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1. *EXECUTIVE OVERVIEW*

1.1. Background, literature study and vision assessment

1.1.1. Background

When Belgium inaugurated its first rail connection in 1835, between Brussels and Mechelen, there were fears that the La Fleche locomotive would hiss and puff to such an extent that scared cows alongside the track would stop producing milk. That was not necessarily a laughing matter since dairy products were a big deal at the time. Fortunately, the cream kept flowing and the rail network quickly became an engine for Belgium's industrial growth.

Twenty years ago, Europeans' concerns over nuclear energy had largely been lulled to sleep when, at night, clouds of nuclear contamination suddenly started spreading from the Chernobyl plant in Ukraine, again raising fears of a technological doomsday.

Fear and loathing about new technologies are timeless. Yet the recent 20th anniversary of Chernobyl serves as a stark reminder that man has to tread carefully when dealing with technology. Little has changed over the years, also in the way that politicians handle new technology. They seek a middle ground between progress and protection. They don't always succeed but the more information they have, the better they can assess the possibilities and dangers ahead.

At the moment, the outlines of the next challenge are being drawn: converging technologies. Behind those seemingly innocuous words lies a realm of possibilities which can change everything, from the way we think to the way we live and the way we die – if death itself cannot be beaten. The technologies will be based on how the different sectors of the nano, bio, info and cogno sciences (NBIC in short) dovetail their applications through smart interaction, creating a true multitude of the sums of their parts.

A vision assessment (as annex 2 in this report) with four well known experts in different disciplines not only gave a creative and original vision to the subject, but also showed that it is meaningful to understand the dynamics of a debate in their individual field of research or technological activity.

Such is the promise that just about everyone involved talks about the 'changing of an age and not the age of changing,' to quote Josephine Green, Senior Director of Trends and Strategy at Philips Design. Together with the computer capacity rate, developments will gain a dizzying speed. All kinds of curves are produced, starting with the agrarian revolution, moving past the industrial one and, now, right up to the dawn of the NBIC technology convergence revolution. It will be spearheaded by such concepts as nanotechnology and cognitive sciences. And if the curve of the first two revolutions only showed a mild rise upward over centuries, the converging technologies will make the curve steeper over the next decades, if not mere years. All this is based on the assumption that computer capacity development continues, unchecked by political intervention. At a certain point, development will multiply so fast that, in theory, the curve will become almost vertical. It is an assumption that by the time we get to this point of 'singularity', it will be driven by machines with superhuman intelligence. Eventually, people like Ray Kurzweil say, man and machine will merge.

New applications will be rife as the development curve surges upward. In the United States, it is driven by defense and military needs and will produce smarter soldiers and better technology doing the work of more humans. In the medical field, aging will be slowed, disease curtailed and life extension will add years of, hopefully pleasurable, living for many millions. The technological drive behind the Human Genome project is a case in point. Some say immortality soon will be no longer a pipe dream. Through ambient intelligence social interaction will change, with the ability to create stronger bonds between citizens and a better democracy. Others say though that the technology will increase social surveillance, bringing visions of '*1984*' and '*Brave New World*' closer by.

So, just as much as a capacity to provide technological answers, the converging technologies also pose philosophical questions about the boundaries of humankind, nature and life. Or, as author Joel Garreau puts it, about technological heaven and hell.

On the one side are the true believers in the potential of technology to make individuals ever more perfect. Transhumanism is a political expression of that. Many believe in what is considered science fiction now. 'Ultimately we will merge with our technology', said Kurzweil. 'By the mid 2040s, the non-biological portion of our intelligence will be billions of times more capable than the biological portion.' It is the theory that mankind has to be enhanced. The individual of the 21st century is now only a primitive specimen compared to what it will be in the future through the application of technologies. Anyone opposing the drastic application of technology to improve and enhance people is denying them a human right, said James Hughes, Executive Director of the World Transhumanist Association. 'Senior citizens should be fundamentally offended by the notion that keeping them alive longer would be bad for society,' he said, adding there is no difference between enhancement and therapy.

On the other side are those that many Transhumanists would gladly describe as the nattering nabobs of negativism, techno-Luddites who never look at the bright side of life. Among the Hell screenwriters too, there is a belief that technology will develop quickly. But instead of driving toward improvement and enhancement it goes the other way, straight toward self-destruction. 'Our most powerful 21st century technologies – robotics, genetic engineering, and nanotech – are threatening to make humans an endangered species', wrote Bill Joy, a computer scientist. There are visions of becoming enslaved to machines, a world in which ordinary humans become subspecies to those that have merged with machines and technology, the Machina Sapiens. The world will be a place where all kind of nano-plagues run rampant.

Another way of assessing the issue is whether we should look at enhancing the individual or whether those new technologies should be used to benefit society as a whole. Very often it is seen as a trans-Atlantic rift, with the Americans seeking personal enhancement and Europeans preferring societal improvements. American-originated Transhumanism wants individuals to have full control over their mind and body, and fully use the new technologies, which, others say, make man more than human. The groundbreaking workshop of Roco and Bainbridge of the National Science Foundation is rightly called 'Converging technologies for improving human performance.' In Europe, there has been a deliberate attempt to step away from the individual approach, and look more at the overall quality of life, social cohesion and global sustainability which should be achieved through the application of technology. Instead of further deepening the wealth gap through an individual enhancement strategy, they seek an all-inclusive approach. The European Commission appointed an expert group, flush with social scientists, ethicists and philosophers, with Prof. Alfred Nordmann as rapporteur, to produce a totally different report based on a different approach: 'Converging Technologies - Shaping the future of European Societies.' Instead of the engineering 'of' the mind, they want engineering 'for' the mind.

While Garreau coined the Heaven and Hell scenarios, he also left a handy way out to prevent the issue from becoming a dialogue of the deaf. He called it Prevail – the only place many experts say European politics should venture. The scenario anticipates immediate and prolonged struggles, yet with victory at the end. It is as good as politics can hope for. The only downside is that it can lead to short-sightedness, or as one European politician once famously said ‘problems only need to be fixed once you face them’.

1.1.2. Synthesis of the vision assessment

The vision assessments include many possible strategies for European politicians, even a Transhumanist one. Hughes sees the political debates on the converging technologies cutting across all classical political lines of European politics. ‘When I plot the strategy for our organization it is daunting because there is no constituency that is not touched by and does not have a vested interest in that project,’ he said. In that sense, he called for caucuses to be set up across those party lines to push the issue in European politics. For him there is no other way than enhancement, if only because expanding globalism has become the economic mantra. If the emerging economies in Asia will embrace the converging technologies, soon Europe will have to follow. Recent rulings by the World trade Organization going against the European Union in the area of Genetically Modified Organisms seem to underscore his point. ‘If they want to be competitive in a way that keeps Europe alive in a global economy, they have to make full use of all the technologies,’ Hughes, an American, said. ‘They cannot just say 'we Europeans we change social things, we don't change people’. Still, European experts claim there is room for a unique European way to deal with the issue.

Green, the British-Italian director of Philips Design, says the EU needs to look for a project which embodies European sensibilities and said it could be found in the immediate global challenge of sustainability and energy. ‘It encompasses everything, driving the technologies in fundamental things like earth, wind. It drives social innovation, since we have to live differently. And underlying it is that we are redefining a quality of life.’ All too often now, she said, the development of new technologies has to fit within the immediate corporate framework of shareholder profit or government principles of GDP growth. Given time, though, technological breakthroughs in energy conservation, anti-pollution measures and sustainability will become profitable in themselves.

Thierry Gaudin, a Frenchman, has many of the same ideas when it comes to the issues where Europe should move. ‘The main imbalance we see now is between mankind and nature,’ the engineer and head of the Prospective 2100 assessment group said. ‘We know that our resources will be close to depletion in the coming decades. It will force us to change our relationship with nature.’ Here too, he is convinced that the latest developments can help. ‘The new technologies are also a mirror of what mankind is doing,’ he said. If technology has yet to produce clean drinking water for the whole world, it is because there has not been enough political drive. He sees a clear role for the EU and its legislature to change course. ‘Absolutely, they can do a lot. The state of public finances in the different member states is such that the EU plays an ever more important role in Research and Development,’ he said.

Baroness Susan Greenfield, a British neuroscientist, also thinks beyond the narrow scope of enhancement. ‘We should harness the technologies in ways that people can be creative and fulfilled. That is more a goal than just 'let's get these enhanced genes going'.’
The Director of the Royal Institute sees that the main issue for European politicians is to raise public awareness of the challenges ahead. Too often people are guided by fear only and politicians just by the next election results. Neither fosters better understanding of the problems facing mankind. ‘People are sleepwalking into these technologies,’ she said. ‘There is this strange alliance between media, science and politics. Politicians will pass legislation that will keep them in power. It is driven by what the public wants,’ she said, highlighting how important it was to increase public involvement.

1.1.3. *Synthesis of the literature study*

The analysis of the literature study (annex 1 of this report) shows at least three reasons why the emerging public debate on NBIC convergence is justified, timely and stimulating.

First of all, the first steps towards NBIC convergence have already been taken. NBIC convergence is taking place in the laboratories and research departments of the contributing convergent disciplines. Conferences are organised that address the cross-disciplinary issues, and research results are published in scientific journals that become increasingly cross-disciplinary. The seed of NBIC convergence has thus been planted in various new fields of research. In addition, policy makers have spotted NBIC convergence as a fruitful policy model to foster research and innovation. This will likely lead to even more efforts in stimulating NBIC convergence. Third, NBIC convergence is expected to lead to a new paradigm, which blurs and challenges the current distinction between living and non-living materials and systems. Such a prospect, whether to be expected in the near or very far away future, brings up delicate ethical and political issues that need to discussed in the public sphere. Even more so, if one assumes that today's research shapes tomorrow's technologies, and the political debate should be about the kind of society we want in the future.

As to the authors of the study, the 'Transhumanists' and 'BioLuddists' should, therefore, be praised for their early-warning function and attempts to put the issue on the public and political agenda. Their Heaven and Hell scenarios grab the attention of the media and policy makers and thus are effective in setting the agenda. Another benefit of these extreme future visions is that they expose the most sensitive issues in the debate and clarify the normative deep core issues at stake. This also explains the fact that the debate on NBIC convergence – although in principle very broad – centres currently on the most delicate issue: human enhancement on the one hand and technologies getting out of control and leading to huge societal catastrophes on the other. Last but not least, the debate between the 'Transhumanists' and 'BioLuddites' makes visible the outer contours of biopolitics, which because of NBIC convergence is expected to play a more and more prominent role within the political arena of the 21st century.

The fact that the Heaven and Hell scenarios form a provocative base for the current debate on NBIC convergence has two dangerous sides to it too. First of all, these two extreme scenarios start from the assumption of exponential development and radical change. The tone of the research efforts, however, is much more mundane than is reflected in many of the roadmaps and future vision documents that have been produced in the endless search for subsidies and new research markets. Moreover, it is largely unpredictable what the future will hold for NBIC convergence. Consequently, there exists a danger that the political debate be dominated by extreme futuristic visions that are speculative and do not reflect the current common day practices in ordinary research and development. In that case, society would miss the chance to see the development of NBIC technologies as an open-ended process, which requires learning, creativity and the involvement of scientists, engineers, policy makers, politicians and society. To prevent an emerging polarisation within the public debate to become locked in, there is a need for developing alternative political images of the future. Even more so, if we realise that NBIC convergence is expected to push biopolitics central stage. These alternative visions should address the normative issues put forward by the 'Transhumanists' and 'BioLuddites', but turn away from the notion of exponential development and technological determinism shared by these two groups. A *down-to-earth* attitude, like the one adopted by the European expert group, is recommended in combination with a serious and visionary effort to develop a consistent view on the many normative issues involved.

1.2. *Synthesis of the outcome of the workshop in the European Parliament*

Based on the literature study and vision assessment a workshop was held in the European Parliament in Brussels on June 27, 2006. Attendants to the workshop were Members of the European Parliament, invited experts and visitors.

1.2.1. Main conclusions of the workshop

In her closing statement, chairwoman of the workshop, MEP Dorette Corbey distilled many of the outstanding issues. When it came to 'Moore's Law' and its exponential curve, Corbey was able to assuage the worriers. In the end, converging technologies may 'not be as exponential as some might fear.' And she also concluded that most of the experts took distance from the vaunted 'Heaven and Hell' scenarios which may polarize the debate. 'The risk is that it is too simplistic if we focus too much on Heaven and Hell,' she said. 'Although such images may be helpful to create awareness, it is not a very fair way to describe the technologies.' They may even prove to be counterproductive as they may create unreasonable fears.

There were different viewpoints on who is leading or will steer the developments. Nevertheless, the meeting concluded there was a need for values and criteria. The scientists should do the first assessment and the stakeholders should stimulate the research community to do it. Because there is still little awareness about converging technologies despite their far-reaching potential, almost all agreed on a need for more public input. 'There is a general consensus to have more public say,' said Corbey. 'The most important thing is the link the parliament has with the public and the responsibility to enter into the public debate ... An arena is needed. Only in an arena you can have the different viewpoints more sharply and the many sides of the debate can learn from each other. The arena has to be organized.' Another issue is the funding of research and development in the area and whether the EU should revise its method of awarding such research programmes. It was a hot debating point among the experts.

1.2.2. Recommendations and further research questions for STOA

The different experts gave their individual recommendations, which may be found in this report.

In conclusion to the workshop, chairwoman Corbey said the converging technologies community was left with four key questions, which had to be assessed by STOA in the future:

1) Who is in the driving seat, determining the future of the developments in converging technologies?
2) Where are converging technologies headed and to what extent can they be contained?
3) What are the values of converging technologies and what is the impact on society?
4) How can we organize the debate arena? And in particular: how can the public get involved and how can mutual trust between society, scientists and technology developers be built

2. *INTRODUCTION AND BACKGROUND*

2.1. Background

At the dawn of the 21st century, some see the emergence of a phenomenon in science and technology: the convergence of at least four main technologies and scientific disciplines: nano– and biotechnology, information and communication technology and cognitive science (NBIC). Singly, each of them has a large potential to change society and mankind, but combined they represent a still more powerful source for even bigger change.
Can and will this convergence transform society and mankind? What are the opportunities and dangers? How should the scientific community, society and politics cope with these developments?

> *With converging technologies are meant the converging of nanotechnology, biotechnology, information and communication technology, cognitive and neuroscience, in general abbreviated as NBIC-technologies. With converging is meant the trend or expectations of synergy of developments in these different technologies reinforcing the development of these technologies and/or creating new applications domains by combining the different technologies.*
>
> *Until now there are two main reports describing the potential of NBIC-convergence: Converging Technologies for Improving Human Performance, Rocco & Bainbridge, NSF report, 2002 and Converging Technologies – Shaping the Future of European Societies, High Level Expert Group 'Foresighting the New Technology Wave', report to the European Commission, 2004*

Although they both urge to give adequate attention to the ethical and social aspects, the American and European reports on converging technologies each present a different view and lay different emphasis. The American report puts forward the (research and political) agenda for improving human performance. The main emphasis is on 'accelerating advancement of mental, physical and overall human performance', that is to say to increase human efficiency and productivity. By focusing (solely) on the goal of human performance the National Science Foundation (NSF) - Department of Commerce (DOC) report gives convergence an explicitly value-laden content. The central focus of the European Report is guided by the Lisbon strategy, i.e. the usage of converging technologies for creating competitive and social European knowledge societies.
On the EPTA 2005 conference (Flemish Parliament, Brussels), one of the central questions was whether the described difference in focus – on the one hand, the make-ability of man, with the emphasis on the individual, on the other hand, the make-ability of society, with the emphasis on the collective – is a small or fundamental one? One of the conclusions of the rapporteurs of this conference was that there indeed is a fundamental difference in societal vision but that this doesn't necessarily mean that these differences can't be reconciled. A possible solution for this reconciliation was offered by Prof. Jean Claude Burgelman who stated that for a sensible development and innovation policy on Converging Technologies (CT), one should start from defining the future needs. These needs can be defined on a personal level, the level of the micro-environment (f.i. housing) and the level of the macro-environment (society).
On the 18th of October, there was a STOA workshop at the European Parliament. At this workshop, officials of the European Commission announced that they needed more information to make a clear research agenda on converging technology for the coming decade (FP 7, JRC). This project aims at making an overview of the future needs and challenges in

European society, by taking into account the technological opportunities of converging technologies and related social, ethical and legal issues.

2.2. Project setup

The project 'Technology Assessment on Converging Technologies', commissioned by STOA and executed by the ETAG-group was intended to clarify some of the issues on converging. A workshop which took place at the European Parliament on June 27, 2006, brought together Members of the European Parliament (MEP's), policy staff, experts, TA-practitioners and other interested visitors to highlight and discuss some of the topics of NBIC-convergence and especially give some guidance as to the future research agenda in the European Union on the domain of NBIC-convergence. In preparation of this workshop, a document containing a literature study on the domain and an assessment of the vision of some four well known experts, was distributed to the MEP's and the experts invited to the workshop . These documents are included as annexes to the final report.

Besides drawing more attention to the subject, the goals set as outcome of the workshop were to gain more insight to the phenomenon and to give some policy guidance to the STOA Panel of the European Parliament.

3. *WORKSHOP*

3.1. Venue

The workshop was held in the European Parliament in Brussels, room A5-G2, on Tuesday June 27, 2006 from 14:00 till 18:00.

The title of the workshop was 'Converging Technologies in the 21st century: heaven, hell or down to earth?'

The workshop was open to the public, although pre-registration was necessary.

The agenda items for the workshop were:

1) Opening statement by the workshop Chair, Mrs. Dorette Corbey, MEP.
2) Presentations by the authors of the:
    a. Literature study (Mr. Rinie van Est);
    b. Vision assessment (Mr. Robby Berloznik)
3) Workshop debate between invited experts
4) Questions/answers (open session)
5) Closing statement by the chair

3.2. Scheme of the workshop debate between invited experts

The main corpus of the workshop was a debate between attendant MEP's and 13 invited experts of different scientific disciplines and from different nationalities in the EU. The short CV's of the invited experts are listed in annex 3 of this report.

The leading questions of the debate were:

1) Emergence of converging technologies:
    - Are converging technologies emerging and what is the time frame of developments in that field? Does technology develop exponentially?
    - What are the main driving forces behind converging technologies? Is it industry, society, science, technology and/or government? What was/is the role of the public research agenda in this?
2) Ethical and political issues of converging technologies:
    - What impact will CT have on human nature and is this a desirable future? Will it enhance human nature, will it change its principal characteristics, and will it support moral progress?
    - How to cope with the fact that different countries and groups may have fundamentally different opinions on this question?
3) What role can the EP play?
    - Is a public debate desirable?
    - Research agenda for converging technologies:
        - How should research in the European Union cope with convergent technologies?
        - What should the European Institutions do for this research?
        - What is the role of the European Parliament and national parliaments in this matter?
        - What are the long term and short term (Program Framework 7) possibilities?

3.3. *Overview of the workshop debates*

Rinie van Est travels the world, surfing the wave of scientific and technological innovation. As the official trendcatcher for the Dutch Rathenau Institute, it is his job to do so. One week, he is in Japan looking at robotic suits to help the handicapped live normal everyday lives and make computer game fanatics feel like they literally climb a mountain from their office chairs. He travels to scientific meetings in Berkeley, California, only to see experts from multinationals that already had sent their representatives half a globe away to Eindhoven, the Netherlands – all plotting the broadest of futurist visions for their companies. It made his assessment on the European political debate and public participation in the emerging field of converging technologies in the European Union all the more sobering.

'If you reflect on the current state of the debate – Do we have an arena? Do we have participation? No,' he said. Pointing to the meeting of invited experts, scientists, visionaries, politicians, civil servants and interested visitors who attended the workshop at the European Parliament, he added: 'This is all the participation we have in Europe.' He continued. 'Do we have information,' he asked, but again it was a rhetorical question. 'In fact, No,' not beyond a few fledgling programmes. 'Is that sufficient? In no way, because we don't have a clue what is happening.' Major companies like Philips and Intel, he said, 'they are getting prepared for this type of future. Why? Because they have a vision. And this is also lacking in this debate. The state of this debate is that we are lacking everything we need to have a proper debate. We have to face that issue.' And movement should come from many of the people assembled in the room of the legislature.

The chair of the meeting and member of European Parliament, Dorette Corbey, conceded too much was still left in the dark. 'Are we talking about real development, which takes, or will take place? Or is it just hype? And, if not, what are the challenges for our society and for Europe in particular', she asked.

Whatever the outcome of those questions, Corbey already saw a way ahead. 'We may be situated in the first and early stage of developments,' she said. 'Even so, this should not prevent us from looking at the issue, for being prepared.'

Van Est insisted political action was urgently needed. 'It is important that policy makers and politicians take their responsibility and get involved in the discussion of Nano, Bio, Info and Cogno science convergence,' Van Est said. 'Actually, now.'

The warning was not wasted on MEP Corbey. In her closing statements, she heeded his call. 'There is a general consensus to have more public say in this. Some might doubt there is the possibility,' she said. 'The most important thing is the link the parliament has with the public debate and the responsibility to enter into the public debate.'

Members of the public also called for more political input. A Swedish visitor insisted politicians should carry a lot of weight since they can be held accountable for their decisions. Wolfgang Bibel pointed out that politicians should be forewarned about the future possibilities. Once they materialize, it might be too late to act, he said. 'It is very important, particularly in parliament, to be prepared for what could happen,' he said, and he pointed to global warming as a prime challenge. Society still had to find the best way to deal with such adversity. 'The question is what kind of mechanisms society will have to make rational choices between alternatives so that society is not moving toward a climate disaster, for example,' he said. 'We must establish mechanisms to do this and this is the reason why we are here.'

On the scientific side too, there was a willingness to break open this closed world and push transparency to promote democratic decision-making, said Robby Berloznik. In his vision assessment of the field, he found that certain themes kept coming back. ‘Everybody pleaded for the building of bridges, looking for new ways of communication on this topic. They also wanted to broaden and deepen the debate,’ he said, offering steps how technology assessment should evolve. ‘You involve stakeholders – traditionally experts – but you can also involve the broad public. There are very robust techniques to do that.’

Domenico Coviello however, argued for the scientists to have a seminal influence in that debate. ‘First, we need a very good discussion among scientists. But then bring the discussion to the public. Because the public needs to understand and needs to have time. And then after the sciences and the public, then the politicians,’ he said. Anja Boisen said the task was to bring scientists from the diverse fields together. ‘It will be a real challenge because we do not understand each other,’ she said. Boisen didn't want to put the scientists too much in the driving seat of the societal debate. ‘Scientists alone would be too biased. We are too much in love with our own research area,’ she said.

Hugo De Man wanted to expand the reference group to be more socially inclusive. ‘We don't do enough to make convergence happen in a correct way,’ he told the meeting. ‘If we are evolving to a society-driven technology, then we have to involve the sociologists and anthropologists.’ He mentioned that a multinational like Intel had hired 100 anthropologists to understand what people really want from future technology. And if it is of interest to companies, it surely must be of interest to the rest of society too.

At the moment, all agreed that politics was playing far too much catch-up, raising the question who was driving the technological project now.

‘There are two driver's seats. The first driver seat is short term: that is industry looking for new applications to make money,’ said De Man. ‘And this is not bad because that is creating wealth, it is creating the funds to create a second driver seat for coping with the singularity of the 21st century,’ including likely energy and water crises and the overarching challenge of sustainability.

Philosopher Jean Paul Van Bendegem looked beyond the pleasures and responsibility of driving. ‘The problem is not so much who is in the driver seat but who owns the fuel,’ he said, adding that from what he heard in the room, mostly ‘the wrong people.’ It did not make the job of parliamentarians easier. ‘As politicians, we are very often in the driver seat with no fuel,’ he said.

When it came to timing, reports of the imminent and unstoppable spread of converging technologies seemed to have been somewhat exaggerated. ‘Singularity,’ the ever exponential development of technology resulting in a vertical growth curve, was said to eventually produce a society where man merges with machine. Not in the foreseeable future, by a long way, many said.

Nick Bostrom, a leading Transhumanist thinker, said that man might not be able to follow the development of computers. Even if microprocessors would be able to continue their exponential growth, society would not necessarily be able to deal with more technological changes than it did over the last century. Bibel also did not believe in the inescapable force of linear exponential growth. ‘Many things do not behave in an exponential way. For example, this parliament,’ he said.

De Man joined the chorus. ‘I want to challenge exponential growth. There is nothing in the world that is exponential forever. It is quite clear there are limitations. In the next 10, 20 years, we will be reaching the physical limits,' he said. 'Everything which is exponential, sooner or later hits boundaries.'

'At the end, by definition, an exponential curve will reach a limit at some stage,' said MEP Malcolm Harbour. The challenge may well be in the way we use technology – the human application. For example, technological capability may become so cheap, that the whole concept of application changes, he said. 'For example, we are now in most areas unconstrained by the cost of data storage so the way we use data has fundamentally changed. Similarly, we are moving toward a stage where broadband capacity and communication capacity will become so large that people don't run up against the constraints of it and therefore you use it in a different way. That is the area of focus – in some cases technology is freeing you from these constraints and makes life actually simpler. It may develop new challenges.'

