REPORT 2004

Nano-Bio-Info-Cogno-Socio-Anthro-Philo-

High Level Expert Group

"Foresighting the New Technology Wave"

Converging Technologies – Shaping the Future of European Societies

by Alfred Nordmann, Rapporteur

Report 2004

Geo-Eco-Urbo-Orbo-Macro-Micro-Nano-

Acknowledgments

The Chair, Rapporteur, and the members of the expert group wish to thank all the staff of the European Commission for their support during the group's work. Particular thanks go to Paraskevas Caracostas, Head of the Science and Technology Foresight Unit of Research Directorate General, Directorate K - Social Sciences and Humanities, Foresight. His tolerance and calm proved invaluable during all phases of the work.

We owe a tremendous debt of gratitude also to Elie Faroult and Mike Rogers of the Science and Technology Foresight Unit. Elie Faroult energised and stimulated the group's creativity. Mike Roger's diligence and persistent contribution advanced and sustained the group's work from beginning to end.

We also wish to thank numerous visitors from other Directorates and from the scientific community who shared their insights with us. Finally, thanks are due to the Norwegian Research Council for hosting the group in Oslo, and especially for organising a day of fruitful discussion.

The contents of this report are the sole responsibility of the working group, whose views do not necessarily reflect those of the European Commission.

Table of Contents

954413_bw 04-02-2005 10:10 Pagina 6

Executive Summary

The European Commission and Member States are called upon to recognise the novel potential of Converging Technologies (CTs) to advance the Lisbon Agenda. Wise investment in CTs stimulates science and technology research, strengthens economic competitiveness, and addresses the needs of European societies and their citizens. Preparatory action should be taken to implement CT as a thematic research priority, to develop *Converging Technologies for the European Knowledge Society (CTEKS)* as a specifically European approach to CTs, and to establish a *CTEKS* research community.

These are the major findings of the High Level Expert Group "Foresighting the New Technology Wave." The expert group was constituted in December 2003 and submitted its report in July 2004. The 25 members of the group – chaired by Kristine Bruland and with Alfred Nordmann as rapporteur – come from a variety of countries and disciplinary backgrounds. The group met formally four times (2-4 February, 14-15 April, 6-7 May, 16-17 June 2004). The report was prepared on the basis of the group's discussions, of individual written contributions by group members, of a scenario exercise, and of reports by four subgroups. Preliminary drafts of the final report were submitted to the group and discussed mainly at the June meeting.

The group was charged to explore in breadth the potential and the risks of CTs. It confronted a dual demand, namely

- to delineate areas of interest and fields of application for CTs, and
- to relate these CTs to the European environment and policy goals.

It met this demand by proposing a European approach to converging technologies: *CTEKS*: Converging Technologies for the European Knowledge Society.

The Challenge

Information and communication technology helped produce the profound transformation of daily life in the 20th Century. Biotechnology is transforming agriculture, medical diagnosis and treatment, human and animal reproduction. Most recently, the transformative potential of nanotechnology has captured the imagination. Add to this that cognitive and neuro-science are challenging how we think of ourselves, or that the rise of the social sciences parallels that of bureaucracies and modern forms of governance.

The convergence of these profoundly transformative technologies and technology-enabling sciences is the first major research initiative of the 21st Century. If these various technologies created controversy 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. In this challenge resides the opportunity for *CTEKS*.

Transformative potential

The expert group identified four likely characteristics of CT applications. Each of these presents an opportunity to solve societal problems, to benefit individuals, and to generate wealth. Each of these also poses threats to culture and tradition, to human integrity and autonomy, perhaps to political and economic stability.

• *Embeddedness:* CTs will form an invisible technical infrastructure for human action – analogous to the visible infrastructure provided by buildings and cities. The better they work, the less we will notice our dependence on them or even their presence. Over the last decades society has witnessed effects on the sense of reality and responsibility of those who are immersed in computer games, Internet surfing, and chatting. Once all of us are living continuously in the pervasively artificial environment of ambient computing, smart materials and ubiquitous sensing, society will be confronted with far more frequent and deep transformations of people's and groups' self-understanding.

• *Unlimited Reach:* Nanotechnology's dream to control everything molecular follows upon information technology's increasing ability to transform everything into information. As the convergence draws in other technologies and technology-enabling sciences, it would appear that nothing can escape the reach of CTs and that the mind, social interactions, communication, and emotional states can all be engineered. This promise is productive and dangerous at once. One can expect that for every problem, someone may propose a more or less creative, viable or desirable technological fix. However, complacency induced by the fix-all potential of technology could be dangerous in the extreme.

• *Engineering the Mind and the Body:* Some proponents of CTs advocate engineering of the mind and of the body. Electronic implants and physical modifications are to enhance our current human capacities. The expert group proposes that CT research should focus on engineering for the mind and for the body. Changes to the cognitive environment or medical self-monitoring can improve decision-making and health. Either way, humans may end up surrendering more and more of their freedom and responsibility to a mechanical world that acts for them.

• *Specificity:* Research on the interface between nano- and biotechnology allows for the targeted delivery of designer pharmaceuticals that are tailored to an individual's genome in order to effect a cure without side effects. More generally, the convergence of enabling technologies and technology-enabling sciences can be geared to address very specific tasks. Reliance on highly specific solutions can also have an unsettling effect, however. The invisibility of CTs raises questions as to their absence or presence. This is equally troubling when they are needed to sustain a specific action and when one does not know whether, like computer viruses, they might appear any time and attack a delicate technical system or organism at some unknown place. Even when they work as reliably and successfully as one could wish, CTs may have a socially destabilising effect as economic efficiency produces greater unemployment, as targeted medical treatments increase longevity, as CTs exacerbate the divide between the rich and the poor, between technologically advanced and traditional cultures.

Tremendous transformative potential comes with tremendous anxieties. These anxieties need to be taken into account. When they are, converging technologies can develop in a supportive climate. To the extent that public concerns are included in the process, researchers and investors can proceed without fear of finding their work over-regulated or rejected.

CTEKS

Converging technologies converge towards a common goal. CTs always involve an element of agenda-setting. Because of this, converging technologies are particularly open to the deliberate inclusion of public and policy concerns. Deliberate agenda-setting for CTs can therefore be used to advance strategic objectives such as the Lisbon Agenda.

Agendas for convergence include "Converging Technologies for improving human performance" or "Converging Technologies for battlefield domination." The expert group does not recommend there or any one such agenda. By proposing "Converging Technologies for the European Knowledge Society (*CTEKS*)," it places the emphasis on the agenda-setting process itself. It envisions that various European CT research programs will be formulated, each addressing a different problem and each bringing together different technologies and technology-enabling sciences. These might include "CTs for natural language processing," "CTs for the treatment of obesity," or "CTs for intelligent dwelling."

CTEKS agenda-setting is not top-down but integrated into the creative technology development process. Beginning with scientific interest and technological expertise it works from the inside out in close collaboration with the social and human sciences and multiple stakeholders through the proposed WiCC initiative ("Widening the Circles of Convergence"). For the same reason, ethical and social considerations are not external and purely reactive but through the proposed EuroSpecs process bring awareness to CT research and development.

Agenda-setting for CT research is a research policy tool that along with the research programs can create a climate of investor and consumer confidence. It also supports the research community be exercising a catalytic effect and focusing creative energy. It invests research and development of science and technology with social imagination by providing a broader vision.

Recommendations

The expert group offers 16 recommendations.

Converging Technologies (CTs) present equally significant opportunities and challenges. CTs converge on common goals or shared visions, and first among the opportunities and challenges is the formulation of such goals. "Converging Technologies for the European Knowledge Society (*CTEKS*)" designates the European approach to CTs. It foregrounds the process of deliberate and creative agenda-setting for CT research.

Establishing CTEKS: Vision and strategy

1. That the European Commission implement the WiCC-initiative ("Widening the Circles of Convergence") in order to create a *CTEKS* research community, in the first instance by establishing a coordinating WiCC office.
2. That the Commission now integrate a CT dimension in FP6 programme calls (in particular in the thematic priorities of nanotechnology, life sciences, information technologies, social sciences and humanities).
3. Member States are encouraged to promote the *CTEKS* process by launching prototype CT research initiatives through national foresighting activities and funding programs.
4. In the context of the seventh EU framework programme for research, Member States should be invited to participate in a European Competition for Centres of *CTEKS* Excellence; the European Research Council should provide visiting fellowships at the Centres.

Harnessing the Dynamics of Convergence: New research agendas

5. Interdisciplinarity should be strengthened, beyond planned or institutional collaboration, in program calls and research policies from the Commission and from the European nations.
6. The Commission and Member States should expand and deepen their commitment to Cognitive Science.
7. Commission and Member States need to recognise and support the contributions of the social sciences and humanities in relation to CTs, with commitments especially to evolutionary anthropology, the economics of technological research and development, foresight methodologies and philosophy.

Developing a framework for CTEKS: The research and support environment

8. A permanent societal observatory should be established for real-time monitoring and assessment of international CT research, including *CTEKS*.
9. That the Commission implement a "EuroSpecs" research process for the development of European design specifications for converging technologies, dealing with normative issues in preparation of an international "code of good conduct."
10. The integration of social research into CT development should be promoted through Begleitforschung ("accompanying research" alongside science and technology R&D).

Dealing with CTEKS: Ethics and social empowerment

11. That a strict line be maintained between military ambitions for CTs and their development in Europe.
12. Upon advice from the European Group on Ethics (EGE), the mandate for the ethical review of European research proposals should be expanded to include ethical and social dimensions of CTs. Funding organisations in Member States are asked to take similar steps.
13. In the face of new models for participatory research governance, transparent decision making processes need to be developed and implemented.
14. The question of intellectual property rights must be addressed proactively and on an international level.
15. Member and Associated States are encouraged to stimulate national discussions of CTs and the *CTEKS* perspective.
16. CT modules should be introduced at secondary and higher education levels to synergise disciplinary perspectives and to foster interaction between liberal arts and the sciences.

1. Introduction

The challenge

The stage has been set for "Converging Technologies" (CTs). Information and communication technology, biotechnology, and nanotechnology are among the last major technology initiatives of the 20th century. Information technology prepared the ground for the computer, cell-phones, and the internet. Biotechnological developments gave us in-vitro fertilisation, genetic screening, more targeted pharmaceuticals and genetically modified crops. Nanotechnology researchers manipulate individual atoms, develop improved materials and aim to miniaturise just about everything.

The first major research initiative of the 21st century is the convergence of these enabling technologies. Info-, bio-, and nanotechnologies complement each other and have begun to join forces with cognitive science, social psychology and other social sciences. This convergence promises to transform every aspect of life.

- Nanotechnology opens the door to engineering at the molecular level. For example, the molecules of a nerve-cell can be combined with those of an artificial sensor in order to restore vision in certain cases of blindness.
- Another convergent technology might use biological substrates as in DNA chips for the diagnosis of personal or environmental health.
- Social science research can guide ambient computing in such a way that human users will more quickly acquire information about the spaces and situations in which they move and act.

To the extent that CTs participate in the continuing trend towards miniaturisation, they will blend into the environment and become pervasive. To the extent that they interact with one another, they can form an invisible technical infrastructure for human action – analogous to the visible infrastructure provided by buildings and cities. Such an artificial environment holds the promise for greater and more equal access to knowledge and information, new therapeutic interventions, improved environmental monitoring, greater safety and security, expanded communicative capacities.

However, the potential benefits of this convergence come with a variety of risks. These could include adverse health effects from novel materials and devices, invasions of privacy, social disruption resulting from profound transformations of work and leisure, the displacement of nature as we know it by an artificial environment, and damage to human integrity, autonomy, and morality. Accordingly, early responses to a CT initiative in the United States raised alarms about transhumanist ambitions to "improve human performance" by turning humans into machines.

The stage has also been set for "Converging Technologies" by European policy makers. European industrial policy calls for an integration of research efforts in the highly competitive sectors of information and communication technologies, biotechnology and nanotechnology, aeronautics and hydrogen energy technology.[1] European science policy demands a substantially increased investment in nanotechnology so that it can focus on its two "most challenging aspects, in particular, knowledge-based industrial innovation ('nano-manufacturing'), integration at the macro-micro-nano interface and interdisciplinary ('converging') R&D."[2]

(1) "Communication from the Commission: Science and Technology, the key to Europe's future – Guidelines for future European Union policy to support research" COM (2004) 353, sec 1.2., prop. 5, p. 2

(2) "Communication from the Commission: Towards a European strategy for Nanotechnology," COM (2004) 338, section 3.1.1., p. 10

Starting the discussion

Three excerpts from *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science – NSF/DOC-sponsored report* (2002):

"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 interactions between people. [...] 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 process." (p. 5)

"In some areas of human life, old customs and ethics will persist, but it is difficult to predict which realms of action and experience these will be. Perhaps wholly new ethical principles will govern in areas of radical technological advance, such as the acceptance of brain implants, the role of robots in human society, and the ambiguity of death in an era of increasing experimentation with cloning." (p. 22).

"A new bandwidth sense might be called a Giant UpLoad Process or the GULP sense. Imagine a sixth sense that would allow us to take a book and gulp it down, so that the information in the book was suddenly part of our wetware ready for inferencing, reference, etc., with some residual sense of the whole as part of the gulp experience. [...] The process of creating new sensory organs that work in tandem with our brains is truly in a nascent state, though the cochlear implant and retinal implant directions seem promising." (p. 95f.)

Formation and Charge of the Expert Group

The European Commission first drew attention to CTs in the June 2003 issue of the *Foresighting* Europe newsletter. It featured a report about two "NBIC" (Nano-, Bio-, Info-, Cogno-) conferences in the US that considered *Converging Technologies for the Improvement of Human Performance*. The newsletter's editorial continued:

"In order to deal with the questions developed in the US NBIC report, the Commission envisages the establishment of a high level expert group on Converging Technologies."[3]

After exploratory meetings in September and December 2003, that high level expert group (HLEG) on "Foresighting the New Technology Wave" was constituted. The group met formally four times (2-4 February, 14-15 April, 6-7 May, 16-17 June).

The expert group was charged with exploring in breadth the potential and the risks of CTs. Rather than develop merely a European answer to the US report, the expert group had to consider also the specific limitations of previous approaches to NBIC convergence. It therefore confronted a dual demand, namely

- to delineate areas of interest and fields of application for CTs, and
- to relate these CTs to the European environment and policy goals.

This demand was formulated already in the June 2003 newsletter. It suggested that the expert group could aim at "improving the understanding of human knowledge and cognition at large" and that it should also help Europe to anticipate issues and reap the considerable benefits of NBIC convergence. The group met this demand by placing CTs in the larger context of the Lisbon strategy for an ageing and diverse European knowledge society committed to just and sustainable living patterns. It developed an expanded vision of convergence, broadly captured in the acronym "*CTEKS*: **Converging Technologies for the European Knowledge Society."**

(3) *Foresighting* Europe, June 2003, issue 2 of the Newsletter of the Science and Technology Foresight Unit, European Commission, Directorate-General for Research, p. 2-4.

The expert group's report shows how this expanded vision can serve to shape research and development (R&D) in the context of the Lisbon strategy. *The aim of the report is to provide advice to the Commission and Member States on the opportunities and challenges presented by the convergence of key enabling technologies*. In a highly competitive global environment, early recognition of these opportunities and challenges allows Europe to invest wisely in converging technologies R&D and to develop economic strengths that harmonise with the values of diversity, social justice, international security, and environmental responsibility.

