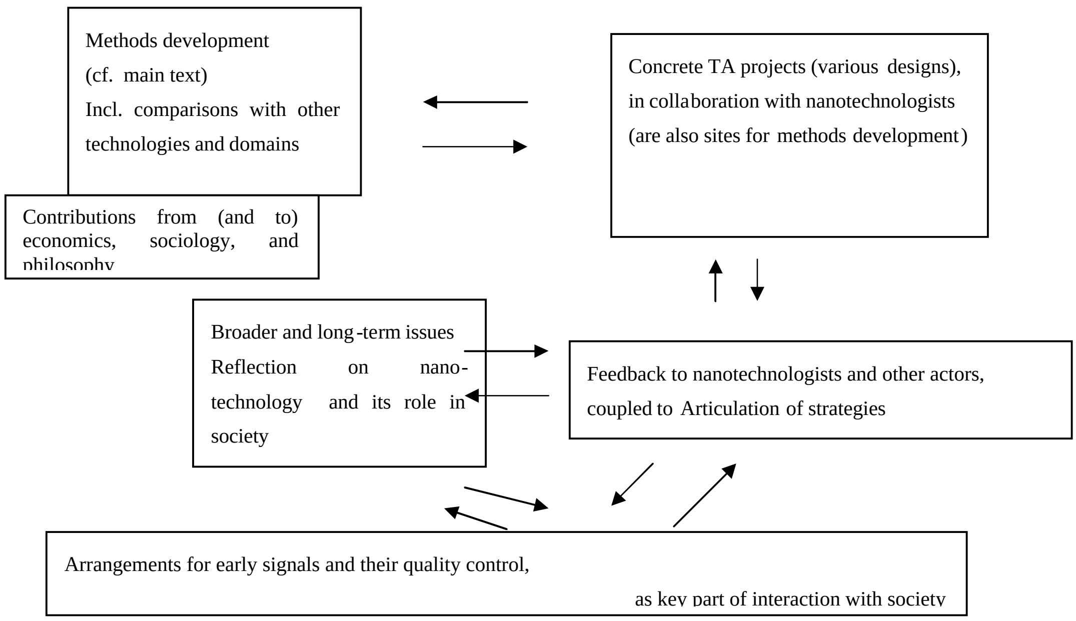
Rather than taking these considerations as messages of despair, we see them as challenges. One concrete implication is that TA studies cannot be a one-off matter, and that feedback to relevant actors and take up in choices is often a more important result than the findings of the study as such.

A broader implication is that TA is not (just) about a particular technology and its potential impacts, but about the co-evolution of technologies and society and the emerging patterns that can be traced in the co-evolution. Such patterns then shape further actions and choices, and in that sense, are predictors for what may happen. But the issue is not just about predictability and thus better management (broadly speaking), but also about reflection.
What does it mean when you can manipulate and control materials at the nano-scale –which will enable changes which the nanotechnologist herself cannot foresee, let alone control?

Such TA studies require inputs from technology studies and innovation studies (interdisciplinary domains which include contributions from sociologists and philosophers), but also evolutionary economics and industrial economics, industrial ecology and political science. They also, and importantly, require inputs from technologists themselves. The latter, and the productive interaction of technologists and social scientists, will be an explicit part of the design of the project.

2. Goals and activities

Overview:



Activities comprise:
Separate studies (by junior and senior science & technology scholars etc)
Methodology development
Dedicated TA studies (with particular emphasis on scenarios and emergent networks and structures)
Begleitforschung of ongoing nanotechnology research and interaction with researchers and other actors

Nanotechnologists adding TA and reflection on nanotechnology to their work
Special meetings and projects (cf. feedback and articulation of strategies)
Collaboration with TA nanotechnology projects elsewhere, and with scholars doing relevant work in sociology and economics of technology
Participation in the fast-moving world of nanotechnology
Link with interactive communication projects about nanotechnology, but no own contribution

These activities will be done by the Dutch TA NanoTech Network, the core members of which are University of Twente, University of Utrecht, Technical University of Delft, and Technical University of Eindhoven, with contributions from other universities and STB-TNO, and from relevant individuals. The TANT Network will be led by Arie Rip (University of Twente).

The TANT Network already has collaborative links with relevant groups, individuals and networks in Europe and outside Europe, and will expand and intensify such links. Examples are the European Network on Social Impact of Nanotechnology (ENSIN), the COST Nanoscience and –Technology Advisory Group (NanoSTAG) with its interest in ELSA studies of NanoTech, and the Technology Scenarios Programme at Risø National Laboratory in Denmark. Interesting developments in the USA, in the wake of the National Nanotechnology Initiative include attempts at interactive TA from CSPO at Columbia University, and the more philosophically oriented projects at the University of South Carolina and their 'NanoTalk' discussion forum.

Because of the increasing interest in nanotechnology, such TA-type initiatives, groups and networks proliferate. It is essential to work in a coordinated manner, and for the Dutch TANT efforts select topics and approaches which will make a difference, rather than reiterate what is being done elsewhere. The dynamics of nanotechnology development and its embedment in society are a global phenomenon, even if uptake of nanotechnology will always start locally. Articulation of strategies will take the specifics of the Dutch situation (and to some extent the European situation, e.g. for the issue of selective concentration) into account.

Some of the activities will be part of the regular work of the groups participating in the TANT Network, or get additional support. The NanoNed funds will be used for three purposes:
To employ researchers (often with an economics or sociology background) on dedicated projects. We expect to have three PhD students and one post-doc employed throughout the period of six years.
To support nanotechnologists in doing small projects (and other activities) adding a TA-component to their work. We expect interest with PhD students, and we shall develop special guidance for such projects.
To support non-research activities of which strengthen and expand the TA component of NanoNed, and enhance reflection across NanoNed as a whole. These activities will include general inputs from economics, sociology and philosophy, offered by internationally known scholars.

The actual projects will be designed as selections from the items in the general approach, and the opportunities and needs of the research and emerging networks in NanoNed.

We will link up with work that is being done already, for example a Constructive TA study of lab-on-a-chip and technological options linked to advances in nanofluidics; and a study of informal and formal scenarios ("fictive worlds") of actors, combined with the construction of integrative socio-technical scenarios by the analyst. We can also profit from collaborations that have been set up internationally with evolutionary and industrial economists, and with sociologists and policy analysts working on expectations about new technologies. There are opportunities to develop new approaches in innovation studies and industrial economics.

Arie Rip

Living in an Uncertain World, I.Pearson BT, October 2003

Introduction

The human world has always been changing, but the pace of change seems to have picked up dramatically in the last decade or two, with no stability visible on even long-range scanners. Rapid change is obvious in all of the technological, political, business and social fields, and there are changes in our environment and ecosystem that are probably caused by this increasing human activity. Rapid change in itself is not a problem for prediction provided that it follows some sort of known trend or algorithm, but the complexity of the human environment means that a surprise change in any field can often disrupt trends across a number of other fields. This interconnectedness and trend vulnerability makes predicting the future more difficult. Instead of stability in the rates of change, every now and then an event happens that introduces a discontinuity. Occasionally, the change may be completely unexpected, but some discontinuity-causing events are called wildcards, and although they may be anticipated in the sense that we know they could happen, they can happen at almost any time, so their timing or their precise nature may be unknown until they happen. (The events of 9/11 were anticipated by many futurists, who predicted a major terrorist incident in the near future in a major US city, but they didn't know when or where it would happen, or in what form. It could just as easily have been a nerve gas release in Los Angeles). Worse still, the frequency of wildcards and discontinuities is increasing.

If even professional futurists find it harder to predict, other people must have even more uncertainty about their future. Faced with uncertainty, people behave in many different ways, and this in itself introduces even more uncertainty into the socio-economic environment. Predictions must therefore take some account of often irrational behaviours that result from responses to perceived changes by large numbers of people who don't have a clear picture of what is actually happening, and have at best amateur planning skills. Companies who want to survive need to adopt strategies that can adapt to a market that is changing fast and often unpredictably. Individuals also need ways of coping with the changes thrown at them, at short notice, and without knowing the full picture.

Some will naturally respond by trying to take control, while others will hide their heads in the sand or just worry about the day ahead. Governments need to hold their ever-changing populations together in peaceful coexistence in spite of increasing pressures and turbulence.

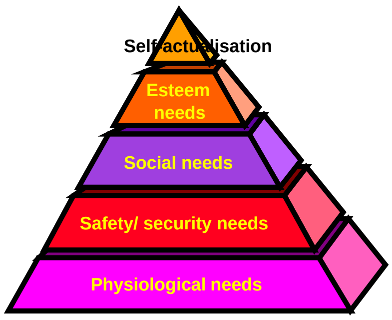
In this article, I discuss some of the changes that are affecting us today and in the future, and some of the ways in which people try to cope with them, hopefully putting us in a better position to work out the consequent changes resulting from the human stimulus/response cycle.

Social complexity & Maslow

Moore's Law has held true in the semiconductor industry for decades and looks certain to last at least another 15 years. Since semiconductor progress underlies most IT advances, this makes the whole of IT quite predictable. Even outside of IT, technology development rates are usually fairly stable too, so technology as a whole is mostly very predictable.

However, although technology is one of the primary engines driving change, the ways in which those change are realised depend on a host of other factors, such as regulation, politics, social behaviour, economic stability and so on. Many of these factors are controlled to a large extent by trained professionals, presumably via a rational, well informed decision making process, which makes them more predictable. By contrast, the two related areas of politics and social behaviour are much more chaotic, often with a decision making process that is far from rational or well informed. Nevertheless, we must take account of these effects when trying to figure out the future, even if we are coming from a technology angle.

Underlying human nature hasn't changed much over the last few thousand years - we still have the same basic needs as our distant ancestors - but the means of satisfying these needs has changed dramatically, and our physical and socio-economic environments have changed equally dramatically. In addition, for most of us in the developed world, the focus of our needs has moved largely from the lower levels of basic survival to higher levels of social status and self-actualisation. The psychologist Maslow argued that our needs can mainly be categorised in a fairly simple hierarchy, and that we must satisfy our needs at a lower level if we are to have any success at higher levels.
While this model is undoubtedly simplistic, it is still a very useful model. Here we use his simpler original model, before he fragmented the self-actualisation layer.



Maslow’s hierarchy of needs

Migration up Maslow's hierarchy of needs is an important factor in determining stability. Meeting our physiological, safety and security needs is a relatively simple process that lends itself to fairly straight-forward modelling, so predictability is high and uncertainty low. The main factors governing it are income, prices and availability. In the developed world, these are all relatively favourable and these needs can be easily satisfied for most people with few surprises.

Meeting our social needs is more complex, since there are many more factors that affect this. Technology progress has undoubtedly changed social structure, but there are numerous interactions between politics, globalisation, democratisation, transport, telecomms, information technology, materials technology, automation, television and media evolution. We are hard pressed even to monitor trends that are already happening and deduce their main causes, let alone predict where they will go next. Models of social change are very therefore crude and unreliable.

The status and esteem layer is increasingly problematic. Most of us want to achieve a high status, but we judge our performance against those with whom we come regularly into contact. Even though we are much richer in this country than in most others, people judge their wealth by the people next door, not against people 3000 miles away. Now with television showing us other people with impossibly idealistic lifestyles (lower middle class families are often shown living in large upper middle class homes), it is easy to feel dissatisfied even if you are comparatively well off.
We may therefore have a much lower picture of our status than our actual lifestyle should suggest.

By the time our population gets to the top of Maslow's pyramid, individual behaviours vary so much that prediction is mostly reduced to informed speculation. We may all need basic clothing, food, shelter, love and security, but in terms of self-actualisation, perceived needs depend much more on individual personality and behaviours are much more varied. One person might just want to feel cool and trendy, while another won't be happy till they have several degrees. Worse still, most people don't really know what they want, or what is available to them. They are searching for something, but don't quite know what. And yet all the resultant behaviours interact in society as a whole, changing the marketplace, the economy, society. Society is being driven by the reactions of many people who don't know where they are going, with no common goal.

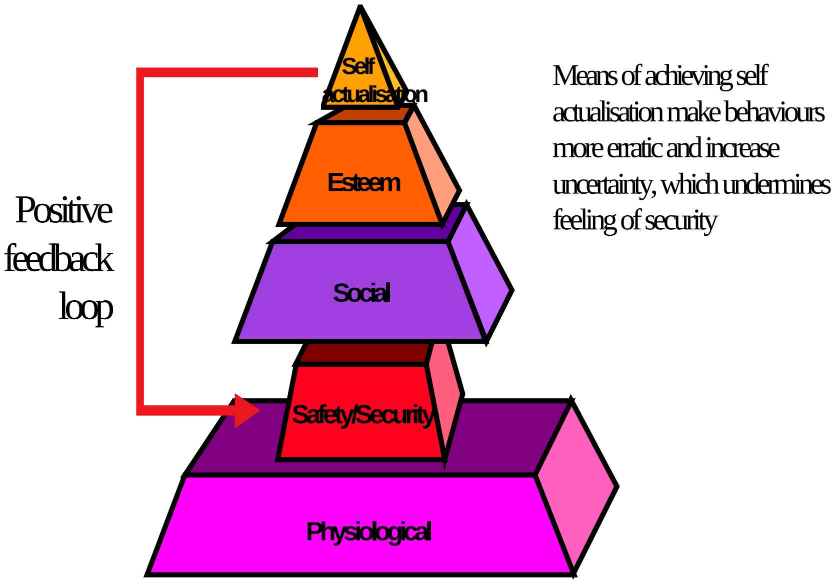
While we may have the occasional insight into some of the forces that will direct change in a particular direction, the complexity of interaction is huge, and the magnitude of these forces often pure guesswork. The most important factors are the sophistication of the human mind itself, and the emergent behaviour of large groups of people with very different interpretations of their personal and collective environment. If people all disagree on the input data, have very different models of the world, and have very different agendas for what they want to achieve, then the interaction matrices are hopelessly beyond computation.

Undermining our security

The unpredictability caused by most of a population inhabiting the top layer of the Maslow hierarchy feeds back destructively into the security level. Uncertainty undermines our feeling of security, even if it is just uncertainty about how we should be self-actualising. Many people have a deep feeling that they aren't doing self actualisation right, that they aren't making the most of their potential. They are aware that they only have one chance at life and want desperately to get it 'right' (hence the recent rapid growth in the number of lifestyle consultants). Also, because of external socio-economic environmental changes, people may be able to easily satisfy their needs today, and yet feel insecure about their position tomorrow, causing them to seek a remedy.

With little experience or reliable advice on which to base future actions, behaviours are very varied, increasing uncertainty still further. Reaction to uncertainty thus increases uncertainty still further. Below a certain level, various dampening mechanisms prevent a runaway effect, but this positive feedback loop makes the human system unstable when the rate of change increases beyond a certain point.

We may already have crossed that point, but we are certainly getting close. An additional factor for concern is that social cohesion and trust is falling for a variety of external reasons, and this also affects people's feelings of security. And of course, rising crime directly undermines actual security. The Maslovian security level is therefore being impacted from several directions. This level was traditionally a problem because of the very struggle for basic survival. Having left that far behind us, we are now approaching it from another angle.



<u>Today's Maslow hierarchy</u>

This effect is somewhat surprising. In material terms, we in the developed world are far better off than ever before. Few of us have worries about basic survival, whereas many people had a long time ago. It is true that people manage to achieve a reasonable degree of happiness even in the most adverse circumstances, but it seems equally true that we can manage to be unhappy in spite of fulfilling our basic needs.
We can be unhappy at any Maslovian level. As the old joke goes, wealth sometimes just gives people a higher class of misery.

If the lower levels of Maslow's hierarchy are undermined by actions at the higher levels as well as external factors beyond our individual control, we may find ourselves materially wealthy, but very unhappy. In fact, some recent surveys suggest that in spite of increasing prosperity, we are less happy than previous generations, which is possible evidence for this interaction already having an effect.

Widespread unhappiness is not a desirable outcome of supposed progress, so we must investigate some of the effects and behaviours that cause the instability and develop strategies to dampen them.

On a positive note, I believe that the problem being discussed here will only be experienced by a proportion of the population. Many, even most of us, will not be affected too badly, but if a significant number are, then it is still a problem worth considering.

The next sections address just a few personal and social responses that people use at the self-actualisation layer that are involved in this destructive positive feedback loop, or that directly reduce quality of life or happiness. There may be many others that aren't identified here.

Uncertainty and instability caused by striving for moral self-actualisation:

Political correctness & 21st Century piety

There is some commonality of flavour between the extremes of political correctness and religious extremism. I have linked these various behaviours together under the term, 21st century piety, which encompasses a wide range of traits that link to the pursuit of inner worth or moral security that are offered to people today. These often seem to fill the moral correctness gap left when people have discarded conventional middle ground religion. This is evidenced by the tendency for people to buy in to a package of such traits - we are all familiar with crystal-wearing, anti-capitalist, earth mothers, in tatty clothes and magnetic bracelets, driving at 29.9mph to campaign against a new road past their Feng Shui home.

21st Century Piety

At the extremes of any of these traits, we sometimes see the same sanctimonious, judgmental attitude more traditionally attributed to religious extremists, but of course, most people manage to subscribe to moderate views and reasonably balanced behaviours in some or all of these areas, without going to extremes. Indeed, the underlying principle from which political correctness has evolved is the desire to achieve fairness in our society. Levelling the playing field for the disadvantaged is simply common sense, and most people would support that. But we are often subjected to nonsensical approaches and decisions taken under this banner.

Often they cause great inconvenience or disadvantage to the majority for a very minor or imaginary benefit for a minority, apparently to show how pious the instigators must be. Consequently, political correctness as a term has now become more associated with its lunatic fringe. The same may be said of some of the other traits too. The feel-good factor for the few sometimes comes at the cost of a reduction of quality of life for the many, even while the supposed disadvantaged may experience little real benefit.

The need to feel morally firm ground beneath one's feet is strongly evident as the world becomes more complex, certainly evidenced at the time of writing by the polarisation of opinion on the Iraq war, with each 'side' claiming moral superiority. Religion may have declined in the UK, but there is little evidence to suggest that the level of sanctimonious behaviour has declined with it.

If these behaviours were based on scientific knowledge or even on a common moral guide, as we had historically, then their predictability would be much higher. As it is, they are a diverse set of beliefs and behaviours that change almost randomly with fashion. They have collectively become a key source of uncertainty, as well as the source of a number of policies that each may have only a small impact individually, but which collectively add up to a significant impact on our everyday lives.

While a few may have gained a little, the majority has also lost a little. The absence of logical thinking in this area makes political correctness and the following 'isms' an important source of future uncertainty. Unfortunately, since they are a common sanctuary for people searching for certainty of self worth, increasing uncertainty in our lives seems likely to increase the number of people behaving in such ways, and will further increase the problem.

Environmentalism & ethical concerns

Environmental awareness is high today, and is often associated with activism. Sometimes, this works indisputably in favour of the environment, slowing or preventing damage. But sadly, some well-meaning activists are poorly educated in the sciences, and absorb environmentalist dogma without challenge, while rejecting claims from government, industry or scientists. There is often also a lack of full-life impact analysis, poor quality input data, or poor understanding of environmental system cross impacts. The occasional result is that the environment actually degrades, because of counterproductive actions. Such behaviours can also adversely affect business. Companies trying to market certain types of products may find a hostile reception that may have little or no basis in scientific knowledge. Environmentalism may make people feel good about themselves in the short term, but occasional severe harm to the environment offsets the benefits by reducing quality of life later.

Of course some (perhaps even most) environmentalism is based on very sound science, and yet may still make the market hostile for some products, or impact on quality of life for good reasons. If this science is not understood by the manufacturer early enough, a great deal of sunk cost in research and development may be wasted. Similarly, later discoveries may prematurely terminate a product life.

We may hope that well-informed environmentalism becomes more widespread and displaces dogma-based activism, but there is no guarantee that that will happen, so we must prepare for more disruptive ill-informed activism, especially as the net will allow more easy mobilisation of grass roots power .

So with a lack of reliable science as its base, environmentalism can be a source of actual environmental instability as it leads to the occasional eco-catastrophe. It exhibits self-reinforcement because every environmental change makes people more worried about the environment, increasing the amount of activism, increasing rejection of science, and thus the scope for making things worse still. It is a key source of both uncertainty and instability.

The growing interest in environmentalism is perhaps part of a wider trend of society taking increased responsibility for a range of ethical issues. Similar ethical attention is often raised by medical breakthroughs, or even by a government's overseas policy. Many people consider that some medical 'breakthroughs' are ethical steps backward. As more people enter higher education, this could result in a better educated population who are even more eager to accept greater responsibility and are well equipped with information to back up their cases.

On the other hand, education has a surprisingly low correlation with people's beliefs (e.g. some university graduates read horoscopes, even though there is no suspicion that they are actually brain damaged). People may be very well informed in a field but still differ greatly in their opinions, perhaps because of education in other areas, or lack of it, or because of a deep ingrained prejudice.

Importantly though, their increased education may still contribute to making them more activist, with greater self confidence, even though they differ greatly in their opinions. So with more groups of better educated people coming into conflict more frequently on a wider range of issues, again we will see greater instability.

<u>Religious extremism</u>

In the early days of the internet, before the world wide web, the world was more or less geographically organised into regions with different religions. While most people managed to get on fine regardless of their religious beliefs or political ideologies, geographic separation managed to restrict the scope for conflict between the less compatible extremes. However, globalisation, and especially the web, has rapidly brought these communities onto a single platform. At the same time, various local wars and economic migration have meant millions of refugees spreading into parts with different ideologies. This has coincided with a strong rise in the number of extremists in each camp. (This of course has been the cause of some of the migration and conflict - sadly, extreme views seem to reside at the opposite poles of each religion, rather than in areas of commonality - we don't see much extremism under the banners of love and peace, which most religions actually claim to advocate). There are consequently far more opportunities for conflict between the different religions now than before. Since religion is one of the biggest drivers for most people's lifestyles and attitudes (even in the UK, some 70% of people still profess belief in some form of God), increasing conflicts between religions will undoubtedly increase social instability. This will remain true globally even though religion is currently in decline among native Western Europeans, at least the numbers of those that are active.

The growth of international terrorism can be partly blamed on increasing religious extremism, and general expectations are that it will increase. Indeed, more recently, the number of cyber-attacks from some hostile regimes has increased dramatically. It looks increasingly certain that the internet will be a key battleground for future conflicts between ideologies. Conflict will worsen extremist tendencies, so we will see increased polarisation and more conflict, in a vicious circle. This is a strongly self-reinforcing trend. This trend also contributes significantly to tribal fragmentation of society, increasing inter-community suspicion and decreasing trust, so reduces the dampening mechanisms as well as making uncertainty worse directly.

Extremism has a high correlation with both literalism and fundamentalism, which are growing responses to moral uncertainty in modern life. As people search for a more solid ground, they permit themselves less scope for interpretation of their holy texts (whatever religion they subscribe to) and are more inclined to seek literal interpretations.

The logic is simple. Taking something literally reduces the potential impact on thinking from modern society, and makes beliefs less vulnerable to the rapidly changing field of public opinion. It also absolves the believer of the need to think for themselves. Fundamentalism increases for the same reasons, concentrating on defending core, fundamental beliefs, rather like retreating to the keep in a castle when under severe attack. And of course by focussing religious attention on a few core beliefs, the ferocity of the defence of those increases. Furthermore, the core beliefs of different religions only coincide on a few points, if at all, so this tendency increases the scope for conflict between competing beliefs. This is even the case within religions, with conspicuously increasing tensions within both Christianity and Islam recently, even while the mainstream of each is trying to narrow the ground between them.