Donald Bruce said that technological advances might not even be the most important part of the development. 'What actually happens in practice – it will be much more difficult to implement the societal change.' Helge Ritter underscored the point arguing society had to be ready when the change would come. 'The important thing might be to be prepared when we enter the new domain of no-longer-exponential growth. Then everything is different ... We always see growth on the positive side. We enhance our capabilities but also we enhance the complexity of our world and this may weaken our abilities to make predictions. We should compare our increasing capabilities due to exponential growth with our shrinking capabilities of dealing with a more complex world and this may be a big challenge.'

Together with Van Est, Corbey agreed, however, that the powerful vision of such unbridled growth was a useful symbol to focus attention. 'The image of exponential growth is important to involve politicians and public debate,' she said. Coviello warned however that people should not have unrealistic expectations. 'We have to clarify to people what will be real progress and what we hope will happen. Otherwise people will have a bad feeling when it doesn't happen.' George Robillard underscored a similar point, arguing that looking too far ahead distracted from the immediate needs. 'It is wrong to talk about life of 150 years. It is a false problem. We have to talk about the short steps, the small steps, because these are the things we are dealing with.'

Harbour put the difference between the small practical steps and the giant stride for mankind in an ethical perspective. 'Brainpower and resources are not unlimited,' he said, highlighting how difficult it already was to tackle such blight as AIDS in Africa. He asked a hypothetical question: 'Are we entitled as politicians to say we should be directing more of our scarce resources toward dealing with these issues because actually in relative terms we could prolong more lives more effectively at a fraction of the cost than in, say, developing some artificial intelligence that might prolong our lives another 10 years.'

Helge Ritter made the point that limitations in themselves should be seen as an acceptable part of life. 'We are accustomed that limitations are something bad, something we have to fight. However, it may well be that we have to make peace with limitations as something that inherently contributes to our human nature. We may need to readjust our attitude to science,' he said, mentioning areas where human knowledge had long been faced with crucial gaps. 'It may make us a little bit more modest and it will help not exhausting all possibilities with technologies,' which may rob us of some of the joys in life. 'Downloading a language may deprive us of the experience of learning a language,' he said.

In contrast, and underscoring the vibrant debate, Berloznik said his vision assessment had indicated that visions still had to be ambitious. 'There is no Man on the Moon project here in our innovation policy in Europe. There is in the United States.' And as a result, the Americans might soon build an insurmountable lead. 'Development in the United States is going very fast, and if we are not careful we will, in five years from now, buy from the new

Intels and Microsofts the developed technology,' said De Man. He and several others said the EU needed to change its funding approach to be more effective. De Man said the United States predominantly relied on university programmes, with all having to include a public outreach commitment. He complained he found far too little on converging technologies in the latest EU Framework Program. 'So I am pretty worried about Europe.'

Bibel and Bostrom denounced the heavy bureaucracy surrounding the EU funding programmes. 'You are scared just to apply for it,' said Bostrom. 'And if you get the money, then you have your hands full meeting all the reporting requirements and the constraints. You got to try to put together a team and have a person from southern Europe, and one from the new member states and middle Europe and Germany. You put together all of this, and then you fill all the reports .... Sometimes some good work can be done but there is this major overhead cost that deters a lot of people from even bothering.' Bibel agreed. He referred to the United States, where there is a more direct and efficient link between money and worthy recipients. 'They give them money and they say here, for two, three years you have a chance and do something. And they mostly do a lot of good things without any bureaucracy and so forth. I believe no Einstein would ever enter a Framework Program and get something out of it. So we must, in complement, not in substitute, encourage individual ingenuity and new ideas.'

Member of the European Parliament Umberto Guidoni agreed, up to a point. 'One weakness is that it is more geared to application rather than knowledge,' he said. 'We are trying through the European Research Council to build a tool that can be used actually to focus on excellence of research rather than a mechanism to get financing.' He insisted more needed to be done to build stronger links between the NBIC sciences. 'We have this line of research: ten areas of research and somehow whatever is in between is difficult to be accepted.'

3.4. Main conclusions of the workshop

In her closing statement, chairwoman of the workshop, MEP Dorette Corbey distilled many of the outstanding issues. When it came to 'Moore's Law' and its exponential curve, Corbey was able to assuage the worriers. In the end, converging technologies may 'not be as exponential as some might fear.' And she also concluded that most of the experts took distance from the vaunted 'Heaven and Hell' scenarios which may polarize the debate. 'The risk is that it is too simplistic if we focus too much on Heaven and Hell,' she said. 'Although such images may be helpful to create awareness, it is not a very fair way to describe the technologies.' They may even prove to be counterproductive as they may create unreasonable fears.

There were different viewpoints on who is leading or will steer the developments. Nevertheless, the meeting concluded there was a need for values and criteria. The scientists should do the first assessment and the stakeholders should stimulate the research community to do it. Because there is still little awareness about converging technologies despite their far-reaching potential, almost all agreed on a need for more public input. 'There is a general consensus to have more public say,' said Corbey. 'The most important thing is the link the parliament has with the public and the responsibility to enter into the public debate ... An arena is needed. Only in an arena you can have the different viewpoints more sharply and the many sides of the debate can learn from each other. The arena has to be organized.' Another issue is the funding of research and development in the area and whether the EU should revise its method of awarding funds from such research programmes. It was a hot debating point among the experts.

3.5. Workshop recommendations for STOA

3.5.1. Recommendations of the experts

Herewith is some of the advice the experts and policy-makers provided for developing the sector of converging technologies in the European Union.

HUGO DE MAN

- How can we in Europe agree on values and make sure that converging technologies will work with these values?
- Create outreach programmes to stimulate public debate.
- Develop programmes for universities to promote converging technologies interdisciplinarity.
- Involve philosophers in technological issues.

WOLFGANG BIBEL

- Which specific technologies can help solve the main problems of society?
- Promote bottom-up scientific advice in addition to the top down funding mechanisms.
- Contain the bureaucracy of the EU framework programmes.

NICK BOSTROM

- Reduce the bureaucracy of the EU framework programmes.

UMBERTO GUIDONI (MEP)

- Improve the interdisciplinary approach of the framework programmes.

CRISTOPHER COENEN

- Use the European parliament as a new forum for debate, facilitating contact between scientists and the public.

ANJA BOISEN

- How do we ensure true converging?
- Create forums to bring scientists from the diverse converging technology fields together.

ROBBY BERLOZNIK

- Unshackle the technology assessment community from previous constraints and increase their impact.
- Increase the involvement of the general public.

DONALD BRUCE

- What are the important values to consider? Are we addressing lifestyle or change of society?
- Increase outreach toward the public and increase the general awareness of the technologies.

GEORGE ROBILLARD

- Center on step-by-step, incremental progress in the area instead of emphasizing unrealistic future visions.
- Improve outreach and communication.

RINIE VAN EST

- Improve the quality and quantity of information.

VITTORIO PRODI (MEP)

- Improve the interaction between technologies and cultures.

HELGE RITTER

- Do not treat converging technologies only as a technological problem.
- Bring in the expertise of the human sciences.
- How can we avoid continual patches?

JAN STAMAN

- Articulate the problems and … the public.
- Governments should not handle the issue alone, bring in NGO's (as interface).

JEAN PAUL VAN BENDEGEM

- Do not amplify existing inequalities of society.

DOMENICO COVIELLO

- Ensure to protect human nature and not to harm human nature.

TORSTEN FLEISCHER

- Look at the drivers of the research agenda.

3.5.2. Further research questions for STOA

In conclusion, chairwoman Corbey said the converging technologies community was left with four key questions, which had to be assessed by STOA in the future:

1) Who is in the driving seat, determining the future of the developments in converging technologies?
2) Where are converging technologies headed and to what extent can it be contained?
3) What are the values of converging technologies and what is the impact on society?
4) How can we organize the debate arena? And in particular: how can the public get involved and how can mutual trust between society, scientists and technology developers be built?

LIST OF ANNEXES

Annex 1: Literature study

Annex 2: Vision assessment

Annex 3: Short CV's of the experts invited to the workshop

Annex 4: List of attendants of the workshop

ANNEX 1:
LITERATURE STUDY

WELCOME TO THE 21ST CENTURY: HEAVEN, HELL OR DOWN TO EARTH?

A historical, public debate and technological perspective on the convergence of nanotechnology, biotechnology, information technology and the cognitive sciences

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1. *INTRODUCTION*

According to many experts, think-tanks and reports we are on the verge of a new renaissance within science and technology (e.g. Antón et al. 2001, Roco & Bainbridge 2002 (a)). For decades we have been used to powerful terms such as information revolution and biotechnological revolution. However at the start of this new millennium two revolutionary key technologies came into view: nanotechnology and the cognitive sciences. Nanotechnology is seen as *the* technology of the 21st century and radical breakthroughs are also expected from the cognitive sciences. There is also a growing realisation that these four key technologies are enabling each other in the journey of human progress. For example, ICT is facilitating rapid progress in the area of genomics research; insights into the functioning of the brain are inspiring computer scientists; nanotechnology is leading to faster chips and more powerful computers, etcetera.

The coming together of areas in science and technology is named technological convergence. This means that progress within a scientific discipline, but also a technological or industrial sector, is increasingly related to developments in other disciplines and/or sectors. In this study we focus on the convergence of nanotechnology, biotechnology, information technology and the cognitive sciences. This is referred to as NBIC convergence. The mutual enhancing effect of these four key technologies is seen as the driving force behind a new technological wave.

The term NBIC convergence was first coined during the workshop *Converging technologies for improving human performances*, which was organised by the National Science Foundation (NSF) in 2001. The workshop presented a very optimistic view about the potential of NBIC convergence, and pointed at a whole range of future technological options. The NSF workshop, in particular, focused on technologies for engineering the body and mind. Among these are life extension technologies, like targeted cancer therapies and artificial organs, and technologies to augment mental functions, like pharmaceuticals to control emotions and neuroimplants to compensate for memory losses, improve our cognitive capacities or enhance our sensory organs.

This envisioned future set of technical options forces upon us the question of how to use these options and where to set limits. Consequently, the perspective of human enhancement has initiated a worldwide debate about basic questions concerning human nature. Are we heading for a post-human future in which our bodies and minds will merge with computer power? Should we actively strive for such a future, or actively oppose it? If so, what does this mean for public innovation policies? How does the wider public think and feel about these issues and how to involve citizens into this fundamental discussion? What role should policy makers and politicians play in this discussion?

Contents

This exploratory study is not meant to give all the answers to the above questions. Its goal is to provide an accessible and well-informed basis for starting the discussion on the social impact of NBIC convergence. In particular, we want to inform policy makers and politicians about how the public and political debate on NBIC convergence is developing and what role they can play in this upcoming discussion. To address this central question, this study first provides three perspectives on NBIC convergence: a historical and a technological perspective, complemented with an overview of the public debate that has risen in the past few years.

Chapter 2 looks at NBIC convergence from a historical perspective. Currently, the term technological convergence is often used in the debate on the information society, and refers to digital convergence of communication networks, media content and devices. NBIC convergence can be seen as a new phase within the ongoing information revolution.

In Chapter 3 we describe the current international public debate about NBIC convergence and discern within this debate different (political) visions of the future social consequences of NBIC convergence.

Chapter 4 gives an impression of the current technological state of affairs. It details the areas in which NBIC convergence is already occurring, the applications concerned and the expectations associated with these. It describes which applications are being developed on the boundaries between ICT and cognitive sciences, ICT and biotechnology, ICT and nanotechnology, and biotechnology and nanotechnology. This chapter largely draws on a study (Van Lieshout et al. 2006) TNO has performed for the Institute of Prospective Technology Studies, situated in Spain (Seville).

In the concluding Chapter 5 we summarise our findings to see what they imply for the emerging public and political debate on NBIC convergence and the role policy makers and politicians may play in this discussion.

Acknowledgements
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2. A HISTORICAL PERSPECTIVE ON NBIC CONVERGENCE

> *Historically the first fifty years after the completion of the Zuse3 computer technologically were dominated by the use of computers as numerical calculating and storage machines. In the eighties the computational paradigm has then started to pervade also the communication and media technology. The result of this novel process may be regarded as the first stage of convergent technology. The computational paradigm has now continued to pervade further areas, foremost biotechnology and engineering, and is on the verge of entering nano- and cognotechnology and thus resulting in the convergent technology termed NBICtechnology. Bibel (2004: 22)*

This chapter places NIBC convergence and its accompanying public debate in a historical perspective. NIBC convergence fits in the information revolution, and is the most modern manifestation of this. Section 1 describes how the term converging technologies was used during the 1980s and 1990s to pinpoint how information technology continues to penetrate the industrial and services sectors. Section 2 describes the rise of a new form of convergence, the way in which information technology and biotechnology influence and strengthen each other. The realisation and hope that nanotechnology will enable the convergence of ICT, biotechnology, and the cognitive sciences has led to the notion of NBIC convergence. The framing of NBIC convergence as a way to improve human performance has led to numerous social debates. Section 3 puts this social debate into a historical perspective.

2.1. IT convergence

In the information technology (IT) sector, the term ‘convergence’ was used more and more during the 1980s. Information technology is responsible for a wave of breakthroughs in many areas, such as novel materials, energy and transport technologies, medical applications, and production technologies (e.g. mechatronics). The combination of optics and electronics led to optical electronics which laid the foundation for the present communication systems based on glass fibre cables. The arrival of Internet is accelerating the convergence of information processing and communication. The abbreviation ICT reflects this convergence, which is currently continuing at a rapid rate in the integration between Internet and mobile telephony. Therefore in his *The Rise of the Network Society* Castells (1996: 62) refers to convergence as an important characteristic of the information revolution:

> *[A] fifth characteristic of this technological revolution is the growing convergence of specific technologies into a highly integrated system within which old, separate technological trajectories become literally indistinguishable.*

The penetration of information technology into a wide range of scientific disciplines and industrial processes, or stronger still in every aspect of society, characterises the information revolution; termed the Third Wave by Alvin Toffler (1980).

Technology fusion

The importance of convergence for the innovative capacity of industry was stressed by the Japanese professor Fumio Kodama (1992). At the start of the 1990s he argued that the old maxim ‘one technology – one industry’ no longer applies. To be truly innovative, companies need to do more than simply focus their R&D on their own core technology. That is because real breakthroughs often take place on the boundaries between sectors. Therefore according to Kodama, the trick is to combine different technologies. He terms this *technology fusion*. According to Kodama, Japanese companies devoted an increasing amount of attention during the 1980s to developments, which initially appeared to fall outside of their own core activities. Searching for technological fusion or convergence has therefore become part of the normal R&D strategy, in which joint research projects with other companies from different sectors are becoming increasingly more commonplace. As previously stated information technology is an important, but certainly not the only, source of convergence. An example is a textile manufacturer who applies his knowledge about artificial fibres to making construction materials or filters for kidney dialysis machines.

2.2. NBIC convergence

Today digital convergence is a reality. Think only of voice over IP, Web TV, on-line music, and looking at movies on your mobile phone. Already in the mid-1990s the convergence of information and communication technology, and the effect of this on a range of sectors was generally recognised. At that moment Castells added a new and less commonly accepted insight to the notion of convergence. Inspired by the book *Out of control: The rise of the neobiological civilization* by Kelly (1995), he saw that information technology and biology were converging, both in terms of applications and materials as well as the conceptual approach.

> *Technological convergence increasingly extends to growing interdependence between the biological and microelectronics revolutions, both materially and methodologically.* (Castells 1996: 63)

This development is best illustrated by the Human Genome project, which was fully underway at that time. The mapping of the human genome is strongly dependent on computer power. Conversely, the logic of biology is an increasingly stronger source of inspiration for computer scientists and the ICT industry, for example neural networks, DNA computers, swarm intelligence and learning robots.

The commercial sector is also capitalising on the possibilities provided by the fusion of electronics and biotechnology. The Japanese company Kaken Geneqs is an early example of this (Yasuda 2005). In the 1970s the company was still making toothbrushes but in the 1980s, with the help of robotic techniques, it developed into a manufacturer of lightweight precision plastic objects. In the second half of the 1990s the fusion of mechatronics and biotechnology became its trademark. Kaken Geneqs became specialised in the production of DNA chips and sold its first micro-array in 2000. At present molecular medicine, in particular imaging, is the area where fusion between the electronics and biotechnology sectors is commonly taking place. The companies involved anticipate breakthroughs in the area of molecular diagnostics and treatment (e.g. *personalised medicine*) (see Box 1).

> ***Box 1.*** *Molecular medicine and the fusion of electronics and biotech giants.*
> *Medical imaging has always been an area where electronic giants such as General Electric (GE), Siemens and Philips have been the major market players. This includes technologies such as radiology and MRI, in which physics and IT play a central role. The expected emergence of molecular medicine does however shift the focus from the physical to the biomedical disciplines. Progress in genomics research has led to the discovery of biomarkers for various pathological processes. These markers have a unique 'biological signature' and can, for example via MRI and ultrasound, be imaged with the aid of certain contrast fluids. They accordingly provide the basis for the development of molecular imaging. If they are to play a role in this development, it is strategically important that companies like GE, Siemens and Philips acquire biomedical knowledge. On the one hand this happens via experts. Hans Hofstraat, director of Molecular Medicine at Philips Research, explains it as follows: 'The time when only 'hard' physical scientists worked here has passed. Nowadays there is a broad range of scientists from chemical engineers to cell biologists.' (Van Opstal 2005). On the other hand biotechnology is acquired by making strategic contacts with contrast fluid manufacturers. In April 2004 General Electric Medical Systems took over the biotech company Amersham. In March 2005 Siemens acquired CTI Molecular Imaging. Philips Medical Systems subsequently entered into an alliance with the German company Schering (Van Weert 2005).*

Era of Transitions

Various research institutes are also aware of the convergence of biotechnology and ICT and the application possibilities which then enter into view. In addition to this nanotechnology is also making its debut. At the end of the millennium RAND's National Defence Research Institute carried out the foresight study *The Global Revolution* (Antón *et al.* 2001). This was done on behalf of the National Intelligence Councils within the framework of the *Global Trends* project, a study published in December 2000. The term convergent technologies is not used in the RAND report. The subtitle *Bio/Nano/Material trends and their synergies with information technologies by 2015*, however, clearly indicates that America, including NASA,
has woken up to convergence. Round about this time, the NASA Ames research centre introduced the triangle biology, nanotechnology and information technology to its mission. The interaction between these areas will lead to a fantastic new innovation wave, which in conjunction with the ICT revolution will ensure an 'Era of Transitions' (cf. Gingrich 2001). RAND foresees a broad, multidisciplinary, and global technology revolution (Antón *et al.* 2001).

The NBIC tetrahedron

> *The phrase 'convergent technologies' refers to the synergistic combination of four major 'NBIC' (nano-bio-info-cogno) provinces of science 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; (d) cognitive science, including cognitive neuroscience. Roco and Bainbridge (2002 (a): ix)*

The designers of the *National Nanotechnology Initiative* (NNI), Roco and Bainbridge of the National Science Foundation (NSF), were inspired by these optimistic signals and in the spring of 2001 they took the initiative to organise a workshop. This led in December 2001 to the workshop *Converging technologies for improving human performance*. Roco and Bainbridge introduced the term NBIC convergence there; the intended integration of nanotechnology, biotechnology, information technology and the cognitive sciences. The NBI triangle of NASA was therefore expanded to the so-called NBIC tetrahedron. This recognises the rapid emergence of the cognitive sciences and also includes artificial intelligence.

The NSF workshop has transferred the ideas about NBIC convergence which existed in the closed world of military research and space research into the public and public science domains. According to the NSF breakthroughs in the areas of ICT and nanotechnology will make large-scale developments in the area of biotechnology and the cognitive sciences possible. This will lead to a technological development which is increasingly focusing on the control of animal and human bodies. It is therefore hardly surprising that the NSF report has led to an international discussion in small circles about the desirability of improving physical and mental performances in humans. The debate about the social and ethical implications of NBIC convergence fits into a long tradition.

2.3. The debate on manipulation of human nature

> *We are at an inflection point in time. For all previous millennia, our technologies have been aimed outward, to control our environment. ... Now, however, we have started a wholesale process of aiming technologies inward. Joel Garreau (2004: 6)*

Not all NIBC technologies encroach on the body and mind. However those that do, give rise to important ethical issues that go beyond questions about health risks, environmental effects or social implications. The subtitle of Garreau's book *Radical Evolution* (2004) indicates the essence of the political-ethical discussion about converging technologies, namely: *The promise and peril of enhancing our minds, our bodies – and what it means to be human.* What it means to be human and how to ensure that our technological culture remains human is not a new question though. In particular developments within biotechnology, such as genetic modification, stem cell research, the cloning of animals and IVF techniques, have frequently led to controversies concerning economic opportunities, quality of life, cultural threats, privacy and bioethical questions.

Merelman (2000) even states that self manipulation or the manipulation of human nature is typical for our present so-called 'postmodern' technological culture, which can be described as the information age. (Toffler (1980) talks about the Third Wave – the Information Age – which is following up on the Second and Third Wave – the Industrial and Agricultural Age. Merelman argues that while modern industrial technologies are aimed at controlling 'nature', postmodern information technologies are aimed at controlling human nature. (also see above quote by Garreau.) Technologies that play a central role in the information age are genetics, neurology, pharmacology, medical technology and ICT. These focus on our memory and personality, human reproduction and physical achievements; in other words the fundamentals of life and human consciousness.

If we follow Merelman's analysis then NBIC convergence with the objective of improving human performance can scarcely be described as a peripheral phenomenon. On the contrary, NBIC convergence and the explicit relation manipulation of human nature is typical for our present-day information age. It fits in a cultural and technological development which has already been underway for decades. NBIC convergence, therefore, presents the next phase in the ongoing information revolution. Correspondingly, the co-evolving political and ethical also enters a new phase, in which the current debate is broadened in various ways. As stated above, it is expected that due to the interrelatedness of nanotechnology, biotechnology, information technology and the cognitive sciences an accelerated development in each area will be possible. As Nordmann (2004) commented: 'If these various technologies created controversies and anxiety each on their own, their convergence poses a major challenge not only to the research community, but from the very beginning also to policy-makers and European societies.' Up to now the debate was dominated by biotechnology and interventions in micro-organisms, plants, animals, and the human body. Through NBIC convergence the number of ways to intervene in the human body will strongly increase, not only by means of biotechnology but more and more also by computer technology. Moreover, besides our bodies our minds will be the object of intervention. It is expected therefore that the applications and effects of NBIC convergence will continue to give rise to heated public discussions. This trend and vision of the future ensures that the question about the role and purpose of science and technology in our culture and society is once again being emphatically posed.

Many thinkers belief that the new NBIC technologies are already creating a new politics and even completely new political boundaries (Rifkin 1983, Garreau 2004, Fukuyama 2002). As James Hughes (2004: 55) argues in his book *Citizen Cyborg*:

> *The political terrain of the twenty-first century will add a new dimension – biopolitics. At one end of the biopolitical spectrum are the bioLuddites, defending humanity from enhancement technologies, and at the other the transhumanist, advocating for our right to become more than human.*

The next chapter shows the first contours of the upcoming public debate around NBIC convergence, which may represent a new dimension within the politics of the 21st century.

3. *A PUBLIC DEBATE PERSPECTIVE ON NBIC CONVERGENCE*

> *In public debate there emerge two views on the meaning of convergence. The first one, the neutral one, is that nanoscience – by its nature and heuristics – will deeply influence the other disciplines. ... In the second view convergence refers to a technological concept of human and nature. Convergence is explicitly given a (moral) value-loaded content. The concept implies that nanosciences and convergence (should) break through the boundaries of man, nature and technological artefacts.* Jan Staman (2004)

Various acronyms are currently in use – NBIC, GNR, BANG, GRIN – for the convergence between nanotechnology, biotechnology, information technology and the cognitive sciences. These acronyms often have an underlying meaning: they indicate whether those who coined them consider the convergence to be full of promises or dangers.

As detailed in Chapter 2, Roco and Bainbridge (2002 (a)) of the National Science Foundation (NSF) talk about 'converging technologies' and NBIC convergence. NBIC is roughly pronounced as 'New Big'. The NSF has positive expectations about this convergence. NSF's vision of the technological and social possibilities of NBIC can rightly be termed utopian. The following quotation from the NSF report *Converging technologies for improving human performance* illustrates the strong belief in the complementarity of different scientific disciplines and the technological developments that will be possible:

> *If the* Cognitive Scientists *can think of it*
> *the* Nano people *can build it*
> *the* Bio people *can implement it, and*
> *the* IT people *can monitor and control it.*

The ETC Group (2003) from Canada was one of the first international public organisations which called for public attention for the social impact of technological convergence. To make its concerns clear, the ETC Group used the term 'super-colliding technologies' and the acronym BANG (bits-atoms-neurons-genes). BANG also refers in a cynical manner to the *Big Bang*; the birth of the universe. According to the ETC Group, NBIC convergence could even lead to a *Little Bang*; the end of the world.

In his book *Radical Evolution* Joel Garreau (2004) discusses various visions with respect to GRIN technologies: genetics, robotics, information technology and nanotechnology. This was probably a deliberate choice as GRIN can have two different meanings in English: smiling or sneering. There are therefore clearly different views about the desirability of NBIC convergence. In this chapter we try to establish which social visions there are about NBIC convergence.