The Work of the Expert Group

The expert group began by identifying the European dimension regarding the creation and diffusion of new technologies, in general, and CTs, in particular. For this, it drew on an historical understanding of the social dynamics of innovation processes. It also developed four scenarios for Europe in 2020 in order to discover robust areas of interest for converging technologies R&D. Throughout, the group aimed to clarify the civil and societal benefits of CT research and to place it in the context of positive social dynamics. Its work was oriented by ten guiding principles which included commitments to realism, integrated assumptions, ethics and sustainability.[4]

The wide range of concerns which seem likely to arise in the process of developing CTs were reflected in the composition of the expert group and in its work. Its breadth of expertise included the bio-, nano-, information and cognitive sciences, nano-, bio- and information technologies, economics and innovation studies, history and philosophy of science and technology, the study of ethical, legal, and social aspects, education, technology assessment and science policy. One of the group's findings is that converging technologies R&D requires a broad interdisciplinary setting for its effective and beneficial diffusion. The group experienced first hand the difficulties and rewards of the envisioned task as it learned to take the first steps towards such interdisciplinarity itself.

More significantly, the discussions within the expert group foreshadowed future public debates of CTs. Do the various risks outweigh the benefits of CTs? Is prudent foresight adequate to address troubling metaphysical uncertainties? In light of porous borders and international markets, can European citizens proactively shape CTs? Such questions cannot be answered at the outset of a technological development. Confident that the continuation of these debates is integral to and productive for the development of CTs, this report nevertheless emphasises the opportunities of CT research for Europe.

Other issues for ongoing debate concern the scope of relevant CTs and the proper role of social scientists or philosophers in the development of European CT research. How credible are certain predictions about the state of technology in 2020? Will nanotechnology prove to be essential to CT research? Can the social and natural sciences come together in the formulation and evaluation of research programs? Regarding these questions, too, only time can provide the answers. For the time being, the expert group adopted a proactive stance that does not foreclose future debate.

The report's aim to outline the opportunities and challenges of CTs has to be distinguished from a study of their impacts. This report is not focused on existing or imminent products and processes that will impact European societies in one way or another. Instead, it considers CTs in terms of their specific potential to generate in the medium and long term new kinds of technological applications. Though it is too early to speak of their likely impacts, it is not too early to consider how the creative development of CTs might address and solve societal problems, how they can build on existing strengths in Europe, orient themselves to social and environmental needs and prompt ethical debate. It is also not too early to assess the promises that are made on behalf of CTs and to address concerns regarding their risks.

(4) See the expert group's mandate (Terms of Reference), pp. 56 and below.

Whatever the present limits of knowledge may be, this much is for sure: Daily life in the future of European societies will be shaped by convergent technologies.

CTs will help transform social interactions among European citizens, the economic base of their livelihood, systems of health care, patterns of ageing, urban life, modes of political participation. This report shows that, more so than isolated trajectories of technological development, their convergence requires deliberate agenda-setting. In other words, how the technologies come to converge and how this convergence will subsequently shape the future of European societies, is itself a matter of shaping.

The Expert Group's Report

This report was prepared by the rapporteur on the basis of the group's discussions, of individual written contributions by group members, of the group's scenario exercise, and of reports by four subgroups.[5] Preliminary drafts of the final report were submitted to the group and discussed mainly at the June meeting.

- Part 1 arrives at a definition of Converging Technologies for the European Knowledge Society (*CTEKS*), contrasts it to other visions and definitions of technological convergence, and identifies general characteristics of likely CT applications.
- Part 2 considers within the context of European policies and needs the economic opportunities, disruptive potential and risks of *CTEKS*.
- Part 3 addresses the challenges and opportunities of *CTEKS* by recommending specific actions for Europe today.

The Conclusion summarises the challenges of CTs and offers 16 recommendations for immediate action in the context of a medium-term strategy.

(5) The separate reports by the expert group's four Special Interest Groups (SIGs) consider CTs under the headings "Quality of Life," "Ethical, Legal and Societal Aspects of the Converging Technologies," "New Technology Wave: The Transformational Effect of NBIC Technologies on the Economy," and "Converging Technologies and the Natural, Social and Cultural World."

Part 1

From CTs to *CTEKS* – Areas of Interest and Fields of Application

The Expert Group defines CTs as "enabling technologies and knowledge systems that enable each other in the pursuit of a common goal." *CTEKS* are introduced as a European approach to CTs. This approach focuses on the need to set agendas or common goals for convergence. In this part of the report, these concepts are explained along with the opportunities, limits, and likely characteristics of CTs.

1. A Brief History of Converging Technologies

The term "convergence" is broad and appealing enough to be applied in many ways to science and technology. Biochemistry, molecular biology, evolutionary medicine, computational linguistics, cognitive psychology, mechatronics can all be regarded as the result of the convergence of previously separate disciplines and domains. In the area of information technology, "convergence" is usually used to designate multi-functionality as the telephone, display screen, computer, internet access, and video camera all merge into a single device. Journalists speak of convergence when a single editorial process integrates print, broadcast, and Internet publication. Historians of technology refer to convergence when technological progress converges with social change over time. In regard to the disciplinary development of science and technology, convergence sometimes refers to a merging of concepts from different systems of knowledge, sometimes to the unification of previously separate domains of inquiry, sometimes to shared practices and devices, and sometimes to a common goal that is approached from different directions.

In recent years, the term "converging technologies" has taken on a new, specific meaning through nanotechnology and the subsequent formulation of "NBIC convergence." The field of nanotechnology can be said to bring about, by itself, a convergence of domains. It is common knowledge, after all, that all material things are made out of atoms and molecules. Nanotechnology enables one to engineer at the nanoscale and thereby perhaps to reconfigure everything molecular. From the point of view of nanotechnology, what used to be separate domains of biomedicine, information technology, chemistry, photonics, electronics, robotics, and materials science come together in a single engineering paradigm.

However, this unification of domains has not been called convergent and is not the sense in which we are here concerned with CTs. When referring to the potential of nanotechnology one speaks of it instead as a key or *enabling technology.*

An enabling technology enables technological development on a broad front. It is not dedicated to a specific goal or limited to a particular set of applications. If nanotechnology is an enabling technology, so are information technology and biotechnology. One can also speak of enabling knowledge systems or technology-enabling scientific knowledge.

For example, the social and cognitive sciences have accrued considerable knowledge about social interactions, effective communication, etc. To the extent that this scientific knowledge is implementable in engineered systems, it can also enable far-reaching technological developments. An important step in the history of CTs was the realisation that, aside from nanotechnology, there are other enabling technologies and knowledge systems that are open to new R&D challenges and ready to enable one another.

Two examples of CT research today

Within the general program of "Converging technologies for improving human performance," research at the **MIT Institute for Soldier Nanotechnology** has received particular, perhaps undue attention:

The ISN was founded in March 2002 and involves 44 MIT-professors in its work. Its mission is to pursue a long-range vision for how technology can make soldiers less vulnerable to enemy and environmental threats. The ultimate goal is to create a 21st century battlesuit that combines high-tech capabilities with light weight and comfort. Bioengineering, robotics, and nanotechnology converge to develop an exoskeleton. Like a second layer of armored skin, it supports the body's metabolic exchange with the environment while adding muscular strength and protection against incoming bullets. Researchers at the ISN are encouraged to explore civilian applications.

Within the EU's "Nano2Life" Network of Excellence, researchers at Lund University in Sweden are pursuing the **Artificial Hand Project:**

The aim is to develop brain-controlled hand prostheses. This involves strategies for motor control based on electrical signals generated from multiple muscle electrodes or microchips implanted in the peripheral or central nervous system. In first experiments, patients have learned to control a virtual hand through brain signals. Functional hand prostheses also involve artificial sensibility. Integrated sensors collect information about surface textures which is then translated into brain stimuli. Researchers on this project come from the Departments of Electrical Measurements, Hand Surgery, Physiological Sciences, Solid State Physics, and Cognitive Science. Similar projects are pursued at research institutions in Europe, the US, and Japan.

This meaning of "converging technologies" was established in a December 2001 workshop organised by the US National Science Foundation and Department of Commerce.

- The title of the published workshop report suggests that converging technologies enable each other in the pursuit of a common goal: "Converging Technologies for Improving Human Performance – Nanotechnology, Biotechnology, Information Technology and Cognitive Science."[6]
- A science and technology foresight report for the Canadian National Research Council soon followed the same pattern: Converging technologies for bio-health, eco and food system integrity and disease mitigation – nanotechnology, ecological science, biotechnology, information technology and cognitive sciences.[7]
- A third example was suggested by a Norwegian researcher. It repeats the pattern: "Converging technologies for salmon-productive aquatic environments – bioinformatics, environmental science, systems theory, salmon genomics, production biology, economics."[8]
- More examples of CT research were considered by the expert group. These include "Converging technologies for natural language processing – information and nanotechnology, linguistics, cognitive and social science," "Converging technologies for the treatment of obesity," and "Converging technologies for intelligent dwelling."

All these CTs agendas provide a list of enabling technologies and technology-enabling sciences, stating that these are converging technologies for the achievement of a more or less general goal. This shared pattern suggests the working definition of "Converging Technologies" that was adopted by the expert group.

(6) Mihail Roco and William Bainbridge, eds., Arlington, June 2002.
(7) Raymond Bouchard, Bio-Systemics Synthesis; Science and Technology Foresight Pilot Project, Canadian National Research Council, June 2003, p. 8.
(8) In his presentation at the Norwegian Research Council, May 5 2004, Stig Omholt (Agricultural University of Norway) proposed a somewhat more general CT research agenda: "Converging technologies for a new production biology to revert world-wide habitat fragmentation and loss of biodiversity on land and at sea."

2. The Definition of Converging Technologies (CTS)

Converging technologies are enabling technologies and knowledge systems that enable each other in the pursuit of a common goal.[9] This definition captures the scientific and technical potential of CTs and suggests opportunities for European R&D. This first and the second part of this report outline some of these opportunities. At the same time, the definition asks to be specified through science policy and particular R&D initiatives: What goals should be set for enabling technologies and knowledge systems to converge upon? The second and third part of the report will address this question by placing it in the larger societal context of CT research in Europe.

In the case of nanotechnology, biotechnology, and information technology, it is particularly easy to see how these enabling technologies enable each other:

- Conceptually, *nanotechnology* enables other technologies by providing a common framework for all hardware-level engineering problems. Everything that consists of molecules can, in principle, be integrated with each other. An understanding of properties at the nanoscale allows for the realisation of desirable architectures at the micro- and macroscale. Instrumentally, nanotechnology enables biotechnology by developing new imaging techniques, probes and sensors.
  It contributes to the miniaturisation demands of information technology. Also, nano-chips and nano-sensors are set to enable advances in the new world of bioinformatics.
- Conceptually, *biotechnology* enables other technologies by identifying chemical-physical processes and algorithmic structures in living systems that are traced to their material basis in cellular and genetic organisation. Instrumentally, biotechnology enables nanotechnology by providing mechanisms of cellular recognition and targeted transport. It promises to enable information technology by developing, for example, the foundations for DNA-based computing. Also, bio-mimetics and the investigation of cellular motors can enable nano-info R&D in nano-robotics.
- Conceptually, *information technology* enables other technologies through its ability to represent ever more physical states as information and model processes with a variety of computational methods. Instrumentally, information technology provides the computing power which is essential to the research process in all technical disciplines. It enables nanotechnology through precision control of patterning and intervention. It enables biotechnology by providing the means to model complex processes and thereby solve difficult research problems. Also, simulation software can enable nano-bio R&D in environmental monitoring.
  This list of enabling technologies and knowledge systems that enable each other can be expanded by including cognitive science, environmental science, systems theory, and social science, including philosophy, economics and the law.
- Conceptually, the *social sciences* and *humanities* can enable science and technology in a variety of ways. Familiar examples include game-theoretical strategies for maximising benefit and minimising cost, models for the representation of economic and other forms of exchange, patterns of gestalt recognition in human perception or by machine intelligence, semiotics as a general theory of humanly and naturally produced signs, etc. Instrumentally, they offer techniques of probabilistic reasoning and statistical inference, methodologies for qualitative research, or an understanding of the social dynamics of the creation and diffusion of technological innovation. Economics and the law enable technology R&D by shaping the incentive structure for its support and diffusion. Philosophy, cultural studies, and ethics provide orientation where new technologies disrupt traditional ways of life. And of course, without an understanding of society, it is all too easy for a technology to be launched improperly and subsequently rejected by society.

(9) Note that the term "(enabling) knowledge system" can be replaced everywhere by "technology-enabling scientific knowledge."

3. Limits of Convergence

The definition of CTs as enabling technologies and knowledge systems that enable each other suggests that their potential is unlimited. This impression is underscored by the addition of further science and engineering disciplines, even the social sciences and humanities, where each appears to expand the power of the others.

A limit of knowledge: the future of the health care system

CTs may prepare the ground for a revolution of the health care system: Lab-on-a-chip technology will be used to instantly and anywhere obtain thousands of measurements of one's current state of health. Such self-monitoring produces not only an immediate diagnosis of one's current state of health, but issues suggestions as to what one should do to improve it – whether to cut down on eating fats for a week, take a brisk walk, or have two oranges. CTs will enable individuals with physical as well as psychological problems to be quickly identified, and courses of treatment tailored to relate to their genome and severity of the illness. Simple depression will be treated by one-to-one counselling between the patient and a suitably programmed, highly sophisticated 'talking head,' that provides 'personal contact' – listening and responding intelligently and supportively to the patient's needs on an ongoing basis. Hospitals will be needed only for the treatment of traumatic injuries and where invasive surgery has not been replaced yet.

Perhaps, this advance of medical technology will end up aggravating the notoriously elusive social causes of physical well-being. The health care system represents not just a curative setting but is also an important social institution. This institution offers personal attention and public recognition to people in need, some of whom may be sick in part because they lack such attention or recognition. Self-monitoring may also open a negative feedback- loop that amplifies anxieties and obsessions. Since anxieties can have measurable effects on physical variables, these may be reenforced for individuals who constantly monitor themselves for changes in their state of health.

Or perhaps, this advance of medical technology will succeed where the present system of health care falls short. CTs can meet social needs more successfully through virtual reality physicians who can spend unlimited time listening and talking to their patients, soothing their anxieties and obsessions.

The very broadness of this promise creates problems of its own. Nanotechnology and cognitive science, information technology and the social sciences are therefore needed not only to enable each other but also to inform each other about present and in-principle limits of convergence.

- CTs create a new challenge for the allocation of R&D resources. Arguably, the dilemma of S&Tdecision-making has never been as dramatic as in the case of CTs. Decisions on rapidly evolving research will have to be taken, if only because of related efforts in the United States, Japan, and elsewhere. Whether for the sake of competitiveness or for the protection and benefit of European citizens, research administrations will have to dedicate substantial resources to research initiatives that cannot yet be expressed in the standard form of work programs. Only an understanding of the medium- and long-term feasibility and limitations of CTs that promise great social benefits and high marketability can justify the allocation of public funds.
- CTs can be used to advance the goal of sustainable development. By the same token, they may over-promote faith in an all-powerful technological fix. It might be thought that consumption and harmful emissions may not have to be curbed if CTs can reduce overall environment stresses. Since complacency induced by the fix-all potential of technology could be dangerous in the extreme, sound environmental policy requires an awareness especially of present and medium-term technical limits.

- The limits of CT research need to be assessed in order to frame perceptions of risk. Nanotechnology's promise to harness physical self-organisation and to make materials with novel properties has led at least one reinsurance company to question the insurability, for example, of nanoparticles.[10] It appears that genuine novelty can be attained through complex processes of self-organisation only if the control of researchers is relaxed and if the novel properties are truly unknown.

  However, genuinely unknown novel properties may obviously pose unknown dangers.

To the extent that CT researchers really set out to produce unpredictabilities, their research must be monitored and constrained accordingly. Here, philosophers of science are called upon to study the limits of the CT research process. They can investigate to what extent scientists and engineers actually draw on theories of complexity and self-organisation and whether these theories can be technically useful for creating genuine novelty.

A limit to knowledge: the future of enhancements

CT visionaries and their critics tend to assume not only that brain implants to enhance mental capacities are technically feasible. They also make assumptions about their diffusion: Since such enhancements provide an advantage over non-enhanced humans, everyone will want or need them. The following science fiction story is meant to illustrate just how questionable such assumptions are.