We may expect that rapidly accelerating social and technological change will increase this trend and worsen extremism again. Sadly, this undermines the positive effects of religion in terms of contribution to self-actualisation and providing a feeling of security.

Extremism can also make a much more hostile and uncertain marketplace for products that conflict with religious beliefs. This is a regular problem in the USA. In most of old Europe, although religion had been decreasing rapidly as a social force, recent immigrant populations have a relatively stronger religious element, with a rapidly growing impact, so we can expect more frequent market resistance on religious grounds. This is especially likely as biotechnology, artificial intelligence, cognitive technology and nanotechnology converge, encroaching on territory that some religions would consider sacred. These industries are already finding themselves regular targets for activists, and while this will not always mean a product ban, it can cause significant restrictions.

In terms of uncertainty, the response to such potential problems can be just as damaging as the problems themselves. Perception is often more important than reality. When political correctness meets religion, the outcomes vary enormously depending on the nature of the people concerned.

We have seen some ludicrous decisions made by various authorities based on a perceived potential for causing possible offence to ethnic or religious minorities, while oppressing any hints of the traditions of the majority. Social and inter-community trust is a regular casualty.

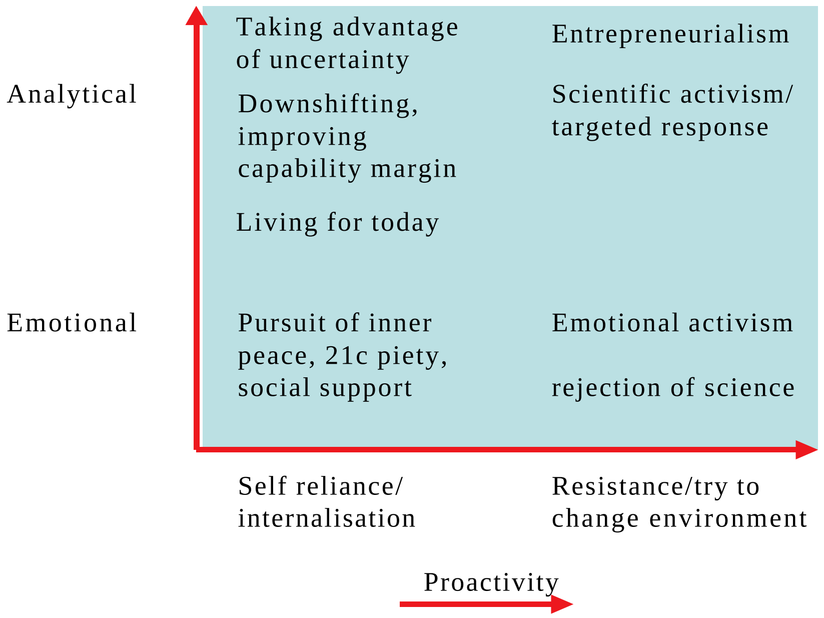
It is interesting that religion used to provide a common moral platform and act as a strong dampener on uncertainty trends. Religious extremism and literalism actually do the reverse in a diverse society, increasing instability and uncertainty, while removing the community trust that used to alleviate tension, even though they are classic psychological responses to uncertainty. They are ultimately self defeating. By contrast, focusing less on dogma and more on the 'love and peace' universal core allows for more commonality in belief, more acceptance of difference, and more resilience to social change. We may not agree with the next person, but at least we can have mutual respect, tolerance and support. History does not give us evidence for optimism on this score.

Social response to uncertainty

People have no choice about whether they live with rapid change and consequential uncertainty about the future, so they have to adopt behaviours or attitudes that help them cope. There are a variety of typical approaches, depending on personality type. Each of them has some merit, but they appeal to different people, and some people adopt a mixture of behaviours.

Some people feel perfectly at home in rapid change, and aren't stressed at all by it. Some would prefer it were different, but adjust their personal situation to cope, changing their lifestyles or attitudes.

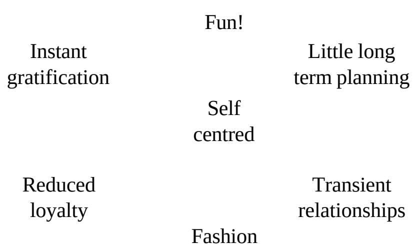
Others are more reactionary, and try to fight changes, some based on emotional knee-jerk reactions, some in more scientific or at least thought-through ways. Some people adopt a mixture of approaches. We can only look at a small subset here.



Some types of response to uncertainty

<u>Living for today</u>

With combinations of real and perceived threats, people are aware that their futures are increasingly uncertain. Often the reaction to this uncertainty is short termism (we have already mentioned another common reaction is the search for certainty by subscribing to a religion or other source of security). People are increasingly living for today, planning less for the far future. They are also showing less loyalty to companies, and these companies are also acting for the short term. As companies prominently drop employees at the first signs of stress, so people feel much less inclined to align their own futures with that of their company. This falling loyalty must impact on productivity.



Facets of living for today

Suspicion of IT & possible anti-technology backlash

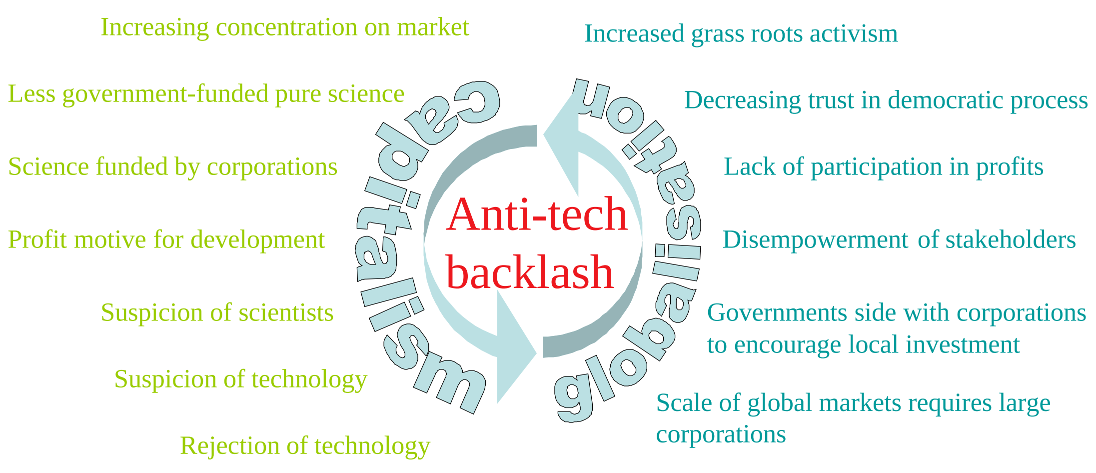
We should expect that e-business will impact on job numbers as uniform administration systems makes it easier for companies to reduce and outsource administrative work and to greatly reduce numbers in such roles on mergers. Third generation IT will make a huge impact on the amount of administration requiring human intervention. Today we are suffering from grossly inflated systems as administrators have used intranets to increase both the number and scope of monitoring and micro-management. This has prevented IT from delivering its promised savings, and in many cases has reduced productivity rather than enhancing it. New competitors will largely avoid such errors as an unnecessary expense. They will be able to undercut the incumbents, with consequential loss of jobs. Many people will thus gain a very negative experience of IT - something that has made their existing work life less pleasant through excessive administration and surveillance, while at the same time helping competitors to make them redundant.

Both inside and outside of work, people will also be exposed to more technological intrusion on their lives, especially with increasing surveillance.

The perceived threats from new technology, and the increased reluctance to trust scientists, have led over the last decade or so to an anti-science subculture (also anti-technology to a much lesser degree, people still want their new DVD player!). Most people have little idea even today how the technology around them works, so are easy prey to people who tell them about its potential harmful effects, regardless of whether any actual evidence exists.

It is likely that we will see a large social backlash against IT before 2010 because of its adverse impact on some aspects of people's lives. Technology is also likely to be blamed for accelerating some other impacts of globalisation.

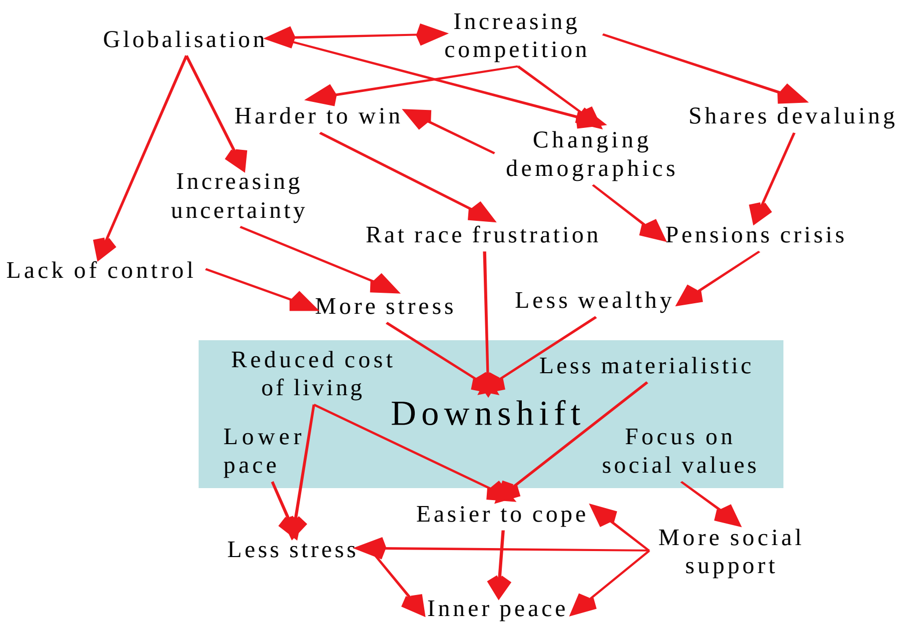
This response type lends itself well to those who want to take control over their situation and do something about it. The increasing number of demonstrations and increased activism generally shows that this is a strong subset of the population. As the number of perceived threats increases and more people become affected, we can expect it to increase.



Reasons for the anti-technology backlash

Downshifting, back to basics

Some people who are fed up with the rat race have opted for a slower but more rewarding pace of life. They may have discovered that there is more to life than material reward, or that the level or reward that they can hope to attain isn't worth the effort and stress. After all, only a few people can actually make it to the top in any field, and doing so requires not just the right skills or effort, but also a large measure of good luck. Also, several recent scientific studies show that there is little correlation between material wealth and happiness. So people may accept a drop in income, but find themselves happier. Doing a job that they find easier, or which makes fewer demands on their lifestyle can be a lot less stressful, and they may regain greater control over their lives.



Downshifting

Downshifting seems a logical approach to increasing uncertainty in the personal world, and appeals to a growing number of people.

For some downshifters, downshifting is simply a matter of working fewer hours, or taking a more junior job, with little other change. However, for many people, it is coupled with a desire to leave behind some other aspects of the modern world, and to 'go back to nature', adopting a simpler existence with much less reliance on modern technology. This does not mean that they are opting out of social contact though, and there may even be an intensification of their involvement in a select social network.

Focus on community, potential neo-tribal conflict

The lack of dependence on modern technology-intense systems gives downshifters less vulnerability to changes in their environment, and more dependence on a social group with whom they have a higher degree of involvement and trust. Again, recent evidence indicates that happiness is closely associated with having a number of high quality relationships, rather than material prosperity, so this behaviour makes good sense.

Even in groups of people who are hostile to much modern technology, we find welcome adoption of technologies that they find useful, or that supports their group, so we often see examples of communes with no televisions or computer games consoles, but with mobile phones and internet access.

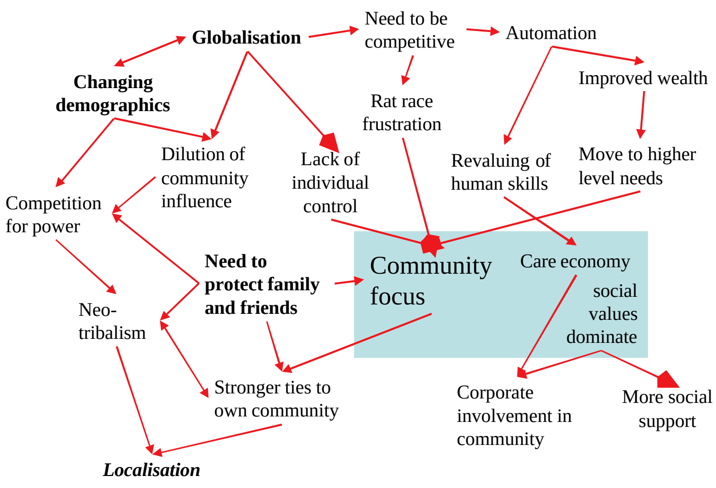
However, increasing focus on community will not be confined to downshifters and communes. They may simply be the first to head that direction. Wider society, especially in the UK, already recognises the decline of social capital resulting from declining trust in our society over the last few decades. Most European governments are measuring an increasing variety of quality-of-life metrics as well as material wealth. Many studies have shown that in the UK, quality of life in the north east is higher than in the south east, where people are generally wealthier, and people are questioning the wisdom of this. We may be seeing a small decline in community strength today, but the recognition of this is the starting point for a reversal of the trend (and perception is more important than reality in driving people's behaviours). It is our expectation that in the long term, this trend will strongly reverse, and as we head into the Care Economy, people will focus much more on relationships and community than on financial wellbeing.

Focus on community will be accelerated by the creation of community networks, especially as broadband rolls out. These will make people more aware of what is going on, and allow people to more easily take part in local activities and decision making, strengthening geographic local communities. These will link into wireless networks to ensure that people can stay in touch with their social networks more easily all the time.

The downside of this will be an increase in neo-tribal behaviour. People will have stronger relationships with more people in their social network, and stronger loyalty to their 'tribe', but will probably as a consequence have less interest in other communities. Competition between communities with different interests is likely, and we might see some actual conflict on occasions. In times of turbulence and change, people will be much more interested in defending the needs of their own community than in others.

It should be noted however that this neo-tribalism is multidimensional. People may belong to groups that are characterised by geographic location, profession, class, age, race, religion or ideology. They may have varying degrees of loyalty to any of these.

Another interesting effect is that although one of the primary drivers is globalisation, one of the likely outcomes is increased localisation. Politics is likely to gradually become more polarised between local and global decision making, with national and regional level politics becoming less significant.



Community focus and tribalism

Coping and taking advantage

Many people are well used to dealing with rapid change and don't find it stressful. In fact, they feel stressed when they are away from it. Self confidence based on experience of many successful dealings with changes gives people the security of knowing that whatever comes down the road tomorrow can be dealt with just as easily. Such people don't find the future particularly threatening, and assume that whatever it holds will be within their ability to cope. They are not upset by uncertainty, but don't necessarily welcome it.

Some people don't just cope with uncertainty but actually thrive on it. If they recognise that many people around them are more threatened by it than themselves, they may see future changes as welcome, since it puts them at a relative advantage. They may even try to accelerate change. Only a small proportion of the population fit into this category, living a fast, entrepreneurial pace of life and not only reacting quickly to changes, but taking personal advantage from them. These are the 'movers and shakers'. Cultural momentum would ensure that change and uncertainty would happen even if they didn't exist, but they certainly increase the rate of change and make the turbulence worse, increasing uncertainty still further.

Mainstream Religion

Having argued above that religious extremism is a negative force that undermines stability and reduces stability, quite the reverse is true for subscription to mainstream religion. Scientific studies show a good correlation between social connectivity and happiness, with happy people typically having a number of good quality relationships. Religion (and for this purpose at least, almost any will do) provides a good social network for followers, and also strongly satisfies the need to feel good, without the negative behaviours of some of the 21st century piety traits. Most religions also provide an emotional safety net that comforts people in times of stress and so helps them to cope with insecurity. Away from the extremes, which have already been identified as negatives, the problems of tribalism are also much lessened, as people in the mainstream have a tendency towards love and friendship rather than towards conflict.

Analysis

Of the above strategies, some ignore the problem of increasing uncertainty, and some actually make the problem worse. Only downshifting and religion actually reduce the problem. Downshifting enhances the dampening effect, while increasing personal happiness. However, the reduction of social status that accompanies downshifting makes it an undesirable strategy for most people, who are caught in an ever faster rat race. Religion at the extremes is a problem, but in the mainstream is a strongly beneficial force.

Dampening mechanisms

Some mechanisms dampen the interactions that could otherwise cause the uncertainty feedback loop to degenerate into panic and social unrest.

One of the strongest is social interaction itself. Talking to other people in different circumstances attenuates personal anxiety but also increases trust in the community over a number of such interactions. However, the diversity of our social networks has declined markedly. Thanks to good communications and easy transport, people tend to associate with others in a similar situation to themselves rather than people who just happen to live nearby. People therefore have strong bonds with a limited cross-section of the community. Community bonds have therefore become weaker, even if people still have good networks of friends. Social fragmentation is therefore reducing the effect of this dampener.

A relatively new dampener, closely related to this, is the network community. Many people today get a great deal of support in times of crisis from groups of people on the net, who are facing similar problems. There are self-help groups on the net for almost any problem. In addition, many people frequent chat rooms, where they meet new friends.
The depth of network based relationships is generally shallower than with friends that people meet physically, but network relationships can certainly augment a physical social life, and of course network based friends can sometimes meet up physically, occasionally leading to very strong bonds, even marriage.

As the net becomes more ubiquitous and pervasive, we may see such network based support becoming more important in people's lives. In this case, it could become a key dampener.

Additionally, many young people partner up in flexible social groups rather than in couples, and it is also much more common to cohabit with several other 'friends' than previously. It is hard to say whether this is a transient phenomenon. but since these groups are small and are composed of people of similar demographic status, they will probably exert only a small dampening effect compared to larger, cross social groups.

On a larger scale, network communities could become a significant power base, which may wield power for good or bad, linking millions of people together at grass roots level, harnessing their raw political muscle. While this could sometimes make things worse, with pressure groups using networked power to fight against each other, it may also be a significant force for good if the power is wielded responsibly.

Another traditional dampener was the church (and still is of course, though to a much reduced extent), for two reasons. Firstly, people mixed together across the whole of society, from the Lord of the Manor to the milkmaid. This gave everyone a good view of what was going on, so they had some degree of certainty about what life would be like tomorrow, even if it was ongoing poverty. Secondly, the church provided a common moral code, which meant that most people would act in similar and predictable ways most of the time to the same stimuli. This dampener is much weaker today. There is less commonality on moral code and little mixing of the extremes of social classes. This also feeds into break down of community bonds and reduction of trust among people. A religious revival would reverse this trend, and is a possible outcome if enough people feel despair. Religion tends to increase in areas where people feel less comfortable. So it still may exert an important dampening effect, albeit at the last minute.

Another dampening mechanism is lack of news. Until recently, most people knew little of international affairs, so they would only be exposed regularly to news of their local area, and at best their country. As a result, there were fewer things to worry about, and less complexity in trying to figure out what would happen next. Today's media is extremely efficient at telling people what is going on all around the world. Consequently, there are far more things causing concern, and the complexity is far too high for people to reach common conclusions about the future. This dampening mechanism has actually reversed into a cause of uncertainty. Interestingly, television directly contributes to other trends that improve people's lives and still others that make us less happy, such as undermining our self esteem, and feeding an insatiable consumerist race that constantly tells us that we still haven't met our needs.

One of the greatest potential dampening mechanism of all is poverty, which forces people to concentrate on the survival layers of Maslow's hierarchy.

If only a few people populate the upper layers, the forces driving uncertainty are almost insignificant. As a society gets richer, more people populate the top level, increasing the numbers behaving in ways that are likely to increase uncertainty. The proportion of people in this position in the UK today is very high.

Finally, I believe that the biggest of all dampeners, in this country at least, is the fact that a large percentage of the population cope perfectly happily with uncertainty, and even thrive on it. Even while the rest of society struggles, they provide a solid backbone that maintains the structural integrity of society, and provide a reference platform for everyone else. They are a permanent 'reality check' against which everyone else can benchmark. When others are rushing around engaging in counterproductive behaviours, feeling miserable because the Jones's next door are self actualising in a better way, the Analytical Self-reliants are keeping the system from breaking down. This group is shrinking as a proportion of the population, but they are falling slowly from a very strong base, and while they persist, we should be OK.

Business Impacts

Increasing uncertainty is generally bad for an economy. Pension funds and other log term investments need a degree of long term predictability, if not stability. Also, it is more difficult to launch products successfully when market reaction is more unpredictable, or likely to be more hostile.

In spite of this obvious downside, there will be many opportunities. Already we see rapid growth of the lifestyle industry, from Feng Shui consultants to personal fitness trainers. If people are unsure how to choose from all the options available or self-actualisation, then a market exists for helping them decide.

From a telecomms perspective, there is a greater social urgency to install community networks and other means for people to engage in more socially fulfilling activities. Broadband networks offer the potential for higher quality communications that can keep people's relationships at a higher quality than the telephone can manage. People move around a lot, and allowing them to keep in touch with friends and family when they move will be a key factor in maintaining their happiness levels.

Progress in technology such as natural language processing can help access for people with language difficulties to relate to other sectors of the population. We are also in a good position to help recreate the physical security that people need by means of neighbourhood watch networks, surveillance system, child tracking technologies etc. Communications is one of the key root causes of the increasing turbulence and the consequential undermining of Maslow's security layer. We owe it to our host society to do what we can to help them cope with the impact, but there is also good business to be had in doing so.

Conclusions

We exist in a country where uncertainty is increasing fast, and some dampening forces are severely impaired. Without action to reverse this trend, we could be heading for some social unrest, and increased unhappiness levels. Although most people may cope reasonably well, the number of people affected could be large.

Without a widespread downshifting movement, or a massive scale religious revival, we may expect that uncertainty will increase, with wilder swings in social behaviours over the next decade with more and more alternative lifestyle fads, as more and more people search for unattainable inner peace. With a greatly undermined security layer, most people will not feel comfortable regardless of their material wealth, and in spite of unprecedented levels of technological support, and we may expect levels of unhappiness to increase. Quite simply, more people will be on anti-depressants in 10 years time.

However, there is no need to conclude that society as a whole will collapse. There are sufficient people who can cope easily with uncertainty and change in positive ways to provide a solid base for both the economy and society.

Finally, the telecomms industry is both one of the causes of the problem and one of the best sources of potential solutions. Helping to alleviate the social problem resulting from rapid technological development will make good business for us in the future.

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Overview of completed and ongoing activities in the field of Safety and Risks of Nanotechnology[56] TEMAS

Extracts from the study, with permission[57] of TEMAS[58]

Objectives

The present survey intends to provide a non-exhaustive overview of worldwide studies, completed and on-going, dealing with safety and risk assessment issues of the rapidly developing field of nanotechnology. The focus of the current report is on the following subject areas of nanotechnology.

Safety assessment of novel drugs and drug formulations (drug delivery) based on nanotechnology, will be taken care of by the current approval process of the US Food and Drug Administration (FDA).

Nanotechnologies bear a high potential for the development of new materials, products and processes with improved performance or even altogether novel properties. At the same time, as with all new technologies, the impact of nanotechnologies on human health, environment and generally on society is up to now most speculative.

Ethical, legal and societal implications

It is widely assumed that society can derive major benefits form nanotechnology, but at the same time the societal impact can not be predicted at this point in time and should not be underestimated. Especially the consequences of nanotechnology in conjunction with information-, bioor medical technologies are difficult to foresee.