Contents

Chapter 2 described the emergence of the term NBIC convergence. Expectations concerning the rate of technological developments have played a central role in the discussion about this. Section 1 considers the claim of various scientists that NBIC technologies will develop exponentially and describes the mobilisation of a loose transhumanist coalition which embraces this technological progress to transcend human limitations. Section 2 starts with the pamphlet *Why the future doesn't need us* by Bill Joy from 2000. This essay is about the future dangers of robotics, gene technology and nanotechnology. Joy's pamphlet formed the starting point for the discussions in the United States about the social impacts of nanotechnology. Two years later Roco and Bainbridge (2002 (a)) introduced the concept of NBIC convergence as a utopian research challenge to improve the performance of humans. This is described in Section 3. This approach has a strongly normative 'transhumanistic' character and rapidly led to critical comments from various parties. Section 4 describes the reaction from the Canadian NGO, the ETC Group. Following on from Joy they sketch three doom scenarios. The European debate about converging technologies is considered in Section 5. In the final section the different (political) visions on NBIC convergence are summarised.

3.1. A future beyond humans

For more than forty years the computer industry has developed according to *Moore's law*, which states that if costs remain the same the calculating power of chips will double every eighteen months. Experts expect that this development will continue over the next ten years. The computing power which you can acquire for a given price has therefore been increasing exponentially for almost half a century. This means that the change over the next eighteen months will be about as big as all of the previous changes put together. Price-performance relationships can change by a factor of one million or even one billion over a number of decades.

The phenomenon of exponentially growing technologies applies to both hardware (*Moore's law*) as well as mass-use software (*Nathan Myhrvold law*) and is not only limited to the ICT industry. Mainly as a result of convergence, exponential growth can also be found in other branches of science and technology. Take, for example, genomics (bioinformatics). The rate for deciphering DNA doubles every 27 months if the costs remain the same. Another example is *lab-on-a-chip* technologies, which play or will play a role in the search for new medicines, chemical or catalytic processes, through to making food. The enormous increase in calculating power has also made other important technologies possible, such as (molecular) imaging and Scanning Tunnelling Microscopy (STM), which in turn are responsible for the blossoming of brain research and nanotechnology research.

The historical phenomenon of exponential growth over many decades, logically gives rise to the question as to whether this continuous acceleration of innovation will continue in the future and if so, for how long? The concept of convergence subsequently gives rise to the discussion as to whether exponential growth will become a characteristic of all sciences and technologies. Antón *et al.* (2001) emphasise that due to the socio-political questions, which in particular are associated with biotechnology, it is uncertain what the outcome of this development will be. This also makes it difficult to estimate the rate of technological development. Scientists such as Ray Kurzweil and Eric Drexler seem to have less interest for the social context and assume an ongoing exponential innovation as the basis for their thoughts about the future. This exponential future thinking gives rise to highly spectacular technological and social visions, transhumanism being the most-developed one.

Strong AI and Nano

> *Ultimately we will merge with our technology ... By the mid 2040s, the nonbiological portion of our intelligence will be billions of times more capable than the biological portion.* Ray Kurzweil (2005)

The most radical technological predictions can be found in the writings of Ray Kurzweil and Eric Drexler. Kurzweil is one of the intellectual leading lights of transhumanism. In his books *The age of spiritual machines* (1999) and *The singularity is near* (2005) he states that ICT will continue to develop at an exponential rate in the future. As a result of this, in 2020 PCs will have the same calculating power as human brains. Eventually computers will be developed with a superhuman intelligence. Such greater-than-human machine intelligence, which keeps on multiplying exponentially would make everything about our world unpredictable. That point in the future is denoted by the term *Singularity*. The belief in the possibility of making machines which can develop a consciousness comes from the world of Artificial Intelligence (AI). The radical forms of this are termed 'strong AI'. Whereas strong AI focuses on stimulating human ways of solving problems, weak AI only allows itself to be inspired by this.

Within strong AI thinking human and mechanical parts of human-machine systems are considered to be functionally identical. Marvin Minsky, one of the founding fathers of AI, saw the brain as nothing more than a 'meat machine'. During a first meeting of the AI community in Darthmouth College in 1956, he foresaw that as a result of AI research a complete symbiosis between humans and machines would be realised in the short term, and in the long-term intelligent machines would be the next step in evolution, a new species, *Machina sapiens*, which would eventually win the struggle against its maker (Noble 1997, chap. 10). Also the possibility of scanning the human brain and downloading this as 'software' in advanced computers is one of the aims in strong AI thinking. People such as Kurzweil believe that this will allow the human spirit to become immortal in the future. This opinion is not supported by recent neurological insights which emphasise the so-called plasticity of the brain; the 'hardware' (neurons) develops in conjunction with the 'software'.

In his book *Engines of Creation* (1986) Eric Drexler sketches the unprecedented possibilities of molecular nanotechnology. He predicts that within two generations (about 60 years) it will be possible to make a so-called *universal assembler*. In theory such a universal assembly machine (sometimes termed a replicator) can make everything (including itself) cheaply and in large quantities. Drexler envisages, for example, the emergence of cheap nanobots for medical purposes which can perform tasks such as destroying viruses and cancer cells and repairing damaged tissue. Drexler's ideas can be termed 'strong Nano' an analogous term to 'strong AI'. Drexler also considers possible dangers. The Foresight Institute he founded is the source of the Grey Goo-scenario, in which self-replicating robots escape into the environment and convert all material into a large grey, continually growing, blubber.

The emergence of transhumanism

Inspired by the above radical predictions, a loose transhumanist coalition has mobilised over the last two decades, which embraces dramatic technological progress to seek personal growth beyond our current biological limitations. It advocates 'the right for those who whish to use technology to extend their mental and physical capacities and improve their control over their own lives.' (Hughes 2004: 177). The improvement of people by the use of technology is seen as a logical next step in history. No fundamental difference is seen between the technological improvement of humans and the use of technology for improving, for example, agricultural or transport systems.

As a politico-philosophical movement transhumanism has its roots in Californian *libertarianism*, which in America has its origin in the classical liberalism from the second half of the 19th century. Faith in small entrepreneurs, technology and the minimum of government intervention are its characteristics. Besides libertarian transhumanism a more European style liberal democratic transhumanism has developed within the *World Transhumanist Association* (WTA). The WTA gives serious attention to the social challenges that are associated with their vision. The executive director of the association, James Hughes (2004), states for example that improving humans must go hand in hand with a radical strengthening of democracy: 'We can embrace the transhuman technologies while proposing democratic ways to manage them and reduce their risks. ... We need a democratic transhumanist movement fighting both for our right to control our bodies with technology, and for democratic control, regulation and equitable distribution of those technologies'. In 1998, Nick Bostrom and others within the WTA have set up the Transhumanist Declaration (see Box 2).

Box 2*. The Transhumanist Declaration (cf. Hughes 2004: 177)*
1. Humanity will be radically changed by technology in the future. We foresee the feasibility of redesigning the human condition, including such parameters as the inevitability of aging, limitations on human and artificial intellects, unchosen psychology, suffering, and our confinement to the planet earth.
2. Systematic research should be put into understanding these coming developments and their long-term consequences.
Transhumanists think that by being generally open and embracing of new technology we have a better chance of turning it to our advantage than if we try to ban or prohibit it.
4. Transhumanists advocate the moral right for those who so wish to use technology to extend their mental and physical capacities and to improve their control over their own lives. We seek personal growth beyond our current biological limitations.
5. In planning for the future, it is mandatory to take into account the prospect of dramatic technological progress. It would be tragic if the potential benefits failed to materialise because of ill-motivated technophobia and unnecessary prohibitions. On the other hand, it would also be tragic if intelligent life went extinct because of some disaster or war involving advanced technologies.
6. We need to create forums where people can rationally debate what needs to be done, and a social order where responsible decisions can be implemented.
7. Transhumanism advocates the well-being of all sentience (whether in artificial intellects, humans, non-human animals or possible extraterrestrial species) and encompass many principles of modern secular humanism. Transhumanism does not support any particular party, politician or political platform.

In recent years transhumanism has received both more support as well as criticism. In America the NSF report *Converging technologies for improving human performance* (Roco and Bainbridge 2002 (a)) seems to embrace the transhumanist ideology. In the United States transhumanism is also heavily criticised by (religious) conservatives, disability rights advocates and environmental activists, like Bill McKibben (2003). A well-known critic is Fukuyama (2004), who considers transhumanism to be the 'world's most dangerous idea' (cf. Miller and Wilsdon 2006 (a): 18-19). As a result of the coalition forming on both sides the debate about the improvement of humans has become more widespread and is no longer solely in the domain of the transhumanist movement. The theme is on the verge to be put on the mainstream political agenda in America and Europe. The following sections map this process of agenda setting in both continents in chronological order.

3.2. A future which does not need humans

At the close of the last millennium, Bill Joy, chief scientist of Sun Microsystems, came across the radical future images of Kurzweil and Drexler. Like the transhumanists, Joy takes their technological predictions very seriously and is concerned about the possible negative consequences of them. He sees himself as a whistle blower. In order to generate broad public attention for the dangers which he sees coming he wrote the essay *Why the future doesn't need us*. The pamphlet was published in the April 2000 edition of Wired, a few months after president Clinton had announced the *National Nanotechnology Initiative* (NNI) on 21 January 2000 during a speech at Caltech. The essay warns for the long-term dangers of gene technology, nanotechnology and robotics, which he refers to as GNR. The famous computer scientist wants to draw attention to the ultimate doom scenario, which he states in the first sentence of his article:

> *'Our most powerful 21st-century technologies – robotics, genetic engineering, and nanotech – are threatening to make humans an endangered species.'*

This dramatic message touched a sensitive chord in many people and within a few hours of the April 2000 edition of *Wired* being published, the editors were inundated with responses from around the world via e-mail, fax and telephone.

Evolutionary struggle between the maker and his creations

Joy warns for the 'living' character that these GNR technologies might acquire and is worried about an evolutionary struggle between these new artificial forms of life and 'natural' forms of life. He sketches a number of doom scenarios in which mankind has completely lost control over its creations and is eventually wiped out by them. He is anxious for a number of forms of destructive self-replication: robotics might produce robots with superhuman intelligence capable of making improved versions of themselves, genetics makes it possible to design viruses that can unleash a worldwide plague epidemic, and nanotechnology brings the so-called *Grey Goo* scenario to mind, in which nanobots, artificial plants or bacteria, can reproduce rapidly and cover entire regions of the world.

A common characteristic of GNR technologies of the 21st century is the ability to reproduce and multiply. According to Joy this makes the dangers associated with GNR technologies potentially more serious than those of the 'old' nuclear, biological and chemical technologies of the 20th century. The processes of self-reproduction and evolution were previously the domain of nature, but according to Joy they are now within the reach of human intervention. Whereas previously nuclear, biological and chemical weapons of mass destruction were developed in mainly military laboratories, the 'new' GNR technologies are being developed by the private sector due to the commercial opportunities that these clearly provide. Joy is very worried about the influence which the GNR technologies will have on human nature and humanity. He wants widespread public attention for the new dangers of GNR technologies and calls for a 'period of reflection'.

3.3. A future which improves humans

> *In the late fall of 1999, President Clinton decided to include the NNI as one of the key budget initiatives for FY 2001, making it the centrepiece of a much broader research initiative to address the growing imbalance in federal funding for biomedical research and the physical sciences and engineering.* Neal Lane & Thomas Kalil (2005)

Where Joy called for time to reflect, the developments seem instead to be accelerating. A letter sent from the White House to all federal agencies in autumn 2000, placed nanotechnology at the top of the list of emerging R&D areas in United States. In November 2000, Congress had already approved the *National Nanotechnology Initiative* (NNI). NNI encompasses materials, physical, chemical and biological research at a nanoscale and stimulates research focused on integrating these disciplines. According to Neal Lane (2004, 2005), former Chief Scientific Advisor to President Clinton and one of the central initiators behind the NNI, this programme serves to revitalise the technical natural sciences, and an important objective in this was to stimulate the strong growth of biomedical sciences in the long-term.

Converging technologies for improving human performance

Convergence thus formed an implicit starting point of the NNI, as nanoscience was seen as a condition for the development of biotechnology and ICT (cf. Roco 2002 (b): 71; Roco 2001).

It is not very surprising, therefore, that out of (the people of) the NNI grew the initiative to set up the NSF workshop *Converging technologies for improving human performance* in December 2001. The workshop was flavoured with radical techno-optimism. According to the participants of the NSF workshop, the twenty scenarios listed in Box 3 can become reality within 20 years – therefore before 2022. For example, fast broadband interfaces between human brains and machines and complete control of the genetics of humans, plants and animals are predicted. It will also be possible to make the human body healthier and more energetic and more resistant to diseases and ageing. In the longer term, 'world peace, universal prosperity, and evolution to a higher level of compassion and accomplishment' is predicted for the end of the 21st century. NBIC convergence will accordingly draw humanity closer together; it will lead to human convergence. This solidarity between people is seen by Roco and Bainbridge (2002 (a): 6) as typical for the next century:

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 enhancement to the productivity and independence of individuals, giving them greater opportunities to achieve personal goals.

Improving human performance through one science

The NSF workshop put two radical ideas forward: science for improving human performance and the unification of science. The first radical step made by the NSF workshop is the shift in the objective of scientific research from curing ill people to improving healthy people. It is expected that it will become technically possible to improve human performance via machine intelligence (e.g. brain implants) or modification of the human body. According to the NSF report technical improvement of mental, physical and social capacities provides an adequate means of solving the present social, political and economic conflicts. With this the transhumanistic thinking with respect to the improvement of humans via technological interventions seems to have gained a firm footing within the public research domain (cf. Van Est *et al*. 2004: 22-23).

The second radical idea within the NSF report is the prediction that NBIC convergence will lead to the unification of science, as a result of which the holistic spirit of the Renaissance will re-emerge. This unification is based upon a number of expectations. Via nanoscience it will be possible to understand how atoms combine into molecules and molecules into organic and inorganic structures. By controlling natural processes novel materials and biological products can be made, as well as machines with a size ranging from several nanometres to several metres. Via this knowledge the behaviour of the system at a micro-scale (e.g. neurons) and macro-scale (such as the growth of a body and a transport vehicle) can, if desired, be controlled. Another assumption is that developments in mathematics, informatics and other NBIC disciplines will make it possible to understand the natural world and cognitive processes in terms of complex, hierarchic systems. Finally it is expected that convergence will lead to new instruments, materials and analytical methods. This can be achieved with powerful support and will stimulate the unification of science.

Box 3 *Twenty scenarios for the next twenty years (Roco and Bainbridge 2002 (a): 4-5).*

1. Fast, broadband interfaces directly between the human brain and machines will transform work in factories, control automobiles, ensure military superiority, and enable new sports, art forms and modes of interaction between people.

2. Comfortable, wearable sensors and computers will enhance every person's awareness of his or her health condition, environment, chemical pollutants, potential hazards, and information of interest about local businesses, natural resources, and the like.

3. Robots and software agents will be far more useful for human beings, because they will operate on principles compatible with human goals, awareness, and personality.

4. People from all backgrounds and of all ranges of ability will learn valuable new knowledge and skills more reliably and quickly, whether in school, on the job, or at home.
5. Individuals and teams will be able to communicate and cooperate profitably across traditional barriers of culture, language, distance, and professional specialization, thus greatly increasing the effectiveness of groups, organizations, and multinational partnerships.
6. The human body will be more durable, healthy, energetic, easier to repair, and resistant to many kinds of stress, biological threats, and ageing processes.
7. Machines and structures of all kinds, from homes to aircrafts, will be constructed of materials that have exactly the desired properties, including the ability to adapt to changing situations, high energy efficiency, and environmental friendliness.
8. A combination of technologies and treatments will compensate for many physical and mental disabilities and will eradicate altogether some handicaps that have plagued the lives of millions of people.
9. National security will be greatly enhanced by lightweight, information-rich war fighting systems, capable uninhabited combat vehicles, adaptable smart materials, invulnerable data networks, superior intelligence-gathering systems, and effective measures against biological, chemical, radiological, and nuclear attacks.
10. Anywhere in the world, an individual will have instantaneous access to needed information, whether practical or scientific in nature, in a form tailored for most effective use by the particular individual.
11. Engineer, artists, architects, and designers will experience tremendously expanded creative abilities, both with a variety of new tools and through improved understanding of the wellsprings of human creativity.
12. The ability to control the genetics of humans, animals and agricultural plants will greatly benefit human welfare; widespread consensus about ethical, legal, and moral issues will be built in the progress.
13. The vast promise of outer space will finally be realized by means of efficient launch vehicles, robotic construction of extraterrestrial bases, and profitable exploitation of the resources of the Moon, Mars, or near-Earth approaching asteroids.
14. New organizational structures and management principles based on fast, reliable communication of needed information will vastly increase the effectiveness of administrators in business, education, and government.
15. Average persons, as well as policy makers, will have a vastly improved awareness of the cognitive, social, and biological forces operating their lives, enabling far better adjustment, creativity, and daily decision making.
16. Factories of tomorrow will be organized around converging technologies and increased human-machine capabilities as 'intelligent environments' that achieve the maximum benefits of both mass production and custom design.
17. Agriculture and the food industry will greatly increase yields and reduce spoilage through networks of cheap, smart sensors that constantly monitor the condition and needs of plants, animals, and farm products.
18. Transportation will be safe, cheap, and fast, due to ubiquitous real-time information systems, extremely high-efficiency vehicle designs, and the use of synthetic materials and machines fabricated from the nanoscale for optimum performance.
19. The work of scientists will be revolutionized by importing approaches pioneered in other sciences, for example, genetic research employing principles from natural language processing and cultural research employing principles from genetics.
20. Formal education will be transformed 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.

3.4. *The doom scenarios of the ETC Group*

NBIC convergence gives rise to major questions, for the sheer fact that it encompasses a large part – and according to expectations the most innovative part and therefore that part with the most effect on society – of scientific endeavour. Converging technologies therefore elicit a broad debate about the direction of science and the social visions which are embedded in this. This was also the case in the 1970s. At that time the criticism came in particular from the leftwing counterculture. One of the few international NGOs which has spoken out about the risks of converging technologies is the ETC Group, environmental activists from Canada.

Doom scenarios in three colours
The ETC Group was highly critical of the NSF report. In its report *The Big Down. From genomes to atoms. Atomtech: Technologies converging at the nanoscale* published in January 2003 it talks in threatening terms about 'Super-Colliding Technologies'. In addition to the *Grey Goo* scenario of Drexler the ETC group introduces two other doom scenarios. A Brave New World scenario (*Blue/Grey Goo* theory) in which intelligent machines gradually take control of complex human and natural systems. These machines assume control of the world or fall into the hands of an elite. The ETC Group states that nano-info-cogno will develop exponentially and forms a major threat for the democratic and critical opposing voices.

The ETC group seems however to be most concerned about the *Green Goo* scenario, in which use is made of living material to simulate machines. This already takes place on a large-scale in the area of microorganisms, but might also become possible with higher life forms. An example given is the military use of insects as flying objects.

Converging NGOs
The ETC Group (2003: 72) states that convergence challenges public organisations to cooperate.

> '*Nanoscale manipulation is the unifying force for converging technologies. Might it also provide a unifying platform from which civil society can understand and address converging technologies? The atomically-modified economy of the future offers common ground for advocates and activists in the field of biotech, toxics, public health, workers' rights, food security, sustainable agriculture, disability rights, sustainable agriculture, disability rights, alternative energy, anti-nuclear and opponents of chemical, biological and nuclear weapons, among others*.'

The ETC Group proposes the organisation of an International Convention for the Evaluation of New Technologies (ICENT), but also mechanisms to inform citizens at a local level and to allow them to have a say.

3.5. *The more down-to-earth Europe?*

At the dawn of the 21st century a discussion gradually arose among social scientists and groups of philosophers and ethicists in particular, about the influence of technology on (the future of) the human body and human nature. In Germany this debate received a strong impulse from Peter Sloterdijk's (1999) lecture *Regeln für den Menschenpark*. This lecture was explained in *Der Spiegel* as a call to 'deliberate genetic selection under the leadership of a cultural elite'. According to this magazine the left-wing intellectual thereby made a jump from humanist to superhumanist (or transhumanist) and from philanthropist to 'über' philanthropist (Boevink 1999). This interpretation of Sloterdijk's lecture led to an impassioned public philosophical debate in Europe about the significance of new technologies for human nature. No mention was yet made of converging technologies. However there was the strong realisation that the human body and mind are nevertheless influenced by all different sorts of technologies and that this development will continue in the future (see Box 4). The American NSF report *Converging technologies for improving human performance* strengthened that debate and also placed it on the (European) policy agenda. In the autumn of 2003 the Directorate-General Research of the European Commission appointed the expert group *Foresighting The New Technology Wave* to formulate a European answer to the American NSF story.

> ***Box 4.*** *European examples of the debate activities about improving humans.*
> *In various European countries the theme technological improvement of humans is gaining attention. In the UK Greenpeace together with the magazine New Scientist organised a debate in April and May 2002 about the impact of new technologies entitled Science, Technology and the Future: The Big Questions. The third debate Technology: taking the good without the bad? focused on the potential effects of new technologies, such as nanotechnology, artificial intelligence, robotics and biotechnology. What is the significance of this development? What are the dangers for us and the environment? Will we be aware that we are giving the power and control over our lives to our creations? The Akademie für Technikfolgenabschätzung from Stuttgart organised the congress 'Zur Zukunft des Menschen. Gentechnologie, Nanotechnologie, Künstliche Intelligenz', from 8-9 July 2002, which was linked to the public exhibition Erde 2.0. Inspired by this the Dutch Rathenau Institute together with the science museum NEMO organised the Technologiefestival Homo Sapiens 2.0 in November 2003 about the technical improvement of humans. The festival illustrated a diverse range of technologies which are trying to make humans 'more beautiful, more intelligent, stronger and healthier'. In 2006 the British think-tank DEMOS picked up this theme and published the collection of essays Better Humans?*
> *The politics of enhancement and life extension (Miller and Wilsdon 2006) in which the central question is whether improvement techniques will increase the collective welfare and the quality of life. Both proponents and critics are well represented in this collection.*

Converging technologies for European knowledge societies

In 2004 the high-level expert group (HLEG) came with its report *Converging Technologies – Shaping the future of European societies* (Nordmann 2004). While the NSF report was predominantly compiled by technical scientists, the European expert group *Foresighting the New Technology Wave* mainly consisted of social scientists, ethicists and philosophers. Therefore at times the approach of the European report significantly deviates from that of the NSF report.

Convergence at product level and between different disciplines (such as bioinformatics, mechatronics, bionics) was seen as an extremely important phenomenon. The concept of the unification of science was not embraced with respect to the development of science and science policy. However the vision that progress in one area has become dependent on developments in other areas was shared. The interdependence of scientific disciplines and technologies forces the policy maker to look at the entire picture, in other words over the separate disciplines, and to explicitly stimulate cooperation and cross-fertilisation. The expectations in the NSF report about the technical possibilities of convergence for the next 20 years were, however, assessed to be extremely ambitious, in other words unrealistic. In particular there was criticism of the technological deterministic approach of the NSF. The European report emphasised that technologies are formed in interaction with the social context. The European expert group on NBIC convergence employs the language of technological constructivism. The cover of the report not only displays Nano-Bio-Info-Cogno, but also Socio-Anthro-Philo-Geo-Eco-Urbo-Orbo-Macro-Micro-Nano.

The European HLEG also criticises the individualistic philosophy behind the American report that in particular wants to deploy convergence for increasing human efficiency and production. With this the Americans have devoted too little attention to the quality of life, social cohesion and major problems currently incurred by mankind, such as sustainability, maintaining peace and the shortage of clean drinking water. Bibel (2004) expresses this criticism succinctly:

> '*It* [the NSF report] *fails to envision the opportunities for all mankind but rather seems to have in mind the already richer and better-adapted segments of our society, including the young, urban, socially-privileged and mobile techno-freaks who both welcome innovation and have money to afford it. To some extent this reflects the philosophy of developing technologies in a world in which the pressure on humans to improve their performance in accordance with a set of standards is increasing by the day in the economic field (as homo economicus), in the social environment (e.g. by pretending eternal youth and beauty), or on the battle field*.'

Ducking the issue?

The European report does not explicitly propose one or more objectives. By proposing *Converging Technologies for the European Knowledge Society* (CTEKS) it tries to emphasise the agenda-setting process itself (Nordmann 2004: 8). However it does state the need to establish an agenda for converging technologies in Europe. This concerns achieving the Lisbon objective. This objective was formulated by the European Commission in March 2000 and means that Europe must become the most competitive and dynamic knowledge economy in the world, in which a sustainable economic growth leads to more and better jobs and a stronger social cohesion. In practice this approach means that convergence can be used for a range of objectives, such as reducing traffic jams, treatment of obesity, intelligent dwelling, natural language processing or improving education. Which technical and social sciences can make a contribution to solving the problem concerned, should be examined per objective from a convergence perspective. In this sense, convergence would very much seem to be a plea (albeit in a new form) for multidisciplinary or interdisciplinary research.

With its choice of words the European HLEG 'literally' distances itself from the American NSF vision of the technological improvements of humans. The European report continually emphasises that technology should be in the service of people. Whereas the American report talks about 'engineering *of* the mind' and 'enhancing the human body' the European report talks about 'engineering *for* the mind' and 'engineering for a healthy body'. It is interesting to observe that the nuanced European vision (in the form of coevolution of technology and the social system, broad objective, convergence as interdisciplinary research, technology for improving health) cleverly circumnavigates the thorny issue of improving humans.