Brain-implants have finally become commercially available. Animal tests have shown that they are safe, controversial tests with volunteers among the military have proved that they can work. These implants give the user access to a wealth of information and can be customised to include data-bases of expert knowledge. Demand is high for this long-anticipated consumer product. But after the first two years, troubling statistics emerge: 5% of implants don't appear to work at all (the user somehow never learns to access them), another 5% of users lose access to the implant within the first three months of use. The rest of users evenly divides into 2 groups, those who can access the implant on the fly while performing other mental operations, and those who close their eyes or must otherwise take time out to concentrate in order to access the information. Also, a small percentage of users suffers irreversible brain damage or goes mad.

Several years before the implant became commercially viable, another technology entered the market: A voice-addressable wrist-band device that provides all the same services.

Consequently, the brain-implants fail as consumer products, leaving manufacturing and stock-holders disappointed.

- While it is possible to invent, manufacture, and fit an artificial leg with little understanding of anatomy, physiology and the dynamics of walking, this would obviously amount to a dramatic technical and economic failure. Similarly, some visions for NBIC convergence imagine cognitive enhancements while underestimating the complexity of cognitive processes. CT research must therefore include a study of current limits. In order to avoid bad public investments, cognitive science research is needed for an assessment of how it can most usefully enable specific nano-, micro- or bio- technologies.
- To the extent that CT engineering is done from the bottom up in the nano-, micro- or bio-domains it is presupposed that the problems can be resolved at their physical basis. This approach is limited by problems that have no physical properties. Arguably, cognition, questions of meaning, patterns of social interaction and emotional response derive from socialisation rather than physical facts. Thus, the true extent to which illness and disease have social, perhaps psychosomatic origins may only become apparent when complete medical self-monitoring CTs give the patient a clean bill of physical health and thereby make him or her feel more poorly still.

(10) Swiss Reinsurance Company "Nanotechnology - Small Matter, Many Unknowns" (2004).

Defining the terms

"Enabling technologies" prepare the ground for a wide variety of technical solutions. Because they unlock vast potential and open the door to radically novel technological developments, they are also referred to as "key technologies." Nanotechnology is a prominent enabling technology. Biotechnology and information technology are also enabling, as is the knowledge base of cognitive, social, and other sciences.

"Converging Technologies (CTs)" refers to the convergence on a common goal by insights and techniques of basic science and technology: CTs are enabling technologies and scientific knowledge systems that enable each other for the achievement of a shared aim. Singly or together, NBIC-technologies (nano, bio, info, cogno) are likely to contribute to such convergence.

"NBIC-convergence for Improving Human Performance" is the name of a prominent agenda for CT research in the US. "Bio-Systemics Synthesis" suggests another agenda for CT research that was developed in Canada.

"Converging Technologies for the European Knowledge Society (*CTEKS*)" designates the European approach to CTs. It prioritises the setting of a particular goal for CT research. This presents challenges and opportunities for research and governance alike, allowing for an integration of technological potential, recognition of limits, European needs, economic opportunities, and scientific interests.

- The broadly transformative potential of CTs sets limits to their public acceptance. The pace of the diffusion of new technologies is constrained by the pace in which societies accept and, if so, accommodate them. Here the social sciences and humanities are needed to inform and accompany CT research and to serve as intermediaries. They should create settings within which science and technology researchers on the one hand and their various publics on the other, can learn from each other.

Nanotechnology and cognitive science, information technology and philosophy, biotechnology and the social sciences need to work together when the prospects, including near- and medium-term limits of proposed CT research programs are determined.

4. Element of a European Approach: *CTEKS*

A European approach to CTs needs to be informed by an awareness of their potential and limits. It acknowledges nano-, bio- and info- as key enabling technologies but recognises that only careful agenda-setting can bring them together in viable and socially beneficial convergent research. "Converging Technologies for the European Knowledge Society" or *CTEKS* exploit the potential of nano-, bio-, and information technologies. They also include

- the social sciences and humanities, and other enabling technologies and knowledge systems,
- explicit awareness and study of limits, for example, with respect to cognition,
- an orientation towards common goals that are formulated within a European policy framework of public process and shared values.

More so than in the case of nanotechnology, it is extremely difficult to obtain data about numbers of self-described CT researchers, CT patents and research projects, or international and European funding levels.

In the case of nanotechnology this is largely due to its partial overlap with chemistry, materials science, biology, and physics research. A major incentive for researchers to identify themselves as nanoscale researchers is provided by funding-opportunities. *CTEKS* require a more meaningful mechanism for the constitution of research communities.

Such as a mechanism for "Widening the Circles of Convergence" (the WiCC initiative) will be proposed in Part 3 of this report. According to this proposal, selected researchers will brainstorm at several seed workshops CT goals in target areas such as health, education, infrastructure, energy, or environment. They will generate calls for abstracts and lists of invitees for *CTEKS* conferences that are organised around specific themes. Each conference, in turn, will conclude with workshop sessions for the development of prototype funding proposals and partnering arrangements. A WiCC office should co-ordinate the effort, establish and maintain a directory of associated researchers, *CTEKS* projects, and institutional resources. Expanding on the EU's "technology platforms" on photo-voltaics, AIDS research or nanoelectronics, WiCC initiatives and resulting *CTEKS* programs will bring together a variety of public and private stakeholders, they will integrate social scientists and ethicists.[11]

5. General Characteristics of likely CT Applications

The novel and specific character of "converging technologies" opens up a wide space for technological development. Just as some CTs are rooted in the nanoscale and others are not, the resulting technical applications do not all share the same defining features. Yet, the mutually enabling technologies or knowledge systems favor particular technological opportunities. These suggest the following list of likely features of CT applications, regardless of whether they originate within the European context (*CTEKS*) or elsewhere. Part 2 of this report will take this list as a template and show how each of these characteristics is associated with certain opportunities but then also with risks.

- *Embeddedness:* In contrast to distinct technical devices or products in the classical sense, CTs can be spatially distributed, pervasive and inconspicuous. They will blend into and perhaps structure the background of human action in work, leisure, health-care, mobility, and communication. This accentuates and exploits the trends towards miniaturisation in information technology, towards molecular engineering in nanotechnoloy, towards gene specific targeting in biotechnology. CTs may thus involve smaller medical implants and devices, 'invisible' sensors, or pervasive and unobtrusive imaging and communications technologies, but our experience of these will be as part of our existence along the lines of climate-controlled buildings or the electric grid: The better they work, the less we will notice our dependence on them or even their presence. Rather than produce artefacts for import into the natural environment (first nature), CTs further the production of an artificial environment.

This second nature challenges traditional boundaries between nature and culture. It makes first nature inaccessible except through a humanly conditioned second nature. It dramatically alters our sense of responsibility for the world we live and act in: This responsibility loses the character of care for a nature that needs to be preserved; instead, it turns ever more into accountability for our temporarily created surroundings.

- *Unlimited reach:* Even when accompanied by the study of its limits, CT serves to expand the engineering paradigm into areas that were thought to be immune to engineering. When "social engineering" and behaviorist technologies were proposed, these were not thought of as materially designed engineering solutions that physically interface with social and cognitive processes.

  Following upon nanotechnology's dream to control everything molecular and information technology's increasing ability to transform everything into information, it would appear that nothing can escape the reach of CTs and that the mind, social interactions, communication, and emotional states can all be engineered. This powerful heuristic of CTs will prove productive even if it is or should be realised to a small extent only. One can expect that for every problem, someone may propose a more or less creative, viable or desirable technological fix.

(11) Regarding the proposed technology platform for nanoelectronics see "Vision 2020: Nanoelectronics at the Centre of Change," EC, Report of the High Level Group, June 2004.

- *Engineering the mind and the body:* In regard to mind and body, there are fundamentally different approaches to CTs. One involves a commitment to hard-wired technology, whether this hard-wiring is implemented at the level of molecular design, traditional microscale engineering, or bio-chemical regularity such as DNA-replication. Especially as it regards the engineering of mental capacities and cognitive processes, it goes beyond the already familiar chemical or pharmaceutical interventions that may dampen or enhance neural activity but do not interfere lastingly with the brain's architecture. In contrast to this "*engineering of the mind*," the second approach recommends the heuristic of "*engineering for the mind*." Video games can impact cognitive capacities. CTs may exploit this causal pathway by creating new tools that change how information is accessed and processed. These new tools may then lead to the formation of new cognitive processes at the organisational or individual level. The hardware and the software approach therefore have in common that the mind will be an explicit or implicit design target of converging technologies. – An analogous contrast arises between "*engineering of the body*" and "*engineering for the body*." Again, whether through the pathway of hardwiring or of changes in the systems of self-monitoring, diagnosis, and health-care delivery, the body will be an explicit or implicit target of converging technologies.
- *Specificity:* Research on the interface between nano- and biotechnology is producing instruments for molecular, cellular, and genomic recognition along with much improved and highly specific sensors. This might enable, for example, the targeted delivery of designer pharmaceuticals that are tailored to an individual's genome in order to effect a cure without side effects. More generally, the convergence of enabling technologies and knowledge systems can be geared to address very specific tasks. At the same time, very specific and local constellations of expertise in a variety of contributing disciplines may yield a unique possibility to unite them in the pursuit of a common goal.

Part 2

Implications of Convergence

CTEKS have been characterised in terms of their potential to create a convergence of enabling technologies for the achievement of more or less specific aims. This potential now needs to be specified, the tasks formulated, and the associated opportunities and risks recognised in the European context. In order to provide a context for the development of CTs, the expert group identified four scenarios for Europe in 2020. Subgroups explored what *CTEKS* mean for Europe today as it prepares for the future. These were dedicated to different societal dimensions of convergence, namely to economic and technological opportunities, cultural challenges, implications for quality of life in ageing as well as diverse European societies, and likely transformations of social and cognitive interactions.[12]

The following consideration of *CTEKS* implications therefore begins by articulating a framework of policies, goals, and scenarios for Europe. It continues with a presentation of economic opportunities, disruptive potential or risks, and research challenges. Throughout, *CTEKS* agenda-setting appears as a science policy tool for the advancement of European objectives.

1. European Contexts

Information and communication technology, biotechnology, and nanotechnology are cornerstones of the knowledge society that is envisioned by European economic and science policy. *CTEKS* agendas focus these technologies by orienting them towards shared goals. The novelty of *CTEKS* is therefore that they explicitly answer to the European agenda for the 21st Century as stated by the EU's Millenium Declaration:

"*On the threshold of a new century and the third millennium, the Union should focus on tasks which are central to its peoples' security and welfare.*"

The formulation of *CTEKS* research agendas is a science policy tool for the concrete implementation of this goal and of the Lisbon Strategy.

1.1. European Objectives

In particular, *CTEKS* allows the Union to focus on the following tasks that were highlighted by the Millenium Declaration:

- to provide for an ageing population,
- to develop human resources through life-long learning and innovation,
- to promote a dynamic and open knowledge based European economy,
- to combat local and world-wide environmental degradation,
- to achieve sustainable development and guarantee a better quality of life for future generations,
- to protect against crime,

(12) The Special Interest Groups (SIGs) dealt with CTs in four separate reports: "Quality of Life," "Ethical, Legal and Societal Aspects of the Converging Technologies," "New Technology Wave: The Transformational Effect of NBIC Technologies on the Economy," and "Converging Technologies and the Natural, Social and Cultural World."

- to work for a more open and stable international economy that benefits also people in less favored parts of the world,
- to create capabilities for managing international crises and providing humanitarian assistance.[13]

What makes *CTEKS* suitable as a science policy tool for the achievement of these European objectives is the fact that they would not even exist without explicit agenda-setting or the determination of a shared objective. The EC's Communication "Towards a European strategy for Nanotechnology" states that "a generic roadmap for nanotechnology is unrealistic since the field is too broad."[14] Where generic roadmaps are unrealistic because the field of enabling technologies and their convergence is even broader, there is an invitation to develop specific *CTEKS* roadmaps for targeted areas of R&D.

1.2. Research for 2020 Europe

The scenario method was used by the expert group to identify robust research interests for the development of CTs. Four developed scenarios compare Europe in 2020.[15] These scenarios were generated by considering three fundamental choices faced by Europe and how they might combine:

1) Public resistance to advances in science and technology may remain largely inconsequential for innovation and economic development, or it may become a major determinant for Europe in 2020.
2) European policies may cherish and foster the cultural diversity of Europe, or they may seek to overcome it for the sake of equal economic, legal, educational and cultural conditions.
3) Europe may value global competitiveness and economic growth above all else or may seek to balance it against values of social and environmental justice.

Among the four developed scenarios, public resistance is consequential only in the "Alternative Lifestyles" scenario. "Competive Europe" and "Regional Calm" value diversity but the former prioritises economic growth, while the latter focuses on social cohesion. In the pursuit of economic growth, "Global Capitalism" represents an increasingly homogenised Europe in 2020.

The main finding of the scenario exercise was that certain research priorities will not depend on the specific course that Europe will take. Europe in 2020 will remain strongly committed to research in the three areas of *health, education*, and *infrastructure (mainly information and communication or ICT infrastructure)*. Research on these topics will generally enjoy public support. Also, Europe in 2020 will continue to have a major interest in the areas of environment and energy. Research on these topics will be contested and subject to public debate at least in some of the scenarios.[16]

The five topical areas can therefore serve to frame agenda-setting for *CTEKS* research. Within these broadly defined topical areas, research should serve to further the European objectives of the Millennium Declaration and Draft EU Constitution.

As in the case of reproductive technologies, cloning, and stem-cell research, the prospect of CTs for human enhancement appear to be the most sensitive to public debate. Under the "Alternative Lifestyles" scenario, at least, human enhancement technologies will be actively discouraged.

(13) Helsinki Millenium Declaration, see also to Article 3 of the Draft EU Constitution.
(14) "Communication from the Commission: Towards a European strategy for Nanotechnology," COM (2004) 338, section 3.1.4., p. 11.
(15) Compare the separate document detailing the expert group's Scenarios Workshop Output.
(16) See the separate report on "Quality of Life," p. 14.

1.3. The European Research Area

According to the Lisbon strategy, "the knowledge-based economy is becoming a reality" thanks, in part, "to the gradual development of the European Research Area." This development is expected to solve the so-called "European paradox," i.e. the contradiction between excellence in scientific research and failure to exploit this for technological and economic benefits.[17]

CTEKS agenda-setting is a science policy tool also for adapting the existing research infrastructure to the goals of the ERA. In particular, *CTEKS* can be used

- to create greater European cohesion in research and to bring together the scientific communities, companies and researchers of Western and Eastern Europe,
- to stimulate young people's taste for research and careers in science,
- to improve the attraction of Europe for researchers from the rest of the world,
- to promote common social and ethical values in scientific and technological matters,
- to set up research along the lines of technological platforms which bring together public and private stakeholders in *CTEKS* initiatives on health, education, ICT infrastructure, environment, and energy.[18]

Economic contexts

Trade is the exchange of goods. What used to belong to the seller, now belongs to the buyer. Knowledge, knowledge-based solutions or products, and services are non-tradable since the sellers retain their goods even as they sell them. The non-tradable component of any economy covers its operating systems such as those for health, education, environmental protection, leisure, security, law enforcement or public transport and administration. They provide employment and income to a sisable share of the population. These non-tradable systems absorb tradable goods. While non-tradable services can be offered in a market context, the decision concerning their functioning are embedded in the social context.

A tradable CT product. Development of the artificial hand (see page) as a tradable product makes economic sense only if it intends a consumer market much larger than the niche market of therapeutic options for the disabled. The artificial hand will be developed initially as a therapeutic aid - with intended spin-off applications for military, entertainment, and general enhancement uses.