In any case, assessment of risks related to self-replicating nano-robots, as described for example in Michael Crichton's book "Prey", belong to the realm of Science Fiction and are not considered in this survey. However, the impact of fiction like "Prey" on the public perception of nanoscience and nanotechnology should not be ignored, especially in view of the announced launch of a movie version of the "Prey" story whose expected release date is not yet known, but assumed to be scheduled for summer 2004.

Clearly, the public perception of nanotechnology is a crucial determinant for its successful establishment as a future driving force in the economies worldwide. However, biotechnology, especially its commercial applications within European agriculture and food industries, is a recent prominent example of how the implementation of a new technology can be hampered by public acceptance. Thus, this report presents also publications assessing ethical, political, legal and social implications of nanotechnology.

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Last but not least, a further goal of this overview is to identify leading scientists and other opinion leaders active in the above mentioned fields of assessing potential environmental and societal impacts of nanotechnology.

<u>Summary</u>

Three recent publications, one commissioned by the Non Governmental Organisation (NGO) Greenpeace and the other two published by the ETC Group (Action Group on Erosion, Technology and Concentration), a Canada-based NGO, take the lead in publicly raising questions about safety of nanotechnology and its future impact on the environment, health and society in general.

Whereas the report initiated by Greenpeace remains quite neutral in terms of policy recommendations, the ETC reports propose that governments should declare an immediate moratorium on commercial production of nano-materials. In addition the ETC authors suggest the launch of a transparent global process for evaluating the socio-economic, health, and environmental implications of the technology. The ETC report on "Atomtech" provoked a vast echo in the international press and has started the public debate about the future of applied nanotechnology. The second ETC report, “Nano´s Troubled Waters”, has only recently been published, but a strong impact on the public debate is to be expected.

On the other hand, consciousness is mounting on the side of the advocates of nanotechnology that scientific studies investigating the effect of nano-materials on living matter are urgently needed, especially now that a number of toxic effects of certain nano particles have been found. Very prominent among them are results lately obtained by G. Oberdörster and by E. Oberdörster (vide infra).

Vicki Colvin, Director of the Center for Biological and Environmental Nanotechnology (CBEN) of Rice University, USA, has published a comprehensive review summarizing the current knowledge of the toxicology of synthetic nano-materials. This review could serve as a reasonable benchmark for further investigations regarding the toxicology aspects of engineered nano-materials.

The limited data available on the toxicology of nano-materials is not surprising, since for example in the United States only a small fraction of nanotechnology and nano-science funding is devoted to investigating nanotechnology's potential environmental impacts. However, this situation seems to change rapidly.

In Fiscal Year 2002, the U.S. National Science Foundation alone awarded ca. $23 million for educational and societal impact studies and ca. $30 million for research evaluating environmental and health aspects of nanotechnology. In 2003 the "NANOSAFE" project was funded within the Fifth Framework Programme of the European Union. NANOSAFE assesses risks involved in the production, handling and use of nano-particles in industrial processes and products, as well as in consumer products. Further calls for such risk assessment projects are planned within the Sixth Framework Programme of the European Union. In addition, in July 2003 the U.S. Environmental Protection Agency invited research applications for the evaluation of potential impacts of manufactured nano-materials on human health and the environment.

Thus, over the last year several studies have been started with the aim to generate hard data that address the physiological effects of nano-materials. Such studies will be the basis for future exposure recommendations.

Spanish Foresight in fields of NBIC technologies, A Morato

Microtechnologies and Microsystems New materials Biotechnology applied to health

FORESIGHT STUDIES OF MICROTECHNOLOGIES AND MICROSYSTEMS

Advanced biomedical products and applications

Nº	THEME	Scientific capacity	Industrial capacity	Date of materialisation
48	Many of the analyses that were carried out in hospital up to now will be performed on out-patients by the use of chips, which will be made in large quantities at low cost (Lab on a chip).	Average to High	High – Average to High	From 2011 to 2015
49	By means of the development of the neurone-microelectronics interface and the development of microsystems implantable in body organs, deficiencies such as loss of balance, physical handicaps, blindness, and deafness can be cured.	Average to Low	Average to High	After 2015
50	By means of the implantation of microsensors in the human body, the state of health of the patient will be monitored in real time. The information will be telecommunicated to a health centre.	Average	Low	From 2011 to 2015
52	The use of surgical microinstrumentation will allow most operations to be carried out by minimally invasive microsurgery.	Average to Low	Low	From 2011 to 2015

The field of biomedicine is one of the sectors applied to microtechnologies that will expand the most over the next few years, despite the fact that the materialisation of the developments involved is a long-term initiative.

The advances expected in biomedicine will allow the diagnosis, prevention, and treatment of health problems in a more and more efficient and rapid manner, with minimum pain to the patient.

In order to do this, microsystems will be developed that will be known as “labs on a chip”, based on microchannels. They will allow the carrying out in a convenient and rapid manner of various analyses, diagnoses, and tests, without the need for attending health centres.
Another system which will facilitate the subsequent follow-up of the patient will be the implantation in the body of microsystems and microsensors which will allow the monitoring of his/her state of health, thanks to the data that the latter will send to the health centre. This application will require much work on the development of radio frequency circuits that allow

the emitting of a signal between the organ (the sensor) and the monitoring switchboard. The main obstacle to the development of this technology is the expense and slow social acceptance.
As well as intervening in the diagnosis, microtechnologies will also facilitate major advances in the cure and operation of certain diseases, thanks to the development of precision microinstrumentation and the miniaturisation of surgical equipment for the carrying out of surgical operations that are as non-invasive as possible, the implantation in the human body of microsystems and, more in the long term, the development of the neurone-microelectronic interface.

Two key factors for the success of all these applications will be in the first place the development of biocompatible materials, such as for example polymerics, which thanks to their properties will feature strongly in this field. In the second place, there is a need for the combination within the personal work teams of different disciplines (medical, electronic, biological, physical, etc.).

Intelligent applications

Nº	THEME	Scientific capacity	Industrial capacity	Date of materialisation
3	The incorporation of intensity sensors of light, temperature, humidity, smell, and others, and the development of new materials with specific properties, will allow the creation of new more intelligent products.	Average to High	Average to Low	From 2006 to 2010
6	The nanostructuring of materials will permit the design of new “Sensing Layers” for specific applications.	Average	Low	From 2006 to 2010

It is expected that in the medium term the use of sensors will become generalised in a multitude of products, affording them greater intelligence and autonomy. There are many types of sensor, which are capable of measuring physical and chemical agents and of converting the measurements into electric signals that permit their processing.

In this sense, the design and the manufacture of a new sensor is hampered by the need to work within a multidisciplinary team, and above all on the development phase of a new material sensitive to incorporation within the sensor, and capable of reacting against a specific external agent.

In association with the development of new sensors and sensitive materials, advances will be made in the creation of new more intelligent materials.

Intelligent materials will be capable of altering their properties as a reaction to a specific external agent. In order to achieve this, the internal structure of the material must be manipulated on a nanometric scale, or otherwise sensors must be built into the material. In the former case it is the material itself, thanks to its properties, which will detect the external agent and act in consequence. In the case of sensorised materials, the sensor will pick up the external agent and will emit some signals that will make the material act against this agent.

CONCLUSIONS AND RECOMMENDATIONS

The main problem existing in Spain in the field of Microtechnologies is the rather modest industrial and research activity in this respect. The situation in Spain is not representative of that of the rest of Europe, where countries such as Germany, the United Kingdom, France, or Switzerland are at the forefront of the development of this kind of technology.

In Spain truly competitive industrial initiatives in order to achieve a full implantation of Microtechnologies are not being carried out. This is due to rapid changes in these still-emergent technologies, the scarcity of technological resources, the lack of specialised human resources, and the high competition on international markets.

All this has created a critical situation that means that the development and implantation of Microtechnologies is very poor in Spain.

Despite all these problems, and as part of the objective of the study, a series of recommendations have been made, the aim of which is to help the Administrations, research centres, and companies in the making of strategic decisions in the field of Microtechnologies.

These recommendations, which have already been referred to in this report, can be summarised as follows:

• Productive capacity: So that the implantation of microtechnologies can be widespread in industrial sectors, the manufacture of extensive series of microproducts at low cost is necessary. In order to achieve this, either new transformation processes must be developed or the existing ones must be modified, and also new machines and other measures must be adopted for serial production. In the same way, the technologies involved, standardisation, and the development of validation processes must be mastered.

• New materials: The requirements of microsystems vary depending on their application. The meeting of these needs involves in many cases the use of one type of material or another. The need to reduce manufacturing costs, the production of microcomponents on a large scale, biocompatibility, the possibility of work in aggressive surroundings, reactivity to specific substances, behaviour as a reaction to physical characteristics (light, force, velocity, pressure…) is in many cases marked by the use of alternative materials to silicon, such as polymeric, metallic, ceramic, or composite materials…, or the development of new materials by means of the modification of their internal structure on a nanometric scale.

• Specific engineering tools: Correct design and simulation can help the development of microsystems and prevent future errors, with a final saving on necessary time and costs. Design and simulation tools, as an essential element facilitating industrial manufacturing capacities, must be specific to the development of microsystems, being adapted to working with considerable precision and with much reduced dimensions, including bookshops of specific materials for microcomponents that take scale laws into account.

• Standarisation: If we want microsystems to become more accepted, costs and development times must be reduced. One way to do this is by means of the standardisation of microcomponents, thus increasing productive demand, the overcoming of scale economy, and allowing the construction of microsystems by the integration of blocks and modules.

• Specialised labour and multidisciplinary teams: Microtechnologies require multidisciplinary knowledge and are present in most industrial sectors. This phenomenon will include the need for highly specialised human resources, with general knowledge of multiple technologies, and the training of work teams with technicians from different disciplines represented.

• The creation of infrastructures: In order to acquire scientific capacities and to disseminate, support, and achieve awareness within industry, the creation of infrastructure will be necessary. This will complement research into and production of microsystems and their basic components, as well as the elaboration of methods and tools for their development and control. Co-operation between companies and research and technological centres should be encouraged, together with the creation of spin-offs and start-ups in order to achieve a better transfer of technology.

Microtechnologies represent emergent manufacturing techniques and their results are still far from numerous. The prevalent idea of these manufacturing technologies and microproducts is that industrial and commercial acceptance will become generalised, but their disadvantage is that much of the research carried out has still not been compensated.

Even today, in spite of the great scientific and technological advances achieved in the field of Microtechnologies and their applications, many companies see them as something belonging to the future.

FORESIGHT STUDIES ON NEW MATERIALS

Nanomaterials

Nº	THEME	IGI	Date of materialisation
24	The development of nanotechnologies in order to obtain ceramic, metallic, and polymeric materials whose structural and functional properties are significantly superior to current ones.	3.56	2011 - 2015
23	The practical use of organic and inorganic nano-compounds with constituents of the order of tens to hundreds of A.	3.40	2006-10 and 2011-15
22	The development of materials composed of organic matrices reinforced with nanotubes.	3.13	2006 - 2010

The last decade has seen the relentless emergence of everything related to nanotechnlogies. The interest in "nanomaterials" derives from the idea of obtaining materials with unusual properties starting from structures with nanometric dimensions (< 100 nm). It is sufficient, for example, to recall the prediction (R.F. Service, "New reaction promises nanotubes by the kilo", Science, Vol. 290, nº 5490, Oct. 2000, pp 246-247) that if current technical barriers are overcome, the materials based on nanotubes could achieve a resistance 50 to 100 times that of steel with a sixth of its weight.
This huge potential for improvement is being confirmed in new areas and applications, which increases interest in and the importance of nanomaterials. Examples of potential use in the transport and energy sectors are becoming more and more numerous: self-cleaning plastic windows that cannot be scratched, tyres with improved adhesion and reduced consumption, more resistant and durable paints and coatings, high-performance materials, membranes and catalytic converters, sensors, photovoltaic cells, materials for storing hydrogen, etc.

DEVELOPMENT OF NANOTECHNOLOGIES FOR OBTAINING CERAMIC, METALLIC, AND POLYMERIC MATERIALS WITH STRUCTURAL AND FUNCTIONAL PROPERTIES SIGNIFICANTLY SUPERIOR TO CURRENT ONES

Position of Spain (1- to 4+)	Critical factors
R&D capacity = 2 Industrial applicability = 1	Knowledge-Science Materials Elaboration of Raw Materials

The introduction of particles, fibres, or other reinforcements of nanometric size into ceramic, metallic, and/or polymeric matrices means that nanoreinforced composites can be obtained. These nanomaterials, together with monolithic materials obtained from nanoparticles, are new materials that are being researched in great detail. The planned structural improvements, some of which have already been contrasted, such as the greater ductility of nanostructured ceramics or the greater hardness of certain nanoreinforced plastics, represent some of its successes. In the field of new functionalities, the contributions of nanobiotechnology with improvements in biocompatibility, bioactivity, etc. stand out...

The fact of working on material units with one or several atomic layers hinders the processing of these materials:
• Increase in grain size during synthesising.
• Poor wettability of the aforementioned nanoreinforcements with the matrices,
• Non-alignment in the case of nanofibres and nanotubes,
• Agglomeration of nanoparticles.

These are some of the technical challenges as to the processing of these materials. There are many others derived from working with such small particles, as for example possible health problems or the risk of contamination, which were unknown up to now.

On the other hand, the characterisation of the material obtained also creates challenges. In many cases electronic scan microscopes are incapable of working at the magnifications necessary for these dimensions. Due to all this, it is necessary to perfect TEM (Transmission Electronic Microscope) or AFM (Atomic Force Microscope) techniques.

Once these challenges have been overcome, nanomaterials will be applicable in new sectors owing to their new features, and their introduction into current sectors will be surpassed with much improved properties.

THE APPLICATION OF ADVANCED HYDRIDES AND NANOTUBES FOR THE STORAGE AND DISTRIBUTION OF HYDROGEN

Position of Spain (1- to 4+)	Critical factors
R&D capacity = 2 Industrial applicability = 2	Knowledge-Science Materials Industrialisation

The use of hydrogen as an energy vector for transport and mobile applications in general depends largely on the development of efficient storage and distribution techniques. The lack of a suitable means for the storage and distribution of this element may represent a significant obstacle to the development of an economy based on hydrogen.
The possibility that under certain conditions hydrogen may be kept in carbonaceous structures such as carbon nanotubes provides another important alternative for the storage of hydrogen. Nevertheless, the great potential assumed a few years ago has not yet been confirmed, due to which, in the absence of new research, the profile of the expectations generated has been considerably reduced.

THE PRACTICAL USE OF HIGH-EFFICIENCY CATALYTIC CONVERTERS BY MEANS OF THE CONTROL OF THEIR NANOSTRUCTURE (2-50 NM)

Position of Spain (1- to 4+)	Critical factors
R&D capacity = 2 Industrial applicability = 2	Knowledge-Science Materials Elaboration of Raw Materials Improvement of Properties

Catalytic converters encourage certain reactions, reduce required temperatures and pressures, and occur in so many products and processes that their economical impact is huge. However, many of the industrial processes could be significantly improved if more selective and more active catalytic converters than the current ones were available.

The control of the nanostructure of the materials looks promising for the achieving of important advancements in catalysis. Development may move in two directions: towards nanoparticles, or nanoporous material (such as zeolites, porous carbons, non-crystalline silica, etc).

Nanocrystalline particles of metallic and ceramic materials, from 1 to 10 nm in size, have a specific ultra-high surface and a high number of active sites, and allow the development of highly efficient and selective catalytic converters with less costly materials.

Nanoporous (or mesoporous) materials, with pores of from 2 to 50 nm in controlled structure and composition, have surprising properties and make possible important improvements in the selectivity of catalytic and separation processes.

The miniaturisation of diagnosis and test devices: lab-on-a-chip.

DEFINITION AND APPLICATIONS

"Lab-on-a-chip" devices, also called Micro Total Analysis Systems (µTAS), involve the miniaturisation of complex analytical laboratory processes, and achieve the optimisation of protocols, and the reduction of the reaction and integration volumes of multiple tests on a single chip.
The microfluid devices are generally chips of glass or plastic; they use a combination of pressure phenomena, electroosmosis, electrophoresis, and other mechanisms to move the samples and reagents (with volumes of the order of picolitres or microlitres) by means of microscopic canals and capillaries. The diameter of these microchannels is approximately from 10 to 100 micrometres, although some of them may be as small as a few tens of nanometres.
Due to the great possibilities offered by this kind of tool, as to cutting costs, saving time, simplifying procedures, etc., it is reasonable to consider that applications of labs-on-a-chip are still being developed. In general, it is a case of separation, detection, and characterisation processes in order to achieve the total integration of:
• DNA analyses or expression studies or gene profiles.
• Protein analyses
• Clinical analyses, among others, molecular diagnoses of genetic or infectious diseases, immunity tests, simultaneous biotests to detect different biomolecules (for example of chemical, electrochemical, and fluorescent separation and detection systems, etc.).
• Cell cultures.

Position: Balanced, although very low competitive factors exist
Advantages: None in particular
Limitations: Scientific and technological knowledge and low availability of human resources
Measures: The financing of projects that improve our scientific and technological capacities
Follow-up indicator: R+ D+ i projects
Date of materialisation: From 2005 to 2010

7. Ethical, Legal and Societal aspects of Converging technology

“Converging Technologies”: Legal, Ethical, and Social Implications, R. Kneucker

Issues; Messages[59]

NBIC is the abbreviation for Nano-, Bio-, Info-, and Cogno-Sciences and Technologies, the combination of which is supposed to start a “ new technology wave”. Two or more of the four scientific fields are seen as “converging”, and through nanosciences as the enabling technology, they are expected to produce novel scientific results and provide new and astounding industrial processes and products, separate from and independent of the progress and successes in each of these four fields individually. Converging technologies are promising, fascinating, and frightening. Similar to earlier examples, such as molecular biology or the information technologies that permeated other scientific areas and created new areas of scientific endeavor, converging technologies will merge existing and create new scientific and technological areas.

Converging technologies will soon reach the national and European S & T policy levels and decision-making procedures – although they are in very early stages of their development and, reasonably, still a matter of national and European foresight studies. “Soon” indicates a time span of no longer than 4 years.

As a consequence, the usual political mechanisms both on the national and European levels will be applied to reach decisions while the new scientific and technological directions remain vague. Despite this veritable uncertainty of research, decisions on rapidly evolving new issues and research areas will have to be taken, since it is urgent to develop policies in order to keep abreast with similar efforts in the United States and in Japan. Never before, not even in the case of genetic engineering, has the dilemma of S&T decision-making been as dramatic as in the case of converging technologies.

On the one hand, research administrations will (have to) appropriate (large) funds to the research on new technologies and, on the other hand, will direct or politically influence research programmes that cannot yet be expressed in the standard forms of work programmes.

The time scales are upside down; what still is, in fact, a mid-term or long-term foresight study – looking ahead 10 to 20 years - will be treated as if it already were a mid-term or short-term research programme – planned for a period of 4 to 8 years.

[59] In writing this paper, I would like to acknowledge the support of D. Andler, G. Altmann, E. Barbieri-Masini, Ch.Bardoux, K. Bruland, J.P. Dupuy, Th. Gaudin, Ulrich Körtner, A. Nordmann, J. Staman, J.P.Tassin, at various stages; they are neither responsible for the mistakes nor for the opinions expressed.

Experts in converging technologies are scarce, and experts will act cautiously, if at all willing to advise on research options. Public awareness is low, or does not yet exist. “Science fiction” might dominate the minds of people, as in the earlier example of biotechnology, while science reality pushes ahead without proper review or control. Will politicians or industrial leaders risk budgetary allocations or investments? Risk assessment, and the methods of assessment, for converging technologies are still far away.

Converging technologies – though not in all aspects – will inevitably encroach on animal life and on human life; in the latter instance, by using or working with human material, implanting objects or (invisible) devices into human bodies, or brains, or vessels, by intruding into human minds, particularly by new drugs, - with the purpose of enhancing human performance or changing or controlling human behaviour, etc.

I suggest that foresight studies on converging technologies analyze the social and ethical dimensions at the same time scientific and technological and economic dimensions are being considered. Within the broader social and ethical issues, the legal questions and questions of human rights should primarily be addressed.

I propose two lines of action:

elaborating a proactive strategy of creating public awareness throughout Europe, and
initiating discussions of experts on the ethical and legal questions of converging technologies at the earliest possible moment.

<u>Elements of a discussion on ethical and social questions</u>

Preparatory working papers refer to several ethical, social, and economic questions but, in my opinion, do not address the two major social and ethical concerns: how to contribute to public understanding and public awareness of converging technologies right from the beginning of the political debate in Europe or, at least, early enough; and how to take into account the various legal aspects, specifically human rights’ questions while developing the new research programmes and attempting technological innovations.

<u>Questions raised in the preparatory papers</u>

Are converging technologies a new area or field of ethics or ethical studies? Yes and no. Converging technologies will accentuate or lead to new interpretations of known ethical issues and positions. For this, there exist sufficient guidelines, or appropriate guidelines that have been recently developed for research (funding) with a view to improving human health. At any rate, there is sufficient knowledge available to identify or structure the problems. Perhaps converging technologies will also pose new questions. Human integrity and/or autonomy might be affected in new ways; borderlines between therapies and enhancement or interference with health, between drugs and devices might be blurred. Interferences might occur involuntarily, or might be forced on persons (see below point 3).

Are there "European" aspects in converging technologies? Yes and no. To call "European" what Europeans do, would, of course, be a banal characterization. European ethics are and remain a part of Western culture and philosophy. Europe shares respect for ethics with many nations. All Europeans subscribe to the same basic values, as exemplified by the draft covenant of a European Constitution, even if there is not yet a common or accepted set of interpretations throughout Europe. Still, it is emerging. As in the case of embryonic stem cell research or prenatal interventions, new technologies are likely to challenge traditional ethics and lead to new differentiations.

"European" will hopefully be a specific policy of promoting converging technologies, designed to enter the global competition in science and technology.

Converging technologies will be of the type of the expensive high tech activities and products, and they will meet with reactions by developing countries similar to the reactions to other high tech developments in the North.

The expensive converging technology applications will aggravate problems of access to health services and, again, raise costs of social security systems. Access for whom? For all? Or for the ones who can afford the new therapies, devices, etc? Which services should be covered by public funds, in the democratic societies of the European Union? They can hardly be withheld in these affluent countries when available, or restrictions in one system will increase the "mobility" of Europeans to other countries for purposes of health delivery.

Converging technologies belong to "dual research" efforts, i.e., to research oriented towards and applicable to both military and civilian uses. Moral standards apply equally to military and civilian research or technology applications. At least, that is the intention when paying respect to ethics. Still, history has taught us that standards, national regulations, and even international legal norms are negated or suspended in times of war or military conflicts. As converging technologies might or will revolutionize arms and warfare in the long run, they will add to existing dangers, possibly by starting a new kind of arms' race.

The definition of combatants and arms is likely to change, if devices are not visible. Similar to chemical and biological weapons banned by the CTBTO Treaty, or possible attacks on information infrastructures and on non-renewable resources, processes and products of converging technologies will initiate new international treaties. Products of converging technologies will equip terrorists with new weapons.

And finally, converging technologies are scientific and technological fields in progress. Will European countries be open for the advances, or - as was often the case in the past - restrict or bar new frontiers of research and industry? Will ethics be used as a pretext? Will there be a balance of values, freedom of research and industrial entrepreneurship on the one hand, and human rights and science ethics, on the other? Creativity, curiosity and courage are not the opposites of respect for ethics; disrespect and negligence are.