3.6. Heaven, hell or down to earth?

In the previous sections a number of different (political) visions with respect to NBIC convergence in connection with the objective of human enhancement were described. In this final section we will reflect on the various positions and group them.

In *See-through Science* Wilsdon and Willis (2004: 33-34) distinguish three types of visions concerning the social implications and the potential to change of nanotechnology. The 'nanoradicals' view nanotechnology as disruptive for the economy and society, because technologically almost everything is possible. The 'nano-realists' emphasise that it concerns incremental innovations and economic benefits. Finally, the 'nano-sceptics' are concerned about the health risks of nanoparticles and question who controls the development of nanotechnology and who benefits from it. Such a three-way split is of course a simplification of the reality. Yet at the same time it also provides a good first impression of the different positions. Hardly surprisingly, visions about NBIC convergence can broadly speaking be classified in the same manner.

Joel Garreau (2005) does that in a constructive manner in his book *Radical Evolution*. He distinguishes three scenarios: Heaven, Hell and Prevail, in terms of the attitude towards the technology which are comparable to the terms ‘nano-radicals’, ‘nano-sceptics’ and ‘nanorealists’. We will first focus on the Heaven and Hell scenarios, because according to Garreau (2004: 175): ‘The Heaven and Hell Scenarios, and those attracted to them, may be the new political divide, the defining political conflict of the 21st century’. After that we will look for alternative positions within the debate.

True believers: Heaven versus Hell

The followers of the Heaven and Hell scenarios represent the ‘hard core’ proponents and opponents of NBIC convergence and the objective of improving human performance. Table 1 details the characteristics of these visions, which Hughes (2004) characterises as Transhumanism versus BioLuddism. Among the proponents of the Heaven scenario are scientists like Drexler, Kurzweil and Stock, and of course transhumanists. The future vision proclaimed in the NSF report *Converging technologies for improving human performance* also fits into the Heaven scenario. The doom scenarios of Bill Joy fit in the Hell scenario. Hughes (2004) distinguishes the opponents to transhumanism into left-wing and right-wing bioLuddites. The anti-corporate ETC Group that opposed to genetically modified food and environmentalist McKibben (2003) with his book *Enough* represent the left wing. On the other side the religious Right is strongly opposed to the transhumanist worldview.

Table 1. Two opposite (political) visions on NBIC convergence (based on Garreau 2004, Hughes 2004).

Scenario	**Heaven**	**Hell**
Development technology	Technology develops exponentially	
Determining factor	Technology determines history (technological determinism)	
Outcome technological development	Progress	Disasters and catastrophes
Development humankind	Human nature is ‘under construction’ Intelligent machines (Übermensch) win the evolutionary struggle with humans	Technology changes the principle characteristics of human nature Humans as a species are threatened by technology
People and parties	Eric Drexler (1986) Ray Kurzweil (1999) Gregory Stock (2002) Roco & Bainbridge (2002(a)) - NSF-workshop Transhumanists, such as James Hughes (2004) and Nick Bostrom (2006)	Bill Joy (2000) Francis Fukuyama (2002) Bill McKibben (2003) President´s Council on Bioethics (2003) Susan Greenfield (2003) ETC Group (2003) Martin Rees (2003)
Political ideology	**Transhumanism**	**BioLuddism**

Despite their opposite world views, the followers of the Heaven and Hell scenarios share many characteristics. Both start thinking that NBIC technologies will develop extremely quickly and will be responsible for radical changes. Both think exponentially either in terms of opportunities or risks. Both acknowledge that NBIC technologies will intervene in human nature and dare to pose the deep normative question as to what it means to be human in the information and biotech era. By sketching extreme future versions the political discussion about the present and future of our information society gains meaning and new demarcation lines for politics in the 21st century appear. On the one side of this new political dimension transhumanism sees itself as a progressive emancipation movement which fights for the right of people to improve themselves (via technology), and which tries to enthuse the present-day culture for their utopian vision. On the other side, the bioLuddites accept the cultural analysis of the transhumanists, but oppose the utopia that they sketch because they experience this as a dystopia.

Down to earth alternatives

The advantage of the Heaven and Hell visions is that they sharpen the discussion and clarify the normative deep core issues at stake. The danger, however, is that the public debate about NBIC convergence will become strongly polarised. Thus it is relevant to look for alternative visions to deal with issues of NBIC convergence in a more constructive manner. In his book *Radical Evolution* Garreau (2004) distinguishes a third scenario in this debate and calls it *Prevail* or *Muddling Through*. Prevail notes a victory in the end. It is thus a positive scenario. The struggle is won, however, only after a hard fight.

Table 2. The Prevail scenario (based on Garreau 2004).

Scenario	**Prevail or Muddling Through**
Development technology	Technology possibly develops exponentially
Determining factor	Human behaviour determines the direction of technological development (technological constructivism / coevolution technology and society)
Outcome development	Outcome co-evolution technology and society is principally uncertain
Development humankind	Belief in moral progress and growth of communication between people under the influence of technology
People and parties	Antón *et al.* (2001) RAND Alfred Nordmann (2004) - HLEG CTEKS Science Technology & Society (STS) community

The followers of the Prevail scenario have a strong tendency to discard the Heaven and Hell scenarios as fables. They prefer to soberly look to the 'factual' developments, in other words the current state of science and technology, than to speculate about exponential developments. Technology and society are thought to co-evolve. Although the outcome of this co-evolution is principally uncertain, there is ample room for humans interfering in this process. The European expert group *Foresighting the New Technology Wave* and many scientists fit into this scenario.

The strength of the incremental and constructive thinking is that it provides openings for creative views of the future which manoeuvre between Heaven and Hell. The focus on the here and now can, however, also lead to short-sightedness and the continual postponement of key questions. Continually removing this angle from the debate due to realism or anxiety for taboos is risky because it avoids the sensitive points of the debate.

4. A TECHNOLOGICAL PERSPECTIVE ON CONVERGING TECHNOLOGIES

The previous chapter described the contours of the public debate on NBIC convergence. In this chapter we examine NBIC from a technological perspective, largely based on a study carried out by TNO on behalf of the European Commission (Van Lieshout et al 2006). The focus of this European study was on the convergence of information and communication technology (ICT) with nanotechnology, biotechnology, materials sciences and cognitive sciences. The convergence between ICT and the cognitive sciences was the most important focus area, as it is still relatively unknown. This study has been supplemented with a literature study into the convergence between biotechnology and nanotechnology that was carried out by the Science System Assessment Department of the Rathenau Institute.

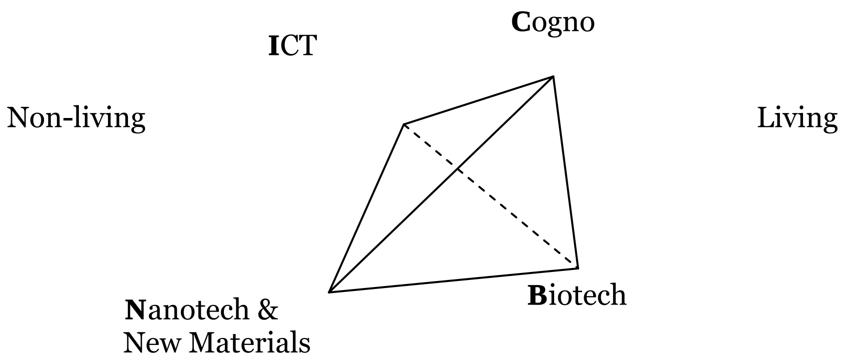
The starting points for the European study were the NBIC study of Roco and Bainbridge (2002 (a)) and the European CTEKS study (Nordmann et al 2004). Both studies present a vision about the future of converging technologies. As indicated in Chapter 2, the NBIC study sketches quite a utopian picture on the basis of unlimited technological possibilities for the improvement of human well-being and welfare (obviously paying a great deal of attention to the American interests). The CTEKS study clearly presents a more nuanced picture and also uses a more concerned tone about what we can expect. No technical scientists were involved in this study, but mainly scientists in humanities and social sciences and philosophy.

The underlying reason for conducting the European study of TNO was the need to provide an empirical basis for the claims from a number of different studies concerning converging technologies. The key research questions were: can convergence between different scientific and technological areas be empirically demonstrated, how does convergence take place and what is the position of Europe compared to the United States and Japan?

Figure 1 shows the four converging areas considered by this chapter: the overlap areas of the four spheres. It is the NBIC tetrahedron with at the four corners nanotechnology and novel materials, biotechnology, information and communication technology and the cognitive sciences. These four areas are linked to each other and exhibit overlap. Furthermore, on one side of the tetrahedron technologies have been placed that are related to inert material (ICT, nanotechnology and novel materials) and the other side addresses technologies that are related to life and living materials. Based on the study of Rocco and Bainbridge (2002a) we argue that the four overlapping areas studied in this chapter, jointly cover the most important parts of the field of converging technologies.

In Sections 2 to 5 we describe the characteristics of the convergence between ICT and the other three technologies and sciences as well as the convergence of biotechnology and nanotechnology. It should be emphasised that this chapter only deals with the two dimensional overlap areas between selected pairs of technology fields in the NBIC tetrahedron. In reality however, multi-dimensional overlaps exist between more than two technologies. For example, bionanosensors stem from the threefold convergence of nanotechnology, ICT and biotechnology. This is reflected in this chapter by addressing those developments in multiple sections. Before we consider the developments within our four convergent areas, Section 1 discusses the results of a bibliometric study to determine whether indications for the convergence of ICT can be found in the scientific literature.

Figure 1. NBIC convergence of the four technology areas



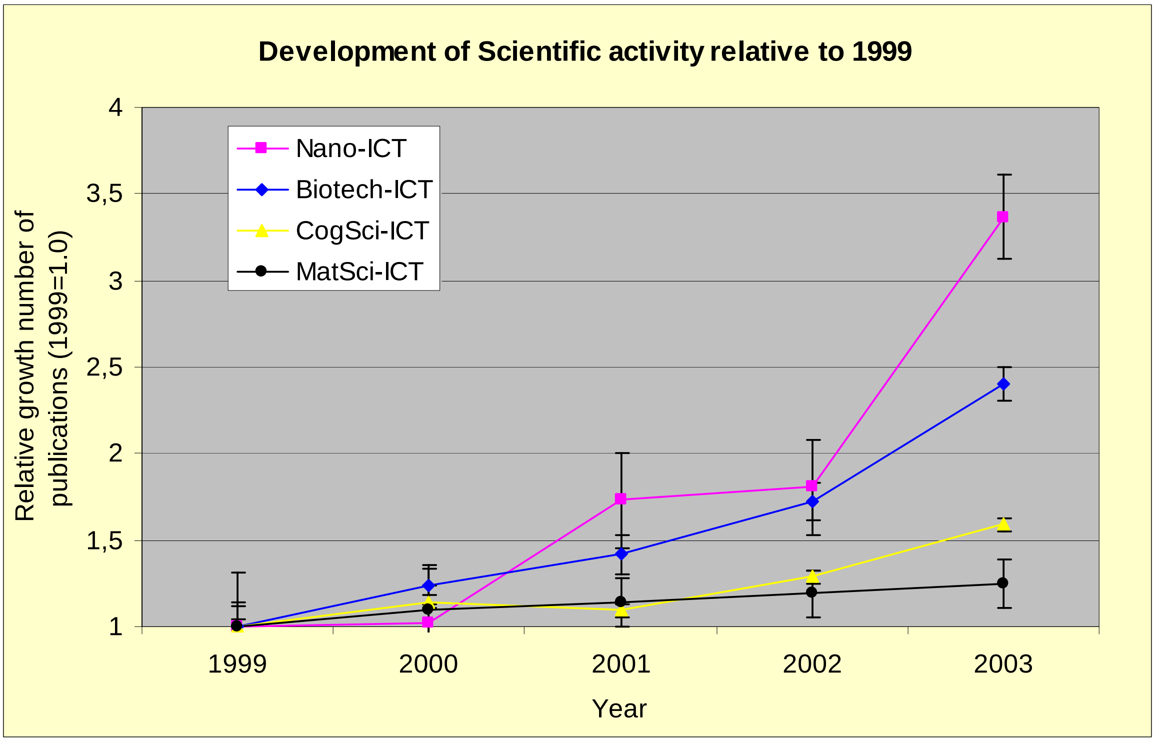
4.1. Bibliometric research demonstrates convergence of ICT with other areas

The bibliometric research showed that for the overlapping areas of ICT with cognitive sciences, biotechnology and nanotechnology and new materials convergence is actually taking place. The bibliometric research method assumes that the convergence is present in scientific publications which lie on the intersections between ICT and other technology and science fields. This overlap was first of all investigated by compiling a set of keywords for each field which provided good representation of the field. Subsequently a search was made in the Thomson Scientific database for publications that contained one or more combinations of keywords for two 'different' technology and science fields. These publications are therefore relevant for both fields.

The number of publications differed considerably per overlap area. The area where ICT and cognitive sciences overlap, showed considerably more publications than the other three overlap areas. In 2003 ICT-cognitive sciences had over 3000 publications while ICT-biotechnology had almost 600 and the other two convergent areas had about 150 publications each.

Figure 2 shows the growth in the number of scientific publications over the period 1999 - 2003, relative to the baseline year 1999. The convergence is clearly illustrated: all four of the overlapping areas investigated show growth of mutually shared publications. The convergence of ICT-nanotechnology shows the biggest growth, followed by ICT-biotechnology and ICT-cognitive sciences. Convergence between ICT and the material sciences shows the lowest growth figures.

Figure 2. Growth in scientific activity over the areas CogSci-ICT, Biotech-ICT, Nanotech-ICT and MatSci-ICT relative to 1999[1].



Source: Thomson scientific database. Searches and calculation: CWTS, TNO and VDI, 2005.

But what are the publications about? How are the converging technologies in these overlapping areas and the overlap area of biotechnology and nanotechnology taking shape? The rest of this chapter considers these questions. The most important converging technologies emerging from the 'overlap publications' with ICT are described. These descriptions are supplemented with future developments as stated in the various foresight studies, trend reports and road maps. At the end of the chapter we present a number of conclusions about our findings

4.2. Trends in the convergence of cognitive sciences and ICT[2].

Cognitive sciences are the study of the cognitive processes involved in thinking and in the brain. The brain is sometimes seen as the material substrate for thought (just like the hardware of the computer is necessary for the software) but, in contrast to hardware and software, the brain and thinking are much less easy to distinguish from each other. The 'hardware' of the brain – the neurons – develop as it were in conjunction with the 'software' (development of cognitive processes, such as feelings, observing, memorising, diverting attention, coming into action, exerting control, learning, affective capacities). Unlike in a computer, you cannot simply just 'load' a computer programme into the brain. This 'intertwined growth' of the brain is also termed the plasticity of the brain.

The new insights in brain research (based on a direct study of brain activity – the cognitive neurosciences) are analogous to *connectionism* in the computer sciences. This enables

[1] The study carried out also examined differences between Europe and the US as well as the scientific impact of the publications. For further information see the IPTS report (Van Lieshout et al, 2006).

[2] For the examples presented in this section, grateful use has been made of the work our fellow researchers Andreas Hoffknecht and Dirk Holtmannspötter from VDI in Germany have carried out within the project.

'learning' computer systems to be made. Connectionism assumes a network of processors (in the brain: the neurons). The processors can generate output signals (in the brain: the firing of the neurons) based on the input of other processors. Processors also feedback the output to processors in a previous layer. As a result of this, complex connections of processors arise, termed neural networks. The opposite of connectionism is the 'traditional' computational paradigm: an algorithmic processing of input data which satisfy certain rules of syntax and semantics. Although in general connectionism is seen as a more adequate description of the functioning of the brain than the computational paradigm, the brain is far too complex to be fully understood from the connectionism viewpoint. For higher cognitive processes, approaches other than connectionism are important. There, the computational approach once again comes to the fore.

ICT plays an important role in translating cognitive processes into concrete applications. These very much appeal to the imagination (robots, 'intelligent' adaptive systems) even though they are only loosely based on real knowledge about cognitive processes. Daniel Andler, a French philosopher who has specialised in developments within the cognitive sciences, talks here about 'shallow applications' in contrast to deep applications (Andler 1995).

In the European study we identified four important areas of convergence between the cognitive sciences and ICT:
- Cognitive systems and models
- Human-machine interaction
- Pattern recognition
- Imaging

Cognitive systems and models

Cognitive systems and models play an important role in a foresight study carried out on behalf of the UK Department of Trade and Industry. According to the UK Foresight panel cognitive systems are 'natural or artificial information processing systems, including those systems that are responsible for perception, learning, reasoning, decision taking, communication and action' (UK Foresight 2003). Artificial neural networks and robots fall under this definition of cognitive systems. Due to the complexity of the brain it is expected that artificial neural networks will be limited to the lower cognitive processes, in particular the sensory processes (and within these sensory processes attention is mainly focused on sight).

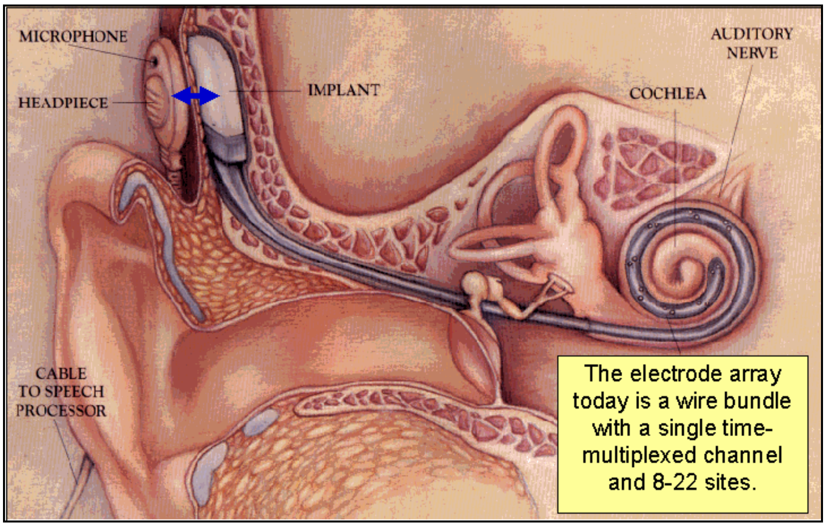
Robots form a class of cognitive systems with a high profile in research and arousing high expectations. In particular the Japanese robotic research appeals to the imagination. Japanese society is aging fast (twice the rate of Europe) and Japan expects to be able to use robots to care for older people; simple robots for cleaning activities – such as hoovering – already exist. The more complex forms of care also require robots capable of offering affection and able to communicate with their surroundings. Japan has been heavily investing in a research programme with the title *Humanoid and Human Friendly Robotics Systems*. This has led to a humanoid robot (a robot with a human appearance) that is 160 cm tall, weighs 90 kg and which can move at a speed of two kilometres per hour (also over uneven surfaces). The European Robot network (EURON, a partnership of 22 European countries) also expects a major role for the use of robots in the household environment. In the short term a shift of focus is envisaged from industrial robots (especially in the car industry) to other areas, including health care. The knowledge-processing aspects of robots are, however, still limited: in particular the higher cognitive processes such as decision taking, learning and action still pose major challenges.

Despite progress in some areas within cognitive systems and models, the provisional conclusion is that many hurdles still have to be overcome before an artificial system will be created which approaches the cognitive capacities of humans.

Human-machine interaction
Implants are an interesting example of human-machine interaction. Neurosurgery is capable of inserting brain implants with considerable accuracy; for example the *Deep Brain Stimulator* (DBS), a neurostimulator to control Parkinson's disease. DBS is in effect a pacemaker for the brain. A wire no thicker than a human hair is inserted into an area of the brain that controls the movement of the human body. The wire is led back under the skull to a small device inserted under the collar bone. The device sends small electrical impulses via the wire to the selected area of the brain and overcomes the uncontrolled movements which are characteristic of Parkinson's disease. On the basis of the results achieved so far for the control of Parkinson's disease, researchers want to extend the use of the technology to control other degenerative brain diseases, such as chronic pain, problems with the spinal cord, epilepsy, depressions and spastic muscles (McWilliams 2004).

Another example are the cochlea implants which help deaf people to hear (see Figure 3). These have been on the market for about 30 years. Cochlea implants can be used if the auditory nerve is still intact. About 75,000 people worldwide use a cochlea implant.

Figure 3. Diagram of a cochlea implant.



Source: www.mech.northwestern.edu/MFG/AML/M4/M4-Files/Warrington/sld006.htm

A cochlear implant consists of a small microphone which is attached to the outside of the ear and is connected to a speech processor. The processed signals are remotely transmitted to the cochlear implant attached inside the ear. Within the ear the signals are converted by a chip into pulses which are spread over a series of 22 electrodes. The 22 electrodes are in turn connected to the auditory nerve, which transports the pulses to the brain. Sound received in this manner, comes across as a very artificial sound. Patients must learn to distinguish speech from noise. People who have been deaf since birth, cannot learn to talk with this method. Research is being carried out into developing ways of improving how the electrodes are connected to the auditory nerve. Better transmission techniques are also being sought, for example, by using the MP3 format.

An interesting application of knowledge from cognitive activity can be found in the brainmachine interfaces that directly link the brain to a machine. Meanwhile experiments are also taking place with a bidirectional brain-machine interface. A machine generates an impulse in brain activity which leads to the associated actions (such as the movement of an arm or foot). The other side of the brain-machine interface transposes ‘think-acts’ into machine activity. By providing (mostly visual) feedback a study subject is able to arrange his thoughts and to focus on performing the desired action.

Meanwhile those experiments have demonstrated that brain-machine interaction is possible. In 2002 humans were able to move a cursor across the screen by activating certain thoughts. Conversely experiments took place at the State University of New York in which a rat was administered stimuli via three electrodes implanted in the frontal lobe and the somatic-sensory cortex. An operator could type in commands which were converted into stimuli and that subsequently resulted in movements in the rat (Talwar et al. 2002). A year later the first test of a brain prosthesis took place by a team at the University of South California in Los Angeles. The brain prosthesis consisted of an artificial hippocampus on tissue from the brain of a rat, and subsequently on living rats. The implanted chip provided the same processes as the damaged part of the brain. In 2004 an experiment was performed in which an electric network was placed on the brains of two patients. This network measured the electrocorticographical (ECoG) activity, which originates directly from the surface of the brain. By connecting this network to a computer screen, two patients were able to play a game of chess, in which they only made use of their brain signals. Since then the US Food and Drug Administration (FDA) has given permission for the start of clinical trials in which small chips will be implanted under the skull of paralysed patients.

Pattern-recognition technologies for language and speech recognition

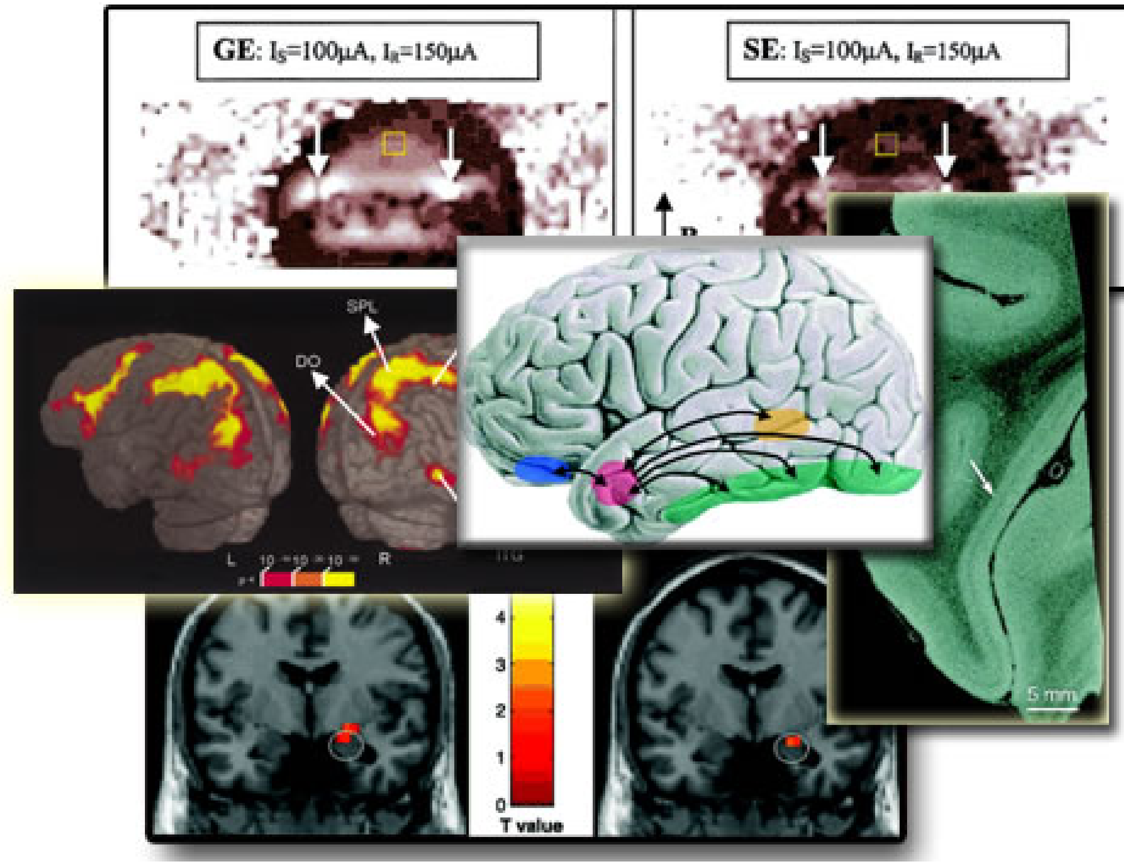
The recognition and classification of structures in large collections of data lies at the heart of many pattern-recognition technologies. This not only applies to the recognition of language and speech but also to the information processing of language and speech. Pattern recognition is a technique widely used in the other three ICT-related overlapping areas. A multitude of mathematical modelling techniques form the basis of pattern recognition. Mathematical models are sometimes aimed at statistical optimisation (example: linear discriminant analysis), sometimes at finding and reducing common characteristics (example: support vector machines, a relatively new mathematical technique), and sometimes at a different manner of representing the data enabling a reduction in the data set to relevant characteristics (example: genetic algorithms). Trends within pattern recognition mainly concern refining the available mathematical instruments and the application of these instruments in everyday applications such as speech recognition and face recognition, and – of course – image recognition techniques such as those used for fMRI (functional Magnetic Resonance Imaging).