Or a nontradable CT service good? The development of the artificial hand as a non-tradable good makes economic sense within the health care sector. Since brain-control is very difficult and highly inefficient, the artificial hand will hardly become a prototype bulk product to be sold in quantity. Instead, it serves as a highly customised solution where no alternative options exist. It will require extensive training to learn the use of the prosthesis as well as careful calibration of the prosthesis to the individual user. The artificial hand here presupposes a social and economic system that supports for the purpose of job- and wealth-generation a highly cost-intensive health care system as a public service sector. In this economic context, the distinction between therapeutic prosthetics and the business of human enhancement will be maintained.

Increasing emphasis on nontradable goods is a hallmark of the Lisbon Agenda's so-called "European knowledge society" and one reason for the label *CTEKS* (Converging Technologies for the European Knowledge Society). Pharmaceutical companies, for example, are shifting from the manufacture of drugs to the development of diagnostic tools. For steel manufacturers, too, the production of bulk material is becoming subsidiary to the creation of targeted solutions. Such knowledge-based solutions consider the entire life-cycle of technology-based responses to consumer-specific needs.

(17) "Communication from the Commission: Science and Technology, the key to Europe's future – Guidelines for future European Union policy to support research" COM (2004) 353, section 1.3., prop. 11, p. 4: "Europe does not have sufficient capacity to transform knowledge into products and services."
(18) See http://europa.eu.int/comm/research/era/pdf/com2000-6-en.pdf – the EC communication of January 2000, and Research in the Financial Perspectives 2006-2013: Commission Proposals February 2004

The following considerations show just how *CTEKS* can accomplish these goals and in which way they can serve to advance the Lisbon agenda more generally.

2. Economic Opportunities, Societal Needs

Innovation studies and the history of technology have demonstrated that even in a global economy the absorption of a new technology and its economic exploitation vary according to the particular society into which it is introduced. We know, for example, that cell-phone technology has developed very differently in Portugal, Germany, Finland, Italy, and Poland. At each location, the diffusion of technology and its integration into every-day life are shaped by economic policies, cultural resistance and support, complementarity with established technologies, and many other factors.

Economic opportunities for *CTEKS* in Europe depend on technological potential, international markets, social attitudes, and European policies. Especially in the case of *CTEKS*, a laisse-faire approach that entrusts economic development to market forces may end up leaving much of the technological potential untapped. In contrast, agenda-setting will serve not only to justify research funding for *CTEKS* but it also helps mobilise *CTEKS's* potential to develop novel solutions to specific problems.

The free-market path of least resistance often favors the continuation of established trajectories, leading to faster, cheaper, stronger and more powerful variants of familiar products and devices.

In contrast, the introduction of goals and constraints need not stifle innovation but can foster creativity. The formulation of *CTEKS* challenges may provoke original and possibly disruptive technological solutions that can open up entirely new markets or strengthen existing economies and research infrastructures.

Such lessons from innovation studies, economics, and the history of technology require further study. Their background assumptions and applicability to the development of *CTEKS* need to be monitored. Does environmental regulation of industry reduce the profitability of European companies or does it generate wealth by stimulating environmental technologies for international markets? Do restrictions on stem-cell research, cloning, and genetically modified foods harm competitiveness or do they stimulate research activities that create new economic opportunities? What is the role of the non-traded sector in generating products for the traded sector? How should *CTEKS* agendas be formulated in order to stimulate creative enterprise without constraining initiative and innovation? The ongoing investigation of European wealth generation – or its shrinkage – through economic and political incentives and constraints should be the subject of research in a European framework that brings together historians, economists, and the science policy community.

2.1. Utilising the *CTEKS* Tool

Each of the likely characteristics of *CTEKS* applications (see pages 17f. above) is associated with economic opportunities. European agenda-setting can make use of these features and gear them towards the fulfillment of European needs.

- *Embeddedness:* Technologically created second nature serves as a habitat for human action in work and leisure. It is sandwiched between original "first" nature with its geographical, meteorological, agricultural conditions, and evolved culture with its local history, traditions, values, ways of living. Since each society or each region finds itself in a specific first nature and has developed its own culture, it will tend to produce a culturally specific artificial environment or second nature. While CTs might serve to homogenise and globalise the world, the *CTEKS* approach accepts European diversity as a challenge and the basis of economic opportunity.

- *Unlimited reach:* The expectation that there might be a technological fix to any problem serves as a powerful research heuristic, policy resource and economic incentive. It encourages a product development process also for non-tradable goods or solutions to social problems. This would include policy-level brainstorming on design specifications followed by multi-disciplinary road-mapping. Once the steps towards achievement of a *CTEKS* solution have been detailed, the economic and scientific viability and limits of the proposal need to be ascertained and compared to alternative solutions, including regulatory and political ones. Normative concerns and questions of disruptiveness should be included in this process. Even if many proposed fixes will not pass muster, this methodology is likely to encourage economic development while addressing European needs and engaging the research community – this integration, in turn, consolidates a knowledge-based society.
- *Engineering for the mind and a healthy body:* As opposed to the "engineering of the mind"-approach, *CTEKS* prioritise engineering for the mind. It favors CT "software" over ambitions to engineer the mind by implanting electronic enhancement devices, creating brain-machine interfaces, etc. Information technology, in particular, offers a vast resource of designs that can support and improve social interaction and social decision-making in a diverse Europe and for ageing societies. Many of these draw on enabling knowledge systems such as social science, cognitive psychology, economics, or the law. For their physical implementation, many rely on nanotechnological miniaturisation trends. In a separate document, one of the expert group's subgroups details this technological and clearly also economic potential.[19] – If information and communication technology takes the conceptual lead in "engineering for the mind," biomedical technology leads a similar *CTEKS* enterprise of "engineering for a healthy body." Again, some of the technological and simultaneously economic opportunities were detailed by a subgroup in a separate document.[20]
- *Specificity*: One of the key points to emerge from historical studies of diffusion of innovation is that smaller countries do not necessarily need to be technology creators to become rich countries. Since the real benefits of a technology can derive not only from its creation, but also from its intelligent application and social absorption, what seems to be necessary is creative adaptation and diffusion. *CTEKS* are conceived as a tool for the creative adaptation of enabling technologies and knowledge systems to highly specific problem-solutions. This allows small countries to develop highly targeted *CTEKS* agendas such as "Converging technologies for salmon-productive aquatic environments." This also allows for an inverse process. After a survey of enabling technology research in a particular country or region, creative goal-setting can draw on existing strengths to promote productive *CTEKS* research. It also invites European CT researchers to develop a *CTEKS* agenda that addresses the environmental, energy, health and education needs of specific developing countries. In all these and many other cases, the identification of societal needs coincides with the creation of economic opportunity.

(19) See the separate report on "Converging Technologies and the Natural, Social and Cultural World."
(20) See the separate report on "Quality of Life."

2.2. Need-Opportunity integration through *CTEKS*

The discussion so far of the economic dimension has shown that *CTEKS* represent a unique opportunity for European economic and research policy:

- European needs simultaneously provide goals for research and incentives for private sector investment.
- Agenda-setting for *CTEKS* research should therefore remedy the disproportionally small private sector involvement that was identified, for example, in the EC's Communication on Nanotechnology.[21]

European needs pertain to global competitiveness, security, governance, social justice, sustainable exploitation of common resources, distribution of wealth, migration, unemployment levels, diversity, and much more.

CTEKS may develop at least partial solutions or technical support systems for any of these. Since in some cases the very definition of the need is contested and the contribution of CTs is not immediately apparent, the expert group recommends that *CTEKS* should be focused initially on the research topics that are valued highly and for which a positive impact is expected under any European scenario. These are the areas of health, education and ICT infrastructure. *CTEKS* are also expected to make powerful and important contributions in the areas of environment and energy which should also be included in the design of CT initiatives.

In these five topical areas of research, it is particularly obvious how technical opportunities can be exploited to address societal needs and how, in turn, technological R&D by addressing these needs create economic opportunities.

- *Health:* While health care expenditures burden European welfare states, the health care sector is also a major motor of wealth-creation. This is exemplified by the fact that it is very labor-intensive. CTs can enhance the economic efficiency of the health care system and relieve, for example, labor-intensive diagnostics. They can do so by providing consumer products for self-monitoring leading to the adoption of healthier life-styles, and "lab-on-a-chip" technologies that integrate nano, bio- and information technologies for fast screening and early diagnosis of disease. The resultant decrease of health care jobs will go some way towards easing public health care expenditures. It also makes room for new labor-intensive *CTEKS* applications such as intelligent prostheses which can be coordinated through an extended training and rehabilitation process with brain signals from patients and transmit sensory information back to them. Here, improvements in efficiency may help create new employment where it matters most, namely in the interaction between patients and therapists.
- *Education:* While educational systems are constantly scrutinised and receive political attention, education is a step-child of technology R&D. A healthy skepticism greets many attempts to propose technological solutions for deficiencies in educational systems. However, the Lisbon Strategy has formulated an educational agenda that goes well beyond the class-room settings for the traditional trajectory from elementary school to higher education. In particular, the promotion of active ageing demands that Member States should "promote access to training for all and developing lifelong learning strategies."[22] For example, fundamental research in psychology and neurology shows that the first years of human life are of great importance for intellectual development. Unfortunately, parents frequently require instruction on how to treat and educate their babies. *CTEKS* may create for their

(21) "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 2, p. 7: "It is important to highlight that, with 56% of overall R&D investment from private sources, the EU lags behind the US and Japan with 66% and 73% respectively," compare also European Commission "Key Figures 2003-2004" (2003).

(22) Spring Report 2004 on the Lisbon Strategy.

homes an invisible knowledge space. Immersed in this knowledge space and surrounded by it, parents and children have permanent access to learning objects that are chunks of information such as documents, experts, experiences, contacts, web-seminars, educational games, lessons, or digital libraries.[23]

- *ICT Infrastructure:* In this area more than others, examples abound of how *CTEKS* can integrate economic opportunity with societal need. Environmental monitoring through ambient sensing devices can provide an informational infrastructure that serves societal needs and personal interests. It can alert agencies to the appearance of pollutants and inform individuals about the distribution of allergens in micro-climates. An ICT infrastructure that integrates information about food products, purchasing and consumption patterns, individual states of health, diet plans, and medical expertise can be used to combat obesity by advising individuals. Aside from reducing a public health problem, this might support epidemiological research of obesity with feedback to regulatory agencies and food producers. Such an infrastructure can be offered as a subscription-based service and – for better and worse – provide a venue for targeted advertisements by restaurants and food suppliers.
- *Environment:* The Spring Report 2004 on the Lisbon Strategy notes that "[i]n the environmental sphere, Member States' performance is generally inadequate." The report sets some goals which various enabling technologies are poised to address in a concerted *CTEKS* effort. These goals have in common that they address the problem at a systems-level and relate engineering solutions to social and ultimately economic effects. For the achievement of the positive economic return, a collaboration of social scientists, nanotechnologists, process engineers and others will be required:
    1) "more efficient use of natural resources contributes to the economy's productivity at the same time as reducing environmental degradation,"
    2) "reducing air pollution and noise can avoid significant impacts on health," and
    3) "reducing transport congestion reduces lost time and therefore costs for both individuals and business."

The report formulates a challenge that has not been met and that could be adapted to a *CTEKS* agenda: "Converging technologies for decoupling between GDP growth and rises in the volume of transport."[24]

- *Energy:* Living conditions the world over are largely determined by access to drinkable water and energy. In regard to the latter, *CTEKS* foster inclusivity by creating new technologies for the generation, transport, storage, and use of energy. It can develop solutions for the exploitation of renewable energies that are maximally adapted to local conditions. The creation of these solutions requires the collaboration not only of photovoltaic, hydrogen, geothermal and solar energy researchers, but also of geologists, geographers, anthropologists, and economists. Once creative solutions are found under local constraints, many may prove to be highly transportable and marketable. Buildings will generate and share energy among each other, invisibly small renewable energy collectors may be integrated in devices in a manner that emulates nature, new energy carriers and forms of energy storage will be explored. The goal of this research could be that within a century nearly all energy needs can be met by way of locally generated renewable energy.

(23) See the separate report on "Converging Technologies and the Natural, Social and Cultural World," p. 10.
(24) Spring Report 2004 on the Lisbon Strategy

Three sample flagship research projects

Converging technologies for natural language processing: Europe's many nations with mostly different natural languages (NL) present exorbitant problems of communication among individuals and institutions. Any substantial technological progress towards overcoming these problems would amount to a tremendous improvement for all Europeans. At the same time Europe is actually leading worldwide in the technology of processing natural language. This multidisciplinary research challenge includes the different modes of written as well as acoustic NL understanding systems, written and spoken NL generation systems, and translation systems. (See the separate report on "Converging Technologies and the Natural, Social and Cultural World," p. 64f. with a challenge also to develop Converging technologies for integrated hybrid transportation systems).

Converging technologies for the treatment of obesity: Obesity is simultaneously a problem of individual and public health, it concerns genetics, physiology, nutrition research, exercise science, the psychology of eating disorders, food producers and sellers, social and cultural studies of gender, ethnicity, class, and the representation of the body in advertisement and popular culture. All these areas of research must converge in the treatment of obesity. They may be aided by nano-tagging of food products, integrated models of consumption patterns, and information technology assistants for self-monitoring of food-intake.

Converging technologies for intelligent dwelling: Buildings can generate and distribute energy, they can process and recycle waste, they can collect and purify water. These capabilities should be improved through bio-mimetic technologies, by integrating photo-voltaics in smart materials, by incorporating environmental sensors in information and regulation systems. In the European city of the future, each building contributes to the maintenance of neighbouring buildings and urban infrastructure at large by exploiting its own specific capabilities that are determined by its location, structure, and material make-up.

Excepting small classes of applications such as certain reproductive technologies or ICTs that potentially invade privacy, CT research on health, education, and ICT infrastructure is likely to be perceived as beneficial. In contrast, environmental technologies and R&D on European energy supply are seen as contested and all the more in need of creative ideas and ingenious technological advance.[25] However, public debate, regulatory issues, and resistance can be expected for many areas of *CTEKS* research. Rather than view these as impediments to technological and economic advance, these should be viewed as forces that shape a process of convergence which is malleable and adaptable by its very nature. Resistance along with agenda-setting and public debate help assure that *CTEKS* solutions are targeted and viable. Indeed, there will be less need for after-the-fact regulation and less anxiety in the business community if these shaping forces enter the process early. By inviting them in early, the *CTEKS* process ensures that research interests, social benefit, and marketability are closely attuned to each other throughout.

(25) See the separate report on "Quality of Life."

Understanding resistance to new technology

History suggests that resistance has been a constant feature of the history of innovation and technological change. Three features have emerged:

- Resistance to new technologies has come from many sources, from business, public administration and politics, interest groups, the public at large, etc., and has played a role in the evolution of the technology.
- Resistance must be understood in terms of interaction between the technology and its social context. It concerned how technologies accorded or clashed with social organisations, cultural values, etc.
- Resistance was by no means irrational. It can be seen as a component of the process by which societies selects among technological options.

If the only standard for judging a technology is productivity, then such resistance might attract condemnation. But societies have social as well as economic aims, and economic perspectives are just one element of social and political values. If a particular culture wishes to retain low-productivity rural fishing communities, or if it wishes to forego the risks associated with nuclear power plants, then economic criteria are no more relevant than any other standard of judgement.

Resistance could thus be seen as a positive part of a social selection process, and not as an obstacle to technological progress.

3. Dimensions of Risk

Where there is opportunity, there also is risk. For example, there is the economic risk of investing in a technological promise that does not materialise. Inversely, there is a societal risk that consumer acceptance of new technologies outpaces the careful consideration of their consequences. Since *CTEKS* risks are the flipside or shadow of opportunity, they can be discussed under the same headings and at the same level of generality. Another type of risk arises from CT applications that originate not only outside the *CTEKS* framework in the private sector or non-European countries, but also as an unintended consequence when the *CTEKS* process is derailed and its goals not attained. A third type of risk is inherited by CTs through the contributions from the various enabling technologies – these are the risks of nanotechnology, genetic engineering, pervasive communication technology, etc. All three types of risk require consideration.