Questions of Public Awareness; a Proactive Strategy

Converging technologies is, indeed, a new area as far as public awareness is concerned. The directions and the issues of converging technologies are still being debated and defined, and yet they should be made the topic of citizens` conferences and/or workshops with a mixed participation of researchers and the various sectors of the public right from the beginning of the European and the national discussions, precisely because they will cause concerns, and moral questions will be asked immediately in the public. It will be important to convene or to involve representatives of the bio-ethics commissions of the EU member states immediately.
Unclear situations create “angst”; and the perception of research by the public and its reality are often radically different.

A proactive strategy for contributing to public understanding and public awareness should include, first of all, correct information on the state-of-the art, on trends and intentions, on programme visions and measures, etc. Such a strategy would also take into account the experiences of earlier public debates and (only partial) public acceptance of biotechnology, genetic engineering, genetically modified organisms, and stem cell research. Mistakes were made; evaluations should be commissioned.

Creating public awareness is almost contrary to marketing. If the public would perceive public awareness activities as marketing, or even worse as advertisement, the strategy would fail.

The strategy would also include commissioning comparative studies on applicable legal regulations in Europe, as well as the mapping of excellence in the fields of nanosciences in Europe.

A public awareness programme of the European Commission would explain that the S&T efforts are still predominantly knowledge-driven, and are still fundamental research. By mid-term, some industrial applications might be possible, in the long run, many can be expected. Nanotechnology, contributing most to developing ”converging technologies”, constitutes a new key-technology: it is already, and will continue to be a thematic priority of the Framework Programmes of the Union.
Yet, how should such a programme element be formulated in a 7th Framework Programme, after 2006? Europe as a whole is being challenged by global competition in nanosciences, Europe – within the boundaries of the European Research Area - is in need of its own competitive research programmes and activities both for nanosciences and for converging technologies.

Questions of Human Rights

Converging technologies are expected to challenge human rights, in particular “human dignity”, the “right to life”, “privacy”, in some respects also the “right to the protection of health”, which is guaranteed in some European countries. The first three former human rights are part of the constitutional law of all EU Member States; they are also protected by the European Convention of Human Rights and Fundamental Freedoms to which all member states are signatory partners; and they are accepted values everywhere in Europe, as expressed by the EU Human Rights Charter.

Recent European discussions on science ethics concentrated on the beginning of life, including the use of embryonic stem cells and permitting or excluding prenatal interventions, and on the end of life, or rather ending the life of human beings (euthanasia).

Converging technologies will touch upon the human life from the beginning to the end of life. They will or might interfere with, or change, or enhance, or control personality, personal integrity, and personal identity. They will raise the question of a contrary "right to imperfection", i.e., of personally accepting or refusing physical and mental challenges and personal fates, which are aspects presently debated in European philosophical circles, with a possible consensus to label the aim of human enhancement as "a science for constant beauty", i.e., as a negative expression of the "zeitgeist", and not as a science in the service of health.

In legal terms, interferences with or intrusions into the human body and mind are prohibited; of course, the rule has exceptions. Among private persons permission and consent will suffice unless criminal acts are intended or carried out; in the relationships between persons and the state authorities, interferences are permitted if certain criteria are met, such as lawful punishment, or crime prevention, or protecting life, security or health of third persons. Referring to this legal maxim must suffice here.

This paper is not intended to explain or analyze the details of the legal implications of converging technologies. The fundamental question to be asked is: will the existing legal framework, or volume of legal norms and court decisions, both on the national and on the European levels, be adequate for preventing unwelcome developments or for banishing the dangers of converging technologies? Experts doubt that it will be adequate, de lege lata[60]. The conceivable revolutionary aspects of the new technologies might, indeed, support such a view and do call for a monitoring process right from the beginning, with a view to examining the legal matters and to discuss appropriate new legal norms if necessary, de lege ferenda. As presently interpreted, the fundamental rights will most likely not provide proper solutions to all human rights questions posed by converging technologies. An assessment of the legal situation in Europe will not be available for some time.

In addition, attention should be paid to three legal instruments complementing (existing) human rights. They are already accepted practice, and are employed to reduce legal uncertainties in periods of rapid societal developments, when law-making would be too slow or not yet advisable:

"finality" of regulations or programmes of actions,
"soft law" regulations,
"adjudication" procedures.

- "Finality" refers to the goals or purposes (of the research programmes), such as binding research efforts to the aims and service of health improvement. The Specific Programmes of the EU Framework Programme VI contain a great number of such orientations, demonstrated best in the wording "life sciences, genomics and biotechnology for health". "Finality" assists legal interpretations, and limits administrative action.

[60] The Latin term "De lege lata" means: "what the law is (as opposed to what the law ought to be)."

- “Soft law” regulations are codes of conduct, written into governmental, or more often into non-governmental conventions, or professional standards. Excellent examples are the Helsinki Declaration on Patients’ Rights, which, for instance, introduced such an important principle as “informed consent”; or the Biomedical Convention of the Council of Europe, with its additional protocols. It deserves mentioning that the draft Constitutional Covenant for Europe “transfers” the originally “soft law” principles of both conventions into a status of human rights. Under the title “human dignity”, it requires of all biomedical activities that informed consent must be established prior to treatment, that eugenics and reproductive cloning are forbidden, and that no part of the human body may be used for commercial purposes. “Soft law” is a set of rules ensuring proper procedures or special care, for instance, in laboratories, often without regulating the substance of the matter directly.

The establishment of bioethics commissions in all member states of the EU, or biomedical committees for reviewing hospital research are examples of “soft law” procedures, as are the procedural regulations in research funding, such as peer review, which is applied today by all research promotion organizations.

- “Adjudication” - Laws can never determine fully the direction of decisions in individual cases. The conditions of individual cases do require interpretations, usually within a frame of general norms or based on legal principles, such as finality or proportionality. Examples are: adjudicating cases involving babies, children, old, or sick or handicapped people for whom curators, trustees, etc., are charged with the special care that dependent persons need.

Can these three additional legal instruments also be used for judging the merits of the individual cases that touch on human rights’ questions in new technologies? Yes, and they are already used for that purpose in a few European states. I even believe that courts, in fact only courts or similar tribunals, are quite able to decide the new human rights’ cases possibly posed by the converging technologies in a creative manner, expanding the present understanding of the human rights in question, especially following the “principle of proportionality”.

“Proportionality” refers to the balance of conflicting values in each individual case; values, such as human dignity or health or the rights of the unborn, but also freedom of research, freedom of industrial endeavour answering to societal demands, etc., apply in different qualities in a given case, and have to be considered according to their relative weights. Whichever value dominates, i.e., which values are specific to the case, will tip the balance in favour of a decision on the merits of the case. Adjudication in the described sense, borrowing from the methods of Case Law, is not totally foreign to the European legal systems that are based on Roman law traditions, although it is still unusual, and the exception rather than the rule. To establish adjudicating tribunals or commissions in the area of science ethics would be a legal innovation in Europe, however, quite compatible with the European Convention on Human Rights and Fundamental Freedoms (see Art 6); it will certainly be a useful new instrument for a period of rapid and unforeseen scientific developments. It will, of course, not substitute for legal regulations when they become necessary.

Recommendations

It will be the responsibility of the Council and the European Parliament as well as the European Commission to address the ethical questions when proposing, deciding and funding programmes of converging technologies. Science ethics will remain an agenda item for all of them.

Council and Parliament - in their decisions on the new Framework Programme 7, for instance – are advised to assure that human rights, both on national and international levels, remain the (legal) framework and the prerequisites for the research and technology programmes for converging technologies, that the principles of "finality" and "proportionality" remain guaranteed by the research and technology programmes of the EU, and that the existing committee of the European Commission, with an extended mandate, will debate the ethical implications of and monitor the research activities in question. Establishing a specialized ethics commission for the implementation of the thematic programmes of converging technologies and for purposes of technology assessment might also be considered; the composition of any of these commissions must be transdisciplinary.

It is recommended to the European Commission:

- commissioning comparative studies (1) evaluating experiences to be gained from earlier public discourses on science and technology, (2) mapping excellence in the areas of converging technologies; (3) on existing human rights, national legislation, international norms, professional codes, and standards, applicable to converging technologies in Europe; (4) on the future regulatory management and on risk management for converging technologies, with a view to contributing to creating common European standards; it is recommended (5) involving the bio-ethics bodies both on national and on European levels in the debates of preparing and implementing the research programmes, (6) establishing monitoring groups, with the right to site visits; and (7) developing a proactive strategy and an Action Plan for creating public awareness concerning converging technologies, in particular by appropriate information, publications, and dialogues with the various sectors of the public.

Conclusion

Clear definitions of and goals and aims for the research in the areas of converging technologies will, when available, contribute to further clarifying the social, ethical, and legal questions that will have to be addressed in the future, and in which sequence. At the same time, the discussion of human rights and the discussion of ethical and social implications, with respect to the converging technologies, will help to focus the goals and aims and purposes of future research themes and research methods. Both debates, on preparing the new research programmes and on their legal, ethical, and social implications, should be started and continued concomitantly.

Technologies for Dealing with Technological Advance, A. Nordmann

The informal label for these technologies indicates that this report does not survey an established field but that, instead, it collects together under a common heading various strands of thought. According to that common heading, there are technologies for dealing with technologies and these technologies include how we think about technology. To consider conceptualizations, ethical and legal codes, even philosophical thought as “technologies” may seem to involve an overly broad notion of technology, one perhaps, that no longer permits a proper distinction of technology from anything else. In the following, thinking and critical reflection themselves, the creation, justification, or assertion of norms are not considered technical processes. However, the use of norms, codes, and ideas to make sense of the world, to normalize novelty, to classify, analogize or contextualize is properly belongs to a cultural repertoire of techniques for maintaining a sense of self and world.

The technologies for dealing with technologies encompass:

- ways of identifying and assessing risk,
- conceptions of naturalness and artificiality, of human, animal, and machine nature and culture,
- habits in the use of technology, for example, with regard to safety, sensual pleasure, efficiency of performance, etc.,
- patterns of evaluation, such as distinctions between legitimate and illegitimate technologies,
- grand narratives of human and technical development, stories of alienation and technological transcendence,
- media representations and other cultural mediations that render technologies invisible to themselves,
- political discourses of innovation and precaution,
- etc.

Such technologies for dealing with technology generally belong to an unconsidered ideological background. They are the routines by means of which we orient ourselves in our technical culture. They become salient as new technologies challenge our old routines.

For example, just as the precarious and difficult-to-sustain distinction between the legitimate goal of therapy and the illegitimate goal of human enhancement has been established and vigorously defended in the arenas of stem-cell research, reproductive technology, and genetics, the political work that went into this distinction is undermined by a nanotechnological research agenda that is unabashedly, some might say: honestly devoted to the enhancement of human performance (on the conceptual work that went into the distinction in the first place, see the studies of Christine Hauskeller; on the comparison in this regard between the nano- and biotechnology arenas, see various comments by George Khushf). In practical or technical terms, this means that the established techniques for regulating and evaluating, interpreting and coming-to-terms with proposed biomedical technologies simply may break down in the face of converging technologies. New techniques will be required and their development may impact the operation of the old ones.

The first author who would allow us to characterize such transformations as a kind of technological change took a historical, that is, comparative approach. Michel Foucault considered epistemic breaks between different cultural moments, where each moment is defined by a certain discipline of body and thought. This discipline creates a particular way of knowing the world and thus affords "technologies of the self", that is, various ways of relating to the world and of cultivating the self aesthetically. For Foucault, the cultural breaks may or may not be associated with technological advances such as the "birth of the clinic."

In the context of more recent technological studies, Andrew Feenberg has drawn attention to the ways in which technologies can be defined also by their users. The most prominent example of this would be the internet. Its applications and thus its character as a technology are very different from the intentions of its original inventors. One might also think, however, of retooled weapons or of art works made from consumer packaging. Implicitly, at least, Feinberg contributes two significant points.

Attention to technologies for dealing with technology undermines any straight-forward technological determinism according to which we experience technological advancement as an unalterable destiny. Still, these advancements represent an inescapable fate. We can shape and alter technologies only by the way we accommodate ourselves to them and the technologies to us. (Feinberg can thus subscribe without the cultural pessimism to Heidegger's or Marcuse's stories of the Gestell or of a global technological threat to an unadulterated authentic self.)

Attention to technologies for dealing with technology foregrounds the dialectic between global and local effects. The ways of appropriating and contextualizing technologies localize the global forces that drive technological development. These local effects may serve as slight or profound resistance to the global drivers; they may serve to drastically alter or, more likely, cosmetically color future developments. (In some ways, the work of this HLEG negotiates precisely this dialectic as it seeks to identify European constraints and opportunities for the convergence of technologies.)

"The intellectual appropriation of technology" has been a focus of study also by the historian of technology Mikael Hård and one of his collaborators, the philosopher of technology Andrew Jamison. Hård studies in historical detail how closure on design solutions does not preclude interpretive flexibility and local styles of practice (Hård 1994). Jamison characterizes the "greening of epistemology" as the development of a new conceptual tool-set along with an ecological framing of new technologies.

Most explicitly of the various authors mentioned here, Sheila Jasanoff contrasts in ongoing work and a forthcoming book "technologies of hubris" and "technologies of humility" as different technologies for dealing with the risks posed by an uncertain technical future (Jasanoff 2002). Technologies of hubris bring an engineering attitude to the questions of forecasting, risk-assessment, and policy making. Their goal is consensus formation on the basis of a fundamental trust in our ability to always find yet another technological fix where things do not work according to plan. In contrast, technologies of humility modestly defer to our limits of knowledge and planning, they aim for an "informed dissent" regarding a variety of possible technological futures.

Inspired by Jasanoff, I recently proposed that we speak of technologies of containment, where I use the word "containment" quite literally, yet broadly, as in "containing the damage" or "putting something in a container". We prevent something from leaking out and spreading by holding it in or by keeping it in place. Similarly, we contain something amorphous and ill-defined by giving it definition and purpose. I will suggest in the following remarks that scientists, engineers, policy makers, citizens, and philosophers are all working - separately and together - towards the containment of nanotechnology.

By speaking of "technologies of containment" I have tried to capture the virtues and necessities of both, hubris and humility. On the one hand, I am appealing to the engineering attitude that containment is always just a technical problem and therefore inherently solvable. On the other hand, we need to acknowledge that cultural discourse can never be contained but will always meander to utopian and dystopian extremes. Negotiating humility and hubris, the various technologies of containment Negotiating humility and hubris, the various technologies of containment are working together to determine nanotechnology in such a way that it becomes a well-defined subject for informed dissent in a democratic society that settles upon its future one technology at a time.

References

Hård, Mikael (1994) "Technology as Practice: Local and Global Closure-Processes in Diesel-Engine Design" Social Studies of Science, 24: 549-585.

Jasanoff, Sheila (2002) "Citizens at Risk: Cultures of Modernity in the US and the EU" Science as Culture, 11:3.

Nordmann, Alfred (2003) "Nanotechnology: Convergence and Integration", presentation at the EuroNanoForum 2003, Trieste, December 9.

Converging Technologies and Culture, E Masini

It is not the place here to discuss the different concepts with which culture has been defined and explained or discussed trough centuries, from the level of education in specific country or social group which was the accepted one till the end of the XIX century when a cultural anthropology definition emerged with Tylor which is that " complex whole which includes knowledge, belief, art, morals, law custom and any capabilities and habits acquired by man as a member of society" (1)as a concept, has been used, in general terms as "everything that has been created by human beings".

To go a little further, following the philosopher Peter Henrici (1), there is a first nature (natural environment) and a second nature, artificial environment, created by human beings which is culture, and is the mediator between human beings and the first nature. All that is created by the human being is culture as he cannot interact with the first nature directly unless though his man made objects , through his concepts, through his laws Second nature, culture, emerges from consciousness and is hence the space also of responsibility. This is where I think that the connection between culture and technologies emerges, specially "converging technologies" as they are part, and emerge in, the present culture with a very strong impact on the future of culture and future generations for their strong influence on human being and on societies. Hence one could speak of the emergence of a new culture.

This is one way of looking at the connection between culture and converging technologies. It is also important to look at this topic as "cultures" in the plural, hence different ways in which human beings relate to first nature.

An other way to look at the issue is the present culture, Western, is it the only one? Present writers, and I refer specifically, as an example, to Samuel Huntington who has in 2002 (3) written that there is indeed an emerging global culture which is "heavily American in origin and content". The American culture is the one that will be the dominant one and he adds, it is the one likely to stay so for the forseeable future as well as the one in which language, in its American form, is the basis for the global culture.

Following the idea that culture is man made, second nature, this could mean that the American culture which, as all cultures, has some dominant traits and in this case it is without doubt that they are the development of sciences and technologies, will transmit such traits to all other cultures. If this is so, the next question is: what is the American culture new impact on other cultures?

Cultures from all regions of the world have developed their own view of nature based on different traditions and hence developed different understanding of the natural world as well as different ways of living their lives. What will happen to these other cultures? Will they continuously change in the process of consciousness? They have developed their own second nature, mediator with the natural environment mentioned previously and will keep it or will the world cultures have the same culture based on converging technologies as the basic trait of such a culture (mediator between nature and human beings).

Let us look at different possibilities, as when we try and look into the future this is ethically important as it is related to present choices.

One possibility which is the one described by Huntington and would mean the end of the mosaic cultures.

Another possibility is that the mosaic cultures may survive both under the impact of communication technologies, as can be seen in different studies, and of biosciences, but will

it survive also with the enforcement given by nanotechnology as discussed in previous meetings? Will the world have one only mediator with nature which is a converging technologies dominated culture?
The Italian anthropologist, Ida Magli, has very recently written that the danger is that of loosing personal and cultural identity as there would be no possibility of control on it by the person itself who is easy to be recognized and controlled from the outside. At the same time the person becomes non existent as somebody or something tells the person whom it is without he or she being able to recognise itself, this is where the danger of being the same as others lies. Identity comes from the relationship with the "other", with who is different from yourself, this according to the author leads to a society " without a face and maybe no future" (3).
I see here the connection with the ethics part developed at the SG#2 in Paris. (See report by Jan Staman)
I would here suggest some possible alternatives to the end of the mosaic cultures as seen by Huntington and Magli from different points of view and the loss of identity as seen by the latter author. By mosaic culture I mean a whole set of cultures that in some way connect as stones in mosaic. No culture is complete in itself but need the others to enrich.
Godwin Sogolo,(4) philosopher from Kenya, uses the metaphor of the core and periphery of cultures which would give the possibility of a mosaic culture survival. On one side the spread of the dominant culture, in this case the culture dominated by science and technology and specifically that which is dominated by converging technologies, on the other a core culture that does not change so rapidly and which survives in every day life through poetry, oral transmission and more so in important moments of life such as the birth of a child, the ritual of marriage and of death.

Even in the presence of an over powering culture the core cultures preserve certain traits which are transmitted through generations and still survive. It is the core of any culture which maybe the strongest to resist to what tries to become the core and maybe only affects the periphery of cultures.
Another author from Africa, Elikia M'Bokolo, stresses the centrality of living cultures or as also, in the same publication, the anthropologist Denis Goulet, who writes of the resistance of cultures which refuse both the dominant cultures and the "museum cultures".
Resistance of cultures seamed only marginal to the dominant cultural forces but after recent events, since September 2001, resisting cultures do not seam to be so marginal.
Another alternative in cultures may be the one emerging from what has been called the "globe-girdling electronic babel" which according to some close observers of cultures (as mediators between human beings and nature) may indeed bring about an heterogeneity of cultures. This is the effect of IT but what can happen with the convergence and re-enforcement with bio and nanotechnology? I am referring to cultures and as such much has still to be studied and developed.
Alternatives may indeed be foreseen in the heterogeneity of cultures produced by increasingly communications and at the same time lead to the co-existence of cultures and not necessarily to conflicts and tensions but rather to a renewed mosaic of cultures.
Susantha Goonatilike,(6) psycho-sociologist from Sri Lanka, in the same publication "The Futures Cultures", writes that it may lead to some kind of cultural liberalization in which weaker cultures may influence the stronger ones. Cultural purity, he says, can no longer exist.

At the same time, and it may seam contradictory, but the future is alternative, some Chinese scholars claim the possibility of the co-existance (see China) of different cultures such as traditional social structures as the family with Western market systems. There may be different patterns of modernization as there are many cultures thus mosaic culture may reappear as no culture is complete in itself.

(1) Tylor Sir Edward Burnet, Anthropology,1881
(2) Henrici, Peter, Essere umano e natura nell'era tecnologica (the human being and nature in the technological era) in Beltrao, Pedro, "Ecologia umana e valori etico –religiosi", editrice Pontificia Universitˆ Gregoriana, Roma, 1985
(3)Berger, Peter and Huntington, Samuel, P, eds Many Globalizations: Cultural Diversity in the Contemporaay World, Oxford University Press, June 2002/374
(4) Magli, Ida, Ci saranno solo tracce fisiche andrˆ perduta l'identitˆ,(Will there be only physical traces and identity will be lost), in La Repubblica, Rome 29-4-2004
(5)Masini Barbieri, Eleonora, The futures of cultures. Unesco Publishing, Paris,1994
(6)Goonatilake, Susantha,"Aborted Discovery: Science and Creativity in the Third World ", Zed, London 1984

The Responsibility of Academics in Our Time, R. Ernst

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See
http://spi.epfl.ch/Jahia/engineName/filemanager/site/spi/pid/5381/AppliedChemistry.pdf?actionreq=actionFileDownload&fid=165984 or see http://www.itas.fzk.de/tatup/022/boeh02b.pdf

Abstract

In this lecture, it is stressed that the responsibilities of academics and academic institutions are not limited to research and teaching. Today, where short-term and self-centered thinking prevail in politics and economics, a third, independent authority with a long-term vision and global responsibility is needed to prevent that our world goes fully astray. There can hardly be any doubt that this is a primary function of universities and of academics, a function that is today painfully neglected. The universities are called for developing again into cultural centers where ethical, cultural, and scientific guidelines for the peaceful and sustainable future development are formulated.

Supporting Responsible Nanotechnology Research Benefits Europe's citizens
R Tomellini, Head of Unit, NAnosciences and Nanotechnology, DG RTD

[Date: 2003-06-24] See http://dbs.cordis.lu/cgi-bin/srchidadb?CALLER=NHP_EN_NEWS&ACTION=D&SESSION=&RCN=EN_RCN_ID:20466

The CCLE[61] Neuroethics project

See http://www.cognitiveliberty.org/proj_neuro.html

[61] The Center for Cognitive Liberty & Ethics (CCLE) is a non-profit public education, law, and policy center working in the public interest to foster cognitive liberty. The CCLE broadly defines cognitive liberty as the right of each individual to think independently, to use the full spectrum of his or her mind, and to engage in multiple modes of thought. More specifically, the CCLE considers cognitive liberty to mediate between freedom of thought and electro-chemical manipulation of the brain.

Social Capital and Public Policy, Bertie Ahern, TD, IRL,

submitted by T Kauppinen, European Foundation for the Improvement of Living and Working Conditions.
See http://www.ex.ac.uk/shipss/politics/research/socialcapital/other/ahern.doc

Social and cultural issues emerging from the NTW: a Foresight approach with some recommendations, E. Masini

Introduction

Modern societies have a high level of complexity and this gives rise to uncertainties and the need for tools to lower them, scenarios are part of such tools. In perspectives where nanotechnology is emerging as a driving component in converging technologies, it is necessary to investigate its cultural and social effects, which are interrelated and thus crucial in the present and future European context. I believe this is the central issue for HLEG's analyses and proposals, as also stated in the preface to "The Dialogue Workshops" in 2000 (1).