Results from speech recognition research are used for improving the processing of speech by cochlear implants. As well as the improvement in speech recognition (improved differentiation between noise and speech due to improved statistical techniques) research is also taking place into multi-modal speech systems in which both visual and acoustic information is used. However the number of successful developments to date is limited. The technical obstacles are so large that experts doubt whether it will be possible to develop a computer during the next fifty years which 'understands' what people say and can respond in a way that humans comprehend.

Many European companies are active in the market of language and speech recognition. In the Netherlands this includes Polderland Language & Speech Technology that has developed spell checkers, grammar checkers, dictionaries and thesauri, and in addition to this is active in converting text into language readers, and in the identification of languages. The big software giant Microsoft uses the products from Polderland. In addition to Dutch, Dutch-Flemish, Friesian, Afrikaans and Papiamento, the company is adding new languages to its repertoire.

Image processing
Image processing techniques are one of the most fascinating aspects of the convergence between cognitive sciences and ICT. Advanced functional *Magnetic Resonance Imaging* (fMRI) not only provides an image of the brain but also a highly advanced and detailed sketch of the activity in the brain. For this fMRI makes use of indirect evidence, namely the magnetic characteristics of water protons in brain tissue.

Figure 4: Images, revealed through fMRI



source: http://fmrif.nimh.nih.gov/splash.jpg

4.3. Trends in the convergence of biotechnology and ICT

In this section we describe four groups of applications within the convergence area of biotechnology and ICT. A first group is bioinformatics and computational biology. This group scored highly in the bibliometric study. Trend reports and road maps reveal three other groups; these three groups of applications were scarcely found in the bibliometric study. In particular, biosensors and biodevices are seen in the trend and roadmap reports as the two most important applications within the overlap area between ICT and biotechnology, partly because in the future they are expected to have the most far-reaching effects on the quality of life. Finally there is a fourth group of – although smaller in size and according to expectations less far-reaching – applications from the convergence between ICT and biotechnology: these are biological computing and ICT for the identification of unique biological characteristics.

Bioinformatics and computational biology

The bibliometric analysis of the ICT-biotechnology overlap area can roughly be divided into two correlated clusters of publications. In the first place it concerns the use of ICT for the storage of data (such as DNA sequences, protein RFLD data, etc.) and for data mining. Examples stated in the publications are: data mining for the response of sugar cane to low temperatures, data mining of a protein databank and web-based tools for data mining of certain databases for anti-cancer drugs.

The second bibliometric cluster encompasses the use of ICT tools (such as neural networks, numeric simulation, computer simulation, genetic algorithms, support vector machines, machine learning, pattern recognition) for identification, characterisation, classification, molecular modelling and rapid prototyping. These are used for a wide range of applications, including the analysis of micro-array data and gene expression profiles, for the analysis of DNA tests in order to determine the origin of, for example, meat and fish products, for the development of per patient designed carriers of biomaterials (scaffolds) based on information from CT or MRI scans, and the dynamic modelling of biomolecular interactions. This cluster concerns bioinformatics in the broadest sense. The examples (from the publications) reveal that bioinformatics is not only used in research for the interpretation of measurements in genomics research with the help of DNA chips but also for a large number of other applications.

Bioinformatics is an outstanding example of the successful convergence of biotechnology and informatics. Initially the term bioinformatics was only used to describe the integration of the methodology and philosophy of informatics in the life sciences. In the United States the *Biomedical Information Science Technology Initiative* (BISTI) of the *National Institute of Health* (NIH) draws a distinction between the terms 'bioinformatics' and 'computational biology'. 'Bioinformatics' is understood to mean research, development or application of mathematical techniques and approaches for the processing of biological, medical, behavioural or health data, including the acquisition, storage, organisation, archiving or visualisation of this data. These are mainly the publications in the first bibliometric cluster. 'Computational biology' is understood to mean the development and application of analytical and theoretical methods, mathematical models and arithmetic simulation techniques for the study of biological, behavioural and social systems. These are mainly the techniques from the second cluster. Nowadays both terms have more or less the same underlying concepts; the differences are very subtle (Shoij and Mogi 2002). Whereas Europe frequently uses the term bioinformatics, in the US computational biology is more commonly used.

Biosensors embedded in an intelligent ICT environment

A second group of technologies in which the convergence of biotechnology and ICT has taken place and of which – if we can believe the various trend reports – major far-reaching applications are still to be expected are biosensors which are part of an intelligent ICT environment. Biosensors have been around for a long time, for example the diabetes kits which diabetes patients use. The integration of biosensors in a clever ICT environment is, however, new and can have important consequences for the living conditions of the patient and for aging humans. This can cover a wide range of applications, such as convenient lab-on-a-chips which physicians currently use (and the patient will eventually use as well), handy devices patients can use to measure certain substances in urine, saliva or blood and which provide the patients with advice about drug use and/or lifestyle, and advanced systems with which patients at home can have various biosensors on or in their body so that the doctor can monitor the patient's condition remotely.

A study from New Zealand expects that in 2012, DNA chips and genetic tests will form a standard part of clinical practice because then the genetic background of more complex diseases will be known and diagnostics tools become cheaper. They may include markers for all human genes and could test for over 100.000 conditions (Future watch 2005). An important driving force behind these developments is the American *Home Land Security* project. In April 2005, President Bush launched two *Homeland Security Presidential Directives* (HSPD-9 and 10) in which a strong increase in research and development activities was announced to defend the American population, economy, agriculture, food and water supplies from biological threats. The 'Biosurveillance Initiative' is a government-wide effort to protect the American public from possible bioterror attacks. It integrates real-time information on the health of the Nation's human and agricultural (plant and animal) populations with environmental monitoring of air, food (domestic and imported, including animal feed), water, and threat intelligence data (OSTP 2005). This policy involves a sizeable investment in research programmes and is focused on the development of biomonitoring systems. These investments in 'biodefence technology development' shall, as was the case for many other US defence research projects, have important spill-over effects in the public sector and will end up, for example, in medical diagnostic systems, food safety systems, etcetera.

As biomarkers will be found for an increasing number of health conditions and diseases, it will be possible to develop more applications of biosensors embedded in intelligent ICT environments. This will make it easier for patients to monitor their health status. Moreover medical information processing systems will also increasingly be able to present the outcomes of data obtained via biosensors and other monitoring systems in patient-friendly terms, so that the patient can be an equal partner in the process of health monitoring and intervention. The American NBIC study states the expectation that as a result of these types of monitoring systems, the ageing process will be considerably delayed, especially because new medical possibilities in the area of converging technologies will help to compensate for failing bodily functions (hearing, seeing, memory, muscle power) (NRC-CNRC 2003).

Biodevices and artificial organs

A third group of future ICT-biotechnology integrated applications, in which nanotechnology and novel materials also play an important role, are biodevices. This concerns extremely small vehicles which carry out their bioactivities in the body. An example mentioned in a Canadian study is that of a sensor which continuously monitors the blood sugar level and which is linked to an electronic pancreas which releases the right quantities of insulin into the blood at the right moments (NRC-CNRC 2003). Examples of biodevices even further into the future are small machines that simulate more complex organs such as the lungs (Jackson 2002: 14).

The trend report *Global Technology Revolution* (Antón et al 2001) discusses a number of developments in the area of artificial tissues, organs, and bionics. It concludes that: in addition to organic structures, advances are likely to continue in engineering artificial tissues and organs for humans. New manufacturing techniques and information technology are also enabling the production of biomedical structures with custom sizing and shape. For example, it may become commonplace to manufacture custom ceramic replacement bones for injured hands, feet, and skull parts by combining computer tomography and 'rapid prototyping' to reverse engineer new bones layer by layer.

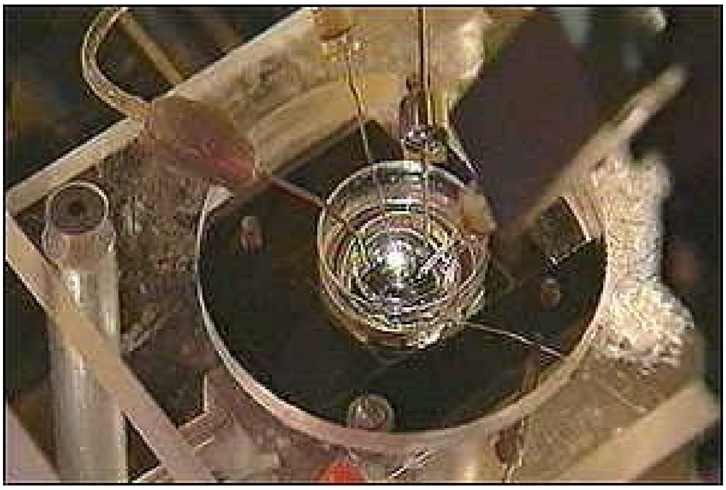
ICT in biotechnology research and for the identification of unique biological characteristics

In the development of computers increasing use is being made of knowledge about natural processes and systems. By studying the brain, computer scientists are learning new ways of looking at computer architecture, both at the level of the individual components as well as at the level of networks of, for example, processors (see above). As a result of evolutionary processes complex natural systems have been developed, which grow and evolve and can therefore adapt to their environment and, to a certain extent, also to damage. This is the inspiration for *biologically-inspired complex adaptive systems* (BICAS) in ICT research. A lot can also be learned from biological systems in the area of energy efficiency (OST 2003).

For the long term the Japanese seventh Foresight report presents developments in the area of using biological molecules for the storage of information, such as the four letters, A, T, G and C which determine the order of base pairs in DNA, in a DNA computer. Once more insight has been obtained into the formation of the specific molecular structures of peptides or proteins, peptide or protein computers could be developed for complex algorithms (NISTEP 2001: 197).

Recently American researchers published the first results of a biological computer made from the neurons of leaches (see Figure 5). The linked neurons were able to perform an addition sum.

Figure 5. Biological computer born: Living computer: interconnected leech neurons can add up.



Source: http://news.bbc.co.uk/1/hi/sci/tech/358822.stm

Virtual environments such as '*The Cave*' of the SARA Computing and Networking Services, Universiteit van Amsterdam, enable scientists to study the geography of their research objects. In this way researchers can examine the interactions between molecules in the cell from all perspectives and see what the effect is when individual molecules are manipulated. A final application is in the area of biometry. This is the science of determining the unique physiological characteristics of person in order to establish his or her identity. Iris scans are already in use, and facial recognition techniques are currently under development. Facial recognition techniques are used in systems for camera surveillance, for example at the Olympic Games in Salt Lake City in 2002.

4.4. Trends in the convergence of biotechnology and nanotechnology

Many processes that are highly relevant for human, animal and plant life occur at a nanoscale. The structures of all important biological molecules and systems (proteins, enzymes, DNA and RNA, ribosome, viruses, etc.) have dimensions of several to hundreds of nanometres. Nanotechnology takes place at exactly this length scale. This enables interaction between human-manufactured nanosystems and the smallest building blocks in biology (KNAW 2004). The convergence of nanotechnology and biotechnology will thereby provide a significant contribution to current and future progress in the medical sciences, molecular biology, biotechnology and pharmacy. This section provides an overview of current trends in bio-nano convergence.

There is no unequivocal definition of bionanotechnology. This is partly because the convergence is occurring in two directions (Roco 2002 (c)). On the one hand there are developments within nanotechnology that are applied to biology, biochemistry and the related areas of medicine and pharmacy. Nanotechnology has produced technological tools with which biological systems can be measured, understood and manipulated at the very smallest level. Previously researchers had to rely on looking at the large scale system and establish the working of molecular processes by deduction. Due to the revolutionary miniaturisation in fabrication routes, nanotechnology provides a whole range of structures (nanoparticles, 'nanocontainers', etc.) which are small enough to be inserted into a cell. So nanotechnology enables actual measuring and active manipulation. On the other hand biotechnology brings both concepts (self assembly) and real physical biological building blocks and fabrication routes to nanotechnology. Both routes lead to a broad range of subsidiary areas, all of which fall under the umbrella term bio-nano. This section considers four subsidiary areas in which convergence is making actual scientific progress. One important area from the first category (nano to bio): nanotools (microscopy and sensors), and two from the second category (bio to nano): biological fabrication routes and biological materials as building blocks (synthetic biology).

Nanotools

In the life sciences there is a considerable need for tools to support research into and the understanding of biological processes. These tools include, for example, imaging techniques and microscopy, optical tweezers, biosensors and high-throughput screening methods.

Since the 1990s, a vast progress has been made in making microscopy techniques suitable for and useful in research on living material. It had been possible to study non-living materials on a nanoscale for some time, using electron bundles for example, but the majority of biological materials cannot withstand this. Frederik and Sommerdijk (2005) describe the recent progress in cryo-electron microscopy, with which living material like liposomes (fat particles) can be studied on a nanoscale. Additionally, by combining these advanced microscope images with image-processing technology, it is possible to obtain a three-dimensional image of a cancer drug stored in liposome particles just 100 nm in diameter (Frederik and Sommerdijk 2005). Optical tweezers are a second tool from the field of nanotechnology that has recently been transformed for use with living material. This is a technology related to microscopy, in which laser bundles are used to pick up individual molecules. Although this technology has been available since 1970, it has only been applied to biological molecules since the mid-1990s. Research into the characteristics of DNA molecules has benefited enormously from this cross fertilisation between physics and biology (Williams 2004 and Kuo 1995). Also the emergence of atomic force microscopy (AFM) has made a range of biological applications possible, not only as a new imaging technology but also for measurements of the strength of bonds between biological molecules and as a component in bionanosensors.

Nanomaterials, such as spheres of gold with a diameter of several tens of nanometres and carbon nanotubes, play an increasingly important role in biotechnology. Hammad-Shifferli et al. (2002) have demonstrated that the behaviour of a DNA strand in the cell can be influenced by transmitting radio signals to a nanometre gold particle attached to it. It has also been demonstrated that it is possible to influence genes via carbon nanotubes inserted in cells (McKnight et al. 2003).

In addition to this nanoparticles are widely used for labelling certain cells or compounds. Quantum dots in particular are frequently seen as an alternative for the present day fluorescent labels, which are not stable and quickly dim. The quantum dot is a typical example of 'real' nanotechnology: the characteristics (luminescence) of the quantum dot can be found within its nanodimensions. Different types of quantum dots are already commercially available, and recent research has focused on improving quantum dots for biological applications. Sargent (Bakeuva et al, 2004) has succeeded in making quantum dots which emit light in the infrared (IR) spectrum (wavelength of 1150 or 1100 nanometres).

Light with this wavelength gives a higher penetration depth in living tissue (circa 5 to 10 cm) than visible light. These IR quantum dots are subsequently covered with DNA molecules so that they are not seen by cells as intruders and can survive in a biological environment.

Bionanosensors are another important development that are opening up new research routes in medicine and pharmacy. The basic structure of the sensor is fabricated via nanotechnology or microtechnology, but DNA, proteins, enzymes, whole cells or micro-organisms serve as the detection material. There are several different types of biosensors.

The most well-known are the high-throughput micro-arrays, also referred to as the DNA chip or biochip, developed the start of 1990s. By applying photolithographic processes that were developed for the manufacturing of computer chips, millions of microscopically small bioreceptors (tiny dots with a dimension of about 5 micrometers) are stuck to a small wafer of quartz. If the bio-substance under investigation reacts with a certain bioreceptor, fluorescence occurs and the dot emits light. The most well-known biochip is the genechip from the company Affymetrix, for testing DNA fragments. Biochips are widely used in scientific research as well as in everyday situations such as demonstrating the presence of legionella bacteria in tap water.

Another type of bionanosensor that has been commercially available for several years are the so-called ‘cantilever’ sensors. Bioreceptors are stuck to mechanical tips, comparable to the needle points used in the AFM microscope. Detection with this type of biosensors has the advantage that an electronic signal is directly emitted by the sensor, allowing the measurement to be made more quickly and accurately. Applications in biological and medical research are already taking place. For example Wu et al. (2001) have successfully used this type of sensor to develop protein markers for prostate cancer.

Nanotools is the convergence area in which innovation and commercialisation have made the largest progress. A large number of companies throughout the world are active in ‘nanomicroscopy’, nanobiosensors and micro-arrays. Simultaneously, the scientific convergence in this area is advancing at a rapid pace: the specific development of tailored nanoparticles and nanostructures for biological applications is becoming more commonplace.

The developments in nanotechnology have made a large variety of coatings and capsules at a nanometre scale possible, which can be used to store and/or gradually release certain drugs or living cells. Scientific research is being carried out into the delayed release of nano-coated tuberculosis drugs. In mice it has been found that after the intake of one pill, the drug could be released into the lung tissue for a period of about 10 days (Pison et al. 2006). By administering drugs to specific locations in the body, for example in a tumour or a certain organ, side effects in the rest of the body can be avoided. This might mean that previously non-approved drugs can now be marketed in a safe manner. Research is also taking place into magnetic particles in a bio-environment. If magnetic particles can be attached to a biological particle, simple and non-harmful magnetic separation techniques can subsequently be applied. Magnetic particles can also ensure that drugs, such as chemotherapy cures, can end up at exactly the right location in the body. In addition to this, magnetic particles can be used for the control of tumours by localised heating or as a contrast medium for MRI scans (Pankhurst et al. 2003).

Biological (supported) fabrication

This third bionano area concerns the use of 'living structures' as a factory. Viruses or proteins are then regarded as a cage or 'reactor vessel' for the manufacturing of nanoparticles. A more far-reaching form of convergence is biomineralisation in which enzymes and viruses are capable of independently producing optical, electronic and magnetic materials as well as ‘biofabricating’ biological materials such as protein nanofibres (Zhang 2002).

The electronics and sensor industry is also looking for a new method to produce patterns nano particles, as the present photolithography process will ultimately not be able to cope with the advancing scaling-down of the building blocks in electronics. Eyes are therefore turning to the biological world for a solution. Although the developments now described are mostly still in the research stage, the industrial interest for these technologies is considerable.

Liu et al. demonstrated in their research that it is possible to empty a virus and to use the empty virus shell as a manufacturing container for magnetic cobalt nanoparticles (Liu et al. 2005). These virus shells can be modified in a relatively simple manner (Rodi 1999; Kasanov 2001; Kay 2001), which makes it possible to selectively attach certain proteins or RNA strands. Nanostructures in specific patterns can also be made by making use of surface layers on bacteria cells. These so-called S-layers (bacterial cell surface layer) have the unique characteristic that they organise themselves in two-dimensional structures with regular 'pits'. Nanoparticles of gold can be deposited in the 'pits' as a result of which an equally distributed pattern of conducting points is created (Bergkvist 2004).

Within scientific research in the area of biomineralisation the ‘Biomolecular Materials’ group of Angela Belcher, at MIT has succeeded in allowing viruses to make thin films of zinc sulphide (Mao 2004). The group of Susan Linquist of the Whitehead Institute in Massachusetts uses prions (protein threads) to thread metal nanoparticles together to create flexible conducting nanowires (Bakueva *et al* 2004) and the group of Alivisatos in Berkeley use pieces of DNA to link nanocrystals together in a controlled manner to create larger structures (Alivisatos 1996). The American companies Genencor and Dow Corning set up an alliance in 2001 to further explore biological production routes for silicon materials (the most important raw material for the electronics industry) (Dow Corning 2006).

Biological materials as building blocks

The computer industry is currently searching for a replacement of the inorganic transistor. DNA could for example be considered as one of the possible replacements. Other biological molecules such as ribosomes can also be used as molecular switches (Bergkvist 2004). These are examples of convergence from biology in the direction of nanotechnology. A third example is the research area *Synthetic Biology*. This includes both the design and fabrication of biological components and systems which do not yet exist in the natural world, as well as the design and fabrication of existing biological systems. Synthetic biology is further building on the knowledge from ‘Systems biology’. In this latter area enormous quantities of data from research into the activity and interaction of genes (genomics), their expression in proteins and the interaction between these proteins (proteomics), and the interaction with the different metabolites (metabolomics) are analysed, to gain insights into the processes which occur in living cells. Synthetic biologists are concerned with simplifying these processes and the design of artificial biological systems based on metabolic reactions. Genes from different organisms are brought together in the genome of a single organism in which the expression of all the genes together forms a new ‘chemical assembly line’ (Nature 2005).

4.5. ***Trends in the convergence of nanotechnology, new materials and ICT[3].***

Nanotechnology is not one specific technology, but – just like biotechnology – it consists of a number of different technologies each associated with one or more scientific disciplines. A classification made in the report *International Strategy and Foresight Report on Nanoscience and Nanotechnology* (Luther 2004) listed nanostructured materials, nanoelectronics, nanophotonics, nanobiotechnology and nanoanalytics.

[3] This section is based on the chapters on ICT- Nanotechnology and ICT-New Materials Convergence in the European study (Van Lieshout et al. 2006) that have been written by Andreas Hoffknecht and Dirk Holtmannspötter from VDI in Germany.

Materials sciences deals with the development of novel materials and the improvement of existing materials and production processes. The overlap of ICT and nanotechnology and ICT and new materials is less extensive compared to the overlap of ICT with the two other technologies.

The bibliometric research revealed that about ten percent of the publications in the overlap area ICT-new materials are the same as the publications in the ICT-nanotechnology overlap area. This shows that there is also a considerable overlap between nanotechnology and materials sciences. Further, also similar convergence can be identified in the publications from both overlap areas, namely: electronics and photonics in telecommunication and simulation, modelling, image processing and pattern recognition, and neural networks. We therefore discuss both overlap areas in a single section.

Nanotechnology and new materials for electronics and photonics

From trend reports and road maps it is clear that electronics and photonics in particular will be the most important application areas for nanotechnology and novel materials. Both can make an important contribution to all aspects of ICT hardware development.

Nano-electronics

Nanotechnology applications in the area of wireless communication, networks and energy saving will, according to a report of the European *High Level Group on Nano-electronics*, provide completely new services which are very reliable and accessible and will be available for everyone (HLEG on Nano-electronics 2004). The most important application areas stated in this report are: ambient intelligence, medical diagnostics and treatment, transport and national safety.

The concept ‘ambient intelligence’ refers to an intelligent environment – house, car, office – that is continually responding to our behaviour and wishes. An example is the intelligent tracking and tracing of products such as drugs or products which can become tainted in the production chain. Ultrasensitive biosensors based on nanoelectronics will be developed which can detect extremely low concentrations of cell structures, antibodies or proteins as a result of which better diagnoses and treatments will be possible. Nanobiosensors will also support the functioning of intelligent implants, molecular laboratories and non-invasive health tests.

In the area of transport, nanoelectronics can support the intelligent use of engines. This will lead to lower fuel use and therefore less air pollution. Safety can also be increased with the help of reactive navigation systems, control of access to the car, entering of driver-specific settings and management of the car's internal environment. In the area of antiterrorism measures and public safety, nanoelectronics can be used in observation, alarm and entry control equipment (including biometry: see also biotechnology and ICT). Finally, in the future nanotechnology will make the revolutionary concept of quantum computing possible. In a quantum computer, the quantum mechanical properties of atoms will be used to perform the calculations (US Congress 2002) Scientific researchers in companies such as IBM, HP and NEC have been working on this concept since the 1980s. It is expected that this technology will be particularly useful for the encryption of data. The Canadian company D-Wave claims to the furthest ahead with the development. It expects to have fabricated a rudimentary quantum computer within three years, on which scientific research groups will be able to test their new mathematical models.

Nanophotonics

Nanophotonics already supports ICT in the area of fibre optics for communication, optical data storage and display technology. Developments in nanotechnology will enable further improvement of these applications. Being able to create the desired photonic bandwidth is the technology with which it will be possible to realise high-speed data communication with fibre optics. It involves making thin layered structures, which are almost literally built atom by atom as a result of which the desired electronic and optical characteristics can be realised exactly. The quantum effects that arise due to the extreme thinness of the layers are crucial for the manipulation of the characteristics (APEC 2002). In the future nanophotonics can make important contributions in the area of optical switches and the distribution and routing of signals (APEC 2002). The laser diodes currently used in CD and DVD drivers are based on nanophotonics. Future developments in the area of optical disk technologies include super high-density optical memories which use near-field optics and holographic memories (Tatsuno 2004). In the area of displays there are a highly-promising developments in the area of nanotechnological flat panel display technologies such as organic light-emitting diodes (OLED) or Field Emission Displays based on carbon nanotubes (CNT-FED) (Luther 2004).

All of these applications require the development and use of new materials in electronic and opto-electronic components and in optical switches and optical data storage components for telecommunication equipment.