Consumerism outpaces ethics

Ethicists are pondering the legitimacy of implants for human enhancement. Consumer advocates combat the use of identification chips that track consumption patterns and threaten invasions of privacy. In the meantime, these technologies develop their consumer appeal. A news article of May 24, 2004 suggests what lies ahead for societal and regulatory debates of commercially developed CT applications:

A dance club in Spain gives new members the option of a standard ID card which they must bring with them to the club, or an implant as an alternative. The so-called VeriChip has the sise of a grain of rice. It is implanted on the upper arm by a trained member of the club's staff. As well as acting as an ID, the chip can be used to pay for items like drinks: The members don't have to bring anything but themselves to the club. Further uses are in envisioned. In case of illness, the chip might download the exact alcoholic repertoire of what has been purchased. Also, limits of consumption can be set. Favorite drinks and their variants can be ordered in advance as members walk in. Contact can be made with peer-group members or those who choose to be recognised for certain characteristics they set themselves.

3.1. The Flipside of *CTEKS*

CTs were defined as enabling technologies that enable each other for the achievement of a common goal. *CTEKS* represent the European approach of setting agendas for CTs that will draw together enabling technologies and knowledge systems towards common goals appropriate to Europe. In a previous section (pages 17f. above), four general characteristics of likely CTs as well as *CTEKS* applications were identified. Each of these represents economic and scientific opportunity (pages 24f. above), but each of them represents also a category of risk.

- *Embeddedness*: The convergence of nanotechnology and other enabling technologies in specific engineering projects expresses an underlying philosophical agenda, namely the total constructability of humanity and nature. To the extent that ambient computing and other *CTEKS* engineer entire systems or artificial environments, they offer a constructed second nature in place of first or original nature. This artificial nature is also culturally determined in that it is a product of human creativity. It replaces the original function of culture, namely to assert the realm of humanity against that of nature. This hybrid nature/culture has been a subject of philosophy and cultural studies for several decades. With nanotechnology and CTs it has been adopted as a declared aim of research. The most direct and profound effect of *CTEKS* is therefore to change traditional boundaries between the self, nature and social environment, where the social environment includes people, groups of people, informal and formal institutions. It also includes arenas and places, both physical and informational, where goods and beliefs are traded and transformed. Over the last decades society has witnessed effects on the sense of reality and responsibility of those who are immersed in computer games, Internet surfing, and chatting. In light of CTs, society will be confronted with far more frequent and deep transformations of people's and groups' self-understanding.

A matter of choice?

Many technologies are shaped in part through consumer choice. DVDs, cell-phones, and the Internet serve as examples of how demanding consumers are shaping consumer products. While new ways have to be found to regulate these products, individuals remain free to purchase them or not.

Other technologies require political decision making. Public transportation systems, sewage plants, and the electric grid are instituted and maintained through public deliberation and decision-making.

Some technologies advance neither through the cumulative effect of consumer choice nor through public decision making. Climate controlled buildings are a case in point. Even the executives who commission office buildings do not explicitly choose to forfeit their option of opening their window, drawing a curtain, or lowering a shade. They encounter this as an effect of a rather different economic choice. As we find ourselves in certain artificial environments, we discover that too many drivers are shaping them and that their interaction does not permit intervention at strategic points. Here, the dissatisfaction of users does not readily translate into changes of design. At the same time, individuals cannot easily opt out.

Then there are diffusion patterns that count on the passivity of consumers. Certainly in the case of "spam" e-mails and perhaps with the deployment of RFID (object identification) tags, the sheer quantity and pervasiveness of offers is meant to be disproportionate to consumer demand. These technologies elude social shaping by diffusing in a quasi-natural manner.

In light of the concern that the development of CTs may not be controllable at all, the pursuit of *CTEKS* applications requires vigilance and care. Especially as they involve the creation of articificial environments, an effort needs to be made to ensure transparency and openness to public deliberation.

- *Unlimited Reach:* The notion regarding the total constructability of humanity and nature is matched by the suggestion that CTs may provide a technological fix for every problem. This suggestion could prove especially problematic in regard to ecological problems. CTs promise less energy-consuming and waste-producing manufacturing, remediation-technologies for pollution, and improved sensing capabilities for environmental monitoring. Taken together, these may produce the dangerous illusion that our ecological problems are under control. This also appears to reduce the need to curb consumption or to recycle. Finally, it undermines awareness of our dependence on nature as a fragile habitat that needs to be preserved.

- *Engineering the Mind and the Body:* Whether of or for the body and mind, CTs raise legal and philosophical issues regarding human inviolability, dignity, and autonomy. This begins with the seemingly inconspicuous case where more and more decisions are delegated to machines. This is initially done for the sake of convenience or security but ultimately with the effect of loss of knowledge and skill and a surrender of autonomy and responsibility. An extreme vision of this are autonomous killing machines that are developed for military purposes and that, once launched, do not require and perhaps cannot accommodate human input into a life or death decision. Equally troubling are plans for using implants and other technologies to transcend human limitations. This presupposes a conception of the world which treats nature as an immense computational machine. Within this world the human being is thought of as just another machine. This may spell an end to ordinary conceptions of morality which are related to questions of freedom and meaning. If humans self-identify with the perfectibility of the machine, they are subscribing, in effect, to a meaningless, mechanistic world in which there is no genuine moral choice. To this "ethical impact of CT's corresponds a legal impact since the existing legal framework, or volume of legal norms and court decisions, both on the national and on the European levels, is not ready to address technological transformations of the human body or mind. For example, how neutral or socially coercive is the decision of individuals to gain an advantage for themselves or their children through artificial enhancement? Inversely, when entire environments are engineered to structure human action, do individuals have a legally and socially protected choice to opt out?

Outside the framework

A review of the legal situation in Europe has only just begun in the case of nanotechnology, let alone for CTs. Even at this very beginning, inadequacies of the current regulatory framework become apparent.

- Currently, medical devices such as syringes are regulated differently than pharmaceuticals. CTs are beginning to develop chemically engineered drug delivery devices that may interact with the body much as pharmaceuticals do. These devices require a re-orientation of the regulatory scheme.
- Currently, chemical substances are regulated in regard to composition and quantity. The regulations tend to apply only if several tons of a certain compound are produced annually. Nanoparticulate chemicals of the same composition may have strikingly different properties. Also, they can be effective in extremely small quantities and are produced accordingly. The need for new regulatory protocols has been recognised.

Similarly, fundamental rights as presently interpreted will most likely not provide adequate answers to the human rights' challenges posed by CTs, especially regarding the inviolability of the human body. For example,

-do the established standards of medical ethics apply to a person who desires an implant for the stimulation of a happiness centre? How does one distinguish here between prescribed psycho-pharmaca, legal life-style choices (TV and alcohol), illegal drugs, and a voluntarily implanted, switchable electrode?

- can or should the laws banning doping in sports be extended to ban the attainment of chemically or electronically induced temporary advantages in the competition for a workplace?

In particular, *the ethical review of research proposals* may need to be expanded. For example,

- where, currently, there is concern about "the use and deliberate release of genetically modified micro-organisms," this will have to be broadened to include technically created quasi-organisms;
- while there is, of course, no human right that the natural environment should be transparent and intelligible, there may be such a right in respect to the artificial environments that permeate and displace the natural ones;
- future debate may add to the list of excluded fields of research all research that considers the natural process of ageing as a disease to be cured.

- *Specificity* : a destabilising and unsettling effect on human relations. This begins with the implementation and diffusion of the technology. Rather than being purchased by individual users, technology that is distributed across an artificial environment makes it difficult to know who its users and beneficiaries really are. The invisibility of CTs raises questions as to their absence or presence. This is equally troubling when they are needed to sustain a specific action and when one does not know whether, like computer viruses, they might appear any time and attack a delicate technical system or organism at some unknown place. Finally, such technology raises issues of control. When, at what point in the process, and by whom can it be switched off? But even when they work as reliably and successfully as one could wish, CTs may have a socially destabilising effect as economic efficiency produces greater unemployment, as targeted medical treatments increase longevity, as CTs exacerbate the divide between the rich and the poor, between technologically advanced and traditional cultures.

This category of risks requires that from its beginning in the WiCC initiative, *CTEKS* provide mechanisms for public deliberation and social engagement, including the participation of social scientists and ethicists in the agenda-setting and research process.

3.2. Use, Dual Use, Abuse

CTEKS come into existence only through the policy process of agenda-setting. This should provide a safeguard against unethical and highly contested CT applications. It is no safeguard against some of the challenges to ethics and human self-understanding that are implicit in the CTs themselves. It is also no safeguard against dual use or unintended consequences of *CTEKS* application, or against the possibly harmful products of CT research by private enterprise or in non-European countries.

Particularly troubling and internationally destabilising are "Converging technologies for domination on the battlefield." They exploit the most dangerous potential of CTs, including technologies for surveillance and invasions of privacy, for the enhancements of soldiers' bodies, for remote manipulation of soldiers' minds, and for autonomous killing machines. CT weapon systems might act to infiltrate and attack computers, combine with selective bioweapons, or target individual politicians. In any event, the very uncertainty about their capabilities may lead to a new, highly unstructured and non-negotiable arms race. New military threats and their perceptions may decrease stability and endanger international security.

Also, many of these CTs may undermine and jeopardise the international law of warfare.

It is easy to imagine that the concerted effort of the armed forces of various countries will inspire abuses by small groups of militants, by criminals, perhaps by businesses and even government. For example, business can market consumer spin-offs of military developments and thus prepare the ground for enhancement technologies and other controversial applications. Also, business and government might employ surveillance technology for sophisticated forms of industrial espionage or to gather data about consumers and citizens.

This dimension of risk requires supra-national, trusted mechanisms for monitoring and assessing national, European, and international CT developments, as well as proactive negotiations of limitation treaties and codes of good conduct.

Military applications

Nanoparticles developed to transport therapeutic drugs through the blood-brain barrier or into specific cells, could also be used to carry incapacitating or lethal agents. Technologies developed for individualised therapy or for selective destruction of cancer cells – such as releasing an agent or triggering a certain molecular action only after a certain DNA pattern has been detected – could be applied to produce selective chemical or biological warfare agents – affecting only people with certain genetic traits, or even only a single individual. Nanocomposite materials may allow all-plastic firearms and micro-missiles that evade detection by x-rays and metal detectors. Extremely powerful computers together with new levels of artificial intelligence and advances in robotics could lead to autonomous fighting robots or vehicles. Cheap very small sensors and mobile micro-robots, even electronically controlled animals, could be sent for surveillance and for (surprise) attack. Body manipulation applied to soldiers (against sleep-deprivation effects, for shorter reaction times) could create *faits accomplis* undermining a broad societal debate also on the civilian benefits and risks of such interventions

Contingencies where the EU would consider "as a last resort the use of force in accordance with the United Nations Charter" (for crisis management or against proliferation of weapons of mass destruction) do not require the most problematic applications of CT. Military efficiency has to be balanced against the effects on the international system. The EU Security Strategy is committed to the "development of a stronger international society, well functioning international institutions and a rule-based international order." It builds on the fact that "our own experience in Europe demonstrates that security can be increased through confidence building and arms control regimes." Accordingly, the EU should act to strengthen existing disarmament treaties such as the Biological Weapons Convention, work for preventive limits on large and small military robots and for international agreements regulating non-medical body manipulation.

In order to monitor and mitigate new threats from terrorism, proliferation of weapons of mass destruction and organised crime, it is prudent for the EU to fund research in the use of CTs for better detection and neutralisation of biological-warfare agents, cyber attacks, invasions of privacy etc.

3.3. Inherited Risk

The convergence of various enabling technologies means that some of the risks associated with the contributing technologies will be imported into CTs. Many of these risks are already subject to debate, especially those of biotechnology and genetic engineering. Also, the potential risks of some aspects of nanotechnology on the one hand, information and communication technology on the other hand are receiving public attention. Since these risks are not specific to CTs, they are not considered here. Expert groups, ethics commissions, non-governmental organisations, etc. will continue to address pressing issues such as genetic screening, nanoparticle toxicity, privacy invasion, etc.

CTEKS research will not only inherit the risks of contributing technologies: the deliberate process of agenda-setting for *CTEKS* can also serve to confine these risks by designing the research process proactively.

4. *CTEKS* for a Coherent Public Research Agenda

The current state of nanotechnology research has been described as as a wide spectrum of unstructured activities , that need to be integrated within a goal-directed research agenda. While there is closely related research on molecular wires, controlled growth and optical properties of carbon nanotubes, etc., these efforts are usually conducted in parallel. Some molecular wires have better or more interesting properties than others. When these are discovered, researchers are often at a loss to see just how these can be made to contribute to ongoing investigations of computer architectures. Accordingly, the EC's Communication on Nanotechnology emphasises the need "to make rapid progress in nanotechnology via interdisciplinary R&D":

"In this context, one must focus on the synergy of research, infrastructure and education – they are indissociable. Such a 'system approach' will boost both knowledge production while also attracting to, and retaining in Europe, the best minds for nanotechnology R&D."[26]

All enabling technologies stand to profit from the proposed system approach. The WiCC initiative and subsequent *CTEKS* agenda-setting fits into this approach by "exercising a catalytic effect" on national and disciplinary research initiatives and by establishing a coherent "framework for major technological projects."[27] A catalytic effect can be achieved only when researchers can freely and creatively respond to significant challenges. *CTEKS* agenda-setting therefore should not be about formulating narrowly defined tasks. Instead it provides the required synergistic impulse by establishing high profile challenges and a forum in which they can be addressed by researchers in nanotechnology and other enabling technologies. By involving many stakeholders in the formulation of these challenges, *CTEKS* expand on the concept of "technology platforms" and thereby advances the EC's policy goal to "improve the coherence of public research agendas throughout Europe."[28]

(26) "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 3.1.1., p. 10.
(27) "Communication from the Commission: Science and technology, the key to Europe's future – Guidelines for future European Union policy to support research" COM (2004) 353, section 1.2., props. 6 and 9, p. 2.
(28) Research in the Financial Perspectives 2006-2013: Commission Proposals (February 2004).

Part 3

European Steps towards Convergence

CTs represent a significant opportunity for a European knowledge-based economy. The High Level Expert Group's first and most important recommendation is therefore to establish *CTEKS* a thematic priority for European research.

The previous sections have shown that "*CTEKS*" is not just another label for the organisation of multidisciplinary research or the name for an agency that offers funding to CT researchers. Along the lines of "technology platforms," agenda-setting for *CTEKS* research intervenes vertically and cuts across a great variety of European work programs. Since it requires the deliberate formulation of a goal or challenge, the *CTEKS* process is a powerful science policy tool for the advancement of the Lisbon strategy (see pages 38 and 36f. above). This novelty of *CTEKS* requires that Europe take swift and bold action to grasp this tool and learn to deploy it.

In order to achieve *CTEKS* solutions by 2020, the current sixth European Framework Programme needs to incorporate preparatory actions on converging technologies. These actions will start the *CTEKS* process. They include the WiCC initiative. The preparatory actions should conclude with the establishment of various *CTEKS* research programs or projects in the general areas of health, education, ICT infrastructure, environment, and energy. In each of these areas, several *CTEKS* programs might be specified, i.e., agendas set and road-maps developed. Full implementation in program calls should follow.

This requires immediate action in terms of research activities, research infrastructure and governance, and foresight for Europe.

1. Research Activities

CTEKS can make better use of existing knowledge by discovering productive relations between enabling technologies and knowledge systems. Through ambitious agenda-setting it can also stimulate basic research and the generation of new knowledge. Both of these approaches call for the development of prototypes.