I concur with Emilio Fontela when he says "there is very limited evidence of NBIC convergence (strictu sensu) and only embryonic contacts, mainly on a two-by-two basis"(2). This, together with the whole spectrum of convergence in NBIC terms, makes it very difficult to envisage the possible social and cultural consequences. I also want to try to understand at least the two-by-two impact of, for example, nanotechnologies and ICT on cultures and societies. It is crucial to foresee the consequences in the short term – and even more in the long term - of this (albeit partial) convergence. Or at least in Europe, which is anyway part of the global social, economic and cultural context.

The idea is to investigate the effects of nano- and biotechnologies and nanotechnologies and ICT on society and cultures. There is a myriad of research and documents as well as institutional support available in terms of the social and cultural impacts of each of these technologies produced by universities and research institutes Europewide with ample bibliographies. At the same time there is not much analysis on a two-by-basis.

One initial recommendation for the "Foresighting the New Technology Wave" HLEG could be to set up a working group of social scientists to:
analyse the potential social consequences of bio- and infotechnologies: on social structures, social behaviour, life styles, etc.
observe the present impact on the social sciences of these technologies in the different EU countries;
investigate, in terms of foresight, what social indicators should be monitored (I believe this has been studied by SG#1).

Some definitions for analysing and foresighting social and cultural impacts

There are many definitions of culture. From antiquity until the mid-19th century it had a humanistic connotation, with a high level of literacy and the emergence of an intellectual elite in a given society or social group. But during this last century and a half an anthropological approach to culture has gradually developed. Clearly this can also be attributed to the discovery of other cultures outside the western world. This discovery of “others” meant that a more useful definition in social terms was needed. The first definition by E.B Taylor in cultural anthropological terms was that culture is “that complex whole which includes knowledge, belief, art, morals, law, customs and any capabilities and habits acquired by man as a member of society”(3). We can consider technologies in the different historical moments to be part of human capabilities. The concept of culture has also lately been used as the network of meanings, traditions, beliefs and attitudes on which choices and actions in a given society are based. This is why the cultural and social effects of technologies have to be studied jointly.

To go a little further, according to the philosopher Peter Henrici (4), there is a first nature (natural environment) which is given and a second nature, artificial environment, created by human beings which is culture, and this is the mediator between human beings and the first nature. All that is created by the human beings is culture as they can only interact directly with the first nature through the objects they make (including technologies), through their concepts and through their laws. Second nature, culture, emerges from consciousness and hence also involves responsibilities, moral laws and norms.

This is where I think the connection between culture and technologies emerges, especially “converging technologies”∗ as they are part of the present culture and will also emerge in the future with a strong impact on human beings and thus on societies. One could speak of the emergence of a new culture where new technologies are all important.

Cultures are at the core of societies as they determine the attitudes and behaviour of social groups and are the basis of the social character, as Eric Fromm calls it (5), of any society. This is one way of looking at the connection between culture and society and new technologies. It is also important to look at this topic as cultures and societies in the plural as well as the different ways in which societies behave in relation to first nature and second nature.

A basic recommendation emerges from the discussion on cultures and societies. Europe is rich in cultural diversity and is becoming increasingly multicultural because of immigration and enlargement. Thus a society which is in a descriptive phase, with multicultural, parallel cultures and societies, is starting to move towards an active exchange of experiences and communication on the basis of awareness of the different values, standards and behaviour which lead to reciprocal respect. It will thus become an intercultural or “mosaic” society where the overall design emerges from the different, interconnected components.

This implies educating towards that interculturality which is imperative for the European Union’s future. I shall try and give some practical indications in the last part of this paper dedicated to policies.

+SG#3 proposed calling them transformational technologies rather than converging technologies.

The new technology wave should be investigated and its different expressions evaluated within this context. Will the new technology support this need for interculturality or will it act against it? Will bio- and infotechnology, reinforced by nanotechnology, help in this sense or might it, as has been claimed, develop a stronger multicultural Europe with a lack of interrelations? Moving towards an intercultural society or remaining a multicultural society: these could be two different scenarios up to 2020, with a likelihood of more conflicts in the latter option. When people move in scale from the local to the regional, national or global level they move from a multicultural identity to a large-scale cultural identity.
They move towards a constitutional identity, towards what a European Commission study has called a virtual community (6), which could be what I have described here as an intercultural society.

Some possible consequences at the cultural and social level of the new technologies seen on a two-by-two basis.

Bio-screening with the support of nanotechnologies could arouse defensive attitudes in different cultures as well as cancel out different cultural traits in terms of language, attitudes and behaviour. This would impoverish each individual culture as well as the European culture as a whole.
If biotechnology and ICT, supported by nanotechnology, make use of personal data for the purposes of security, information or even dissemination or manipulation, this could cause not only a feeling of insecurity but also antagonism, with the result that important information could be withheld.
The possibilities as well as the dangers of ICT and nanotechnology might not be fully understood in the educational world, were schools at all levels have inadequate tools for coping with the new technologies. Dangers for young people could include addiction to new technologies followed by negative effects such as depression and social isolation.

The lack of communication between the different social institutions (family, education, health, political institutions) and the scientific community could cause ICT and nanotechnology to raise excessive hopes or fears, creating social insecurity and social and political upheavals. In addition, if the public institutions are unable to meet the excessive demand, then the private sector will respond in certain areas, for example in health services at greater expense for citizens, whereas it is unable to respond to educational and familial needs.

The new technologies will have varying consequences on the family, bringing social benefits as well as higher costs. There will be a greater life expectancy and a greater percentage of older people in Europe as a whole (15% of the 727 million inhabitants at the end of 2003) thanks to the impact of the new technologies on health.

<u>This will widen the generation gap in different ways:</u>

more older people in need of care from the family or the public sector, fewer workers and increase of non-active population with the need to shift responsibilities to the public sphere, hence fewer and older people of working age. According to IPTS (7), the median age of workers in Europe started to increase in 1995 after being stable at 40 for 20 years. It is expected to increase by 2.5 years by 2015, even if older people are living longer and are healthier (8). This would also cause a reduced geographical mobility of people within Europe;

possible increase of unemployment because of greater need for highly skilled workers and lesser need for the lower skilled, including immigrants, leading to social conflicts and development of a dual society;

more than three generations living in one family, increasing cohabitation problems and widening the psychological and behavioural gap between the different generations, co-resident or not;

ever smaller families with fewer children plus the use of genetics or adoption of children from other parts of the world (increase in both trends) causing ethical issues. Also increase in one-parent families and singles

Gender differences could both increase and decrease. They could increase in favour of women in employment sectors such as research and ICT because of the higher female educational level in many European countries. They could decrease because of the onus on the family of the older generations and growing unemployment in many sectors.

Possible confusion between different cultures' perceptions of each another thus creating conflicts or at least misunderstandings.

Suggestions for EU policies

Surveys in European countries show a general lack of knowledge about nanotechnologies and converging technologies and their possible cultural and social consequences. The ideal would be to preserve cultural differences (multicultural Europe) while at the same time moving towards an intercultural Europe. What kind of policies do we need in this regard?

1. Educational policies

Teacher training must include knowledge and know-how of different cultures. Multicultural training and tools must aim at intercultural communication among young people. This training should be especially aimed at primary and secondary-school teachers.
Teacher training must be focused not only on ICT but also on new technologies and specifically on basic nanotechnology.
Teachers must be given the tools to teach children from primary level the basics of the new technologies and the possible changes they could bring about in their lives.

Teacher training should include games for imparting this knowledge. Tools could be used such as videos, exhibitions of paintings or scientific experiments by pupils and animated puzzles, as well as encounters between children from other parts of the country or from different countries, for a basic understanding of the new technologies and their possible consequences.
Teachers should be given tools to encourage pupils to use their imagination in depicting the future, helping them to relate to events (also related to new technologies) remote in time or space, or letting them see the different consequences of their decisions (or those of others). They will thus learn that there is not only one possible future but many different ones, ensuing from different decisions based on different perspectives, values and cultures.

2. Communication policies

Social instruments should be devised to bring the scientific community closer to the public and vice versa, preventing the general tendency of short-term optimism that ignores long-term risks.
Clear, simple and correct scientific information should be provided, with attention to the differences in the audience: general public, various social levels, different intellectual or educational levels, scientists in areas not related to new technologies.
The social scientists' mapping of the European population on different age, social income, education and employment groups should be unified on the basis of data already available in the EU so as to prepare different groups of listeners and communicators.

Conclusions

Much has still to be done in terms of identifying the present and future consequences of the new technologies and of converging technologies, especially as the latter is still in its development stage. I have thus attempted here to look at the impact of two-by-two technologies. I have also indicated possible policies, bearing in mind the in fieri situation of the new technologies. These policies should be preventive to guard against any possible damages caused by the new technologies which are such an important part of the present and future of European cultures and societies.

NOTES
(1) Preface by Achilles Mitsos, in Angela Liberatore, ed. Dialogue Workshops: An Experience in Citizens' Knowledge, Directorate-General for Research, Citizen and Governance, 2000-2001.
(2)Fontela, Emilio, Remarks on the possible economic impacts of NBIC, prepared after Leuven 16 April and for Madrid meeting May 2000.
(3) Taylor, Sir Edward Burnet, Anthropology,1881.
(4) Henrici, Peter, Essere umano e natura nell'era tecnologica (The Human Being and Nature in the Technological Era) in Beltrao, Pedro, "Ecologia umana e valori etico –religiosi", Editrice Pontificia Università Gregoriana, Rome, 1985.
(5) Fromm, Eric, The Sane Society, Routledge and Kegan, London, 1959.
(6) Angela Liberatore, ed. Dialogue Workshops: an Experience in Citizens' Knowledge, Directorate-General for Research DG RD/K.2000-2001.
(7) IPTS, Demographic and Social Trends Panel Report, Futures Report Series 02, Seville, 1999.
(8) Cagiano, Raimondo and Capacci, Giorgia, Invecchiamento e svecchiamento della popolazione europea (Aging and counter aging), ARACNE, Rome, 2004.
So what's Transhumanism?

See World Transhumanist Association at http://www.transhumanist.org/
See Better Humans at http://www.betterhumans.com/Features/Ask_an_Expert/answer.aspx?articleID=2004-01-09-1
See transhumanism at http://transhumanism.com/index.php/C3/

8. Related policy initiatives

European dimension in education, D. Polsek

This paper concerns education as a horizontal issue within a broader range of topics dealt with at HLEG "Foresighting the Technology Wave" of European Commission. The purpose of this paper is to sketch the role of educational issues related to the envisaged process foreseen by convergence of NBIC technologies (nano-, bio-, info-technologies, and cognitive science).

The first part consists of an overall framework description in which European educational approach and the process of converging technologies are supposed to overlap. The second part points to educational directives that should be followed in order to enhance competitiveness of European research and technology, and they primarily concern contents of education, i.e. curriculum reform.

Two main educational frameworks for European technological development: EHEA and ERA

Today, Europe has over 530 universities with about one million students in forty one countries, and is accordingly the world's greatest knowledge centre (EURIDICE/EUROSTAT, 2002). Only recently it was brought to public attention that this is a vast social capital, and Europe has so far not made a common use of it. Because of language barriers and enclosure of educational systems within national borders Europe has not exploited all its competitive potentials on the world knowledge market. This is one of the reasons why many EU documents concerning tertiary education are based on the idea of mobility of students and faculty, and the idea of international collaboration on all levels. At the Ministerial Conference in Prague 2001 on the creation of a European Higher Education Area, and at Rectors' Conference in Salamanca 2001 on trends in higher education, Declaration on European Research Area were adopted, encouraging unification of social resources in the area of science and education. The main documents that preceded this Declaration were Sorbonne Declaration on Harmonisation in 1998 and more importantly, the Bologna Declaration of 1999.

Behind these declarations was the realisation that only by unification of its resources Europe will be able to compete with USA, Australia and Asia, its main competitors on the word's knowledge market. Such initiatives did not come from universities as the main creators of knowledge but rather from the top, from the EU.

The main unification means of reform in European tertiary education is called the Bologna Process. Bologna Declaration and its follow up documents, i.e. the Bologna Process, along with Lisbon Convention on the mutual recognition of academic degrees are the basic instruments with which EU, the accession countries and others are attempting to realise common aims in the area of higher education. The BD was signed by 29 European countries on June 19 1999.

Bologna Declaration points that higher education is a social area which can create a "more perfect and influential Europe", particularly by building and reinforcement of common democratic, cultural, social, scientific and technological dimensions. Its aims of it are:

Acceptance of easily identifiable and comparable academic and professional degrees system, and the introduction of diploma supplements in order to enhance employment and mobility, as well as the international competitiveness of the EHEA.
Acceptance of a uniform system of two study cycles for undergraduate and graduate degrees. The first three-year course is a necessary qualification on the European labour market, and the second leads to a master's and further to the doctor's degree.
Introduction of a credit system (ECTS), which might be accumulated even outside the formal system, through the lifelong learning programmes (LLL). This is important in order to enhance student mobility, as well as to keep adult population in touch with current developments in science and technology.
Promotion of mobility and surmounting all barriers to free movement for students, teachers and researchers.
Promotion of European co-operation in quality assurance.
Promotion of the European dimension in the area of higher education.i

Several key principles of the Bologna Process have remained vague or have been left to national system's regulation. For example, will courses for foreign students be free of charge? Are mobility programs going to be based on special contests and tenders? Is recognition of diplomas going to function in reality? Will a single curriculum be established? Will shortening of studies create sufficient quality for a knowledge-based society? Are joint curricula going to jeopardise diversity and national traditions? Can envisaged reforms and unification be effectuated by 2010? At the national or regional level, it is still an unsettled question whether shortening of studies will lead to unemployment in HE sector, especially in countries that have the most urgent need of social capital. Will the ECTS be the only source of evaluation of quality of courses? Is a market criterion going to be introduced? Considering the resistance to reforms in some important countries that do not have a national educational policy, or in others, where there are fears that common criteria for the evaluation of quality will jeopardise their national cultures, the key principles are still open to further negotiation. One of the most notable ones is the uniform study system (3+2+3). Therefore, Bologna Process is precisely what it says it is, a process of democratic negotiation on generally desirable resources and objectives of integration.

European Commission tracks progress in higher education by issuing special reports, called Trends in Higher Education. Monitoring of measures and progress in the integration of HE is tracked by European Commission, i.e. by General Directorate for Education and Culture. In the elaboration of reports, contacts are made with the European University Association (EUA), European Associations in Higher Education (ERUASHE), National Union of Students in Europe and the Council of Europe. To date, three reports have been publishedii. The European Commission and its members finance special seminars on topics from the area of the BD. The reports include analyses of the structures of higher education, analyses of legislation and reforms in the pipeline, and analyses of other aspects of higher education, particularly those related to the objectives of the Bologna Process.

Report Trends I concluded that HE systems showed a great deal of complexity and diversity of national systems, and that there was no significant convergence on the 3-5-8 (or 3-2-3) structure of study. Introduction of the so-called binary system (university vs. higher education professional teaching) is not universal; a comparison of countries shows a great diversity.Trends I shows that the need for unification of systems is a priority considering international competition, and also that in the area of labour and the market there is an increasing need for shortening of studies. Therefore, it recommends adoption of the BD objectives.

The objective of Trends II was to compare parameters that should lead to a common HE system. As for unification, in the 1999-2001 period, when Trends II was written, there were several institutional and real reform advances, and the aims of the BD were built into the strategic plans of most signatory countries.

The first institutional and legislative advance was the foundation of the European Network of Quality Assessment Agencies (ENQA) in April 2000. The point of the network was the establishment of a single unified system for assessing quality of education. The reason for the meagre result of ENQUA is a concern that a uniform quality system might benefit only the best, as well as the fear that its standards will not be met by some countries. Many countries show concern that the greatest importers in the knowledge market (i.e. of students) will be those where English is the official language of studying.

The situation with the ENIC/NARIC network is very different.iii In order to fulfil the first objective, the European Commission, pursuant to the Lisbon Convention, together with UNESCO and CEPES created a separate network, the co-called ENIC/NARIC, which creates information networks about higher education systems and institutions, in order to enhance recognition of degrees. Since the absence of national ENIC/NARIC group entails barriers to mobility of its citizens in the future, countries of Europe were eager to join.

According to Trends II (p. 17) the objective of student and faculty mobility had the greatest support. The EU has set up a number of programmes with considerable financial resources earmarked for the realisation of this objective (Socrates/Erasmus/Phare) and for international collaboration within Framework programmes.

According to Trends II employment is a controversial objective of BD, since many EU member countries cannot foresee the consequences of such mobility for domestic labour markets. Trends II however concludes that BD “pays attention to the pan-European dimension of topics related to employment”. Competition as a concern is particularly visible in Britain, Ireland, Norway, Belgium and Switzerland, and least visible in the countries of SE Europe. France has expressed concern for a decreasing attractiveness of European tertiary education, manifested in the declining number of European students from non-member countries (Trends II, p. 22). Some less developed states express the need to increase competitiveness at domestic level in order to diminish the brain drain. Some countries, like Sweden, Germany and Britain, have created programmes for marketing of their national higher education in the world, and the topic of advertising is of increasing importance. Some countries are motivated by non-financial motives, and some, like Britain, almost exclusively by financial ones. Further, BD motivated signatory countries to discuss the binary system. In an increasing number of countries diploma supplements were introduced, along with ECTS.

While Trends II focused on the legislative reform trends, particularly in SE Europe, and on strengthening of common features in the integration processes, Trends III was able to make a more thorough analysis of agreement and disagreements. Trends III covered analyses of views of heads of institutions of higher education, ministers and officials of HE, and from these, some conclusions were drawn.

Like previous reports, Trends III follows European indicators related to Bologna objectives: mobility, structure of qualifications, ECTS and programmes for LLL, as well as internal and external systems of quality control. Mobility of students and researchers increased, but the migration is on the side of countries that have programmes in English (apart from Britain and Ireland, Holland, Denmark and Sweden are mentioned, while France is an importer from the non-European areas). Only 30% of respondents from European HE institutions claim that in their countries and their institutions there is a targeted marketing for student recruitment. Countries that do systematically carry out such marketing aimed at the student population are the greatest importers and the greatest beneficiaries.

Trends III also mentions an increasing number of countries that have or are introducing two tier studies – undergraduate degrees and master's degrees – as well as a binary system (university and polytechnic courses), which is important for attainment of unanimity about the value of a given degree.

By tracking the number of programmes with joint university qualifications, it was evident that their number is still very small. In most countries there is no legal basis for awarding joint (international) university degrees.

The status of the Lisbon Convention is an essential indicator of the unification degree of European higher education area. It is still in a rudimentary state. In spite of the fact that many countries have signed Lisbon convention, it does not mean that institutions monitoring qualification structure actually function, nor that national ENICs/NARICs are consulted. According to Trends III only 20% of higher education institutions work with the national ENIC/NARIC commission, 25% do not collaborate, and 28% do not know what it is or that there is an ENIC/NARIC commission. Recognition of diplomas is unstructured, and this often depends on a university or even a faculty at which a student wishes to study.

Two thirds of HE institutions in Europe, according to the report, use ECTS as system of credit points, and the others use some other credit system. However, the authors add that such a high number of users of ECTS is improbable, and therefore should be further tested, since it does not seem to correspond to reality.

As a conclusion to this section, it may be said that the joint efforts towards building of the EHEA are very visible among most participant states. There is no doubt that all forecasting in scientific development and technological progress in EU should rely on the assumption that EHEA and Bologna aims are going to be realised by 2010.iv Further, most of the aims are by the same token the means of unification of European scientific systems and as well as the common technological efforts of EU.

Along with Framework programs, other joint scientific projects and new institution building, the basic framework for scientific unification in Europe was designed by EU documents on ERA (European Research Area). Main objectives of ERA, and the rationale for designing ERA were given by the report of European Commission "Towards a European research area" (2000). This document expresses the concern that European economies will show stagnation and a decreasing competitiveness if new efforts towards investment in science and research are not going to be made. Europe lags behind R&D investments in US and Japan, and the gaps seems to be widening. Similar trend is visible in the number of researchers. Trade balance in High-Tech products shows E20b deficit yearly, and also seems to be on an increase. There is 50% more European students in US than American students in Europe, and this migration seems to siphon European resources and social capital. Since R&D investment accounts for 25-50% of economic growth, and influences competitiveness, employment and quality of life, these facts point to a number of problems which should be resolved in the nearest future.

A roadmap, or a set of directives was created. It included:

- networking of existing centres of excellence in Europe, and the creation of virtual centres for interaction of institution and projects.
- creating means for financing large research facilities
- coherent implementation of European research activities and more co-operation among European partners.
- better use of resources to encourage investment
- establishment of common system of scientific and technical reference
- more abundant and mobile human resources (with a sub-aim to stimulate “young people’s taste for research”)
- enhancement of regional investment and transfer of knowledge
- bringing together of scientific communities, companies and researchers from all over Europe
- improving attraction of Europe for researchers from abroad
- promotion of common social and ethical values in scientific and technological matters.

Two more recent documents, “Investing in research: an action plan for Europe” and “Some Key Issues in Europe’s Competitiveness – Towards an Integrated approach” from 2003, focused on an analysis of factors which play the most significant role: investment and its consequences for competitiveness on the world market.

D.Polsek

Education in converging technologies, D. Polsek

By most traditional scholars, education is not seen as having a prima facie significant role in assessment of converging technologies or in tackling their social implications. But this perspective is likely to change drastically very soon. An important number of educational problems may already be seen or foreseen in the process of NBIC construction, as well as in its assessment. Further, the pace of social and technological change is likely to be even faster than today, and radically new technological changes require fast personal adaptations and value reorientations towards such changes.

We should pay attention to both kinds of concerns. First, in order to enhance NBIC development; secondly, to prepare the broader public for the future changes. Without systematically dividing these issues, here is a list of educational concerns with NBIC:

<u>1. scarcity of competent scientists attracted to NBIC fields.</u>

Far too few good students are attracted to the fields relevant to NBIC. With notable exceptions, in the last decade a number of enrolled students in social sciences is on the rise. There will be a problem of attracting (and rewarding) best students to enroll in intensive interdisciplinary and technical courses. This problem is especially acute and relevant for NBIC because a very large number of scientists, engineers and technicians will be needed in the future, from which an interdisciplinary perspective will be required.

<u>2. building of multidisciplinary teams with in-depth knowledge and background in plethora of relevant fields.</u>

Development of NBIC is likely going to depend upon multidisciplinary teams of highly trained people with backgrounds in plethora of disciplines, such as: biology, medicine, applied and computational mathematics, physics, informatics, chemistry and in electrical, chemical and mechanical engineering, medicine etc.

<u>3. present educational systems of specialization do not endorse a broader technological and social view.</u>

Building of multidisciplinary teams relevant to development of NBIC will present a significant challenge to our present educational institutions with a four-year degree and two year degree programs. They have all so far mostly favoured compartmentalized learning. Because current educational trends, unlike the foreseen teams for NBIC development favour specialization, there must be fundamental changes in our educational systems.

4. this interdisciplinarity without sufficient depth of knowledge should also be avoided.

However, new degree programs in NBIC built upon the presumption of interdisciplinarity is likely to provide a shallow overview of many disciplines. Students will therefore not have sufficient depth to make major contributions, and the courses may not give students the sufficient training needed to meet future challenges. Therefore we should be concerned with and come to decisions on the right balance of overview and the in-depth knowledge.

5. costs of new technological settings may not be covered by educational institutions alone.

Education in NBIC will require highly specialized and costly laboratory settings. High costs of their creating and maintainance will face colleges, engineering schools and other public and private educational institutions with new organizational and financial problems. Innovative solutions will be required, and are likely to be found in partnership with industry, shared by consortia of colleges, universities and engineering schools. A recommendation that presents itself is to establish long-term partnerships between industry and educational institutions in order to foster mutual benefit: first, in order to sufficiently educate students, and second, to build the adequate future research base and expertize for the industries.