Advanced nanomaterials for electronics and photonics
The transistor is one of the most prominent examples of the effect of innovative developments in the material sciences on ICT. The success of Moore's Law (a doubling of the number of transistors per square millimetre each 18 months) can largely be attributed to the specific material properties of silicon oxide, as a result of which continued miniaturisation has been possible for more than 40 years. However the limits of this paradigm are now in view. To find out if Moore's Law can still be applicable after 2015, the semiconductor industry commissioned the International Technology Roadmap for Semiconductors (ITRS) to produce a road map (ITRS 2005). This revealed that the materials sciences are particularly important for the future of this industry. The road map contains a list of developments in this area, such as silicon as an insulator, silicon-germanium and new non-volatile memories on the basis of ferro-magnetic, ferro-electric or nanocrystalline materials.

The American study *Materials Science and Technology: Challenges for the chemical sciences in the 21st century* (NRC 2005) expects that in the long term molecular electronics, with ‘materials’ such as carbon nanotubes or DNA, will be realised. Also semi-conducting organic materials (such as linked aromatic monomers, oligomers, or polymers) make ultra cheap electronics for certain applications possible, such as larger displays, memories, sensors and identification tags. The report states further that the long-term developments in the area of photonics of communication applications are strongly correlated with the possibilities of these materials to realise data traffic over long distances. The development of photonic ‘bandwidth’ materials, non-volatile memories and materials with a negative refractive index are crucial for this.

Simulation and modelling
In particular in the United States simulation and modelling are an important part of nanotechnology (US Congress 2002). They therefore occupy an extremely important place in the road map *Nanomaterials by Design* (Vision2020 2003). In addition the Strategic Plan for the American *National Nanotech Initiative* (NNI) (NSET 2005) states that ‘new mathematical and simulation capabilities are among the strategic priorities of the NNI’. This concerns many different modelling and simulation techniques with which the characteristics of nanomaterials and other structures on a nanoscale can be calculated, predicted and designed. These techniques are also deployed for the design of production processes for nanomaterials. Telenanotechnology is presented as an important convergence between nanotechnology and ICT: the telemetric use via Internet of modelling and simulation applications and algorithms for imaging, characterisation and production at a nanoscale (NSET 2005). In addition to this, there are also contributions from ICT in the area of image-processing and pattern recognition techniques, and neural networks. These clusters of convergence between ICT and nanotechnology and ICT and new materials were apparent from the bibliometric analysis; they are not mentioned in the trend reports and road maps.

Image-processing and pattern-recognition techniques are used in nanotechnology for the analysis of experimental results and the output of nanosensors. In addition to this there are certain nanodevices that have specific image or pattern-recognition characteristics. Examples stated in publications are the use of image-processing and pattern-recognition techniques (so called IPPR techniques) for nanosensors which simulate natural taste and smell organs, such as nanostructured Langmuir-Blodget films, nano-structured films of conducting polymers, thin films of gold crystals and nanocrystalline SnO_2.

In the material sciences sensor signals are also analysed with the help of IPPR techniques. Together with the development of new sensor materials, IPPR techniques can be used to develop sensitive gas detection and classification systems with which measurements can be made at a molecular level; this is not possible with electronic equipment (Gelperin and Hopveld 2002). This is an important aspect in the development of electronic tongues and noses (Chimenti et al. 2003).

Simulation and modelling techniques are often stated as being the most important tool that has helped the material sciences to develop from the empirical stage to a mature, predictive science. Initially novel materials were mainly developed by trial and error. With the help of simulation and modelling techniques, materials can be developed with desired and predictable characteristics, the product quality can be enormously improved and the costs for test and trial materials can be enormously reduced. These techniques have also made significant contributions to obtaining insights into the characteristics of solid substances, as well as the materials physics and the structural characteristics of materials (WING 2003). There are a number of advanced calculation techniques which are also important in the material sciences for the recognition, classification and manipulation of structures on the basis of large data sets. Neural networks are used to optimise the parameters for the synthesis and manufacture of novel materials, in particular those for steel, matrix composites, biomaterials, cement and catalysts. Neural networks are a certain 'intelligent' form of IPPR techniques. Just like the IPPR methods they are suitable for interpreting the results of complex sensor measurements. In nanotechnology they are mainly used to understand, design and optimise the behaviour of nanosystems, such as nanopowders and nanocomposites.

There is therefore a clear reciprocal convergence in this area: ICT tools such as signal analysis, and pattern and image recognition are used for the improvement of materials and sensor systems and ICT benefits from novel materials in nanotechnological electronics and devices.

4.6. Conclusions and discussion

This chapter considers the question: do converging technologies actually exist and if yes, how do they look like. The CTEKS study stated that science and technology areas converge if area A enables developments in area B and at the same time area B enables developments in area A. If we use this definition to establish whether NIBC convergence is actually taking place between ICT and cognitive sciences, biotechnology, nanotechnology and material sciences and between nanotechnology and biotechnology, then we come to the following conclusions.

ICT-Cognitive sciences
The convergence between ICT and the cognitive sciences is clearly reciprocal. Developments within the cognitive sciences make refined approaches for human-machine interfaces possible, which take into account cognitive and mental processes in the assessment of, for example, large quantities of information offered. Yet the main conclusion is that in the

development of practical applications, computer scientists scarcely make use of the truly innovative insights made by cognitive scientists in recent years. On the other hand informatics provides, for example, the pattern-recognition techniques used in image-processing programmes that enable cognitive scientists to test refined models of human cognition. In addition to this mutual endorsement various useful ICT-applications in which knowledge of cognitive processes has been used (albeit in a rather superficial manner) have rolled out of the lab.

ICT-Biotechnology

ICT makes it possible to process and store data of biotechnological research which can be shared with other researchers for analysis and modelling. ICT also has made it possible to develop the DNA chips that has enabled genomics research to develop so rapidly. The Human Genome project is often stated as the prime example in this context because without the presence of sizeable calculation facilities and the DNA amplification, synthesizing and sequencing equipment controlled by ICT it would never have been possible to complete the project in such a short period of time. At the same time biotechnology and the life sciences have also exerted effects on ICT, even though these are not as big as that of ICT on biotechnology. For example ICT researchers are increasingly looking to how living organisms survive in their natural environment. Examples are the development of self-restoring networks and safety systems based on the characteristics of cell membranes.

Nano-Biotechnology

The life sciences have strongly benefited from developments in nanotechnology. The development of DNA chips referred to above is one example of this, but also the large quantity of research into the application of nanoparticles in a medical context. In return nanotechnology has benefited from developments in biology and biotechnology. The genetic manipulation of viruses to produce specific inorganic materials would not have been possible without biotechnology. Concepts from biology, such as self-assembly, play an important role in nanotechnology. Therefore this also points to a clearly recognisable reciprocal dependence for the convergence between biotechnology and nanotechnology.

ICT-Nanotechnology and material sciences

Further the convergence between ICT and nanotechnology and material sciences is bidirectional. The ICT tools signal analysis, and pattern and image recognition are used for the improvement of materials and nanosensor systems and ICT (especially electronics and photonics) benefits from material sciences and nanotechnology.

What does this convergence mean?

The term ‘convergent’ is relatively new in R&D and innovation policy. One might therefore conclude that something unique is occurring in the history of scientific and technological development. That is not the case. In the development of science and technology the merging of previously separated science and technology domains is quite usual. Science and technology develop by bringing together previously separated scientific and technological disciplines, and in a parallel process also the related scientific and technological communities and their journals and conferences. ICT, cognitive sciences, biotechnology, nanotechnology and material sciences thus all arose from the convergence of underlying disciplines, such as physics, chemistry and electronic engineering (nanotechnology), biology, chemistry and medical sciences (biotechnology), electrical engineering, mathematics and physics (information technology), chemistry and physics (materials sciences) and psychology, linguistics, informatics, philosophy and anthropology (cognitive sciences).

However, it is interesting to note that the term converging technologies is used, and not converging sciences. This is mainly due to the instrumental character of the convergence, the hope that the convergence will also yield social and economic returns, and the fact that technical sciences are mainly characterised by the technical, design-based and constructive approach as opposed to the exploratory and theory-forming approach of science.

Should we therefore conclude that the convergence discussed in this chapter is ‘more of the same’ or is a qualitatively new development taking place? We would argue that the latter could well be the case. A significant part of the new converging developments is taking place at the boundary between life and artificial life, between human and machine in which thought and artificial thought, intelligence and artificial intelligence are contained.

Despite the enormous increase in technical possibilities, the unravelling of the mystery 'human' is still a long way off. The knowledge acquired so far, is still very limited compared to the complexity of human functioning whether this be at the genetic, molecular or neural level. The utopian future images (a simulated brain, self-replicating nanobots) are therefore no more than that: utopian (and for some dystopian).

Nevertheless, we would argue that a new era is emerging. For each of the fields we have presented the current progress as a logical consequence of the research lines which were initiated twenty or more years ago. In this sense no really new scientific or technological areas are being entered and the scientific progress made today is not significantly larger then in the past. However, in many of the scientific and technological areas which have been considered in this chapter, scientists are searching for the building blocks of life or of living material, also and this is new: increasingly in relation to each other. This has become feasible due to the development of new technical instruments that gradually become more diverse, more complex and in particular more far-reaching. The next step could then be to combine these instruments to make new products. From discovery and mapping to construction and design. Gradually living and non-living material, living and non-living systems are not being viewed as separate worlds anymore but mainly as an interrelated whole, which is reflected in the new products that can be made on the basis of this knowledge. This could signify the start of a new paradigm in a world of converging technologies.

5. *SUMMARY AND CONCLUSIONS*

Within this final chapter we present a summary of our findings and present some observations and conclusions. NBIC convergence is analysed from the angles: a historical perspective, a public debate perspective, and a technological perspective. In the conclusive section, we will reflect on our findings to see what they imply for the emerging public and political debate on NBIC convergence and the role policy makers and politicians can play in this discussion.

5.1. A historical perspective on NBIC convergence

Technological convergence implies that the progress within a scientific discipline, but also a technological or industrial sector, is increasingly correlated with developments in other disciplines and/or sectors. Technological convergence is seen as a key characteristic of the information revolution. Not surprisingly, therefore, the term has often been used (by policy makers) in the field of information technology over the last decades. During the 1980s convergence referred to the penetration of IT into a wide range of industrial processes and services (automatisation), in the 1990s to the convergence of information and communication technology (ICT), and nowadays (digital) convergence points at the rapid integration between Internet, telephony, TV, et cetera.

In the course of the 1990s a new type of convergence was signalled by social scientists and technology strategists: the growing interdependence between the biological and electronics revolution. This awareness has grown ever since and has culminated into the coining of the concept of NBIC convergence during the workshop *NBIC convergence for improving human performance*, organised by the National Science Foundation (NSF) at the end of 2001.

The NSF workshop defined NBIC convergence as the synergistic combination of four major provinces of science and technology: (a) nanoscience and nanotechnology, (b) biotechnology and biomedicine, including genetic engineering; (c) information technology, including advanced computing and communications, (d) cognitive science, including cognitive neuroscience.

NBIC convergence can therefore be seen as a new phase in the ongoing information revolution. It thus fits in and supports a technological and cultural development which has been underway for decades. Very high expectations surround the notion of NBIC convergence, some even predict a new wave of (exponential) technological progress – an 'Era of Transition' – which will strongly increase the technological possibilities to intervene in micro-organisms, plants, animals and human bodies. In particular, the mind – the centre of human personality - has become central stage as an object of intervention.

This anticipated future set of technological options provides important ethical and political challenges and forces upon society the question of how to use these options and where to set limits? A public debate on NBIC convergence is emerging that follows in the footsteps of the biotechnology debate of the last decades. However, it also broadens that debate in various ways. For example, next to genetic engineering, computer technology, nanotechnology and cognitive sciences have entered the debate in a more prominent way as means of intervening in the body and mind. NBIC convergence is therefore expected to increase the importance of biopolitical issues on the political agenda. Scholars like Rifkin (1983), Garreau (2004), Fukuyama (2002) and Hughes (2004) even predict, therefore, that bioethics will turn rapidly into biopolitics, which will add a new dimension to the political terrain of the twentieth century.

5.2. *A public debate perspective on NBIC convergence*

Although certainly not all NBIC technologies encroach on the human body and mind, those that do – like neuroimplants to improve our cognitive capacities - have led to a debate on human enhancement, which has become a main focus and starting point of the social debate on NBIC convergence. This discussion centres around questions like what does it mean to be human, what are the borders between man and machine, and will enhancement technologies make things better? Three mindsets can be distinguished in this emerging debate. In his book *Radical Evolution* Garreau names them: Heaven, Hell and Prevail.

The Heaven and Hell scenarios start from the assumption that NBIC technologies will develop extremely fast, and will lead to radical changes. Both perspectives anticipate on applications into the far future (e.g. the possibility of changing the genetic make-up of our children or greater-than-human-machine-intelligence). The two views, however, differ strongly in assessing the involved risks and opportunities.

The Heaven scenario is promoted by transhumanists, who argue that human beings should be guaranteed freedom to control their bodies and brains, and plea for people's right and access to human enhancement technologies. They see the improvement of people by use of this technology as a logical next and positive step in the evolution. The transhumanist worldview has a strong influence on military and space research in the United States. The NSF workshop *NBIC convergence for improving human performance* signalled the appearance of this view within the public research domain in the United States.

In America a loose coalition of groups, ranging from (religious) conservatives to disability and environmental activists, severely criticise transhumanism. The bioLuddites are fearful of the dangers related to future NBIC technologies and present various Hell scenarios. In his essay *Why the future doesn't needs us* computer scientist Bill Joy warned in 2000 for various catastrophes: nano-plagues, bio-plagues, class divisions, robots with superhuman intelligence. The environmental organisation ETC group feared a Brave New World type of society in which the elite uses NBIC technologies to control the masses. Fukuyama, a member of the President's Council on Bioethics, also has advocated a conservative position on human enhancement. Based on a natural argument he fears that enhancement would threaten the equality of humans.

The followers of the more moderate *Prevail* scenario disapprove technological determinism and do not take exponential technological development for granted. They think that technology and society co-evolve, and that it is possible to intervene in the development of technology. Moreover, they discard the Heaven and Hell scenario as far-fetched and unrealistic. This down-to-earth position is taken up by the expert group *Foresighting the New Technology Wave*, set up by the European Commission in the autumn of 2003 to look at the meaning of converging technologies for Europe. Whereas the NSF workshop focus on the objective on using NBIC technologies to improve human individuals, the European expert group promotes these technologies for the benefit of all mankind. From this perspective, NBIC technologies can be applied to address all kind of societal problems. This in fact opens up the process of setting the research agenda for converging technologies. To put it positively, this open European position shows that there is more to NBIC convergence than human enhancement. From a negative perspective one could say that it is circumventing the thorny issue of NBIC technologies and human enhancement.

5.3. *A technological perspective on NBIC convergence*

NBIC convergence includes both technologies (ICT, biotechnology, nanotechnology) and sciences (cognitive sciences, material sciences). Actual convergence between the four NBIC areas is already on its way. Convergence is, for instance, clearly visible for the convergence between ICT and the cognitive sciences. Developments within the cognitive sciences make refined approaches for human-machine interfaces possible, which take into account cognitive and mental processes in the assessment of, for example, large quantities of information offered. Computer scientists focus on the development of pattern-recognition techniques which, for example, can be used in image-processing programmes. Similar dependencies have been shown to exist for ICT with biotechnology, nanotechnology with biotechnology and ICT with nanotechnology. The Human Genome project is often stated as a prime example in this context because without the presence of sizeable calculation facilities and the DNA amplification, synthesising and sequencing equipment controlled by ICT it would not have been possible to complete the project in such a short period of time. Simultaneously the life sciences have become a main driver for the development in massive and super computing.

For each of the fields the current progress in science and technology is often no more than the logical consequence of the research line which was initiated twenty or more years ago. In this sense no new scientific directions are being initiated and the scientific and technological progress made is not significantly 'larger'. But in many of the scientific and technological fields scientists are searching for the building blocks of life or of living material and do this increasingly in relation to what has been found in other fields. This has become possible due to a range of technical instruments that is gradually becoming more diverse and more complex.

The next step is to combine these building blocks into new products. The goal of scientific research and technological development changes from discovery and mapping to construction and design. At the same time this new knowledge generates new insights for other science areas. These developments in converging technologies will gradually lead to a new paradigm, where living and non-living material, living and non-living systems will no longer be considered to be separate worlds. While our current images of the future are bordered by our current frame of reference based on the current paradigm of life and non-life being distinct categories, the actual future will be shaped by the new paradigm.

It should be stressed that on the brink of this major paradigm change, the lines into the future aren't straight and easily foreseeable anymore. Moreover, despite the current enormous increase in technical possibilities, the knowledge acquired is nothing compared to the complexity of human functioning whether this be at the genetic, molecular or neural level.

5.4. *Conclusions*

What do our findings imply for the emerging public and political debate on NBIC convergence and the role policy makers and politicians may play in this discussion?

Our analysis shows at least three reasons why the emerging public debate on NBIC convergence is justified, timely and stimulating. First of all, the first steps towards NBIC convergence have already been taken. NBIC convergence is taking place in the laboratories and research departments of the contributing convergent disciplines. Conferences are organised that address the cross-disciplinary issues, and research results are published in scientific journals that become increasingly cross-disciplinary. The seed of NBIC convergence has thus been planted in various new fields of research. In addition, policy makers have spotted NBIC convergence as a fruitful policy model to foster research and innovation. This will likely lead to even more efforts in stimulating NBIC convergence. Third, NBIC convergence is expected to lead to a new paradigm, which blurs and challenges the current distinction between living and non-living materials and systems. Such a prospect, whether to be expected in the near or very far away future, brings up delicate ethical and political issues that need to discussed in the public sphere. Even more so, if one assumes that today's research shapes tomorrow's technologies, and the political debate should be about the kind of society we want in the future.

The transhumanist and bioLuddists should, therefore, be praised for their early warning function and attempts to put the issue on the public and political agenda. Their Heaven and Hell scenarios grab the attention of the media and policy makers and thus are effective in setting the agenda. Another benefit of these extreme future visions is that they expose the most sensitive issues in the debate and clarify the normative deep core issues at stake. This also explains the fact that the debate on NBIC convergence – although in principle very broad – centres currently on the most delicate issue: human enhancement on the one hand and technologies getting out of control and leading to huge societal catastrophes on the other. Last but not least, the debate between the transhumanists and bioLuddites makes visible the outer contours of biopolitics, which because of NBIC convergence is expected to play a more and more prominent role within the political arena of the 21st century.

The fact that the Heaven and Hell scenarios form a provocative base for the current debate on NBIC convergence has two dangerous sides to it too. First of all, these two extreme scenarios start from the assumption of exponential development and radical change. The tone of the research efforts, however, is much more mundane than is reflected in many of the roadmaps and future vision documents that have been produced in the endless search for subsidies and new research markets. Moreover, it is largely unpredictable what the future will hold for NBIC convergence. Consequently, there exists a danger that the political debate be dominated by extreme futuristic visions that are speculative and do not reflect the current common day practices in ordinary research and development. In that case society would miss the chance to see the development of NBIC technologies as an open-ended process, which requires learning, creativity and the involvement of scientists, engineers, policy makers, politicians *and* society.

Second, the extreme Heaven and Hell scenarios are a recipe for a dialogue of the deaf. To prevent this emerging polarisation within the public debate to become locked in, there is a need for developing alternative political images of the future. Even more so, if we realise that NBIC convergence is expected to push biopolitics central stage. These alternative visions should address the normative issues put forward by the transhumanists and bioLuddites, but turn away from the notion of exponential development and technological determinism shared by the transhumanists and bioLuddites. A down-to-earth attitude, like the one adopted by the European expert group, is recommended in combination with a serious and visionary effort to develop a consistent view on the many normative issues involved. Because biopolitics is expected to play a major role in the political arena of the 21st century, there is a big responsibility for policy makers and politicians to engage in the discussion about NBIC convergence and make a very serious and timely effort to develop and formulate their position.

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7. *About the Authors*

Rinie van Est is both a physicist and a political scientist. He works at the Rathenau Institute, the Dutch national technology assessment organisation, since 1997. His current function is trendcatcher science, technology and society. He also lectures Technology Assessment and Foresight at the Department of Technology Management at the Technical University Eindhoven. His recent Rathenau projects deal with nanotechnology, brain sciences, converging technologies, ambient intelligence in health care, digital generation and synthetic biology.

Christien Enzing is an expert in the field of innovation policy studies in the field of biotechnology/life sciences and nanotechnology, its social and ethical aspects and economic impact in industrial sectors. She has been leading several national, EU and international projects on socio-economic and policy issues in these field. She was coordinator of the OECD project on Case studies of Biopharmaceutical Innovation systems and national expert of the OECD TIP focus group on Case Studies on Innovation. Already in 1985 she joined TNO, where she now is dept. head of the Innovation Policy group.

Marc van Lieshout has extensive expertise in the field of foresighting developments within information and communication technologies and has acted as project leader in several national and international projects in this field. His main focus is on studying societal and policy implications of new developments within ICT. He is programme manager of the knowledge programme on Societal and economic implications of ICT within TNO. Before joining TNO in 2000 he worked at the Radboud University of Nijmegen, the Rathenau Institute and the University of Maastricht.

Anouschka Versleijen is the coordinator at the newly established department of Science System Assessment of the Rathenau Institute. As Science and Technologoy Attaché in Silicon Valley, California she spent the four preceding years in technology trendwatching and analysis. Main topics in her work were nanotechnology, information technology and research and innovation policy. Prior to that Anouschka was the programme manager of a governmental research programme for universities and research institutes on surface technology and thin layers. She holds an MSc in Materials Science from Delft University of Technology in the Netherlands.

ANNEX 2:
VISION ASSESSMENT

Authors: Robby Berloznik, Raf Casert (viWTA)

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1. *JOSEPHINE GREEN*

Josephine Green was appointed Senior Director of Trends and Strategy at Philips Design in 1997. She promotes new thinking and new knowledge in the fields of Foresight and Society, Cultures and People Research, and its application to strategic thinking, sustainable innovation and new value creation. She pioneered the Strategic Futures™ Program that helps companies and organizations think about and implement a human focused approach to innovation and growth. She has worked both in international sales and marketing in the health and beauty sector and for a leading institute on social cultural research and change for strategic innovation and marketing. She has consistently helped customers introduce new thinking and sustainable development into their culture and processes. Green was born in the United Kingdom and has studied History and Politics at Warwick University in England. She has lived in England, Italy and the Netherlands[4].

GDP and Wellbeing

At the heart of the 'Witte Dame' Philips Design Research centre in Eindhoven, Josephine Green was fretting, glumly, about the current state of technology and where it was heading. All too often it was seen as little more than a vehicle for growth, a potential percentage point of Gross Domestic Product to help close the gap with overpowering global competitors. Where was humankind in all this, the director of trends and strategy of the Dutch multinational asked? Quality of life? Was technology in Europe just a rat race for profit? Or worse, a race of lemmings leading straight to some imaginary doomsday cliff?

Just a few days earlier, European Union Science and Research Commissioner Janez Potočnik was addressing the London School of Economics and Political Science. There was a pretty bleak undertone to his speech. 'The European Union produces almost one third of the world's scientific knowledge,' he said, yet quickly added the EU was 'running a trade deficit in high tech products of €33.7 billion. The EU has been unable to increase its share of this market, while countries such as China have experienced stellar growth.'

'To be blunt,' he went on, 'the problem is that the very best research _ that is to say, the research that will have a truly outstanding impact on the world of tomorrow _ is often not being done in Europe.' Given that context however, Potočnik said politicians had finally taken heed. 'Never before have political leaders so clearly acknowledged the central contribution of research and innovation for underpinning the European economy, and for improving the wellbeing of European citizens.'

And just there, in those last words of the quote, was a meeting of minds between Potočnik and Green. Because even if she disapproves of the 'underpinning the European economy' argument to drive technology, she passionately cares about using high-tech research to improve the quality of life. And it is exactly there that she sees opportunities for Europe to get back into the game.

4 Source: Philips Design

Economy first or community first

‘We see science and technology too much as the driver rather than the enabler,’ she said. With a few clicks of the mouse at the computer in her office, she showed the kind of use technology should have. The company's Living Memory project uses high-tech applications in coffee tables and kiosks to let people from all over a community _ a village for example _ get connected and share immediate information about anything from bus schedules, to the availability of books in the local library to requests for baby sitters. She sees all this as part of the social development of people trying to reconnect more with their communal core, a step away from the rampant individualism of the turn of the century.

This sense of community is too often missing in technological development now, Green said. ‘Progressively through the 20th century what we've done is replace the social considerations by the technological or economic ones. Technological and economic considerations go hand in hand because what we have done in our minds is convince ourselves that to drive growth and GDP, and maintain competitiveness, we have to keep the technology coming in successive waves.’ In a sense, she sees that strategy as a dog chasing its own tail until it has lost all sense of direction.

‘People see the future as an empty space and what we can do is simply fill it with more technology. Then, there is the assumption that it will somehow drive growth. They see that it will somehow be synonymous with a quality of life. We also come from an idea that standard of living and quality of life are similar. You increase productivity, so your GDP goes up. Hence you make more money and your standard of living increases and you are happy. There is a major problem with that. And we are now beginning to see that that is actually dysfunctional,’ she said. ‘Let the market work it out and we will all be happy. It just doesn't work.’ She points out the most obvious problems. Environmental sustainability and mental health.