1.1. Mobilising Knowledge for *CTEKS*

Multidisciplinary programs often start with a survey of related fields to ensure that the relevant disciplines are in the team and enabling contributions can be made. In the case of *CTEKS*, such surveys serve the purpose of discovering projects of promise.

The European approach to CTs assumes that nano-, bio-, and info-technologies are not the only enabling technologies capable of enabling each other. This assumption affords a fresh look at extant disciplines and their knowledge systems. Enabling technologies and knowledge systems in the engineering, natural, social, and human sciences should therefore be identified on regional, national, and European levels. After their characterisation and placement on conceptual as well as geographic maps, connections and complementarities between various endeavours can be discovered or constructed.

The resulting database should allow for conceptual experimentation, for example through the introduction of hypothetical *CTEKS* goals or regional alliances. These experiments might be conducted algorithmically or in brainstorming sessions of small expert groups or in combination of the two. This heuristic methodology can be used to generate proposals for *CTEKS* research. Once this methodology is in place, the proposals are made available to the European and National Research Councils, also serving as inputs to the WiCC initiative.

The survey and collation of existing knowledge is continuous and always incomplete. The formulation of *CTEKS* research agendas does not depend on its completion. Even as the WiCC initiative is only beginning to widen the circles of convergence from a core of CT researchers, a prototype can be developed and refined for the heuristic process of discovering opportunities for *CTEKS* research. This prototype "ConvergenceDiscovery" heuristic seeks to identify effective mechanisms for generating with social imagination a potentially viable *CTEKS* vision from a limited sample of enabling technologies and knowledge systems.

A separate survey of existing knowledge is required with regard to the cognitive sciences. The expert group proposes the formation of an international expert group that develops an opinion about the inclusion into the engineering paradigm of cognitive processes ("engineering of the mind") as in the US approach to NBIC. This is best achieved by way of a conference that scrutinises the implicit cognitive science assumptions of the report "NBIC Convergence for Improving of Human Performance."

1.2. Stimulating Research through *CTEKS*

A different prototype methodology needs to be developed and refined for the inverse process of identifying European needs and using them as catalysts for convergence. Here, the expert group recommends a prototype "EuroSpecs" process. It begins with European needs in general areas of health, education, the environment, etc. as identified in the Millenium Declaration, Lisbon Agenda, or forthcoming European policy initiatives. It goes on to offer design specifications for *CTEKS* solutions that address these needs. Somewhat like a competition for architectural designs, these specifications constitute a call to public and private sector researchers to submit design proposals. For the most compelling among the entries, detailed road-maps will then be developed. They specify conceptual, economic, and technical resources and obstacles towards implementation, time-lines, social costs and benefits. Finally, a normative assessment compares the proposed engineering solutions against political, regulatory, and laisses-faire approaches. This assessment should be socially inclusive and ethically aware. When a *CTEKS* design proposal is approved by stakeholders ranging from expert scientists to NGOs and ethicists, a corresponding call for proposals can be issued.

Both, the "ConvergenceDiscovery" and the "EuroSpecs" process of discovering and stimulating *CTEKS* agendas rely primarily on the expertise of CT researchers. Assessments of scientific and technical feasibility can only be made by them. Other stakeholders contribute to the refinement and selection of agendas. By investing social imagination into the creative process, they may also help CT experts see expanded possibilities for convergence.

1.3. Design Challenges for *CTEKS* Solutions

The expert group's sample flagship research proposals (see page 27 above) identify challenges for *CTEKS* research. As sketchy as these proposals are, they have an implicit design component in that they suggest that the sought-after solution to problems of European communication, obesity, or energy should be in tune with European values and fit within certain parameters or specifications.

This "product development" approach to science policy presupposes that there may be "General Design Principles for European CTs." The expert group therefore recommends a EuroSpecs process for the exploration and formulation of such guiding principles. Innovation studies, ethics, social science, process engineering, science and technology studies, economics, product development, and political actors should come together in this effort. As a research process on the history, adequate formulation, and implementation of such technology design specifications EuroSpecs can extend the work of the FP6 thematic priority "Science and Society" and closely integrate it with the research of scientists and engineers. Institutionally and as a normative process, EuroSpecs can develop in parallel to and co-ordinated with the European Group on Ethics (EGE).

Early discussion of these design principles allows Europe to take the lead in an international consideration of norms for technological development. They might underwrite, for example, an international "code of good conduct" as envisioned in the EC's Communication on Nanotechnology.[29]

In support of the *CTEKS* process, research is needed also about the processes of innovation and diffusion, the economies of artificial environments, conditions for multidisciplinary, interdisciplinary, and transdisciplinary work.

1.4. Supporting research

The assessment of the prospects and limits of *CTEKS* requires scientific research in cognitive science, evolutionary anthropology, economics, philosophy and ethics. Effective monitoring of *CTEKS* and societal feedback to the agenda-setting process requires Begleitforschung (accompanying research alongside science and technology R&D).

- This report highlighted on various occasions the need for the support of basic cognitive science. For the purposes of *CTEKS*, cognitive science needs to investigate the physical and social determinants of cognition as well as their interplay. The role of commonsense psychology as the basis of social science research has to be questioned. The potential and limits of "engineering for the mind" and "engineering of the mind" need to be determined. Also, the effects on cognitive processes by technical environments should be investigated: If the video game culture has altered how students learn, the pervasively artificial environments of the future will have a more profound effect.

As CTs pursue the perfectibility of humans and society, evolutionary anthropology needs to study and communicate the meaning of seeming imperfection, diversity and human limitation. Some processes in human brains work more slowly than those of animals with superior reaction-times. This slowness, however, gives us time for reflection and allows us to distinguish instinctual and deliberate responses. What happens when technology is used to speed up human response-times? Similarly, evolved notions of how the mind works (commonsense psychology) need to be investigated, their value and limits determined.

- Reports and surveys about nanotechnology and converging technologies, including this one, make economic assumptions as they compare international expenditures and corporate profits, evaluate market potentials and consumer demand, or predict returns on public investment. These assumptions require careful scrutiny. Also, pervasively artificial environments may create new economic dependencies that need to be investigated. They can also offer new opportunities and constraints for wealth-generation.
- The construction of an artificial nature requires philosophical and social orientation and critique especially as it regards the foundation of ethics and societal values in concepts of freedom and human nature.

(29) "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 5, p. 22.

- EU and US research policy on nanotechnology calls for Begleitforschung ("accompanying research"). It serves to "raise the recognition of research on societal implications to the level of scientific and engineering topics as agents of change, and involve social scientists and economists in R&D groups."[30] Inclusion of social scientists and humanities scholars as participant-observers in the WiCC initiative and *CTEKS* R&D promotes awareness of the entire life-cycle of technology-based responses to socially identified needs. It fosters mutual understanding and cooperation of scientists and engineers, consumers and producers, citizens and policy makers in *CTEKS* research. It allows for the identification of alternative pathways of technological development.

The proposed supporting research need not await the establishment of *CTEKS* as a thematic research priority. Since it affords important background knowledge for the design of *CTEKS* research, it should begin immediately.

A normative setting

Candidate norms or design specifications for deliberation and debate in the EuroSpecs process include the following:

- Instead of delegating human responsibility to automated machine-like processes, *CTEKS* ought to support and sustain responsible judgement. Instead of deskilling production and design processes, they should further qualify a highly skilled European workforce.
- Even as they become invisibly small, integrated with the surrounding environment, and pervasive, *CTEKS* ought to be transparent and provide a technological infrastructure for observing, monitoring, and controlling their operation. They should not destabilise human practice by introducing uncertainties about the presence or absence of technological processes that take place beneath the threshold of perception and that either sustain human action (interactive sensor systems) or undermine it (erosive or surveillance technologies).
- The technological and social infrastructure ought to support the choice of opting out of CTs. Their introduction should not produce coercive effects in a free-market environment, for example, pressure to alter one's or one's children's mental innate abilities for the sake of survival or success. At least, potentially coercive impacts should be taken into account before funding the development of a technology.
- The development and diffusion of *CTEKS* ought to be accompanied by technological and educational strategies to empower individuals. *CTEKS*-literacy should go beyond general knowledge how the technologies work in principle. Technical and conceptual tools need to be provided for detecting *CTEKS* applications, interacting with them, screening them off, etc. The development and educational diffusion of such counter-technological tools ought to be included with technology R&D. While successful technologies tend to become a "black box," counter-technologies open the black box and reveal the inner workings of the system.
- Just as knowledge of the human genome must not be privatised, the operating systems or media for the creation of information and communication technologies ought to be "open source." Similarly, the tools and techniques for the nanotechnological creation of molecular architectures belong to the commons. The basis or medium for the development of knowledge-based technological solutions should not be privatised.
- Though CTs could be used to promote an increasingly homogeneous technical culture, *CTEKS* ought to be a tool for the development of local solutions that foster natural and cultural diversity.
- CTs might pursue engineering of the mind by physically altering or enhancing the human brain. In contrast, *CTEKS* should be dedicated to engineering for the mind and to improvements of the cognitive environment.
- The precautionary principle ought to be applied where *CTEKS* pose known risks that are unknown only in regard to their likelihood and severity. When even the nature of possible harms is unknown, the risks of *CTEKS* ought to be entered in a deliberative setting together with the citizens of Europe. Where arguments fail to persuade that such unknowns are worth engaging, other research avenues ought to be preferred.

2. Research Infrastructure

The research infrastructure for *CTEKS* research has to be created along with *CTEKS* itself. The expert group's main recommendation to establish *CTEKS* as a thematic priority for European research therefore requires a number of support actions. The most prominent among these demands immediate action. It concerns the institutional infrastructure offered by the WiCC initiative and the coordinating WiCC office. Other support actions concern a European Competition for Centers of *CTEKS* Excellence and the educational infrastructure for attracting *CTEKS* researchers.

As with other technology R&D in Europe, perennial infrastructural problems need to be solved for the establishment of effective public/private partnerships. These regard Europe-wide regulatory standards, a unified patenting system, appropriate protections of intellectual property, and frameworks for a strengthened relationship between producers and users or consumers during the development-phase.

Though these issues are not specific to *CTEKS*, the expert group welcomes that a process will be launched in preparation of the next Framework Programme.[31]

2.1. Widening the Circles of Convergence (WiCC)

The goal of the WiCC initiative is to establish *CTEKS* within a limited time-frame of 3 to 5 years as a thematic priority for European research primarily in the general areas of health, education, information and communication infrastructure, energy, and the environment. It sets ups and implements research agendas of social and economic relevance as envisioned in a February 2004 Commission Proposal:

> *"Examples of these partnerships would include the development of a new generation of clean and economic aircrafts at the horizon 2020; the development of hydrogen networks and fuel cells, mastering electronics at the nano-scale, investment in future mobile and wireless technologies and applications, enhancement of joint efforts in embedded systems, as well as new technologies in solar energy, and European co-ordinated effort in advanced chemistry, for multiple industrial applications and social purposes."*[32]

Coordinated by a WiCC office, several seed workshops with selected CT researchers will prepare topically oriented conferences. Each conference surveys scientific and technological potential in a particular domain such as health care, energy supply, information and communication infrastructure, etc. It concludes with an agenda-setting workshop, the development of prototype program calls, and partnering arrangements. Expanding on the EU's concept of "technology platforms," WiCC initiatives and resulting *CTEKS* research programs will bring together a wide variety of public and private stakeholders, including social scientists and ethicists. The WiCC initiative ensures that *CTEKS* include an outreach dimension and that they draw on mechanisms for public deliberation and social engagement. By stimulating social imagination for *CTEKS*, the WiCC initiative and subsequent *CTEKS* agenda-setting have a catalytic effect on national and disciplinary research initiatives. They establish a coherent framework for major technological projects.

The WiCC office serves therefore to coordinate discussions, ensure transparency, and create resources such as an Internet platform, a database of surveys of CT and enabling technologies research, and a partnering exchange for *CTEKS* proposals.[33] The office also promotes *CTEKS* research within the EU by negotiating strategic sites for vertical *CTEKS* interventions that cut across work programs.

(30) "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 3.5. See also Mihail Roco, "Broader societal issues of nanotechnology" (Journal of Nanoparticle Research: 5, 2003, 181-189, p.189
(31) "Communication from the Commission: Science and technology, the key to Europe's future – Guidelines for future European Union policy to support research" COM (2004) 353, section 1.3., prop. 12, p. 4.
(32) Research in the Financial Perspectives 2006-2013: Commission Proposals (February 2004).
(33) This platform can be modeled on or should be an extension of www.nanoforum.org.

The move from WiCC initiative and prototype development to *CTEKS* research programs corresponds to the creation of an "innovation network."

Strong interdisciplinarity for *CTEKS* research

CTEKS engineering for the mind sets out to improve the environment in which humans sense, think, communicate and decide. The idea is to present information in such a way that it is optimally attuned to the requirements of human reasoning. In order to achieve this goal, social scientists, information and communication technology researchers, cognitive and neuroscientists need to collaborate. Moreover, they need a shared understanding of how the human mind works. Without this understanding, they cannot improve, let alone optimise the cognitive environment.

Most social scientists and software engineers base their work on a more or less refined commonsense psychology. This commonsense psychology is a theory of the human mind that works in most circumstances of daily life. However, there may be areas where commonsense psychology breaks down due to technological advances (decision-making in complex human-computer networks) or cultural changes (times of war, emotional disturbance in today's workplace). In particular, the pervasive artificial environments created by CTs may produce interactions between mind and world that can no longer be accounted for by commonsense psychology.

CTEKS engineering for the mind reflects and constructs a world that is increasingly structured by science and technology. In order to do so effectively, it will move from commonsense psychology to the accounts offered by cognitive science. *CTEKS* research therefore cannot simply embark on an interdisciplinary project. Interdisciplinarity has to begin with cognitive scientists criticising the theoretical assumptions of social science – and vice versa. Social scientists will acknowledge the difference between commonsense psychology and the scientific description of the mind. They may insist, however, that human culture and society has never been based on this scientific understanding but on a naturally and culturally evolved self-understanding that is supported by commonsense psychology. Accordingly, they may reject the notion that they should adopt cognitive science as the foundation of their work.

Such mutual criticism between disciplines puts interdisciplinarity to a severe test and presupposes stable professional and institutional relations in an atmosphere of respect.

An innovation network organises the production of knowledge by way of its four main characteristics:

- Innovation networks are co-ordination devices that enable and support learning by accelerating and supporting the diffusion of new technological know-how.
- Within innovation networks the exploitation of complementarities becomes possible, which is a crucial prerequisite to master modern technological solutions that are characterised by complexity and a multitude of involved knowledge fields.
- Innovation networks constitute an organisational setting that allows for the exploration of synergies through the amalgamation of different technological competencies.
- Innovation networks provide a reward structure for creative and entrepreneurial engineering that seeks to integrate economic opportunity with public good.

2.2. Interdisciplinary Excellence

Innovation networks and *CTEKS* research programs require and produce new standards for interdisciplinary research. Interdisciplinarity usually means that researchers from various disciplines pool intellectual and technical resources as they address a problem together. This form of interdisciplinarity is insufficient when the *CTEKS* agenda-setting process requires critical and comparative assessments of the viability of proposals. Mutual criticism across disciplinary boundaries is required especially when current or medium-term limits of CT research need to be determined. Such mutual constructive criticism presupposes understanding and trust. Funding incentives for collaborative research is not enough to produce this kind of interdisciplinarity.

Program calls and research policies of the Commission and Member States should foster standards of interdisciplinarity that go beyond planned or institutional collaboration. In order to build and sustain understanding, trust, and respect between disciplines, researchers need to work together at one physical location. The expert group therefore recommends that Member States should be invited to participate in a European Competition for Centers of *CTEKS* Excellence.