6. reform of curricula

Exciting intellectual, economic, and social opportunities of nanotechnology will be required to attract young scientists to such programs. However, this may not be enough: by the final years of secondary education, students are likely to have already built their preferences. Therefore, elements of excitement for NBIC should be introduced into secondary-level curricula. Similar problems as the ones above (of compartmentalization) are visible in second-level education, so the recommendations for reform (unification of technical and natural science curricula) are likely to be the same for such programs.
Therefore, NBIC concepts should be introduced at all educational levels, into all relevant subjects.

7. insufficient training in science for liberal arts students

There is a problem on the back side of the coin: an insufficient number of social scientists with a technical background and research orientation to conduct competent research on social implications of NBIC. Social science colleges give far too low a priority to scientific literacy, which render their graduate students incapable of a proper assessment of social implications of NBIC. Social science societies and universities will have to make a long-term commitment to attract talented young social scientists to this area of research in order to gain necessary professional skills for NBIC, and to be able to conduct a higher level of social science research in the field.

Insufficient training in ethical sensitivity and on social implications of hard-core scientists

Also, as a flip-side of the coin, there is a problem of insufficiently respecting ethical issues and social implications of technological research. Such concerns should form a part of the curriculum of the future NBIC researchers, in order to avoid counter-productive disputes between "science" and "the public".

8. the earlier introduction of NBIC topics the better

In view of the aforementioned, exciting and technical issues, which would attract students to NBIC programs should be introduced to programs with the motto: the earlier the better. This would provide a standard for technological and social science studies of NBIC alike.

Considering the foreseen impact of NBIC, its potential benefits as well as the potential for negative consequences, a number of fora, political and educational bodies have provided recommendations and educational principles for development of NBIC programs. They include:

9. making NBIC research a high priority in education.

Interesting courses dealing with social role of medical and biological studies, informatics technologies and the like should be built into curricula at the earliest grade possible. Educational and scientific (Mertonian) values such as openness, dustribution of scientific results, public participation should be built into such educational programs.

10. educational role should not be constrained to young scholars

EU has developed LLL programs for elderly. It is quite significant to involve broader public in education for NBIC for several reasons. First, the huge changes in personal lives are expected as a consequence of NBIC development. Second, they will affect primarily and mostly (aging) generations that have passed their formative age. Informing these generations will be crucial for their adaptation for maintaining the quality of life in the old age. Third, the demographic curves of aging in EU show that these generations are going to be cental for political decision making. Therefore, the role of LLL in assessing the merits and costs of NBIC is likely to be even greater than foreseen today. A recommendation: to encourage the development of forums for continuing education in order to involve professionals in public discussions, and to inform the public of the costs and benefits of NBIC.

11. building institutions for monitoring sources and challenges of NBIC

The pace of personal and social changes is likely to be even faster than today. Therefore, several scholars and groups have emphasised necessity to build new institutions with the task to inform the public, to monitor costs and benefits of new NBIC products and technological processes, and to provide timely information (feed-back) relevant for institutions involved in NBIC production, as well as for the user groups.

12. foreseeing the short-term and the long-term future

In order to reorient their economic capacity and sustain development, societies should have a future oriented view towards the processes of technological change. Creation of institutional infrastructure capable of producing, sustaining and evaluating NBIC scientific, technological and social implications should be created. These institutions should regularly evaluate all such contributions and potential dangers, and view NBIC products and processes in terms of the expected short-term and long-term costs and benefits.

13. the sooner-the better principle valid for researchers too

The educational principle the sooner-the better should not be constrained to curricula alone. It is valid for the involvement of researchers and social scientists at the very onset of the problem (concerned with NBIC). This will provide single researchers with the broader view, and will involve the public in the discussion about the future developments, and about the potential dangers and conflicts with ethical values of societies. The responsibility to introduce such information and/or disputed scenarios should be allocated to a particular governmental or non-governmental institution.

14. integration of objectives to enhance flexibility

Since many of the future scenarios are not precise, societies may react differently to the envisaged future. It is essential to integrate social objectives (within national or international short-term, medium-term and long-term plans) to enable societies to react appropriately and flexibly, i.e. to reorient their future policies.

15. creation of the reward-system for cutting-edge science education

Since in general economic benefits of NBIC are not viewed as to be immediate, the envisaged process of NBIC education is unlikely to happen without the system of educational or financial rewards. A system of investing into (and rewarding of) innovative educational programs should be introduced. In giving such rewards, responsible public insitutions should pay attention to the educational merits of such programs, while at the same time giving concern to ethical and value-issues involved.

16. studies of broader social implications to avoid social disruption and conflict

NBIC research is not created in a void. While crating an educational system and a reward system for the best science and education, societies should conduct broader discussion on issues of workforce, economic implications, the role of disruptive technologies, i.e. to assess the potential winners and losers within the society, and to create scenarios for avoiding social inequality and other types of social disruptions.

17. educating policy makers to provide synergy required

In many societies, there is an insufficient coordination of diverse interests of industry, educational institutions and the government. They lack a "triple-helix" necessary for a productive economic and knowledge-society outcome. In such cases, basic requirements for development and sponsorship of NBIC is also lacking.

Since a synergy of such constituences in a precondition for greater public involvement, the function of educating constituences should not be minimized. (Public is too-broad a word). It means that all strains of the technological "triple-helix" should be involved, and mutually educated or informed. The role of governmental institutions responsible for NBIC (and technology development in general) is to select the proper forum, while enhancing the role of the mutual education of these broad constituences.

All points mentioned may be logically developed into specific recommendations for targeted institutions in order to allocate responsibility.

However, it should be noted that many tasks foreseen, and many processes involved in NBIC production and in education are by their nature holistic. This means for instance that new educational programs may not be feasible without proper funding by the government and the industry; that such funding is not likely to happen if there is no public support for such programs; or that such support is not likely to happen without proper information of the uninvolved public.

EU, the Commission, and our HLEG is carrying (and accepting) the task to be the prime mover in starting various aforementioned points and processes at the more local levels of decision making.

Fusion and NBIC, N. Nakicenovic IIASA

ITER will hopefully be approved soon. Once built it is expected to operate for some 20 years or so before a pilot power plant could be built that generates power. This might take another decade or so before it is on line if things go smoothly. After a few years of operation, this might lead to further orders. This would be sometimes in the late 2030s or early 2040s and would correspond to where fission was some 50 or 60 years ago
Therefore, fusion is not likely to be an energy source of great importance over the time frame I envision for emergence of new wave of technology convergences. However, the opposite may the case - new NBIC could provide some of the enabling functions for fusion. These would not be unique only to fusion, but could enhance other advanced energy systems in particular fission or photovoltaics. Examples are self-organizing power and hydrogen grids and end-use systems that could manage energy flows and needs. Another are autonomous agents for repair in hazardous areas. Further example is the need for immense precision in design, construction and operation of fusion devices.

Another issue is one of scale. Most of the NBIC technologies are on the opposite end of scale compared to huge scale of fusion devices. It looks like bigger the fusion power plant is - the cheaper it would be. (By the way the same applies to most energy generation systems including curiously also wind power.) My understanding is that they would start with minimum of say 1GWe installed and go toward 5GWe and more, perhaps up to 20GWe for a relatively cheap source of electricity toward the end of the century. One possible conclusion is that such gigantic power plants would only make sense in integrated, global (or at least continental) electricity and hydrogen (hydricity) grids. For example, EPRI has proposed what they call "energy pipelines" for such a grid - they would consist of two concentric superconducting tubes to conduct DC electricity and would be filled with liquid hydrogen both for cooling and transporting hydrogen as the second energy carrier. The capacity would be about 100GWe and 100GW of hydrogen. A good system to connect 10 fusion power plants to huge metropolitan areas in China or India. Not very attractive by current standards for Europe.

<u>Greenpeace on Future technologies – To-day’s choices</u>

This report is subtitled “Nanotechnology, AI and Robotics, a technical political and institutional map of emerging technologies”, and therein lies the scope clue. Commissioned from Prof Arnall of Imperial College, UCL, it has been almost a year between being written and being released. It is very much based on nanotech as a fundamental technology enabling other areas. IT is a little UK-centric, but will be used internationally. It just predates the Royal Society study I think.

It sees the new technology not only as a threat but also as an opportunity to take a step forward to environmental sustainability. As such it is a more balanced viewpoint than one often finds, also due the involvement of New Scientist in some founding debates possibly. The EC’s FET programme was consulted but not, it seems, the nanotechnology or Biotechnology programmes.

The context is interesting; asking (but not really answering) the following questions:

- who is in control, if anyone
- who can one trust
- what information can one trust
- on what terms is the technology coming
- what are the risks
- what are the certainties
- who is exposed to the risks
- are the certainties positive
- who benefits and loses from the certainties
- who takes responsibility for impact finally

The public in increasingly unwilling to accept the governments or an MNC word on science and technology issues. As science, technology and markets become more tightly coupled, this mistrust will grow. Equally, as (UK) government takes a 10 year view of Science, it is a unique opportunity to engage the public in the debate at an early stage, in a technology which it sees more powerful than any government, more powerful than any one politician. Equally they accept the problem of top down public views on technologies coming bottom up in unpredictable forms and routes. They focus on areas around ITC, energy and defence, without deepening the two last ones very much.

Two interesting points are made for 2003-4 which have not been mentioned before; and need verification because of their implication for the focus of the now:

1. Japan will spend more than US in Nanotech R&D
2. private sector investment will exceed public sector,

both being used to suggest that the train may already be moving too fast for “local” public opinion to jump on.

For AI they suggest that weak AI (rule based support systems) is more likely to percolate into products than “Strong” AI (simulating complex logic and cognitive models); which seems reasonable, and that these will perform very efficiently. Robotics as an extension of AI is regarded as less likely than robotics as autonomous vehicles, remote control systems and routine screening with mechanical elements. It expects little if anything from the cognitive Sciences.

Convergence they feel will come at the nano-bio interface first, with green-goo issues ahead of grey-goo. Whereas the debate related to AI will not change much (it is just more efficiently implemented) and be on responsibility, trust and privacy; the nanotechnology debate is too premature to call at this stage – the picture is too dynamic, too fragmented and too uncertain. However, if science believes what it promises, then it should open the debate to the widest engaged public, convince them and create momentum for a new future.

Contrasting nanotech with ICT and AI is clearer – both blur the boundary of the inanimate and the animate; but what both actually do is remove the boundary by promising to create a continuum. AI has the Turing test, Nanotech has self assembly…AI has failed to deliver once, and still suffers from this; while nanotech has survived the first credibility challenge to real progress – the Henrik Schoen[62] saga. It is suggested AI will see a new dawn on the back of radically improved performance enabled by nanotechnology, but omits where the cognitive breakthroughs will come from.

They do see a possibility of the unification of physics, chemistry and biology, which would have profound effects because at no time before has it been possible to bring individuals from basic disciplines together on such a scale (indeed, disciplines are bifurcating all the time).

Also, at this level the science is the driver, the technology the vehicle and the innovators can take it from there, the integration happens at the lowest possible level to create functionality; not at the macro-component level.

One avenue explored is the branding of nanotechnology as a natural extension of micro-mechanical-technology and MEMS, but that does not do justice to the concerns about size-related impacts; which do not occur at MEMS technology levels. A more covert market route would be to develop the market for sensors, which are not seen as intrusive or aggressive, but as security and health enhancing, even if made using a "risky" technology. This, like the use of nano-components in ICT products, will be less contentious.

Where they are clear is the increased need for assessment of impact is in areas where release of nanotechology particulates into the environment will have some sort of impact. However, there it sees benefits as well as risks in a more balanced view. Energy is a key to gaining a positive environmental footprint from the technologies involved. Where these breakthroughs occur, industry, transport and domestic consumption will see swings in resource demands.

They guard against the dangers of future over-optimism, but offer little in the way of historic perspectives to search for lessons learned. It concludes with the statement that society will only accept what is acceptable. This is the social market route. Defence will accept a lot more, and these directions will ultimately percolate down to the domestic markets.

Based on a rapid read through.

[62] Dr. Schön averaged one scientific paper every eight days, but were found to be based on forged experimental results.

Converging Defence Technology Research for a Secure Europe

Introduction

The Commission has successfully managed co-operative EU research programmes for years through the various Framework Programmes. This experience is vital in the area of security research. The activities foreseen in a future Security Research Programme are not intended to replace other efforts in this field, but rather to support and supplement them. Efforts to develop a European Security Defence Policy (ESDP) are in full swing. Current thinking on this issue is evolving rapidly for a range of reasons: increasing threats on the security of citizens and modern society; the fact that it is impossible to have a credible security and defence policy without a strong and competitive defence industry and a healthy environment for R&D investment; the high cost of duplication and fragmentation of research; and the strategic role of security research in the Lisbon Strategy for a competitive EU economy.
Therefore, the Commission is exploring the development of a EU security research initiative at Community level. The Preparatory Action should demonstrate the added value of EU co-operation in security research using the community approach and help develop appropriate means of dealing with intellectual property legislation, co-funding, etc.

European integration is at a critical juncture

After intensive debate and consultation in the Convention on the future of Europe, work on a draft constitutional Treaty has now been successfully concluded. A new constitution will bring major changes to the Union's institutional framework. Next month, in May 2004, the widest-ever EU enlargement will become a reality, bringing together the two halves of a continent artificially divided for almost five decades. As a union of 25 States, with over 450 million people producing a quarter of the world's Gross National Product, the European Union is a global player and it should be ready to share in the responsibility for global security, but we spend almost nothing on this[63]!
Enlargement will generate new security challenges for a new Europe that directly borders less stable regions. The political and factual context, the institutional landscape and the concept of security is changing over the years to come. In order to maintain a secure Europe in the midst of these changes, it has become imperative to develop a new “security culture” in Europe that is more in tune with today's security requirements.
Consequently, the EU is at risk of becoming more dependent and vulnerable in this essential area.
Within Europe, the lack of a co-ordinated and coherent security approach between Member States, a certain degree of duplication and fragmentation, and the lack of security system interoperability in Europe, emphasise this risk and the urgency to act now. Council,

[63] The combined budgets for RTD in the defence sector in all EU Member States is approximately 5 times less than the corresponding budget in the US. In fact, the new US Department of Homeland Security (DHS) will receive $669 million in R&D funding from the federal budget in 2003, nearly triple the $266 million for comparable programs in 2002. In 2004, the DHS will receive $1 billion. Similarly, the R&D budget for the US Department of Defence (DoD) was recently increased by $8.8 billion (or 17.6%) to reach $58.6 billion, according to Washington analysis of US federal budget 2003

Parliament and industry have repeatedly encouraged the Commission to undertake specific actions[64] that would strengthen Europe's long-term security capabilities.

Recent public opinion polls show that European citizens also expect government to take a more international approach when it comes to their security and are increasingly in favour of the development of a common European Defence Policy.

Piloting a new programme

The Preparatory Action is, in essence, a pilot phase that will help prepare for a future Security Research Programme. To accomplish this, it will aim to:

Identify appropriate methods and institutional settings for the future organisation of security-related research.

Examine how to relate the Commission's existing research activities to the specific needs of security.

Explore possibilities to enhance industrial competitiveness and improve the cost-efficiency of technological co-operation in the field.

Answer questions that are necessary for a long-term strategy, for example:

How to define and implement a comprehensive research strategy that corresponds to the new security challenges?

How can potential synergies between civil and defence research be exploited?

How can the Commission involve (national) customers in a community programme?

This would be implemented by:

Launching a series of RTD activities supporting European wide security issues complementing those undertaken in regional, national and inter-governmental contexts.

Establishing a consultation and consensus-building platform with the relevant stakeholders to develop a long-term vision and a strategic research agenda for Europe in this area.

Demonstrating that the Community can respond with appropriate actions to some of the immediate challenges that Europe is facing.

A total budget of €65 million will be proposed. It is expected that considerably more money will be needed to seriously address Europe's security research needs in the future.

In the short term, research covered under the Preparatory Action will be mission-oriented. These "missions" call for innovative solutions, and this is where R&D will come into play. Technical capabilities must be developed by industry and research establishments to support operational requirements. The following topics are examples of the subjects that may be addressed in the Preparatory Action:

Interoperability of systems and standards for information and communication

Crisis management (incl. evacuation and search and rescue operations, using a variety of resources)

[64] European Parliament: Resolution 172 (April 2000) and Presidency Conclusions of the Brussels Spring Council (21 March 2003)

The Conclusions of the EU Competitiveness Council (13 May 2003)

The Conclusions of the EU Thessaloniki European Council (20-21 of June 2003)

Star 21 (Strategic Aerospace Review for the 21st century) (2002)

Security in a distributed environment, applied to existing infrastructures and using European space-based assets
Protection of vital public and private infrastructure, including electronic networks.
Protection and remediation against incidents with bio-chemical and other substances
Concepts and technologies for situation awareness, applied for border surveillance, monitoring of infrastructures and public space, etc.
Non-lethal means against terrorist actions.

Converging Technologies involved could include

Technologies could include: iris scan technologies, genetic/DNA technologies, face recognition, bio-chemical analyses, combination of various technologies to improve reliability, reduce time for analysis, etc.
Technologies to enable tracking & tracing of visas throughout the Union including: active methods using transponder technologies, passive technologies using automated inspection; novel ideas on issuing visas.
Temporarily label luggage throughout the handling at airports; remote visual control systems to spot abandoned luggage
Autonomous bio-chemical analysis of contents of luggage and freight;
Computer-aided visual inspection of content; decision support: technologies to automate/aid understanding of luggage content from the combination of multi-sensor information.
Technologies to enable rapid detection & alarm in case of attacks with biological agents;
Technologies to enable efficient neutralisation of chemical agents used in attacks.
Protection of satellite surveillance systems of sensitive areas (water tanks, nuclear sites, etc.)

Institutional Issues

This is a new area for the Commission. Exact details and parameters associated with a proposed European Armaments Agency have not yet been established. The Commission sees Security Research activities as necessary elements to be developed on the road to improve security in Europe and the competitive position of the European industry.
Discussions regarding how a future Agency would be organised and how both would fit in a European security policy will be discussed in the near future. There is a growing need for more effective co-ordination and consistency at a European level in the area of security.
Research and technological development activities can help build shared capabilities and competencies. Vast opportunities exist for convergence between civil and military research and between the public and the private sector, and the relevant technologies. The fact that a pilot action for RTD has been promoted by 2 Directorates in the Commission are a good omen for an interdisciplinary workprogramme.
It is rare that there is a new field such as this opening up at such an Institutional level, where there is already so much activity; and the NTW group must look at the possibilities here for potential suggestions for European action and infrastructure that meet the needs of all citizens and can help a European identity to emerge in an extremely difficult technical, political and emotional domain.

First call for proposals under the Preparatory Action for European Security Research[65]

The European Commission has published the first call for proposals for projects and supporting activities in the scope of the Preparatory Action on 'The enhancement of the European industrial potential in the field of security research'.

The activities to be funded[66] under this call are defined as collaborative multi-disciplinary, multi-stakeholder projects that will strive for a broad, strategic perspective in considering the topic areas addressed, but give tangible outcomes that will provide the basis for the future Security Research Programme.

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[65] To see the whole call text, please visit: http://www.cordis.lu/security/calls.htm

[66] The total indicative budget for this call is 13 million euro for six to eight projects and some supporting activities. For further information, please contact: European Commission, The Preparatory Action in the field of Security Research Information Desk, Directorate-General Research, JII-79 0/01, B-1049 Brussels, E-mail: rtd-pasr@cec.eu.int,

9. Other Reviews

Ethno-technology for converging technologies, T. Gaudin

Ethno-technology was initiated during the mid seventies by a high level interdisciplinary research group composed of social science researchers (ethnologists and sociologists), historians of technology, design teachers and engineers. The group was sponsored by the innovation department of the Ministry of Industry which was in search for a better understanding of Technology-Society interactions, as a help to elaborate more sound policies.

Previous to this work, an ethnologist called Robert Jaulin[67] had published several articles and a book on the concept of « ethno-cide ». By this word, Jaulin meant, not the destruction of a population (genocide), but the destruction of a culture, which may be accompanied by an increase of the population. He observed some cases in the ameri-indian tribes, but the most significative case was given by another well known researcher, Robert Gessain, regarding the Greenland eskimos, named Amassalimiuts. Here is a summary :

In the north, technology means survival. Any mistake in the manufacturing of a kayak or in clothing isolation is paid in human lives. The introduction of the steel knife, in exchange of some sealskins, was felt as positive by both parties, but has the following outcomes:

The old technology (a knife made out of seal bones) is depreciated.

The elderly people mastering the ancient know how loose their social status.

The young ones, adopting faster the new technology, start despising the olders and do not listen anymore their teachings. The whole culture is damaged.

The former know how is no more transmitted. One generation is enough to sink it into oblivion, though it had been used for millenniums.

Productivity grows. Maybe the population grows too, but it is now depending upon external supply, and the terms of exchange escape to its will. The population looses at the same time its autonomy, its regulations and its internal equilibrium. The detailed description of the consequences is made in Gessain's book : « Amassalik ou la civilisation obligatoire ».

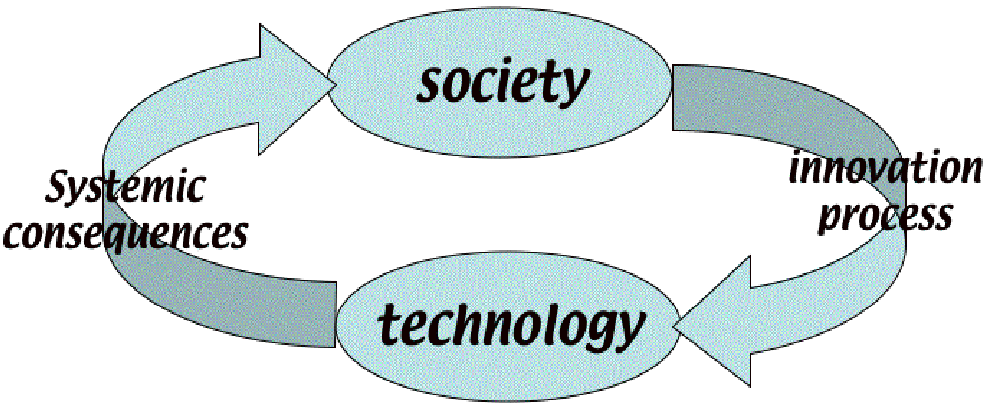
« They eat the children of their children » say amerindians to criticise the lack of foresight of the merchant civilization.

Anyhow, foresight of technology-society relations is difficult, because of its systemic complexity, as shown in this example.

The starting point of ethno-technology was therefore quite critical, and be felt as uncomfortable by conformist minded people, but the question raised by ethno-technology needed and still needs more work. The relationship between technology and society cannot be studied as if technology were a global entity. Each technology has its specific mode of

[67] http://perso.club-internet.fr/vadeker/corpus/pariseptisme_ethnologie.html

innovation and interaction. Technologies have to be studied one by one, according to the following scheme:



The ethno-technology group worked on the case of the cement, the bicycle, the toys and many other devices. For some, interesting results appeared, for others none…

It took also into account the lecture given by Heidegger in 1953 in an engineer school under the title « Die frage der teknik » (the question of technology). In this conference, Heidegger says : « the essence of technology is nothing technical ». This means that the utilitarian approach of technology does not stand facing philosophical criticism. And he goes further saying : « The essence of technology is the Being itself », therefore, man shall never control technology, because he is unable to control the Being. The group was impressed by this strong statement. Most economic and technical actors behave as if technology were only made of tools, totally under human control. This is an appearance, a common illusion, and work is needed to overcome it.