Brent crude was peaking at 70 dollars a barrel at the time of the interview, just unheard of a few years ago. CO_2 is already an economic commodity and global warming an ever pressing issue. At a personal level, mental diseases are on the up. ‘The way we are driving productivity and the whole issue around production and consumption is messing up our environment, causing a great gap between the rich and poor and most importantly, it is driving us insane. They reckon the highest rate of illness will soon be mental,’ she said. ‘We continue to see GDP go up, but GDP is only a measure of productivity. Why is depression good for GDP? Because it sells more Prozac.’

Because of the pressing challenges, it makes the timeliness of the debate on the future of technology all the more important. ‘It amazes me that, in front of all of the evidence, all of the facts that continuously tell us this paradigm is no longer working, we continue to believe in it. We are at a critical point to act.’

And at this all important time, despite so much evidence to the contrary, Green remains hopeful. Especially because she is convinced people will turn away from rampant consumerism and use technology in a much more social and sustainable way. She already sees the seeds of a more interconnected and social society. In the end, it will also be beneficial for technology-driven companies like her own.

A change of age

‘We are not going through an age of change because we are going through a change of age. Not just the technology changes, the very social fabric of society changes too and therefore we have to rethink the kind of social and economic models that we want,’ she said. ‘We see that people now realize that even if they have more, they may not be happier. The new technologies, the information science and the medical science technologies will enable us to rethink the ways in which we deliver quality of life and value.'

So her vision is to move the technological rationale away from the immediate impact of the market. 'I am asking for a new consciousness. We must start with a human-focused approach and not base ourselves on what is meaningful for the economy, or shareholders. Interestingly for this new consciousness, the technologies are coming along. Technologies begin to show us new ways of creating value in this new world.'

These technologies however need careful stewardship, making public and political guidance essential. Although Green's job is to push the technological envelop, she fully realizes the inherent dangers of the burgeoning technologies. Even if she is not a devotee of Garreau's Hell scenario, she does see the potential for doom, both biological and sociological. 'How can we be mindful of the future when we have powerful technologies that we have no idea what their impacts are 20 years down the line. How do you know, like GMOs, how they will develop. What I do know is the following: 'lets go to the precautionary side if we don't know.' She stressed she did not want to kill the spirit of innovation at all. But if the dangers were just too immense, it would be reckless to 'marry the idea that 'let technology rip' because it will drive the economy and the market will sort it out.' Sometimes, she sees it as a rolling rock going down a slope, inexorably. She has seen the experiments whereby a professor implants chips into his own body to attain the next level of human achievement. 'My fear is that this is where it is where we are going. It is already a machinery that is going. Scientists love to do it. If we are going to have a Brave New World of Aldous Huxley well, how do we stop it?'

Energy and sustainability

While one kind of technology, or the political and economic application of it, can drive society to the brink, Green is also convinced that another application can safeguard society and nurture it. And this is where she sees a crucial role for Europe. 'We have a big problem to drive innovation and growth,' she said, arguing there was not really an established primary taker in the EU, unlike Washington. 'The United States has a big customer _ the military and defense. What Europe needs is one big focusing idea. And that idea needs to drive technology, social innovation and wellbeing.'

At that point came the essence of her vision. 'True to Europe, it needs to be around energy and sustainability. That is one of the major problems we will face. It encompasses everything, driving the technologies in fundamental things like earth, wind. It drives social innovation, since we have to live differently. And underlying it is that we are redefining a quality of life.' And she is convinced that even in the economic realities of the immediate future, it will be much more than just a well-meaning concept. 'It makes also economic sense because, at the end of the day, the world will need that knowledge and technology. It will release more and more growth and wealth.'

Now, there is still the gap between practice and reality and it is there that politicians need to step in, at national and especially international level. No technology will bridge that gap. It will take something more. 'Courage by the European Union. Courage. At the end of the day simply a willingness to walk Europe's own path,' she said. Once the fundamental commitment is made, the application becomes technical in nature. 'The chief challenge is to get the technology right and to accept that what we want to do with the technology, at the end of the day, is empower people,' Green said. 'That is where the political challenge comes in, in terms of facilitating innovation and financing research. They put billions into research & development technology and science and they put very little into the social and the humanities.'

After all, there should be leeway enough in the budget to set the right priorities. The EU's seventh framework programme has a total budget of €54.5 billion[5] over the next seven years, about a 60 percent increase over the previous multi-annual programme. Mentalities need to change too, changing priorities. ‘We will only truly, actually, do what we claim we want to do in all economics, which is drive growth through our technologies, if we socially innovate first. The true potential of growth of our new technologies will only come when we have found the relevant social innovation to allow them to truly drive forward. The connectivity will give us new directions for prosperity beyond neoclassic liberal economics. It will be sustainable.’

Politicians can turn all they want, if companies do not follow suit, all will be for naught unless they move away from the current corporate mantra. Key will be how companies like Philips can embrace such new principles and allow them to take root in current corporate soil. Green said her position within Philips was proof enough that the nurturing of alternative strategies is possible. There needs to be a groundswell. ‘Philips alone cannot change it. Nor do we want to see Philips go. However, there are choices waiting to be made. We are seeing new trends coming up. First of all, we seems to be ready to move toward a stakeholder capitalism rather than shareholder capitalism. Companies need to have a license to operate. They have to behave. A company has to be seeding the future. This is where Europe has to move,’ she said.

Take public health, another critical sector, one where Europe will soon come face to face with the aging problem. Here too, technology can be applied in a politically and socially sound way, said Green. Ever more, technology should allow people to take care of themselves. Diabetic patients already know the advantages, surveying and managing their disease on a daily basis.

‘We have a massive problem in the public health sector. Chronic disease, aging population, limited resources. The biomedical and the information science technologies are in a position to rethink the whole way in which we deliver health. They can bring it more into everyone's home. The technology is there now to improve quality of life because there is nothing better than being treated in your own home. You can be connected to the health system, to your carers, to clinical coaches. That is the big message. We will take a lot more medical technologies into the home.’

Again, the medical application brings home Green's vision for the future. It is not about creating the perfect human being, nor about driving GDP. It is about making people live better.

‘Technology has been too much the next big growth factor to drive the economics and we have not given enough attention, even on its own logic, how technology truly should drive it. It will only drive it when you marry the new values that you can bring to people through placing their wellbeing central and making systems that are socially relevant,’ she said.

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5 Provisional figure (March 2006).

2. *SUSAN GREENFIELD*

Baroness Susan Greenfield graduated from Oxford and spent time in postdoctoral research at the College de France, Paris and New York University's Medical Centre. She is also co-founder of a university spin-out company specialising in novel approaches to neurodegeneration, - Synaptica Ltd. Professor Greenfield has written 'Journey to the Centres of the Mind Toward a Science of Consciousness' (1995) and 'Private Life of the Brain' (2000). Her latest book 'Tomorrow's People: How 21st Century technology is changing the way we think and feel' explores human nature, and its potential vulnerability in an age of technology. She is also Director of the Institute for the Future of the Mind, part of the James Martin 21st Century School. She has also written 'The Human Brain': A Guided Tour (1997), a best seller. She held the Gresham Chair of Physic from 1996-1999, and has received 28 honorary degrees. In 1998 she was awarded the Michael Faraday medal by the Royal Society and in 1999 was elected to an Honorary Fellowship of the Royal College of Physicians. In response to a request in 2002 from the Secretary of State for Trade and Industry, she produced the Greenfield Report 'SET Fair: A Report on Women in Science, Engineering, and Technology'. She was awarded the CBE in the Millennium New Year's Honour's List and Life Peerage (non-political) in 2001. In 2003 she was awarded the Ordre National de la Legion d'Honneur. She is a director of the Royal institution of Great Britain [6].

Dinner date with Perfection? No, thanks.

The quaint London cabs seemingly hadn't changed in decades as they weaved their way through morning traffic. Neither had Queen Square, with its neat little garden park lined with health care buildings. Even the Institute of Neurology, with its grey, 1960's facade, already had acquired a patina of age.
It seemed too timeless a place to look for a new vision of the future. Then again, Baroness Susan Greenfield doesn't want to lose an imperfect past in the technological quest for the perfect future.

The luggage of the past

'Do we want a kind of sanitized society? A saccharin society,' the acclaimed neuroscientist rhetorically asked, pondering what technological enhancement for man and mankind would truly mean. 'Let's just say we want to give everyone a healthy and long life without suffering and pain. We all want that. But if you met someone who had no pain ever, no suffering ever, would you want to have dinner with him?'

Sitting high up in the Institute of Neurology, the scientist and policy adviser seriously leaned toward a resounding 'no.' It only was a small step toward the fake happiness drugs of Aldous Huxley's Brave New World. And Greenfield said Huxley continues to hold such appeal because, for all the scientific promises in the world, there is nothing we hold as dear as the peculiarities of each and every one of us. 'This mid 20th century novel anticipated the things we are talking about. Are these technologies, are they good things? We still read these books because we prize the individual,' she said.

Hence, she scoffs at the ideas of such Transhumanists as Ray Kurzweil, who seeks immortality and has no qualms about man being fused with superintelligent machines into some posthuman cyborg.

'Someone like Ray Kurzweil is missing the main point, even leaving aside his rather naive view of biology because he is a physicist _ his rather naive view about downloading

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6 Source : http://www.pharm.ox.ac.uk/academics/greenfield

memories, and some. The main question is: what is the meaning of someone's life. How do they get fulfilment?'

'How do we harness the technologies to give someone a meaningful life.' Since she fully grants the advancement of technology its place, it makes her less of a Luddite as some make her out to be.

Greenfield raves about the potential of nanotechnology, especially how it affects her medical sector of brain science. She mentioned a man paralyzed from the neck down, who now can move a cursor on a computer screen all because of a brain implant. 'There are already amazing feats,' she said. 'The implants can create huge medical advances.'

Here too, though, she wavers whether to choose for the individual or for society as a whole. She took the example of a Parkinson's patient who had been given a brain implant to stop shaking. It worked, but such breakthroughs do have a cost _ literally. 'That operation cost 20,000 pounds. So this is another issue. Do you spend that 20,000 pounds on one person or do you spend it on nurses and care for 100s of people,' she asked. 'It is a tough call.'

'On that theme. Ninety percent of the babies by the middle of the century will be born in the developing world. Already one in four doesn't have access to drinking water. So we could have a very dangerous situation of those in the West _ with our Prozac and Botox and enhanced Playstations and genes _ and other people still in the 20th century in terms of sanitation and water. Clearly in humanitarian terms this cannot happen. Economically and ecologically this cannot happen. This is not going to work. The planet will not work like that. It is a global problem.'

Competition vs. fulfilment

In that sense, she feels that much of the technological enhancement philosophy is too self-centred. Instead of individual fulfilment, Greenfield feels the quest for human enhancement is too often about competition.

'My fear is that implicit in the agenda for enhancement is the desire to be better than somebody else. Why do we want to be better? You get into a sort of arms race of 'you got a better memory, so I get an even better memory'.'

Take smart drugs that affect the brain as an example. In the United States, Ritalin and other such medicine is already subscribed to millions of students to be sharper, smarter in the classroom. The potential for improvement is still huge. The issue of such competition could soon hit home, together with a sad student coming back from school, seeing herself sink compared to the overall level of her class. 'If your kid comes up to you and says 'I am bottom of a class because everyone else is taking a drug', what do you do? It is a really interesting ethical issue,' she said. It fits into her larger picture of enhancement. 'The whole point of enhancement is that, if not everyone has it, why bother otherwise? Why would you want a better memory, unless it is to be better than his memory? Why should the whole world want a better memory, the baseline will be the same.' 'You can argue that when everyone is enhanced you will have a ceiling effect, you will all converge to the same level.' Then, she highlighted a theme close to her heart. 'Will not that take away from our individuality?'

Help through the application of new technologies is essential, Greenfield said _ but up to a point. 'You have to draw the line between someone who needs help and between a lifestyle. Someone can say 'I am shy and therefore this is affecting me. So give me a drug that will help with shyness.' So is that an illness?' Greenfield's area of expertise _ neuroscience _ becomes ever more essential in the West because there is the luxury to worry about one's own mindset, and it often leads to depression. 'We have the leisure and the expectations now. In my mother's days, people were just concerned with dodging bombs,' she said.

‘Our main concern is about the brain. The biggest illness in the 21st century, according to the World Health Organization, is going to be depression. Twenty percent of the world population is going to be suffering from depression. So the issue is very much centred on the mind and the brain.’

All those problems _ and all within the ordinary lifespan as we know it today. It raises the question what to do with life extension by a few decades. ‘The issue is not how rapidly the advances come. But if you were to give someone a longer lifespan and no suffering what are you going to do with that time? If you live 150 instead of 75, what are you going to do? The average person already feels depressed because he feels inadequate. The more interesting thing is what are we going to do with our lives if we are going to eliminate suffering.’

The Eureka moment

Despite all the new brain technologies, the fundamental question will remain a philosophical one, she says _ how to give someone a meaningful life. She looks back and ahead in a search for answers and comes up with four models on fulfilment and individuality, most of which end up in disappointment.

The first is consumerism or ‘how to get people to buy things they don't want. It gives you an illusion of individuality but you are not fulfilled.’

The second is fundamentalism. ‘It is the opposite. What people do is that they define themselves by some collective narrative,’ she said, as in the Christian, Jewish or Muslim religions. ‘People buy into a story as a collective. Although it is very fulfilling, there is no individuality. You can be a homicide bomber and it doesn't matter. You have no room for being an individual. So it is fulfilled but not individual.’

Within the realm of technological advancement, she sees a third one and coins it 'technoism.' ‘It is just being happy, happy. Happy experiences all the time. Not in the past, or the future. It is just having experiences all the time. Increasingly, we will have the computer screen to do this. We will be increasingly lost in the Cyberworld. It will be neither individual nor fulfilled.’

Which leaves the only option of being fulfilled and individual. ‘That is the Eureka moment _ the loveliest feeling in the world. You have an insight that no one else has. They are our own thought connections. It makes you feel fulfilled and individual. It is the way we can define ourselves.’

It brings Greenfield to her policy statement. ‘We should harness the technologies in ways that people can be creative and fulfilled. That is more a goal than just 'let's get these enhanced genes going'.’ The next challenge is to pass on that message to the public at large and the policymakers.

Scientists, communicators: Unite

For the moment, only two kinds of people lead the public debate on an issue far too important to be left to the techno elite alone, Greenfield said. And they pretty much fit the first two parts of Garreau's ‘Heaven, Hell, Prevail’ scenario.

‘Either they are very excited about the developments and think they are all good. And everyone else is a Luddite. They don't even question why things have to improve, but they have to be better. They are a means to an end, but they have to be better and you have to define your end. There is no point in having a better memory. What are you going to do with that condition,’ she said.

She was equally unimpressed with the sounds from Hell. ‘Then there is the opposite, people who are completely anti-science and who are as bigoted as the people who think that science is evil and all science is bad. That is silly as well.’

Besides those narrow groups, the public at large has no clue. ‘People are sleepwalking into these technologies,’ she said. And this is exactly where the scientists, politicians and the media should step in. Too much is at stake. In the coming age of embedded computing, Google in your watch and ubiquitous screens and cameras, too many questions remain open _ from health care to privacy and security. ‘No one is addressing these questions. The questions are so big and people are scared,’ she said.

And the longer it will take for the situation to change, the worse for all. Greenfield called for a ‘true public debate where people are empowered rather than overpowered by technology, by the scientists, and by things they do not understand. Now, it makes them feel inadequate and frightened and they take more drugs and they feel completely disconnected. This is the way we are heading unless we really think about society.’

One prerequisite is that people will have to become scientifically literate, able to think about the mid- and long-term effects of technologies. Greenfield blames scientists and politicians more than she does the public at large. First of all, politicians have to learn to look beyond the next election when it comes to science. ‘Politicians by definition work on a two-to-three year cycle. They are more concerned about the immediate knock-on effect,’ she said.

On the other hand, scientists have to abandon their ivory towers and learn better how to interact with society. And they have to do so by becoming media-savvy. ‘If scientists don't talk to the media, they only have themselves to blame because the media would demonize them. Normally, the scientists up until now have done nothing, just put the receiver down. Then they complain that they are called Frankensteins,’ Greenfield, a notable exception to that rule, said. ‘In terms of public debate, we need to engage with the media.’ Her proposal? Open up universities over the weekend for public debate with scientists. A sort of ‘popular issues for the terrified.’

‘It reduces the fear of the scientists and lets scientists communicate at a more human level. The university is gaining because it is no longer an ivory tower. So everyone wins,’ she said. At the same time scientists also need to open up more to politicians. So in the end, ‘there is this strange alliance between media, science and politics. Politicians will pass legislation that will keep them in power. It is driven by what the public wants. And that is driven by what the media tell them.’

‘In all these debates the media has to be involved because they are the most powerful. They reach out to millions and millions of people in a strong way.’

3. THIERRY GAUDIN

Frenchman Thierry Gaudin, 66, is Ingénieur Général des Mines in France. He graduated from the 'Polytechnique' and Mining engineering college in Paris. From 1971 to 1981 he was in charge of creating a national innovation policy in the ministry for industry. He was president of the 'Six countries programme on innovation policies' between 1981 and 1983. From 1982 to 1992 he managed the Centre for Prospective and Technological Assessment in the Ministry for Research and Technology, leading projects on international technological awareness, prospective foresight and assessment of research and industrial strategies. In 1993, he became member of the CNRS French science foundation [7].

Technological Progress : The mirror of our souls

Thierry Gaudin sat at his home in Vaour _ a cosy hamlet of 248 souls close to the wild Grisigne woods in southern France. It is as bucolic as any place in Europe, a region full of meandering roads, fertile fields, vineyards and medieval villages. Yet when Gaudin moves around with his laptop inside the village, he doesn't have a problem. There is Wifi all around, proof that technology can serve any community, and that any community can organize itself to have technology at its service. 'We have a small association here that set it up. You see local initiative can function,' he said. 'Small rural communities can be just as well informed, thanks to the Internet.'

The nano-revolution

The little scene symbolized so much of what Gaudin stands for. He wants to use technology to offer small-scale solutions which can raise the awareness of all citizens. Through the Internet, even the most faraway people can be empowered to link up and help improve living conditions worldwide. For Gaudin, the future of technology not so much lays in hi-tech laboratories where chips may be fused to brains and where lives are extended and enhanced by artificial means. Instead it is right here in the countryside, where man faces his biggest challenge of the next century: restore the balance with nature. 'The issue we face is not at all the enhancement of performance. On the other hand, we have to take the responsibility of being guardians of nature. We are part of nature and if we take care of it, it will stand us in good stead.' New technologies should be used to raise awareness at grassroots levels.

Even as the sun moves lazily as ever over Vaour, Gaudin realizes the speed of time will be essential over the coming decades, just as much as steel and oil were the essential elements of the previous revolution. 'My vision is based on the movements of technology and changes therein,' said the engineer. 'The essential point in all this is that the industrial technology was based on materials and resources _ steel, concrete, fossil fuels. The result is that we now spend 4 to 5 tons fuel equivalent per year per person. It is enormous. Those quantities will not last,' he warned, citing it as a main reason for the current imbalance between man and nature. 'The industrial revolution led us to consumption which is counted in tons of CO_2.'

Now, with the new economic revolution, comes hope. 'After the industrial revolution we face the so-called cognitive revolution, and it will be based on the contraction of time' instead of raw materials. 'Things will be counted in nano seconds' and together with the deciphering of the human genome, it offers fresh opportunities.

With hindsight, he can see that an imbalance with nature through progress can have devastating effects. 'Take the Middle Ages. In between the 11th and 13th century, the population density doubled in Europe. From 20 to 40 people per km2. At the same time, the forests dwindled. And after 1315 the world, within its limits, was full. The first famine came in

7 Source: gaudin.org

1315 and the Black Death in 1348 and in two centuries, the population came back to 20 people per km2. So, because there was this imbalance with nature, we came back to square one in two centuries,' he said.

He feels we could be facing the same problem right now. 'We know that our resources will be close to depletion in the coming decades. It will force us to change our relationship with nature,' he said. 'So will we anticipate the problems because the new technologies allow us to raise awareness and manage our behaviour to face the challenges, or will we continue at the same breakneck speed until we have our back against the wall,' Gaudin asked.

In this sense, he sees technology as a neutral element, dependent on the whims of how we will apply it. Gaudin says we will find the essence of ourselves in technology. 'The new technologies are a mirror of what mankind is doing. This mirror can be as global as a satellite image or very local like a network of measures.' He has his own wireless network in Vaour to show for it.

However, he sees many dangers. Gaudin's Hell, based on Garreau's Heaven-Hell-Prevail scenario is linked to a society with an overpowering ruling class, much as he sees among the extreme right in the United States. It is a dark prospect. 'An arrogant ruling class can say 'the people will not regulate spontaneously, so we have to do what's needed to regulate them. So we create conflicts here and there.' Because once in a nano-world, you are not visible so you can act unbeknownst to the people that you target. It is an essential point which totally undermines the economic doctrine of Adam Smith and liberalism which is based on the principle that presupposes that a consumer is perfectly informed of the choices before him. If the consumer is no longer informed, we are in a situation where man domesticates man. In that scenario the arrogant elite will do its utmost to diminish the population without the people realizing it, using nano-technology,' he said. 'It opens the spectre of a 1984 scenario.'

In less literary terms, he applies his principles to Genetically Modified Organisms. Here too, the technology is not necessarily bad but its application might be. 'A good deal of GMOs do not pose any problems.' Then again, GMO's become the mirror of our soul and he sees the abuse of technology in some commercial applications, which is sometimes forced upon farmers with little options but to conform. 'It is a power grab,' he said, trapping the farmer and leaving the farmer and consumer little choice.

Political options

Politicians should be no innocent bystanders as technology and science race ahead, said Gaudin. 'If we want to control what happens we need to use converging technologies. Satellite technologies already show us who pollutes,' adding other examples that promote a common good, including energy-saving technologies. Through the promotion of Research and Development, politicians have a direct impact, especially at the European Union level. 'They can do a lot. The state of public finances in the different member states is such that the EU plays an ever more important role in Research and Development.' With it comes bigger political leverage. 'Up to now, the (EU's executive) Commission has functioned a bit too much under the pressure of powerful lobbies. The common good cannot be reconciled with the pressure of these lobby groups,' he said. 'The common interest is something which transcends the interest of the lobbies.' To illustrate opposition between the two, Gaudin highlighted the current fight in the French legislature over Internet copyright.

At the time of the interview, the government's plans to tighten the piracy laws were in shambles after grassroots pressure forced it to review an essential part of its proposal. For Gaudin, it showed people's power in the Internet age. He said the French government initially had bowed to the 'beau monde' of media stars demanding protection. Then, unexpectedly, came opposition. 'There was this popular reaction. One of the main actors was the union of families, not exactly left wing fanatics. They saw their kids kept on downloading music and movies, and the threat to jail them for that seemed totally abhorrent. A reaction was launched on the Internet and the freeware community, and it created a real political debate. It left the government facing a parliament which voted something else than what it had proposed. It showed society functioned differently than a few years back,' he said. 'We need our best brains to grasp the issues of intellectual property rights and to develop a new system that serves the common good. The case in France show that there is a popular general interest, symbolized by the families.'

'Aux armes, Internautes!'

Gaudin saw this as a prime example to raise awareness at grassroots level through the Internet. It can be used for other purposes as well. 'The Internet is a place to raise awareness about things. The Googlers immediately create a global consciousness. The same goes for the global weather picture, which we take for granted now. But it is only a step further to take that image and create a global awareness about the decline of the Amazon forest.' The Internet becomes ever more potent, Gaudin said. 'We have recently arrived at a billion Internet users in 2005. One sixth of world population uses it and raises consciousness about issues.'

Just by itself, raising consciousness is essential in solving a problem, he said. 'Experience shows that, even in developing nations, it can have an immediate effect. If you place a measuring device someplace, e.g. in a polluted river, then pollution diminishes because people have information about it and they regulate themselves. There are not only classic political decisions, but there is also a mirror effect which allows a multitude of decisions by individuals if they have pertinent statistical information. This is why, when we are discussing new technologies, we should also include measurement equipment and spread it among the local population.'

Such awareness can be further promoted through independent research. 'There is a role for politics in this. There is this problem of awareness-raising at all levels. Because there is not only the issue of politics or multinationals but there are also elementary decisions of each individual to be taken every day. These individuals have the right to know what they consume. They have the right not to be trapped by nano-objects _ just think of the invasion of privacy. I tell you, there is a lot of work to be done.'

However, local logic does not always prevail. Politicians also need to counter the excesses of the profit principle with regulation. When it comes to global world problems, Gaudin said he already sees that human fertility is stabilizing. The second challenge is to reduce energy consumption, where more political will is needed. 'We could regulate ourselves and restore that balance in a century or century and a half. It is not a given since self-discipline needs the organizational means. The market economy is not a solution. So you either need to strongly regulate society or find an alternative to the market forces that now deplete our natural resources. We see that the world population is spontaneously regulating its fertility now. When it comes to energy consumption, we don't see that yet,' he said. Here too, the new energy-saving technologies could offer a way out.