2.3. Measuring *CTEKS*

No *CTEKS* research community exists in advance of the WiCC initiative. This is one way in which *CTEKS* present a new challenge for the allocation of R&D resources. Investment in this initiative must precede measures of research activity. To be sure, artificial measures of national and international CT funding, publications, and patent applications can always be generating through creative key wording and re-labelling of ongoing research. However, a more appropriate way to evaluate *CTEKS* research must be found.

The characteristic feature of *CTEKS* is that it gives extant research projects a particular unifying direction, namely their convergence towards a common goal. Since the various contributing enabling technologies and knowledge systems are already subject to documentation, current activities and strengths are measurable in regard to the contributing disciplines. This information should enter into assessments of the viability of proposed *CTEKS* actions. In contrast, the appropriate standards for evaluating the *CTEKS* programs themselves are provided only by benchmarking. When specific goals for convergence are formulated, this will go along with the development of benchmarks and roadmaps via a foresight processes. In regard to these benchmarks and roadmaps, the progress of *CTEKS* research can be evaluated. These evaluation criteria can include considerations of transformative or disruptive effect, economic, social, and environmental significance, and public response.

Key 2020

The EC and Member States should contribute to the European Empowerment Campaign Knowledge Europe Year 2020. This campaign provides a forum for educational initiatives, idea competitions, and public debates that develop visions for shaping the future of Europe through the convergence of KEY or enabling technologies.

Since enabling technologies are not dedicated to a specific goal or limited to a particular set of applications, they tend to be judged by the visions that go into them rather than by the results they produce. Since these visions reach far beyond disciplinary perspectives, scientists and engineers, policy makers and philosophers, businesses and citizens are all called upon to develop social imagination for *CTEKS* applications. The KEY 2020 campaign serves as an umbrella to recruit public participation. It fosters awareness of the new technologies and their creative potential. It raises trust in the public process while generating feedback for research and market directions.

The traditional model for science policy and funding has been challenged through the rise of application-dominated research. It breaks down entirely in the case of *CTEKS*: It is not possible to assess current strengths in *CTEKS* and only then allocate funds in order to build on strengths, to create new areas of strength, to abandon areas of weakness, etc. *CTEKS* research comes into existence only when a goal for convergence is set and when a support structure is instituted. The prospective assessment of likelihood of success therefore requires a different set of tools.

A new social contract between science and society

In order for the *CTEKS* process to succeed for the benefit of European societies at large, an approach is needed

- to interest the many public constituencies in what is at stake,
- to invite and empower them to take part in the discussion,
- to regard them as an important resource rather than an obstacle,
- to develop a language and a platform for integrated discussion.

One element of this approach is the Societal Observatory of Converging Technologies: The expert group recommends the creation of a standing committee for real-time monitoring and assessment of international CT research, including *CTEKS*. The primary mission of this observatory is to study social drivers, economic and social opportunities and effects, ethics and human rights dimensions. It also serves as a clearing house and platform for public debate. Working groups will deal in multidisciplinary collaborations with issues of patenting, the definition of the commons, and the allocation of intellectual property rights.

Among the core members of the committee should be social scientists and philosophers who also participate in WiCC initiatives, Centers of *CTEKS* Excellence, and the EuroSpecs research process. In close collaboration with *CTEKS* research groups, the observatory monitors roadmaps, benchmarks, and public response. These core members in the societal observatory thus represent policy and ethical perspectives while developing substantial technical and scientific expertise in CTs. They serve as intermediaries that bring societal concerns to the research community, and relate research visions to various public constituencies.

The proposed WiCC initiative provides one such tool. Comparison of expenditure for alternative strategies to obtain particular *CTEKS* goals is another such tool. In particular, investments in *CTEKS*-based solutions need to always be compared to low-tech or no-tech alternatives provided by voluntary action, cultural change, incentive structures, or legislation. This includes consideration of the consequences of not adapting a present or future technology. Yet another tool comes from innovation studies, history of technology and theory of technological development. The combined resources of Science and Technology Studies should be mobilised to integrate historical knowledge with on-going assessments of current developments regarding the creation and diffusion of new technologies.

2.4. Proactive Education

Numerous educational initiatives need to strengthen the research infrastructure and to attract young researchers to the field of *CTEKS*. Elements of excitement should be introduced into secondary-level curricula and extend into lifelong learning programs. For example, the creation of an instructional module on “enabling technologies” in secondary schools might be accompanied by a European competition for *CTEKS* visions. By learning to conceptualise a field of research as an enabling technology or knowledge system in schools as well as universities, students are encouraged to imaginatively integrate social problems with potential technology solutions. This will encourage liberal arts students to think creatively about science and technology approaches. It will also encourage science students to think beyond curricular compartmentalisation towards the synergy of various natural and social sciences.

3. Research Governance

CTEKS require a transparent and open political process which should be advanced by a Communication from the Commission on Converging Technologies.

Because of its openly political character, *CTEKS* may well gain broad public interest and support. After all, *CTEKS* research is explicitly geared to recognised needs and normative design specification. And yet, no matter how positive the *CTEKS* agenda may appear, ethical concerns regarding its implicit assumptions and regarding the technologies that contribute to the convergence will be raised. It is paramount that these concerns are engaged in an open and self-critical manner – not only because the conditions for public support should be created, fostered, and maintained but also because public resistance and debate can have a positive shaping effect on the process. Various measures build trust, create legitimacy, and draw on public debate as a resource and inspiration for *CTEKS* agendas.

- A transparent process of *CTEKS* agenda-setting ensures the participation of public and private stakeholders, including social scientists and humanities scholars. This should be reflected also in the assessment of particular research proposals. Broadly ethical and cultural considerations of originality and social cost/benefit can inform the review process. This can be done by including advisory social scientists or philosophers in review panels, and/or by adding to the review process input statements on the social value of a proposal.
- In order to meet the legal challenges posed by *CTEKS*, the EC should commission comparative studies on existing human rights, national legislation, international norms, professional codes, and standards as they might apply to converging technologies. With a view to creating international or, at least, common European standards, such studies should consider future regulatory management and risk management for converging technologies.
- On the policy level, in particular, a strict line must be drawn between military ambitions for CTs and *CTEKS*. In the context of international negotiations about codes of good conduct, issues of arms regulation should be raised with an insistence on unambiguous adherence to international agreements.
- The EC's communication on nanotechnology stresses the need to share knowledge internationally in regard to health, safety, and environmental aspects.[34] A comparative perspective and co-operation on an international scale is necessary also for the societal dynamics of the creation, diffusion, acceptance and rejection of CTs. This includes international discussion of European design specifications.

4. Foresight for Europe

The *CTEKS* challenge is to recognise European strength in the global economy and to exploit this strength. As it compares itself to the US and some Asian economies, Europe sees its particular strength not in the development and manufacture of mass-produced goods for a global consumer market but in the skilled craft, design of processes, and creation of sophisticated tools, customised solutions, alternative technological approaches, etc. As it compares itself to the economies of developing countries, Europe sees that its wealth creates an obligation towards these countries and that there is economic opportunity also for Europe if it meets this obligation wisely. For example, Europe can help establish non-tradable systems of energy generation or manufacturing which require for their sustenance a framework of international security as well as political and economic cooperation.

(34) "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 5, p. 22.

As a science policy tool in pursuit of the Lisbon strategy and a knowledge-based European economy, *CTEKS* rely on foresighting activities for the achievement of their goals. Foresighting can suggest how closely or loosely research agendas should be related to policy goals. Foresighting can indicate to what extent *CTEKS* solutions should be addressed specifically to European or third world problems, and it might show how even highly specific solutions ensure a continued return on the investment.

The foresighting methodology itself should be extended, however, as to address the demands of *CTEKS* research.

- The diffusion and final shape of a technology depends largely on how it is received and debated. Since the impact of current technology R&D cannot be predicted straightforwardly, foresighting therefore needs to include a consideration and assessment of present visions for the technological future. These visions express the hopes and ambitions that motivate and justify science and technology R&D.

  By making these visions subject to public debate, technology assessment moves upstream: Instead of considering the products that come out of the development, vision assessment addresses the hopes, dreams, and promises that go in and inform it.

- Through real-time technology assessment, foresight activities become integrated with the research process. This is in accordance with *CTEKS*'s demand for explicit agenda-setting, road-mapping, and self-monitoring: Through *Begleitforschung* and the participation of social scientists, critical reflection becomes installed in the process. It allows for the identification in time of possible alternatives with fewer negative social consequences. Regular reports from this ongoing assessment would serve as input to resource-allocating agencies, it would inform ethical and societal review and public debate.

- As technology assessment is moved upstream and foresight oriented towards the input of agendas, visions, and ideas, the history and pitfalls of foresighting itself become increasingly relevant. "Retroforesighting" might be used to reflectively explore how foresighting has shaped or failed to influence and anticipate the course of events. Also, since foresighting can build trust among research community, policy makers and public constituencies, it might include trust assessment and thereby bring together historians, social science researchers, and the various stakeholders.

- Finally, conceptions of freedom, morality, and human nature should be brought to normatively assess the visions that go into CTs or the philosophical agenda that implicitly sustains its research practice.

Together with EuroSpecs research, this expanded foresight methodology recruits cultural traditions for the careful deployment of a tool which will be used to shape the future of Europe. *CTEKS* may profoundly transform the world as we know it. But *CTEKS* can only succeed if its transformative potential can be integrated into the diverse social and cultural fabric of Europe. Just as innovation always countenances tradition, *CTEKS* require hindsight for foresight.

Conclusion and Recommendations

Converging Technologies (CTs) present equally significant opportunities and challenges. CTs converge on common goals or shared visions, and first among the opportunities and challenges is the formulation of such goals. "Converging Technologies for the European Knowledge Society (*CTEKS*)" designates the European approach to CTs. It foregrounds the process of deliberate and creative agenda-setting for CT research.

The citizens of Europe will benefit if *CTEKS* are geared towards health care, information processing and communication, environmental remediation, energy supply, and other areas of public interest and personal concern. *CTEKS* allow for the exploitation of technological potential and economic opportunity to satisfy pressing needs in Europe and in the developing world.

Confronted by deeply transforming and potentially disruptive changes in relation to nature, society and individuals, citizens and governments shoulder grave responsibilities. They will have to find a course between the necessity to control the development of CTs, and the sense that these pervasive technologies bring about cultural and moral dislocation.

Though it does not foster basic research for its own sake, agenda-setting for *CTEKS* will have a catalytic effect on science and technology R&D and will therefore invigorate the scientific community.

European competitiveness stands to benefit from *CTEKS* when knowledge-intensive customised technology solutions are marketed internationally. The socially inclusive agenda-setting process will act as an incentive for an increase in private sector research investment.

CTEKS represent a powerful science policy tool for the advancement of the Lisbon strategy; they establish a "critical mass of resources," provide the "framework for major technological projects" and a "research infrastructure of European interest" that are stated goals of the June 16, 2004 EC communication on the future of EU research policy. They strengthen the European Community by benefitting European citizens and by including them in the policy process.

In order to take up the challenge and to exploit these opportunities, the present report developed a series of recommendations on:

- vision and strategy
- new research agendas
- wider research frameworks and support environments
- ethics and social empowerment

1. Establishing *CTEKS*: Vision and strategy

Challenges:

To use the potential of Converging Technologies (CTs) to develop ambitious research programs and thereby advance European social, economic, and research policy goals.

To swiftly create multidisciplinary communities of CT researchers for the development of scientifically feasible, economically attractive, and socially beneficial *CTEKS (Converging Technologies for the European Knowledge Society)* proposals.

Recommendation 1: That the European Commission implement the WiCC-initiative ("Widening the Circles of Convergence") in order to create a *CTEKS* research community, in the first instance by establishing a coordinating WiCC office.

Coordinated by a WiCC office, several seed workshops with selected CT researchers will prepare topically oriented conferences. Each conference surveys scientific and technological potential in a particular domain such as health care, energy supply, information and communication infrastructure. It concludes with an agenda-setting workshop, the development of prototype program calls, and partnering arrangements. Expanding on the EU's concept of "technology platforms," WiCC initiatives and resulting CTEKS research programs will bring together a wide variety of public and private stakeholders. The WiCC office should establish an internet platform that provides the research community, various publics and special interest groups information and exchange about technological development and science policy issues.

Recommendation 2: The European Commission is advised to integrate now a CT dimension in FP6 programme calls (in particular in the thematic priorities nanotechnology, life sciences, information technologies, social sciences and humanities).

Preparing for the establishment of CTEKS as a thematic priority for European research, this should aim at flagship research partnerships such as CTs for Natural Language Processing, CTs for the Treatment of Obesity, CTs for Intelligent Dwelling.

Recommendation 3: Member States are encouraged to promote the *CTEKS* process by launching prototype CT research initiatives through national foresighting activities and funding programs.

Recommendation 4: In the context of the seventh EU framework programme for research, Member States should be invited to participate in a European Competition for Centers of *CTEKS* Excellence; the European Research Council should provide visiting fellowships at the Centers.

Center of Excellence are needed to attract internationally mobile talent to CTEKS research. The European Research Council can support this process by awarding the winners of the competition high prestige visiting fellowships at these Institutes.

2. Harnessing the Dynamics of Convergence: New Research agendas

Challenges:

- To consolidate and support multidisciplinary CT research, allowing for focused and sustained technical developments.
- To conduct background research necessary for the scientific, economic, historical and normative assessment of *CTEKS* proposals.
- To assess the prospects and limits of CTs.

Recommendation 5: Interdisciplinarity should be strengthened, beyond planned or institutional collaboration, in program calls and research policies from the Commission and from the European nations.

For the purposes of CTEKS and starting with the WiCC initiative, interdisciplinarity is needed to identify feasible cooperations in the first place. Also, CTEKS require mutual criticism across disciplinary boundaries, for example, between information technology and cognitive science.

Recommendation 6: Commission and Member States should expand and deepen their commitment to Cognitive Science.

> *For the purposes of CTEKS, this includes basic research on social cognition, the replacement of commonsense psychology as the basis of social science research, an investigation of potentials and limits of "engineering of the mind"- approaches, and the study of the effects on cognitive processes by technical environments such as video game culture.*

Recommendation 7: Commission and Member States need to recognise and support the contributions of the social sciences and humanities in relation to CTs, with commitments especially to evolutionary anthropology, the economics of technological research and development, foresight methodologies and philosophy.

- *As CTs pursue the perfectibility of humans and society, evolutionary anthropology needs to study and communicate the meaning of seeming imperfection, diversity and human limitation.*
- *Reports and surveys about nanotechnology and converging technologies, including this one, make economic assumptions as they compare international expenditures and corporate profits, evaluate market potentials and consumer demand, or predict returns on public investment. These assumptions require careful scrutiny.*
- *Current Foresight methodologies should be expanded through a "Hindsight for Foresight" program. Innovation studies, history of technology, science and technology studies, technology assessment and philosophy of science will use historical knowledge and the analysis of international drivers of CTs to shift emphasis from the consideration of presumed outcomes to an evaluation of the visions that go into CT research. Case studies on scientific and technological development should be comparatively investigated to make transparent the underlying dynamics of 'rational development.' Technology assessment should be moved upstream also through the consideration of anthropological dimensions and the promoting or retarding effects of public resistance in the shaping of CTs.*
- *The construction of an artificial nature requires philosophical and social orientation and critique especially as it regards the foundation of ethics and societal values in concepts of freedom and human nature. It also may create new economic dependencies, opportunities and constraints for wealth-generation that need to be investigated.*

3. Developing a framework for *CTEKS*: The research and support environment

Challenges:

- To establish a monitoring and assessment system that is adequate to the potential of *CTEKS* and their specific mode of development.
- To prepare a regulatory process that is appropriate to CTs.

Recommendation 8: A permanent societal observatory should be established for real-time monitoring and assessment of international CT research, including *CTEKS*.