<u>The case of nano and converging technologies</u>

Regarding nanotechnologies, the question is still more difficult, for a very simple reason : nanotechnologies are not yet in operation. They only exist in labs, therefore no observation can be made regarding the social transformation they generate. We can only speculate about the possible systemic consequences they would have on society, according to what we know on the consequences of other technologies.

This speculations are to be discussed and should help to built scenarios. As a starting point, let me give some simple statements of the points that should be taken into account :

The first point is that nanotechnologies are invisible. Their products are a hundred thousand times smaller than the smaller dimension the human eye can perceive (It was not the case of microelectronics : even if the micron engraving is not visible, the presence of a chip on your credit card is visible). Through history, mankind has already faced invisible beings : for instance the microbes, particularly through the great plagues (the one of the middle ages, in 1348, killed one third of European population in one year) ; another example is the nuclear radiation, as for instance the radioactive cloud from Tchernobyl. In both cases, invisibility is associated with phenomena out of control generating fear.
The intensity of the fear is related to the situation of the individual. He is deprived of control on the event, and has to rely on the institutions. And the obligation to trust is a factor of

distrust. Therefore, we should be prepared to the idea that “nanos” might be a new generator of fears and distrust in scientific and industrial institutions developing them, particularly if they might be used as weapons. In the case of microbes, the trust only recovered after Pastorian work, which provided spectacular evidence of a new control of the situation, and established during the 20th century a faith in progress and science still vivid nowadays.

The second point is that nanos will need heavy equipment to be explored and developed. It was also the case of silicium smelting, but the use of microprocessors to built small computers could be, according to the legend, developed in a garage. Now, we can reasonably doubt nanos to be the source of garage technologies developments, for one simple reason: thinner is the technology, heavier are the instruments necessary to measure and control what you are doing. Therefore, they should stay in the hands of big companies or big research institutions, be protected by a set of patents and generate monopolistic situations. This should be felt as highly unpleasant, as well in developing countries as in the developed ones. In developing countries, it should be felt as an increase in dependency on foreign firms. In developed ones, it should be felt as a growing influence of big firms, reducing the opportunities given to individual entrepreneurship success stories and pushing the small and medium firms towards subcontracting and subordinate positions. The use of internet has boosted free communication, micro-initiative, free software and a wide renewal of libertarian feelings. Nanos opens the perspective of a come back of the dominating influence of big companies, inevitably bureaucratic. Presently, the game at work in United States is to generate, through a public opinion movement, the necessary billions of $ of public procurements, mostly defence ones, out of which the contracting companies will file the patents and capture the technology world wide for the next 20 years.

The third point is that at nano-scale biotechnology and microphysics converge. The so-called « converging technologies » include nanos, bio, info and cogno, says the US NSF report, showing the most enthusiastic faith in the unity of science. But nothing appears concerning science and society interactions, except that these converging technologies could provide new genetically manipulated organisms, new weapons, new treatments for genetic illnesses and new forms of control on our thoughts, through cognitive sciences developments. Anyhow, one does not need a doctorate in philosophy to be aware of the ethical problems raised by such perspectives. The elementary questions : who manipulates what ? and even : who manipulates whom ? are enough to generate tough controversy involving religious and other ethical authorities all over the world. Faith in science is obviously not rooted enough in public opinion to allow scientists (sponsored by big companies, eventually through military procurements) to manipulate freely life and consciousness. Therefore, we should be prepared to strong reactions, and acceptability of such developments should not be taken as granted.

Ethno-technology is not aimed at assessing technology. It is aimed at analysing the situations taking into account as completely as possible the society technology interactions. Therefore, the above considerations should not be taken as a criticism, but as elements to help at scenario building.

Innovation in a historical context: some issues for policy, K. Bruland

Introduction

The aim of this paper is to suggest ways in which historical analyses can inform debates and our thinking about current developments in the NanoBioInfoCogno field (usually described as a process of convergence), and ultimately contribute towards the formulation of policies for research and related mechanisms in the area. The basic argument here is that a historical perspective can help us to see the NBIC field in the context of the factors that will shape its evolution and spread.

There are four areas at least where a historical perspective may be useful. First, the concept of convergence is problematic and has been defined in different ways – some seeing it as a process whereby technologies and technological practices converge, others in terms of converging knowledges. Historically speaking, what do we know about converging or co-evolving technologies or knowledges? Second, there are strong tendencies to regard current developments within the field of NBIC as the start of a new 'technology wave'. Such waves are usually based on the notion of pervasive technologies that drive large-scale processes of structural change. What is the state of historical knowledge and debate on waves, and what are the implications for our understanding of the NBIC area? Third, there are more or less complex links between social and technological change. Sometimes it is argued that society and technology 'co-evolve', but our only resource for studying and evaluating such processes is historical material. Fourth, it is very difficult to establish any kind of firm, empirically based, view of what in fact is taking place in this area, let alone to assess the realism, or robustness, of current trends as far as actual developments are concerned. (a recent French report argued that no more than 10% of work within nano was serious, the rest was 'hype' or 'fashion'). What can we say from a historical view point about the empirics of technology creation and spread?

In short, the task of this group is to try to analyze something which is difficult to define, and which raises serious analytical problems. A central method the group is using is foresighting, and building of scenarios - so we are asked to envisage where things are moving in the next decades. This in turn is an input to strategic choices, in the sense of pinpointing areas which should be supported, and describing what support mechanisms should be created, especially at the European level through the Framework Programmes. We are asked to consider the social dimensions of NBIC. This is often thought of in terms of what impacts we believe NBIC will have on society, but on the other hand, our project could be thought of more in terms of shaping the directions of this technological development and thus thinking about how society impacts technological developments rather than the other way round.

What can history bring to the debate?

The first thing to say about history in general, as well as the history of science and technology, is that it does not offer us any neat lessons. History is invariably contested, with serious issues of uncertainty, limitations of evidence, and interpretation. These problems are compounded by the fact that those who look to history for lessons often oversimplify the issues: this is especially a problem in the vigorous field of innovation studies, where it is common to find an extremely schematic use of historical material, which seems to be aimed more at supporting come current position than in really understanding the complexities of historical evolution.

One clear argument for taking a historical approach to technological change and knowledge evolution is that major technologies often take a long time to develop and to have impacts. It was nearly a century before the steam engine had really significant economic effects, and such technologies as electric motors, or the dynamo, or the laser, or even computers, took many decades before impacts could be identified. These long time periods are not simply gaps or 'lags' as they are sometimes called: they are periods in which social, economic or technological evolution is occurring; they involve the history that is crucial to the development of the technology. It is in these long developmental periods that uncertainty is extremely high, since there is no guarantee that any particular technological opportunity will actually develop, and no information as to how markets will react to a technology when fully developed.
It simply is not possible to understand the factors affecting the trajectory of a radical change like NBIC without drawing on a reading of the histories of other forms of technological change.

Although history offers no neat lessons a careful reading in economic and industrial history nevertheless provides us with much scope for reflection. Beginning with economic history, what are the main features that emerge from the growth record of the advanced countries? In historical analyses of the growth record of the past two centuries, the primary result must be that we are not simply looking at a process of secular expansion. The overall growth process exhibits complex features which present difficult explanatory problems. These include:

first, apparently cyclical fluctuations in growth and employment, both in a long term sense (such that we appear to have broad 'eras' with similar growth rates within the period, but large differences between periods) and in a short term sense (with large macroeconomic fluctuations affecting output and employment).
second, major structural changes which have reshaped economic systems at least twice since 1800 (with first, a shift in the output and employment structure from agriculture to industry, and then more recently from industry to services); this has often involved large shifts in the relative weights of industries, and deep-seated adjustment processes.
third, incessant technological change, persistently reshaping products and processes in both radical and incremental ways. These technological changes are not simply the 'heroic' innovations such as steam power or ICT, but pervasive small scale changes across the whole range of technology employed in the economy. During the first industrial revolution in Britain, for example, there were vital changes not only in steam power and textile machinery, but in agricultural equipment, food processing and distribution, small metal products and

household goods.[68] A problem which has not been resolved is the relative importance of radical versus incremental innovation over the long run, especially because many so-called incremental innovation can be tied up with deep social changes.
fourth, an extremely uneven global diffusion of the effects of industrialization and growth, in terms of income levels, technologies, growth capabilities, etc.

These historical trends do not appear to be changing over time, although they certainly take new forms. The problem for the historical interpretation of technological change is that of understanding the technological dynamics that both underpin and are shaped by, these economic and social phenomena.

History of the innovation process and the scope of innovation through time

Let us consider one of the issues that have been sketched above, namely radical versus incremental innovation. It seems tempting to view NBIC as a radical innovation, and as such it seems to fit neatly into a widely-used schema for putting radical innovations into a historical framework.

From the later eighteenth century, the capitalist economies have been characterised by instabilities - periods of boom and recession or depression, of more or less severe character. On the one hand, this has led to attempts to characterise different 'eras' of economic performance, characterised by different rates of output growth and total factor productivity growth. On the other hand, we have attempts to view these 'phases' as evidence for a technology-driven wave process in economic growth, which involves major disequilibria springing from technological innovation.

The introduction of innovation as a driving force is usually held to derive directly from Schumpeter's Business Cycles.[69] Schumpeter in fact offers no theory of the generation of innovation, but he makes three important points which he seems to treat as empirically founded. These are:
Innovations are clustered together and 'are not evenly distributed in time'
Innovations 'concentrate on certain sectors and their surroundings'
There are discrepancies between the growth of sectors: 'some industries move on, others stay behind'

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68 K.Bruland, "Industrialisation and technological change", in Roderick Floud and Paul Johnson (eds.), **The Cambridge Economic History of Modern Britain**, pp. 117-146, Cambridge: Cambridge University Press (2004).

69 J.A.Schumpeter, **Business Cycles: a theoretical, historical and statistical analysis of the capitalist process**, New York and London, 1939.

This has lead to a kind of periodization of economic growth in terms of 'waves' or 'phases'. Schumpeter himself talked in terms of three great phases of growth - driven by what he called 'carrier' technologies. These phases were the age of steam and textiles, the age of railways, and the age of electricity. This kind of periodization has become extremely popular, and it is often assumed that we can explain economic growth in terms of these big new technologies and the economic upswings they generate. Perhaps the most recent example of such an approach is Freeman and Louca's book As Time Goes By. From the Industrial Revolutions to the Information Society.[70]

The problem in this kind of approach is that the economic history is in fact misleading. There are a number of points that should be noted about such "Schumpeterian" schema. Firstly, there are many chronological problems - the chronologies are often rather arbitrary, and no chronological evidence is offered to suggest that the periodizations are accurate. Second, there is no evidence offered on the patterns of use of the technologies during the periods in questions: it frequently appears that the innovation of a particular technology is being confused with its diffusion. Thirdly, there is no evidence on the economic impact of these technologies - general evidence is offered to suggest that some of the sectors grew rapidly and reached large levels of output, but there is nothing on whether this could account for the growth rates which were achieved over the periods concerned. Fourthly, the allegedly 'epoch-making' innovations are invariably chosen in an ad hoc way. It is frequently unclear why some innovations are regarded as primary sources of growth and change while others are not. Finally, there are serious methodological problems. On the one hand, what we have here is technological determinism: there is no account of how these technologies emerged, and the idea seems to be that they emerge from 'limitations of the previous techno-economic paradigm' and that society then faces problems of adaptation. On the other hand, we have a method which is based simply on giving examples which are alleged to represent some general truth; but there are no evidential connections between the examples and the wider trends they are supposed to drive.

Arising out of these analytical problems, modern work in the history of technology has shifted the focus of attention away from the alleged 'carrier' technologies, and towards small scale innovation across many economic and social sectors. The point here has been that it is often rather mundane sectors – such as food processing or clothing or agriculture or transport – that have driven both technological change and economic growth. One way in which they have done this is by being the site of application of new process innovations, a point that is surely relevant to present day NBIC, or converging technologies. For example, it could readily be argued that two of the most important innovations of the modern world are the production line, and replaceable parts. Both of these actually arose in the first industrial revolution in Britain, in the production of biscuits, and in agricultural equipment (specifically ploughs).[71]

What all serious historians seem to be aware of, and to take as central problems, are two things (in this they differ from many students of innovation). The first is complexity – the fact that economic and technological activity is an extremely multi-faceted phenomenon, involving a vast range of activities, some of which are integrated, some not. These multifarious activities rest on different types of product and labour markets, different inputs, different techniques, etc. But they also rest on complex social and institutional foundations.

[70] C.Freeman and F.Louca, As Time Goes By. From the Industrial Revolution to the Information Revolution, Oxford: OUP, 2001.
[71] K.Bruland, op.cit.

The second phenomenon is location. What we often seem to have are locationally-specific patterns of differentiated production. Do we have some way of getting an analytical grip on this complexity and locational behaviour in the case of NBIC?

Diffusion

A final key element in the history of technological change and innovation is that much of it explores not innovation but the diffusion of technology. Here there is a big and rather robust result: most cases of technology diffusion are slow, long drawn-out processes.

The diffusion of innovation across boundaries in history

Innovations do not spread evenly: some countries succeed in acquiring, adapting and implementing new knowledges and technologies, others do not. What are the factors determining their success or failure? Which parameters should we take into account? One source of insight is historical analyses.

Economic historians are increasingly looking to culture when seeking to explain the North West European lead in technological advance in the 18th and early 19th centuries. They have assigned a critical role to the cultural climate that encouraged disagreement and debate and made it possible for inventors to be heard. Differences in scientific cultures, and the different extent of institutional integration of scientists and engineers are regarded as significant factors: they account for the dissimilar reception of Newtonian ideas, and their exploitation within Europe, and ultimately why some regions, but not others, experienced early technological revolutions.

When new steam technology was transferred to Sweden in the early 18th century, the effort failed: there were economic, geographical and technical reasons (the machine frequently broke down), but the most decisive underlying factors were social and cultural: foreign technicians were not integrated in the community and the key person behind the project left as soon as the machine had been successfully demonstrated and his admittance to the Royal Swedish Society ensured.

When technologies were transferred in the eighteenth century, individuals and institutions played key roles: inter-regional and international diffusion of ideas and techniques were spread across Europe by travelling artisans, backed by the guild systems and governments. Innovations were spread by legitimate or illegitimate means, and were integrated and developed in regional clusters (in glass and iron making, textiles, brick and tiles, etc). Most European states appointed spies to access and transfer foreign knowledge – albeit that their servants frequently ended up in jail – and the enticement of British skilled workers to emigrate (which was forbidden by law until 1824).

The institutionalisation of technological development in a specialised capital goods sector producing process innovations for other sectors first took place in Britain in the 1820s. This changed the wider diffusion environment: when seeking markets abroad the challenge was to provide inexperienced customers with technology that could operate in foreign contexts. The industrialization of nations and regions from the mid-19th century rested on imports of complete technology “packages” (including people and thus tacit knowledge) supplied by such firm, and the repeal by the British governments in 1843 of laws forbidding machinery exports.

Are studies of [72]technology transfer in the past irrelevant to current European concerns? Certainly, conditions were very different in the past. But that is the reason why they are useful: spreading or transferring innovations across boundaries, from one context to another involves a shift to a location where conditions are different. Historical studies are valuable because they increase our knowledge of the kinds of factors that have been important, and of their relative significance – be they social, cultural or economic.

References: See in particular N.Rosenberg, "Factors affecting the diffusion of technology", Perspectives on Technology, Cambridge 1977); S.Lindqvist, Technology on Trial: The Introduction of Steam Power Technology into Sweden, 1715-1736, Uppsala, 1984; and K.Bruland, British Technolgy and European Industrialzation. The Norwegian textile industry in the mid-nineteenth century, Cambridge, 1989/2003.

For major technologies, it is common to find diffusion processes that last for many decades. For example, the time-lag from the discovery of the principles of lasers to widespread application was about 80 years. Einstein discovered the principle of laser in 1916-17, but the scientific principle did not lead to development. It was the invention of Maser in 1954 and the laser in 1960 that made possible subsequent developments, but even so it took many years before there was full diffusion of laser technology. The construction of a bridge between recent scientific discoveries and technological innovation typically requires considerable time: Faraday's demonstration of electromagnetic induction in 1831 was not followed by any significant technological applications (except for the telegraph), yet this scientific discovery laid the foundations for one of the defining industries of the late nineteenth century's "Second Industrial Revolution", namely electrical equipment and electric power generation.[73] Such time lags are common also for relatively 'mature' technologies, such as the steam engine in the early nineteenth century: the wide application of the steam engine took about 100 years.[74] A great number of such instances can be found, and they seem to point to a general phenomenon.

There are several historical reasons for lengthy diffusion periods. One is that many technologies are in fact multi-technologies, and require the complex co-evolution of different technologies to develop. The evolution of the hand-held calculator required the co-evolution of light-emitting diodes for the displays. But it is also necessary for technologies either to change to fit existing social organizations, or to co-evolve with the social organizations that put them to work. For example, mobile phones were originally conceptualised as high-value tools for business use. It was only when they evolved in such a way that they fitted the specific needs of a large social group, namely teenagers and young people, that they really began to diffuse. These diffusion issues are likely to be particularly strong in the case of NBIC and converging technologies. It follows that it is important to identify where diffusion obstacles might lie. Without some conscious hard work on this, we might say that it would be very unusual if widespread applications of e.g. nanotechnology occurred within the next fifty or so years.

[72] See J.L. Bromberg, **The Laser in America 1950-1970,** Cambridge, MA: MIT, 1991.

[73] See K.Bruland and D. Mowery, "Innovation through Time", in Jan Fagerberg, David Mowerey and Richard Nelson (eds.), **The Oxford Handbook of Innovation**, Oxford: Oxford University Press, (forthcoming 2004).

[74] G.N. von Tunzelmann**, Steam Power and British Industrialization to 1860,** Oxford: Clarendon Press, 1978.

Focussing of innovation

One important result of historical work on innovation is that the process of technological change is not general but focussed, and that this is one of the primary explanatory problems which technological advance presents. Against this background the history of technological change is in fact one of advance in quite specific directions, often concentrated not just on particular sectors of the economy, but on particular processes within sectors subject to change. In a word, there appear to be priorities.

If the explanation of technological change should be understood in terms of explaining the direction of technological change then we should seek to explain why technological advance has specific trajectories. This is in large part a matter of looking at the social and technical problems which the innovator seeks to solve. Nathan Rosenberg has proposed three such "problem areas". They are:
technological complementarities, in which imbalances between technical processes induce correcting innovations;
supply disruptions of various kinds, leading to innovations to provide substitute products and processes; and
labour conflict, in which strikes or plant-level struggles generate "a search for labour-saving machines"[75]

In related work Rosenberg has pointed out that the development of a technology often depends on the co-evolution of forms of knowledge, or on convergence between areas. So the development of computing was sharply limited by its dependence on valve technology, and depended on a convergence between computing knowledges and solid state physics.

One area of innovation dynamics, of especial relevance to nanotechnology at the present time, is the drive towards miniaturization. This is certainly a “focussing mechanism” for innovation, driven largely by the fact that smaller technologies seem to be capable of handling greater technological complexity.
So the evolution of greater complexity in technologies prompts a drive towards miniaturisation; analysis of where this focussing mechanism might lead us in the future would be an important contributor to understanding the trajectory for nano- and converging technologies.

Creation versus use of technologies

An important issue for modern technologies is whether or not the real benefits of a technology derive from its creation or its intelligent application. One of the key points to emerge from studies of the historical diffusion of innovation is that smaller countries in particular do not necessarily need to be technology creators to become rich countries. What seems to be necessary is creative adaptation – the ability to deploy advanced technologies as tools for upgrading industries that may be quite mature or traditional in character.

This is certainly an important part of the development history of the Nordic area, but it also applies to many other countries (such as Canada, Benelux, Australia) that have played little

[75] N. Rosenberg, "The direction of technological change: inducement mechanisms and focussing devices", in **Perspectives on Technology**, (London, 1977), pp.110, 117, 121.

part in the main technological revolutions, but have succeeded in deploying the technologies that resulted from them.[76]

There is really an important question about modern technologies related to this point. In some cases, such as ICT, it appears that countries can follow an “import and adapt” policy for the use of the technology, and can grow on the basis of being an intelligent user of technology supplied from outside.[77] But does this apply to technologies such as biotechnology and nanotechnology? Are these technologies cases in which benefits can be appropriated by using the technology without mastering its underlying core? Historical studies may throw light on such questions.

Social factors in the shaping of the history of technology

A key element of recent history of technology has been its attention to social factors. In understanding the role of social factors in the history of technological change, there is a range of explanatory problems, at different levels. There is, for example, a quite abstract level at which the general propensity of an economic system to such change is explored. Then there are questions about why particular sectors of the economy exhibit a propensity to technical change: here one would have to consider questions of how technological opportunity emerges, of industrial structure, of the development of markets and patterns and levels of demand, of the structure and capacity of producer goods industries, of state economic policy, and so on. Finally, there are questions about why specific technologies develop, and what factors shape their diffusion. All of these levels have been researched, in one way or another, from a social perspective.

But it is probably the last issue which has formed the most important focus of recent research, and in which social factors have been to the forefront in the analysis of how technologies originate and diffuse. As a recent study covering aircraft, fluorescent lights, steel, atomic energy, and electricity production and distribution claimed:

Technologies do not, we suggest, evolve under the impetus of some necessary inner technological or scientific logic. They are not possessed of an inherent momentum. If they evolve or change, it is because they have been pressed into that shape …Technology does not spring, ab initio, from some disinterested fount of innovation. Rather it is born of the social, the economic, and the technical relations that are already in place. A product of the existing structure of opportunities and constraints, it extends, shapes or reproduces that structure in ways that are more or less unpredictable.[78]

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[76] See eg K.Bruland and O.Wicken, “Modern Norway”, entry in Joel Mokyr (ed.), **The Oxford Encyclopedia of Economic History**, New York: Oxford University Press, 2003.

[77] An illuminating study is Alice Amsden, The Rise of “the Rest”. Challenges to the West from Late-Industrializing Econoomies, Oxford, 2002.

[78] W. Bijker and J. Law, ‘General Introduction’ in W. Bijker and J. Law (eds), **Shaping Technology/Building Society. Studies in Sociotechnical Change** (Cambridge, Mass. And London: MIT Press) 1992, pp.5, 11.

The more traditional, and still to some extent dominant, view is that technology is something that might have profound social effects, but which has developed and spread on the basis of rather autonomous processes of artisan development or, in the modern era, scientific and engineering advance. This kind of determinism has however in recent years been supplanted by approaches that seek to set technical or engineering processes against the background of the social environments in which they are generated and put to work. From this perspective, technology immediately begins to look more complicated, and we can begin to see ways in which the social environment shapes technological evolution, as much as being shaped by it.

Causes versus impacts

One central issue arising from the history of technology is that historians are much better at talking about the impacts of a new technology than about causal factors. This is partly because, as the "social shaping" approach to technology suggests, the causal factors are very complex. But this ought to be a central field of research for the potential future technologies such as NBIC.