Gaudin's issues are totally centred on society instead of individual enhancement which is key to some other groups like the Transhumanists. The Frenchman has little affection for them. 'We checked on the Transhumanist publications and when you scratch the surface you have the impression they say that humankind is in a sorry state and we have to move as fast as possible to become the next species and nano-technology will allow us that. It is a discourse reminiscent of a sect,' he said. Transhumanism however can have huge financial implications on how research money will be spent. 'The media launch of nanotechnology and converging technologies in the United States is aimed to raise several billions of dollars from the taxpayer to finance operations which will primarily be destined for the defense ministry. You can say that Scientology can be counted in millions of dollars but that the Transhumanists count in billions of dollars. Hence they find support among industrialists who could profit from this.’ It is as far as you could possibly get from Gaudin's target group.

4. *JAMES HUGHES*

James Hughes serves as Trinity's Associate Director of Institutional Research and Planning. Dr. Hughes also serves as the Executive Director of the Institute for Ethics and Emerging Technologies and its affiliated World Transhumanist Association. Dr. Hughes produces the weekly syndicated public affairs talk show Changesurfer Radio, writes the Change Surfing column for Betterhumans.com, and contributes to the democratic transhumanist Cyborg Democracy blog. Dr. Hughes is the author of Citizen Cyborg: Why Democratic Societies Must Respond to the Redesigned Human of the Future. Dr. Hughes lives in rural eastern Connecticut with his wife, the artist Monica Bock, and their two children[8].

Huxley in Reverse

James Hughes was feeling at ease. At the so-called World Forum on Science and Civilization _ Tomorrow's People _ in Oxford, he was among many kindred spirits. And they weren't even genetically cloned that way.

For four days, scientists, philosophers and social critics talked about the wave of technological progress. Many predicted it would be rather a Tsunami of the future, surprising just about everyone, except those in the know. 'People don't understand what is coming down the pipeline, how quickly those questions will be before us,' Hughes said.

Without a hint of irony, some people discussed the chances of immortality within our lifetime. The uploading and downloading of brains. Humanoid robots and robotic humans. Within popular culture, it all goes down extremely well, but only as fiction.

The prospect of human enhancement

Hughes realizes however that, step by step, it could turn into the next best reality show. And he is trying to galvanize a political movement to help mankind leap into what he sees as the next important step _ into the realm of Transhumanism. Over the past years, it has become a force in the scientific and political debate surrounding the issue of technological progress and converging technologies. The doctrine is 'based on the premise that the human species in its current form does not represent the end of our development but rather a comparatively early phase,' the World Transhumanist Association says. In Hughes' own words: 'The core idea is that people should be guaranteed the right, and work toward full access for everyone, for human enhancement technologies _ technologies which are being opposed because they make us more than human.'

In our society there is no need for a debate about the benefits of curing illness. But to improve on, to enhance, the human condition by artificial means is something completely different. In perception, 'smart pills' to boost intelligence are something completely different compared to anti-flu shots. Hughes wants you to think again. 'One of the fundamental things that politicians have to understand is that there is no difference between enhancement and therapy. All the things that have been done in the past _ birth control for example _ is a modification of the body which allows us to do things that we didn't do before _ have sex without procreation. There is no distinction between birth control and genetic engineering. Both are a technology that provides choice. Challenging the technology enhancing distinction in policy is a key goal,' he said.

He looks at efforts to extend life by decades beyond what we are now accustomed to. 'The degree to which we can provide a pill or drugs which will reduce the likelihood of developing

[8] Source: http://changesurfer.com/Hughes.html

a whole range of age-related diseases _ it doesn't make sense to say that it’s an enhancement and not a therapy. There is no distinction.’

While some talk about the ethical dilemmas when facing the sometimes narrow distinction between therapy and enhancement, Hughes says that making the mere distinction is actually an ethical failing in itself. ‘Senior citizens should be fundamentally offended by the notion that keeping them alive longer would be bad for society,’ he said. Empowerment of this ever-bigger demographic group in the West is essential and technological enhancement can take it there, said Hughes. ‘You make sure they are not chronically ill, you make them as smart as you possibly can,’ he said. ‘In a fundamental sense, a significant part of the population is disempowered by the weaknesses of the body and human mind _ by aging. Senior citizens are chronically vulnerable because of the aging process. There are cognitive constraints on our ability as citizens to engage in democratic participation.’ So bring on smart technology and anti-aging medicine, Hughes said. ‘Information technology and cognitive enhancement will give us the possibility of becoming stronger citizens. The whole trajectory of the last thousands of years is that as people become more literate and had more leisure time and as lives got longer, democracy got stronger. So I have a strong faith that that could happen more in the future. It might lead to radically decentralized, it might lead to a referendum democracy.’

A better Brave New World

Compare that to the road toward totalitarianism some have predicted. One of the things Hughes has to keep fighting against is the legacy of one book _ Aldous Huxley's Brave New World, where technological advancement leads to totalitarianism. ‘One of the key problems of cognitive enhancement is the enduring metaphor of Brave New World that there is somehow a connection between people using drugs to change their mood and totalitarianism,’ he complained. ‘The implicit argument of Brave New World is that if you use drugs to make you happy, you will be a happy slave of a totalitarian system. Instead, all the research shows is that what makes people passive is depression. Happiness and optimism make people more dynamic, more able to accomplish things. They become less realistic about their prospects of failure and more optimistic about their prospects of success,’ he said. Hughes added that recent research also showed that half of what makes a person happy is determined by genes, another argument for enhancement.

The political challenges of enhancement cut across almost every political issue _ from aging, to GMO food and development policy. And it makes it especially difficult to unite a following. ‘It is beyond classical politics. I call it ‘biopolitics’ and it is at a cross angle to classical politics. Of all the value commitments of Transhumanism, the defense of individual liberty _ the right to control your own body, your own brain and your own reproduction _ is the most core commitment above politics. The people attracted to our policies are libertarian left wingers and neoclassical thinkers.’

Currently, the World Transhumanist Association claims 3,280 members in over 100 nations across the globe, representing just about every possible political hue imaginable. He claims some 30 percent of membership is socialist and a quarter libertarian as the two major groups. ‘When I plot the strategy for our organization it is daunting because there is no constituency that is not touched by and does not have a vested interest in that project,’ he said. ‘We have a huge internal diversity of viewpoints. They will all influence public debate in many different ways. Some people are so focused on their personal life transformations _ live longer, use drugs, whatever. There are people for whom the interest of the developing world is their driving force. For everyone it is a different answer. There are key leverage points,’ he said. ‘There is something to be offered from a Transhumanist perspective for every social policy question because almost no policymakers are taking account of the rapid acceleration of these technologies or what consequences they will have for social policy and health care. You can fit it into anything,’ he said. It even includes such issues as crime and security. ‘We are going to have a serious set of questions about cognitive liberty when we are able to fundamentally change the brains of people who are incarcerated. We are already facing that question. For example: with sex offenders we have the ability to suppress their testosterone and radically reduce the recidivism rate. Some think it is a violation of civil rights.’ Overall, Hughes said, such questions have to be brought into the political debate.

A Political Catch 22

He said the best way to boost the leverage of Transhumanism is to create ad-hoc 'caucuses' within existing political structures. According to Roger Scruton's Dictionary of Political Thought, 'caucus' has two meanings. Either a caucus is a private meeting of party members to streamline interests and policy or a secret or exclusive organization within the officially recognized party-political system. Hughes sees the need for caucuses because it cuts across so many divides. ‘The key issue is the accelerating change.’

Within Joel Garreau's scenario of Heaven, Hell, Prevail, the Transhumanists are reaching for the sky. Yet Hughes says they are far from blind as to the dangers lurking ahead. ‘Individual liberty is absolutely important. But the one thing that trumps individual liberty in our perspective is the threat of apocalypse. We are not uncritical utopians. We do not think that the technologies without regulation lead to the Promised Land. There is the possibility of nano-plagues, bio-plagues, the possibility of class divisions that become class wars. The Hell scenario is there too.’

Sometimes Transhumanists are criticized for painting too rosy a picture of the future, hence his call for a regulatory framework. ‘How to provide access and how to assure safety. These are legitimate questions. These technologies are being developed so quickly and they have such far-reaching implications, so what are the regulatory models that actually guarantee this,’ he asked.

Too often though, Hughes finds himself in a Catch 22 situation when strategies have to be planned. Politicians want advance planning, yet quickly call anticipated projects 'science fiction' unworthy of further debate. Hughes sees his opponents as the bio-conservatives. ‘On the one hand all the bio-conservatives say to us, 'we can't do these things because we have to think about them ahead of time.' So, OK. Let's think about them, and we say 'we think this is what is going to happen in the next 10 years.' Then they say 'you cannot talk about that because it is science fiction.' Well, if you cannot talk about things that sound like science fiction today then you are not really taking account of what might happen as a consequence of the things we are doing right now. Some of the things are not here and may never be here. The technical unfeasibility is just a non-starter,’ he said.

Yet even if he clears that hurdle, the so-called bio-conservatives throw up others. ‘The second step in the argument is that if they do happen, we don't like them because of x,y and z,’ he said. Here, Hughes aimed his darts at Europeans, many of whom seek to centre on the advancement of society over the advancement of the individual. It is an often recurring trans-Atlantic distinction. ‘That is like saying we are not going to cure cancer, we will only get them to stop smoking. And guess what? It is harder to stop people to stop smoking. Another example: obesity. We can come up with another diet, another way of running around the block, but why not come up with a pill that can make people lose weight,’ he said. He laughed off criticism it was just technological fix. ‘Yes,’ he shouted, ‘it is a technological fix. And it has a better chance than seeing how much exercise they get because that is not going to work at all.’

A global challenge

Hughes also looks at the development of technology in the global economic framework, and roughly uses the analogy of Thomas Friedman in his bestseller The World is Flat. The book shows how the world is increasingly interconnected, allowing savvy individuals from India and China to compete with other economies in an increasingly globalized market. For Hughes, Asia is the next global challenge and within global competitiveness it could well be sink or swim if binding international regulation is not approved. He looks at China and India and if the latter is seen as a positive example, Hughes has worries about China. ‘You have to be concerned about cognitive enhancement. The Chinese don't give about any of the bio-conservative handling that the religious right and the greens do in our country. When Falun Gong does it in China, they get sent to prison. If there is authoritarian Transhumanism then the Chinese government is authoritarian Transhumanism. We need international agreements about this,’ he said. ‘The Chinese are never going to sign on to anything that says you are not allowed to enhance your bodies or minds in ways that will allow you to compete with the West more effectively.’

Europe too needs to take action to avoid a population implosion and have an old-age dependency problem which could destroy the EU social model, Hughes said. ‘If they want to be competitive in a way that keeps Europe alive in a global economy, they have to make full use of all the technologies, including human enhancement technologies, that are coming to the fore. They cannot just say 'we Europeans we change social things, we don't change people'.’

5. *About the Authors*

Robby Berloznik

Robby Berloznik studied political science at the Free University of Brussels (1979). After a research career in technology assessment he entered the Flemish Institute for Technological Research in Mol in 1991 were he became the advisor for technology assessment to the managing director. This until 1997 when he became research manager in the fields of technology assessment, technology foresight and sustainable development. In December 2001 he was appointed by the Flemish Parliament as the first director of the Flemish Institute for Science and Technology Assessment (viWTA). This institute supports the Flemish Parliament in its science and technology decision making. ViWTA performs several tasks concerning the social impacts of science and technology developments, such as: short evaluations for Parliament, in-dept evaluations, organization of societal/public debate, annual analysis of regional needs in R&D, recommendations to the Parliament and international networking. In the mission of viWTA high importance is given to the integration of public participation in parliamentary decision-making.

Raf Casert

Raf Casert studied Communication Science at the Free University of Brussels (1982). A recipient of a Belgian American Educational Foundation fellowship, he earned a Master of Arts degree in Journalism from New York University. He has written about Belgium and the European Union for over two decades.

ANNEX 3:
SHORT CV'S OF THE EXPERTS INVITED TO THE WORKSHOP

Editor: Robby Deboelpaep

ROBBY BERLOZNIK

Robby Berloznik studied political science at the Free University of Brussels (1979). After a research career in technology assessment he entered the Flemish Institute for Technological Research in Mol in 1991 were he became the advisor for technology assessment to the managing director. This until 1997 when he became research manager in the fields of technology assessment, technology foresight and sustainable development. In December 2001 he was appointed by the Flemish Parliament as the first director of the Flemish Institute for Science and Technology Assessment (viWTA). This institute supports the Flemish Parliament in its science and technology decision-making. ViWTA performs several tasks concerning the social impacts of science and technology developments, such as: short evaluations for Parliament, in-dept evaluations, organization of societal/public debate, annual analysis of regional needs in R&D, recommendations to the Parliament and international networking. In the mission of viWTA high importance is given to the integration of public participation in parliamentary decision-making.

Wolfgang Bibel

Em. Prof. dr. Wolfgang Bibel is currently Professor emeritus for Intellectics at the Department of Computer Science of the Darmstadt University of Technology in Germany. He also maintains an affiliation with the University of British Columbia in Vancouver, Canada, as an Adjunct Professor. His more than 200 publications including about 20 books cover a variety of topics in Artificial Intelligence/Intellectics and applications as well as science and technology foresighting analyses. He is one of the founders of Artificial Intelligence in Germany and Europe and received numerous awards from various organizations, most recently the Herbrand Award from the international organization for Automated Deduction (CADE Inc).

Anja Boisen

Professor Anja Boisen was born in Copenhagen, Denmark in 1967. Anja received her M.Sc. degree in physics in 1993 from the University of Roskilde and her industrial Ph.D. in micromechanics in 1997 from MIC institute of micro and nanotechnology and the company Danish Micro Engineering A/S. Since 1997 she was an assistant research professor at MIC, and since January 1999 she was associate professor and project leader of the Bioprobe project. As of January 2005 she has been appointed full professor and leader of the NanoSystemsEngineering section at MIC. She has a thorough knowledge on micromechanics and nanotechnology and has more than 10 years experience in microfabrication and cantilever-based sensing. She is co-author of more than 70 peer reviewed papers and nine patent applications. Her group consists of 15 researchers and she is collaborating with European universities and Danish companies. In 1999 Anja achieved the competitive FREJA grant for female research leaders (acceptance rate of less than 3 %) from the Danish Research Foundation to establish her group. Since then she has attracted external funding through several EU and Danish research programmes. Anja was awarded the AEG Electronics prize in 2000 for an extraordinary contribution to the electrotechnical field and is currently a member of the Danish research council on technology and production. Moreover, Anja is the Danish governing board member of the European network of Excellence called Nano2Life and was in 2004 a member of the Danish foresight committee on Nanotechnology. Anja is cofounder of the company Cantion A/S, which was established in 2001.

Nick Bostrom

Dr. Nick Bostrom is the director of the Future of Humanity Institute at the University of Oxford. The FHI is a new interdisciplinary research institute, which is a part of the Faculty of Philosophy and of the James Martin 21st Century School at Oxford. Dr. Bostrom has a background in physics, computational neuroscience, and mathematical logic as well as in philosophy. He has previously held positions at Yale University and as a British Academy Postdoctoral Fellow. Bostrom is a leading expert on the practice, ethics, and social consequences of human enhancement and of emerging technologies such as nanotechnology and artificial intelligence. His research also covers the foundations of probability theory, scientific methodology, and risk analysis. He has published more than 100 articles and three books. His writings have been translated into 15 different languages.

Donald Bruce

Dr Donald Bruce holds doctorates in chemistry and theology, and formerly worked in nuclear energy and risk regulation. Since 1992 he has been the Director of the Church of Scotland's Society, Religion and Technology Project (SRT), set up in 1970 to examine ethical and societal issues in current and emerging technologies. He directed major pioneering assessments of the ethics of GM crops and animals, cloning and stem cells, and is a regular speaker, writer and broadcaster, and since 2003 has examined ethical issues in nanotechnologies. He is a member of the ELSA board of the EC Nano2Life European Network of Excellence and drafted its review of nanobiotechnology ethics. He is setting up a working group on human enhancement ethics in the EC NanoBioRAISE programme. He is a member of the advisory boards of the Institute of Nanotechnology and the UK Engineering and Physical Sciences Research Council. He was formerly a member of the Scottish Science Advisory Committee. He is much involved in the UK debate on the role of public participation in research and new technologies.

Christopher Coenen

Christopher Coenen is a political scientist and since 2002 member of the scientific staff of the Office of Technology Assessment at the German Parliament (TAB), run by the Institute for Technology Assessment and Systems Analysis (ITAS) within Research Center Karlsruhe. He is working primarily in the research fields social, political and cultural aspects of ICT, nanotechnology and converging technologies.

Domenico Coviello

Dr. med. Domenico Coviello is a medical geneticist, currently Head of the Laboratory of Medical Genetics, ICP- Milan, Italy (Mangiagalli Clinic, University Hospital of Milan). He has been working at University of Modena (1998-2000), and at University of Genoa (1989-1997). His research activity has been dedicated mainly to laboratory activity (cytogenetics and molecular genetics) and to genetic counselling with particularly interest in education of professionals. He worked in several international labs: 1978-Cytogenetic Laboratory, Guy's Hospital Medical School, London; 1984-William Dunn School of Pathology, University of Oxford; 1987-1988-Department of Molecular Genetics, M.D. Anderson Cancer Centre, University of Texas, Houston, Texas, USA; 1991-Human Genetics Branch, NICHD, NIH, Betesda, MD, USA; 1995 and 1997-Department of Genetics, Harvard Medical School, Boston, MA, USA.
Organiser of the *Satellite Meeting of the European Society of Human Genetics* (ESHG) Conference (1997) '*Education, Training and Responsibilities of Non-MDs Genetic Counsellors*'; Co-Organiser of the workshop of the ESHG conference (2000) on '*Training of*

non-medical genetic counsellors in Europe'; Member of the Public and Professional Policy Committee of the ESHG; Member of the Educational Committee of ESHG.

Hugo De Man

Em. Prof. Dr. Hugo De Man was professor in electrical engineering at the Katholieke Universiteit Leuven, Belgium since 1976. In 1975, he was visiting associate professor at U.C.Berkeley teaching device physics and IC design. His early research was devoted to the development of mixed-signal, switched capacitor and DSP simulation tools as well as new topologies for high speed CMOS circuits.
He is cofounder of IMEC (Interuniversity Micro-electronics Center), where he was Vice-President from 1984-1995, in charge of design methods for DSP and telecom oriented chip architectures. Since then he is a Senior Research Fellow of IMEC, working on design methods for low power post-PC systems in nano-scale technologies.
The work of his research team at IMEC has lead to many novel tools and methods in the area of high level synthesis, hardware-software co-design and C++ based design now available through a number of spin-off companies.
In 1999 he received the Technical Achievement Award of the IEEE Signal Processing Society, The Phil Kaufman Award of the EDA Consortium and the Golden Jubilee Medal of the IEEE Circuits and Systems Society . In 2004 he received the lifetime achievement awards respectively of the European Design and Automation Association (EDAA) as well as the European Electronics Industry.
Hugo De Man is a Fellow of IEEE and a member of the Royal Academy of Sciences in Belgium.
Since October 2005 he is professor Emeritus of the Katholieke Universiteit Leuven.

Torsten Fleischer

Torsten Fleischer studied physics in Berlin. He was since 1991 Junior Researcher at the Department for Applied Systems Analysis, Nuclear Research Centre Karlsruhe. From 1995 to 2000 he was a staff member at the Office of Technology Assessment at the German Parliament, Bonn / Berlin and since 2000 he works as Senior Scientist at the Institute for Technology Assessment and Systems Analysis (ITAS), Research Centre Karlsruhe. Since 2003 he is the Project Coordinator Nanotechnologies at ITAS.
Research Interests: Technology Assessment and Innovation Research in the fields of Nanotechnologies / New Materials Technologies and Energy (currently involved in the TA Projects NanoHealth, Contecs, NanoCare and InnoMat). He is author / co-author of 4 Books and some 50 articles.

Helge Ritter

Prof. Dr. Helge J. Ritter studied physics and mathematics at the Universities of Bayreuth, Heidelberg and Munich. After his PhD. at TU Munich in 1988 and stays at the Helsinki University of Technology and the Beckman Institute for Advanced Science and Technology at Urbana-Champaign/Illinois, he moved to the University of Bielefeld where he became Full Professor in 1993. His main interests are principles of neural computation, in particular self-organizing and learning systems, and their application to machine vision, robot control, data analysis and interactive man-machine interfaces. In 1999, Helge Ritter was awarded the SEL Alcatel ResearchPrize and in 2001 the Leibniz Prize of the German Research Foundation DFG.

George Robillard

Prof. Dr. G. T. Robillard is an American citizen who has been working in the Netherlands since 1974. He spent three years at Princeton University and Bell Laboratories before joining the faculty of Mathematics and Natural Sciences at the University of Groningen. His research interests include the structure and function of membrane transport proteins and the design and use of bio-macromolecules in nanosystems. He has served as chairman of the Department of Chemistry and director of the Groningen Biomolecular Sciences and Biotechnology Institute. In 1999 he founded Biomade Technology Foundation, a research institute and, in 2000, co-founded Applied NanoSystems B.V., a Dutch Limited company. These organizations focus on nanotechnology research and commercialization, respectively. Honors include election to the Royal Netherlands Academy of Arts and Sciences.

Jean Paul Van Bendegem

Prof. Dr. Jean Paul Van Bendegem is full-time professor at the Vrije Universiteit Brussel and part-time professor at Ghent University. As mathematician and philosopher, he is responsible for courses in logic and philosophy of science. He is also the director of the Center for Logic and Philosophy of Science (http://www.vub.ac.be/CLWF) and he is editor of the logic journal '*Logique et Analyse*'. His research interests are logic, philosophy of mathematics, philosophy of science and the relations between science and society. At the present moment, he is also Dean of the Faculty of Arts and Philosophy at the VUB.

Rinie van Est

Rinie van Est is both a physicist and a political scientist. He works at the Rathenau Institute, the Dutch national technology assessment organisation, since 1997. His current function is trendcatcher science, technology and society. He also lectures Technology Assessment and Foresight at the Department of Technology Management at the Technical University Eindhoven. His recent Rathenau projects deal with nanotechnology, brain sciences, converging technologies, ambient intelligence in health care, digital generation and synthetic biology.

ANNEX 4:
LIST OF ATTENDANTS TO THE WORKSHOP

Editor: Robby Deboelpaep

Adang, Dirk	UCL/MOD
Aerts, Ann	University of Antwerp
Aitken, Katee	Cabinet Belgian Minister of Finance
Baum, Tomas	Vlaams Vredesinstituut
Beckert, Berno	FHG-ISI
Beel, Dirk	WERVEL
Berloznik, Robby	viWTA
Bibel, Wolfgang	University of Technology, Darmstadt
Boisen, Anja	MIC (Technical University of Denmark)
Bontoux, Laurent	EC, DG JRC
Bostrom, Nick	University of Oxford
Bruce, Donald	Church of Scotland, Society, Religion & Technology Project
Busquin, Philippe (MEP)	European Parliament
Chloupkova, Jarka	EP, DG IPOL, POL DEP A, STOA
Ciornei, Silvia	ALDE Group
Ciornei, Silvia (MEP)	European Parliament
Claessens, Stefaan	CD&V advisor
Coenen, Christopher	TAB-ITAS
Corbey, Dorette (MEP)	European Parliament
Coviello, Domenico	University Hospital of Milan
De Graeve, Johan	Vlaams Parlement
De Man, Hugo	KU Leuven, IMEC
Deboelpaep, Robby	viWTA
Dedulle, Michel	
Dossche, Francine	
Enzing, Christien	TNO Innovation Policy Group
Evers, Johan	KU Leuven, Centre for Science Technology and Ethics
Fleischer, Torsten	ITAS
Friedewald, Michael	FRAUNHOFER-ISI
Goorden, Lieve	University of Antwerp
Guidoni, Umberto (MEP)	European Parliament
Györffi, Myklos	EP, DG IPOL, POL DEP A, STOA
Harbour, Malcolm (MEP)	European Parliament
Hennen, Leo	ITAS
Hongenaert, Mark	Facilitator (for viWTA)
Hoffknecht, Roland	VOI Technology Center
Hullmann, Angela	EC DG Research
Karapiperis, Theo	EP, DG IPOL, POL DEP A, STOA
Keustermans, Luc	VMW
Kusstatscher, Sepp (MEP)	European Parliament
Larosse, Jan	EC DG RTD
Macsween, Hannah	Care for Europe
Maris, Ulrike	VITO
Melotte, Joseph	
Miklos, Anna	MEP assistant
Nolet, Lot	TU Delft
Prodi, Vittorio (MEP)	European Parliament
Quendt, Christiane	ITAS
Rader, Michael	ITAS
Ritter, Helge	University of Bielefeld
Staman, Jan	Rathenau
Steyaert, Stef	viWTA
Tarand, Andres (MEP)	European Parliament

Targa,Grazia	EC, DG JRC
Toxopeus, Paul	Student UR Wageningen
Van Bendegem, Jean Paul	Vrije Universiteit Brussel
van Est, Rinie	Rathenau
Van Oudheusden, Michiel	University of Antwerp
Van Rossum, Marc	IMEC
Vercauteren, Zeger	Johnson & Johnson
Vermeulen, Sabine	viWTA
Vernik, Jernes	MEP assistant
Walhout, Bart	Rathenau
Weiler, Raoul	Club of Rome
Wreford, Anita	MEP assistant
N., Andreas	MEP assistant