History of science-technology interaction

Within contemporary innovation studies, it is common to assume that innovation has been increasingly scientized over time, and that innovation is increasingly based on scientific advance. It is sometimes hard to distinguish these ideas from these of the so-called 'linear model of innovation' with its sequential and discovery-based approach to innovations. But historical studies often uncover more complex interactions.[79] Certainly in early industrialization it was often the case that scientific advance tended to follow from attempted solutions to industrial problems. The case of thermo-dynamics, and its derivation from a consideration of the steam engine is well known. Another case is chlorine: there is little evidence that the discovery of chlorine and the techniques for using it in bleaching owed anything to chemical theory.[80] A more spectacular case, perhaps, was Pasteur's discovery of micro-organisms as a result of work on spoilage of wine, under contract to the wine-grower's association of Bordeaux. This phenomenon is not something confined to the past - there are more recent examples of ways in which technological problems generate scientific research programmes. In general science-technology interactions exhibit the complexity referred to above, and many frontier science areas (especially in the life sciences) are characterised by very close links to technological applications. NBIC are hardly exceptions to these interactive processes, so this also is a field in which a historical synthesis might illuminate current problems.

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[79] J.Mokyr, The Gifts of Athena. Historical origins of the knowledge economy, Princeton and Oxford, 2000.

[80] R.Fox and A.Guagnini, **Laboratories, workshops, and sites. Concepts and practices of research in industrial Europe, 1800-1914**, Berkeley, 1999, p. 21.

Resistance to new technologies[81]

Resistance to new technology appears to be a constant feature in the history of technology. Three broad points can be made about it. These are, firstly, that resistance to new technologies (particularly technologies of external origin) can come from many sources, and should not be seen - as it has been in much of the historical literature - primarily in terms of a form of ‘Luddite’ labour resistance to innovation. The perception of negative effects is not something confined to workers; on the contrary, there are many potential points of resistance to innovation in business, public administration and politics. In the case of Scandinavia, resistance from all of these quarters played a role in the technological evolution of that region.

Secondly, when resistance is seen in this broad way, it can really only be understood in terms of the interaction between the technology and its social context. It is not simply a matter of specific workplace interests being threatened by new technologies, but a much wider process concerning the ways in which technologies accord or clash with social organisations, cultural values, and so on. Thirdly, resistance is by no means irrational. While resistance is invariably based on particular social concerns and interests, it can also be seen as a component of the more general processes by which society selects among technological options. Taken together these points raise questions as to what we understand by the term 'resistance' in the face of technological innovation; this issue is discussed in a final section.

How should we understand the nature of 'resistance'? An important point is that, from one perspective, resistance is simply part of the selection process through which new technologies are adopted or rejected. Modern market economies tend to generate many technological opportunities, but relatively few are diffused into widespread application; resistance can be seen as simply one of the ways (failure in the market is another) in which technologies fail to achieve acceptance. Recent theories of technological change tend to follow an evolutionary perspective, in which the dynamics of technological change are based on some process which generates variety and diversity among technologies, and some mechanism which selects among the new varieties.[82]

It is important to note that in the evolutionary perspective the selection mechanism is not simply the market: it involves the whole complex of non-market decision processes, and there are many ways in which technology can be accepted or rejected by relevant actors. These non-market decision processes may involve, for example, public or semi-public procurement decisions, or political decisions to regulate, control or promote a technology. When there is continuous generation of technological variety, selection among alternative lines of technical advance is always necessary, and this selection process can easily be pictured as 'resistance'; but we should not see this as resistance to technological advance as such. The necessity of selection is integral to the technological change process as a whole.

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[81] Based on K.Bruland, “Patterns of Resistance to New Technologies in Scandinavia: An Historical Perspective”, in M.Bauer (ed.), **Resistance to New Technology**, Cambridge, 1995.

[82] See Richard Nelson, **Understanding Technological Change as an Evolutionary Process** (Amsterdam: Elsevier), 1987 for a succinct overview of the evolutionary approach. See also J.Mokyr, “The Political Economy of Technological Change: Resistance and Innovation in Economic History”, in M.Berg and K.Bruland (eds.), **Technological Revolutions in Europe. Historical Perspectives**, Cheltenham, UK; Northampton, MA, USA: Edward Elgar, 1998.

Many modern technologies, in particular biotechnology, genetic modification and nanotechnology, are already encountering some resistance in Europe, and a deeper understanding of the character of this resistance is necessary if these technologies are to become genuinely useful in our society.

Conclusion and further research

Despite the fact that simple or unambiguous lessons can rarely be drawn from historical studies, it remains the case that much can be learnt. The development of technology is fundamentally an evolutionary process, in which the new emerges from the old, and a grasp of the old is often central to understanding the potential of the new. In terms of future research, three areas stand out:

Science technology interactions, and there links to the applicability of the technology
Factors affecting diffusion paths of a knowledge field or technology
The role of social resistance in shaping technology trajectories (a process that has been of considerable importance in the life sciences, and has already proved significant in nanotechnology)

Conclusions from "Innovation Through Time"[83], K. Bruland, D. Mowery

Introduction

History rarely presents neat lessons for generalization, and the historical study of innovation is no exception. The primary lessons from our historical discussion concern the heterogeneity of the innovation process across time, across sectors and across countries. Much of the surviving historical evidence that guides the historical study of innovation tends to highlight the formal and obscures the informal processes of knowledge accumulation, learning, and dissemination that underpin technological change and that contribute to its economic benefits. An important area for further research is the enrichment of our historical understanding of the informal processes for knowledge accumulation and diffusion that have been neglected in historical research on the "First Industrial Revolution" in particular. In addition, as we pointed out in our introductory discussion, a key historiographical mystery remains—why was northwest Europe the locus of the first transition to sustained, innovation-led growth, rather than Asia or some other region of the global economy? Much of the discussion of this age-old question relies heavily on sweeping generalizations, and more research on the (asserted) failure of non-European economies to make the transition to sustained economic growth during this early period is needed.

One of the defining characteristics of innovation through time is change in the structure of the innovation systems that influence the development and dissemination of knowledge and innovations. The "innovation system" characteristic of the First Industrial Revolution relied on a craft-oriented, trial-and-error process, in which familiarity with basic woodworking and metalworking techniques was valuable. Inasmuch as demand factors appear to have influenced the upsurge of innovation on a broad front during this period, the institutional changes that laid the groundwork for growth in incomes and the expansion of markets for consumer goods also were important.

By contrast, the scale and organizational complexity of the innovation system that characterizes the Second Industrial Revolution are vastly greater. A new system of innovation emerged, pioneered by German and U.S. firms in the electrical-equipment and chemicals industries, characterized by organized innovation activities in large firms interacting with a public R&D infrastructure. The innovation process during this period was institutionalized within large enterprises of unprecedented scale, and the Second Industrial Revolution in the United States relied heavily on the creation of a national market of great size and homogeneity.

[83] See K.Bruland and D. Mowery, "Innovation through Time", in Jan Fagerberg, David Mowerey and Richard Nelson (eds.), **The Oxford Handbook of Innovation**, Oxford: Oxford University Press, (forthcoming 2004).

The Third Industrial Revolution defies summary description, but its characteristic innovation system relied on the state to an even greater extent than the Second Industrial Revolution. The role of the state as R&D funder and (in many cases) "first customer" for the high-technology industries that develop during the Cold War also contributed to another novel feature of the innovation system of the Third Industrial Revolution that is highlighted in Pavitt's chapter in this volume—increased collaboration and interaction among different institutions. State actions also contributed to the spread of innovation-led development to Asia, as the military alliances and economic institutions of the post-1945 period supported the expanded international trade and capital flows that were indispensable to "catch-up." In addition, Asian governments' strategies for technology transfer and industrial development were of great importance (see Fagerberg and Godinho in this volume).

Recent historical research stresses the wide distribution of innovation within the industrializing economies of the First Industrial Revolution, in many cases involving sectors overlooked by the previous historical research that has emphasized the "key sectors" of steam and textiles. This characterization of the process of technological innovation has not been sufficiently integrated into conceptual and theoretical work in innovation studies. The integration of recent historical evidence with the broader conceptual frameworks employed in the field of innovation studies represents an important task for future research. More research also is needed on the factors underpinning innovation in sectors other than the "leading industries" of the First Industrial Revolution. Although the patent data indicate that consumer goods were an important focus for such innovation, the factors triggering this upsurge remain poorly understood. Similarly, the development of organized innovation during the Second Industrial Revolution outside of the electrical equipment and chemicals industries has received far too little attention.

Institutional change in areas ranging from managerial hierarchies and enterprise control to the training of scientists and engineers are of central importance to innovative performance and to change in the structure of innovation systems over time. In many cases, these institutional changes have occurred in response to pressure from innovators and entrepreneurs, and are best characterized as "co-evolving" with change in industries and technologies (See Engerman and Sokoloff, 2003, for a useful discussion of this point). The transformation of the German and U.S. university systems, as well as the much more limited restructuring of British universities, is but one example of this co-evolution; the development of intellectual property rights systems is another. But the conditions under which such political pressure arises, as well as the factors contributing to the success of failure of such pressure, remain poorly understood.

Although it now is widely celebrated as a hallmark of 21st-century "knowledge-based economies," science-based innovation is in fact a relatively recent development. Indeed, it appears well after the institutionalization of R&D within industry in the early 20th century in the United States and Germany. Moreover, even "high-technology" sectors such as biotechnology and semiconductors continue to rely on experimental methods that at their heart are "trial and error" approaches (see Pisano, 1997; Hatch and Mowery, 1998).

Our approach has been limited both in time and geographical coverage. Perhaps the two most important omissions from this account are the spread of industrialization beyond Germany within 19th-century Europe, and a full account of the rise of the Asian economies after 1945 (see Fagerberg and Godinho in this volume for a fuller account of the process of economic "catch-up" in Asia). In the first of these cases it is important to remember that the smaller European economies, now among the wealthiest in the world, have benefited from the import and adaptation of technology during the 19th century, and that Ireland since 1970 has enjoyed rapid growth from similar sources. The post-1945 growth of Japan and Korea was originally based on altogether different scales and types of innovative industrialization - adaptation of foreign technologies, largely in such mature industries as automobiles, steel, and shipbuilding (see also the chapter by Fagerberg and Godinho in this volume). But both of these episodes highlight the importance of broad institutional change, rather than the "strategic importance" of any single industry or technology, similarly to the three "Industrial Revolutions" described in this chapter.

Personalities and NBIC, D. Polsek

The issue here is the potential role of personalities in chanelling public discussion on converging technologies. I shall try to assess merits/costs of engaging public personae in promoting or otherwise influencing development of NBIC.[84]

Two mistaken views on the role of personalities in public disputes are widespread in the public. First, that persons can do very little in shaping social views on singular public issues. According to this view everyone expresses his/her own particular view, and the outcome of the public dispute is resolved by the public vote, by the principle "single voter – single vote", whereas a resolution is viewed as a sum of all participating parts. Second mistaken view is a alleged factual statment that personalities in fact do contribute very little for various reasons, either because their interest is not at stake, or rather because of the perception of their minimal role. One further common misunderstanding concerning these issues is the view that personalities have to make a public statement in order to be involved in a public discussion. There is a number of cases, when personalities have simply published a book or an article, which has later become the object of a public discussion. Additionally, there is a plethora of statements published by actors who have become "personalities" only after their topic has become the issue in a public discussion.

In spite of the fact that a large number of public discussions are not affected by the influence of "strong" personalities, it is neverheless the fact that quite a number of them are. It is precisely such cases which we should be interested in, as well as the cases when "common" actors have become public "personalities" only after their participation or assessment thereof in public discussions.

It is an interesting fact that in a number of cases a public issue is "in search of its character, a name", meaning that the issue is easily remembered when someone takes the stand, which accordingly bears his/her name. Take for example notorious cases of a Marxist view, a Hayekian laissez-faire, a Rawlsian "distributive justice", a Freudian "psychoanalysis", Kuhnian "paradigm" and many more. Even less common names and views in particular sciences have the same function. Such accreditation is so common in academic practice, that scolarly discussions could barely do without them.

Further, according to sociologists of science, a very peculiar norm is shared in science; it is called "The Matthew effect" ("The one who has, to him shall be given"), bearing the name "Mertonian" upon Robert Merton, which focuses on the fact that scientific research is focused around the work great personalities. This gives such personae more credibility, authority, and money for research, and since the rewards in science are not immediate, it evolves as a means of rewarding their previous merit (when their actual benefit to society might have already been over).

[84] By "personae" or "public persons" or "strong personalities" I shall refer to all actors in a public dispute that for some reason are percieved as having more authority than others. "Public discussion" is defined as a discussion which has been broadly transmitted and talked about in the media.

Personalities typically do have a justified authority to scrutinize public discussions which influence crucial decisions. The role of the Nobel Laureate John Watson in launching and conducting Human Genome Project was immense. He was a zealot of sorts, and conducted public discussions in order to shape opinion in favour of that grandiose research. But so too was his opponent, French Anderson, with a dubious moral, but a grand scientific charisma on the side of private enterpreneurship. In physics, the cases of Einstein, Bohr and Heisenberg (especially in their role of public figures in catalysing decisions on whether to build atomic bomb) are notorious. In either case, (Einstein and Bohr for building it, Heisenberg allegedly against it), they were prominent, or almost exclusive experts to listen to. Other technologies also have their "Matthews". In informatic technology today, it is Bill Gates, who was allegedly a bigger role model for contemporary youth than the former American president. In nano-technology it is undoubtedly Karl Drexler, who has early on announced a number of technological forecasts. Cognitive science may have not invented its own guru so far, but they have quite a number of them instead, called Pinker, Dennett, Damasio and the likes.

But there are also other kinds of cases, where authority may not have been justified, where it was shown that credibility of a person was misplaced, where it was being created along with the controversy, or when the authority was established because of misplaced charges against personalities. Einstein famously remarked that "God does not play dice" against quantum mechanics, Kelvin doubted the evolutionary theory, Popper doubted the scientific character of evolution... Russell once said that all scientific autorities are likely to make a gross error at some time or the other. So, personalities, even with enormous scientific credentials may not be absolved from making mistakes.

Other kinds of cases involve broader public disputes with more or less scientific import. Take for example the s.c. "Wars in Science" which have been waged since 1996, and broadcast on major TV stations, after physicist Alan Sokal published his "hoax" in a respectful social science journal, aiming to show the ignorance of the reviewers and the well known social scientists in the editorial board of the journal.

Sokal may not have been influential in physics, but his name has served since, as a shorthand description for all subsequent debunking of "imposters" in social science. "Scandals" like Sokal's are getting more common. Accreditation of Ig-Nobel prizes for instance serves similar purposes for fraudulent, funny or unneccessary science.

Consider the dispute on the alleged role of Napoleon Chagnon in infecting Yanomamo tribe in the Amazons. Chagnon might never have achieved his celebrity and popularity outside of the field of anthropology without the charge (of which he has been cleared).

Similar disputes abound. Take Lomborg's Skeptical Environmentalist, the charge against him for factoring the data, and the subsequent disputes about environmental issues, but also on a great number of ethical issues, on social and organizational issues and publication in science.

Arpad Pusztai research on GMO transmission (still seemingly unresolved) has also catalyzed some public discussions on GM food, GMO transmission, as well as on regulating publishing procedures, and on norms of scientific conduct. The scandal with Nancy Olivieri's removal from Children's Hospital at University of Toronto, after she published that Apotex drugs had harmful efects on patients, scrutinized the discussion about autonomy of science and about the influence of big farmaceutical companies (and their money) on various academic institutions. These cases show that there is no unique way to get public credibility. It presents instead a number of ways of achieving celebrity, and their social functions.

Another kind of cases concern scientific "prophets", individuals or in groups, and their work in forecast studies, which have focused on - until then – invisible, or publicly unnoticed social trends. Some have called such personae "genius forecasters". They include Club of Rome, Rattray Taylor's Conditions of Happiness and Biological Time-Bomb, John Nisbitt's Megatrends, or Alvin Toffler's The Third Way, Future Shock, or Power Shift. These authors had no particular scientific credibility apart from their forecasts. But their work still presented the powerful catalysis for discussion, which may have hugely influenced future trends in science and society.

Further examples of the influence of personae on public discussion are transmissions of legitimate expertise in their respective fields to the fields outside their expertise. Richard Dawkins' and Stephen Jay Goulds' expertise in evolutionary biology has been transmitted to the issues concerning the relation between science and religion. Philosopher Peter Sloterdijk's publications on genetic engineering have been very influential in Germany, and a number of serious discussions have followed after his rather benign laudations of GT. Jeremy Rifkin's publications on environment, genetic technology or his colleagues publications on organ donation and similar topics may have served the oposite purposes, to curtail scientific advances.

Public discussion among personalities may also be structured, say by a governmental body. For instance, philosopher Mary Warnock has been elected for her moderate character and other merits a president of the Committee of Inquiry into Human Fertilisation and Embryology. Her task and the task of her group was to provide UK Government with a definite set of policies concerning fertility issues connected to the new technologies. A more typical case involves setting of a more-or-less permanent commission to conduct a public discussion. In 2002 for instance G. Bush set the President's Council on Bioethics, which consists of a number of scientists and political activists. However, the role of personalities in such bodies is doubtful. In this particular American instance some dissenting scientists were replaced. But there is a number of other ways such a commission, or some personalities involved, might miss the public interest.

So far we have provided examples of scientific personae and their influence on the public discussions. But non-scientific personalities may also influence them, even in a more powerful way. An army of priests and bishops, primus-inter-pares, the Pope, have been influential in conducting public discussions mostly against "unnatural conduct" or "evil consequences" of contemporary scientific advances. These pronouncements have been very influential in several European societies, and by making certain procedures illegal, have in effect curtailed their scientific advances. For certain political or private reasons, many famous politicians have exerted their influence on behalf of this scientific view or another. Apart from religious leaders and politicians, similar role is sometimes exerted by artists. Since the influence of such personae on scientific issues can be even bigger than of the scientists themselves, their role should not be neglected. (I, for one, am not keen to give them this role, nor to be affected by their pronouncements. But that is not the reason for a descriptive neglect, nor for the practical neglect of the principles of public discussion.)

Let me summarize, by giving a list of proposals:

Descriptive ones:
According to the Mertonian "Matthew effect", authority and credibility is given to personalities in science according to their past merit. (This may also be a note of caution: they may not merit in the present.)
Authority and credibility of personalities may come from plethora of sources, and be accredited by a number of different social mechanisms.
Personalities and their authority may be justified by their credible work and expertise in certain scientific field.
But they may achieve their reputation by debunking fraudulent research, or by sustaining their integrity against charges.
In some societies and circumstances, their credibility may also stem from their "moderation" or moderateness, and not from their expression of extreme (and/or true) views.
In many cases a personality or a name is a simple shorthand ("simbolic") description for a larger process, a more or less extreme view, or for a body of research.
Many types of (non-scientific) personalities may exert influence in a public discussion. Their role in scientific debates is normally correlated with the general scientific illiteracy.

Normative ones: (which may answer the question: "What should be the role of personalities in NBIC?")

A policy of promoting a certain technological advance or an intended course of technological action should if possible involve scientific role-models: scientists with a great authority, credibility and moral integrity. Their advocacy should begin as soon as a certain technological trend becomes visible.
Such personality should be popular in scientific circles (for writing say an excellent popular science book), or popular in broader public, for expressing interesting views and news from the forefront of science.
(Popularity may not be the only criterion. Scientific authority is still not to be equated with popularity. Neither it is to be expected in technological sectors.)
In order to close the visible gap between the "vision" of the future, and the present, a personality which might channel discussion would do well to give down-to-earth examples of short-term merits of proposed technology. This should prevent labeling someone "a visionary" (with a connotation "laughable").
Several discussions on NBIC have recommended that social scientists had to be involved in the discussions and disputes from the early stages of technological development, but
the organizer of a discussion would do well to ensure that non-scientists or experts in other fields do have a sufficient expertise in the field discussed in order to make valid and valuable claims.
Several discussions on NBIC have emphasised the role of foresight in shaping of future developments. Since we may not know what scientific and technological advances will definitely take place in the future, a broader view ("Tofflerian") toward the future trends may generate more appropriate personalities to conduct public discussions.
While discussing views of influential but "dissenting" personalities, it is useful to draw broader economic consequences of curtailing future technological advances.

Engaging Developing Countries

Exploring the impact that converging technologies will have in developing countries was Jim Hurd, NanoScience Exchange, and Sarah McCue, UNDP. See: http://www.corante.com/brainwaves/archives/002104.html

The Global Technology Revolution – 2015

Life in 2015[85] will be revolutionized by the growing effect of multidisciplinary technology across all dimensions of life: social, economic, political, and personal. Biotechnology will enable us to identify, understand, manipulate, improve, and control living organisms (including ourselves). The revolution of information availability and utility will continue to profoundly affect the world in all these dimensions. Smart materials, agile manufacturing, and nanotechnology will change the way we produce devices while expanding their capabilities. These technologies may also be joined by "wild cards" in 2015 if barriers to their development are resolved.

See http://www.rand.org/publications/MR/MR1307/MR1307.sum.html

[85] The Global Technology Revolution, Bio/Nano/Materials Trends and Their Synergies with Information Technology by 2015 Philip S. Antón, Richard Silberglitt, and James Schneider.

Foresighting the New Technology Wave – Expert Group

State of the Art and related Papers

Appendices

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i For the new action plan of the European Commission in the area of higher education, see European Commission, 2003. It includes the expansion of the "European dimension of education" to other continents.

ii Guy Haug, Jette Kirsten (1999); Guy Haug, Christian Tauch (2001); Sybille Reichert, Christian Tauch (2003). All documents are available online: e.g., www.bologna-berlin.do or www.eua.uni-graz.at.

iii More about ENIC/NARIC at www.enic-naric.net

iv In parallel with this trend towards unification and mobility, other, and sometimes opposed trends have been noticed. One such trend is increasing enrolment quotas, i.e. increasing number of students enrolled in tertiary education in almost all countries. During the 1990s, the average number of students enrolled in Europe rose by more than 20%.

But there is an opposite trend of diminishing of state investment in higher education, or an increasing state pragmatism with respect to the institutions of higher education. This trend is visible not only in diminishing of budgets, but in the new imperatives the public imposes on academies. Instead of the traditional idea of the Humboldtian university, which stressed the education of the individual and the autonomy of knowledge, there is an increasing trend to adjust to public needs and taxpayers. In order to encourage such financial accountability, some governments have decided to reform universities, and to create new institutions, either as branches of international universities or by accrediting local, private universities. In order to squeeze the budget, some countries introduced fees that will shift the burden of the financing to the actual users.

At the end of 2003, the position of EU countries was still vague with respect to the negotiations within WTO, i.e., GATS, on the General Agreement on Trade in Services which would concern education.

In the context of the increasing need for accountability on the part of educational operations towards their sources of financing, i.e., the public, with the knowledge that on the world market competition is increasingly knowledge-based, and in order to address the problems of unemployment, there is an increasing need to put knowledge at the disposal of figures in the economy. This trend is manifested in a number of ways: attempts to abbreviate courses, ever-increasing stress on the technical capacities of students, and the emphasis on life-time education, and the need for the retraining of personnel that have already qualified. The inertia and rigidity of traditional institutions of higher education lead them to resist such governmental attempts. For these institutions, such new imperatives entail numerous technical difficulties: how can one recognise the value of others' qualifications: In which way can the values of individual courses or subjects be compared? How can a curriculum be abridged and pragmatised without impingement on the personnel structure?

All these trends indicate that there is a very dynamic reform process in higher education in Europe, and that in spite of all declarations, because of the opposed interests local level stakeholders, the outcome of these reforms is far from clear. In some countries there is resistance to the abridgement of first degree courses. In others, there is fear that the introduction of uniform quality criteria will threaten the national culture and language. For this reason, declarations of the EU give governments the means to start off reforms at the domestic level.