> *Building on existing models of European Observatories, it should study social drivers, economic and social effects, ethics and human rights dimensions. Comparative studies on legal, regulatory, and normative frameworks should be commissioned by this Observatory as CTs pose novel challenges that escape traditional regulatory categories. Existing regulatory approaches in Member and Associated States, on the European level, and in the international arena should be canvassed for similarities and differences, conceptual gaps, and creative solutions – with a view towards a proposal of European standards especially for CTs that are developed outside the CTEKS research process.*

Recommendation 9: That the Commission implement a "EuroSpecs" research process for the development of European design specifications for converging technologies, dealing with normative issues in preparation of an international "code of good conduct."

Following the "Science and Society" action line in EU FP6, economists, social scientists, philosophers, product designers and process engineers should together address the history, adequate formulation, and implementation of technology design specifications. Their interdisciplinary research will be closely integrated with the research of scientists and engineers. Institutionally and as a normative process, EuroSpecs can develop in parallel to and co-ordinated with the European Group on Ethics (EGE). This will give Europe a leading role in the global discussion and negotiation of normative issues towards an international "code of good conduct."

Recommendation 10: The integration of social research into CT development should be promoted through Begleitforschung ("accompanying research" alongside science and technology R&D).

Informing the work of the CT observatory and of the EuroSpecs process, Begleitforschung proceeds alongside science and technology R&D. It promotes the consideration of the entire life-cycle of technological solutions, from R&D beginnings to social adaptations. It fosters the cooperation of scientists and engineers, consumers and producers, citizens and policy makers in CTEKS research. It allows for the identification of alternative pathways of technological development by identifying critical junctures in R&D.

4. Dealing with *CTEKS*: Ethics and social empowerment

Challenges:

- To ensure the consideration of ethical concerns from the beginning and in advance of the developments of norms for *CTEKS* development through the EuroSpecs process.
- While some approaches consider engineering of mind and brain, to promote in Europe engineering for the mind and improvements of the cognitive environment.
- While some approaches to CTs promote an increasingly homogeneous technical culture, to pursue *CTEKS* as a tool for the development of local solutions that foster natural and cultural diversity.
- To balance CT-based solutions against low-tech or no-tech policy alternatives.
- To promote sustainable development, environmental awareness, precautionary approches.
- To empower citizens and consumers to understand, use, and control CTs and to maintain a sense of ownership.

Recommendation 11: That a strict line be maintained between military ambitions for CTs and their development in Europe.

CTEKS R&D should be confined within the stated parameters of the new "European Security Research Programme." In the context of international negotiations about codes of good conduct, CTs must be developed in a way that supports the Geneva Convention and international agreements on arms regulation. New agreements need to be pursued as necessary. The European security research programme should promote the study of potential abuse and monitoring of CTs.

Recommendation 12: Upon advice from the European Group on Ethics (EGE), the mandate for the ethical review of European research proposals should be expanded to include ethical and social dimensions of CTs. Funding organisations in Member States are asked to take similar steps.

For example, the integrity of natural systems has to be considered in the context of enhancement research. Also, the concern about "the use and deliberate release of genetically modified micro-organisms" will have to be broadened to include technically created quasi-organisms.

Recommendation 13: In the face of new models for participatory research governance, transparent decision making processes need to be developed and implemented.

Since CTEKS involve at their core collaborative agenda-setting, rational decision and control structures should be developed in a multidisciplinary, technology-supported and participatory framework.

Recommendation 14: The question of intellectual property rights must be addressed proactively and on an international level.

CTEKS produce mostly non-tradable technical goods and targeted solutions. In analogy to current discussions regarding computer operating systems, the boundaries between publicly shared resources and patentable products and techniques need to be negotiated. The EuroSpecs research process and the societal observatory on CTs should include working groups on issues of patenting, the definition of the commons, and the allocation of intellectual properties right in multidisciplinary collaborations.

Recommendation 15: Member and Associated States are encouraged to stimulate national discussions of CTs and the *CTEKS* perspective.

Beginning with conferences that survey national CT research, national research councils and funding agencies can contribute to the WiCC initiative and the development of prototype CTEKS research. They should join together in a European Empowerment Campaign KEY 2020. The campaign provides a forum for educational initiatives, idea competitions, and public debates that develop visions for the contribution of key technologies to Knowledge Europe Year 2020.

Recommendation 16: CT modules should be introduced at secondary and higher education levels to synergise disciplinary perspectives and to foster interaction between liberal arts and the sciences.

This can be stimulated through European competitions for students and teachers. European Centers of CTEKS Excellence and particular CTEKS research programs and projects should engage in educational activities ranging from public outreach to the introduction of postgraduate summer schools and programs. In analogy to computer literacy, standards of CT literacy need to be developed through the EuroSpecs process.

Members of the expert group

Chairperson

Professor Kristine Bruland
Department of History, University of Oslo. Norway

Rapporteur

Professor Alfred Nordmann
Institut für Philosophie, Technische Universität, Darmstadt; Adjunct

Professor of Philosophy
University of South Carolina. Germany

Members

Dr. Jürgen. Altmann
Physicist and Peace Researcher, Universität Dortmund. Germany

Professor Daniel Andler
Philosophy, Universite de Paris-Sorbonne (Paris IV); Director of Cognitive Studies, Ecole Normale Superieure. France

Dr. Thomas Bernold
Communication and Policy Consultant, Visiting Research Professor at the School of Public Policy, George Mason University. Switzerland

Professor Wolfgang Bibel
Intellektik, Darmstadt University of Technology and University of British Columbia. Germany

Professor Jean-Pierre Dupuy,
Philosopher, Ecole Polytechnique, Paris, and Stanford University. France

Professor Donald Fitsmaurice,
Head of the Nanochemistry Group UCD; Chief Technology Officer NTera Group, Board/Advisor Draper Fisher Jurvetson. Ireland

Professor Emilio Fontela
Universidad Autónoma of Madrid; Hon Prof of Economics, University of Geneva; Visiting Prof University of Seville; Chair of the Expert Group on Developing Foresight on Research/Higher Education Relation. Spain

Dr. Thierry Gaudin
Président de Prospective 2100, Ingénieur général des mines, Membre du Conseil Général des Mines, Author, Futurist. France

Professor Raoul Kneucker
Ret. Director General Research & International Affairs, Austrian Federal Ministry of Education, Science and Culture; Director of the "Gallery of Research" of the Austrian Academy of Sciences. Austria

Dr. Günter Küppers
Physicist and Social Scientist, Institute for Science & Technology Studies (IWT), University of Bielefeld. Germany

Professor Eleonora Barbieri-Masini
Sociologist and Futurist, Gregorian University, Rome. Italy

Dr Ana Morato
Technical Director of the Spanish Observatory of Industrial Technology Foresight, OPTI. Spain

Dr Michael J. Morgan
Chief Executive (retired), The Wellcome Trust Genome Campus, Cambridge, UK

Dr. Nebojsa Nakicenovic
Head of the Transitions to New Technologies Project, IIASA; Professor of Energy Economics at the Technical University of Vienna. Austria

Dr. Ian Pearson, Futurologist, BTexact, Author. UK

Professor Darko Polsek
School of Law, Univ of Sagreb, former Deputy Minister of Science and Technology. Croatia

Dr. Gill Ringland
CEO and Fellow, SAMI Consulting. UK

Professor Arie Rip
Scientific Director: Graduate School of Science, Technology and Modern Culture; Head of Philosophy of Science and Technology , University of Twente. Netherlands

Dr. Francoise Roure
Inspector General, Ministry of Economy, Finance and Industry, MINEFI, Conseil General des Technologies de l'Information. France

Ms. Ottilia Saxl
Chief Executive, Institute of Nanotechnology. UK

Dr. Jan Staman
Directeur, Rathenau Instituut of the Koninklijke Nederlandse Akademie van Wetenschappen. Netherlands

Dr Jean-Pol Tassin
Neurobiologist, Director of Research INSERM, Collège de France. France

Professor Walter van der Velde
(to April 2004), former Director of Research at Starlab; Co-Director, AI-Lab VUB; Contributor, EC's Vision Book Project; Scientific Director, DISC. Belgium

Contributions by members of the expert group

The experts contributed in various ways and across various disciplines during the group – here are some of the significant individual contributions of some of the members as in the State of the Art Report.

Jürgen Altmann "Military Nanotechnology: Perspectives and Concerns"

Daniel Andler "What does the 'C' stand for in the NBIC Acronym?"

Wolfgang Bibel "ICT and AI in View of CT"

Kristine Bruland "Innovation in a Historical Context – Some Issues for Policy"

Jean-Pierre Dupuy "Complexity and Uncertainty"

Emilio Fontela "OECD and 21st Century Technologies"

Thierry Gaudin "Ethno-technology for Converging Technologies"

Raoul Kneucker "'Converging Technologies': Legal, Ethical, and Social Implications"

Eleanora Barbieri Masini "Social and Cultural Issues emerging from the NTW:

A Foresight Approach with some Recommendations"

Michael Morgan "Biotech To-day, and Future Trends"

Ana Morato "CT and Pharmaceuticals"

Nebojsa Nakicenovic "Fusion and NBIC"

Alfred Nordmann "Technologies for Dealing with Technological Advance"

Ian Pearson "Summary of the State of the art of NBIC convergence in ITC"

Darko Polsek "Education in Converging Technologies"

Arie Rip "Technology Assessment of NanoTechnology"

Ottilia Saxl "Nanotechnology Markets"

Jean-Pol Tassin "Neuro-scientific aspects of Foresighting the NTW"

List of contributors and hearings

Members of the Export group were invited to encourage additional input, via submissions to a brief questionnaire, or to appear briefly and present their work and views.

Prof. Enrico Alleva
Head of Behavioural Neurosciences, Istituto Superiore di Sanità, Rome, ITALY

Dr Raymond Bouchard
Drachma Denarius, Ottawa, CANADA

Darian Brookes-Hefets
Warwick Business School, University of Warwick, UK

Professor José Luis Encarnação
Chairman ISTAG, GERMANY

Dr Thomas Bernold
Vision+, Communication and policy Consulting, SWITSERLAND

Baroness Prof Susan Greenfield
Director, The Royal Institution of Great Britain, UK

Members of the "Jean Monnet Round Table on Europe"
Cambridge University, UK

Prof Ron Johnstone
School of Electrical and Information Engineering, University of Sydney, AUSTRALIA

Prof Michael Søgaard Jørgensen
Department of Manufacturing Engineering and Management,
Technical University of Denmark, DENMARK

Prof G Lansavecchia. Editor la Nuova Sciensa, ITALY.

Ms I Makar, Prof P Nightingale
SPRU, University of Sussex, UK; Research Fellow, THECIS, CANADA

Prof Lars Montelius
Head of Exploratory Nanotechnology Group, Lund University, SWEDEN.

Members of the UK's Nano-Micro Club
Institute of Nanotechnology, Scotland, UK

Prof Stig Omholt.
Agricultural University, NORWAY

Petteri Repo. Senior researcher, Ph.D. (Econ),
National Consumer Research Centre, FINLAND

Bibliography

R. Bouchard (2003) *Bio-Systemics Synthesis: Science and Technology Foresight Pilot Project,* Ottawa: Canadian Resarch Council.

Health and Consumer Protection Directorate (2004) *Nanotechnologies: A Preliminary Risk Analysis*, Brussels: European Commission.

M. Gorman (2002) "Combining the Social and the Nanotech: A Model for Converging Technologies," in M. Roco and W. Bainbridge, eds. *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science*, NSF/DOC-sponsored report, Arlington, pp. 325-330.

G. Khushf (2004a) "Systems Theory and the Ethics of Human Enhancement: A Framework for NBIC Enhancement," in M. Roco and C. Montemagno, eds. (2004) "The Co-evolution of Human Potential and Converging Technologies," Annals of the New York Academy of Science 1013, pp. 124-149.

G. Khushf (2004b) "The Ethics of NBIC Convergence for Human Enhancement: On the Task of Framing a Responsible Future," presentation at NBIC Convergence 2004: *Converging Technologies for Improving Human Performance*, New York City.

Nanoforum General Report (2004) *Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology*, see www.nanoforum.org

M. Roco and W. Bainbridge, eds. (2002) *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science*, NSF/DOC-sponsored report, Arlington.

M. Roco and R. Tomellini, eds. (2002) *Nanotechnology: Revolutionary Opportunities and Social Implications (EU-EC/NSF Lecce Conference Report)*, Brussels: European Commission.

M. Roco (2003) "Broader Societal Issues of Nanotechnology," *Journal of Nanoparticle Research 5*, pp. 181-189.

M. Roco and C. Montemagno, eds. (2004) "The Coevolution of Human Potential and Converging Technologies (Conference Proceedings Converging Technologies for Improving Human Performance 2003)," *Annals of the New York Academy of Science* 1013.

J. Schmidt (2004) "Unbounded Technologies," forthcoming in D. Baird, A. Nordmann, J. Schummer, eds. Discovering the Nanoscale, Amsterdam: IOS Press, pp. 35-50

Group mandate

Introduction

The objective of this paper[35] is to define the methodology and scope of the group. In the broad, we want to find out what convergence is, how it will impact the future, and what Europe could do to meet its own policy objectives.

The starting point of this reflection was the US NSF report, which was analysed and discussed but does not constitute the focus point of reflection. It is a question of reflecting and proposing a European approach of the convergence of the sciences/technologies in relation to European cultural, ethical, socio-economic approaches; and European strengths and weaknesses in these technological fields. Cognitive sciences were considered as the most innovative research area for a European approach. Questions – sometimes profound reservations – need to be specified, often they express legitimate concern on the use of these technologies for ideological or military purposes. It is a priority to clarify the civil and societal benefits of this research to give them a new legitimacy and to put them firmly in a context of positive social dynamics. The principle of precaution should be taken into account to fix the framework of the research.

A number of themes that recurred throughout are:

- What is it all about? (Reality, expectations and hype)
- Is there a European vision?
- What is the role of the social sciences?
- How do cognitive sciences fit into the picture?
- What horisontal issues arise?
- What is the educational impact?

It was concluded that in order to develop a European approach a top down approach was needed, with some concept of the way society is progressing and can impact the interplay between science systems and technology based systems. The focus is on convergence as interface, where the interesting players and issues sit (notwithstanding the need for basic sciences who generate the interfaces).

General objectives

Three general objectives should guide the work of the group of ca 25 experts:

1. Develop a research agenda focused on social sciences research on co-operation models (this dimension being specifically European). The objective being to show how this approach can break with the idea of the individual performance being the only criteria for measuring success.
2. Whether to develop a programme building on the experience of application programmes targeted on specific fields like hearing, vision, ageing, cognition.
3. How to develop research agendas on "contextualised technology",[36] which would have the advantage of being addressed to third world countries, but also to emergent countries (India,

(35) This is an abbreviated version of the expert group's Terms of Reference that were prepared by the Science and Technology Foresight Unit.

Brasil,) having currently mobile and often unexploited research worker resources.This would focus on the genuine emergent needs of the societies concerned, and the concern for rapid market implementation, which remains a priority for competitiveness.

Questions to be addressed

Once the question of what converging technologies are is addressed, and why are they important, the European picture needs to be painted and then possible European responses identified.

The main questions are as follows:

1. Why adopt a *convergent* approach? What's the contribution or value added of this approach in relation to the European research and technology policies, but also in relation to the other policies of the Union?
2. What research would be the most urgent, important and/or necessary in Europe today in the fields of cognitive and social sciences to answer better comprehension of the convergent approach?
3. What are the ethical and societal concrete questions that the implementation of the technologies concerned raises?
4. How to articulate a competitive approach and simultaneously a co-operative approach? Does co-operation matter? What new instruments are necessary to answer this strategy, and at what level are they best implemented?
5. *As the FP6 proceeds, can one identify near terms research which can in some cases be deepened by investigation now?*

These objectives and questions will be steered by 10 "Guiding Principles" which need to be implemented throughout the work.

Guiding principles

The concept of "guiding principles" is to have, at each stage of the reflective development process, a series of perspectives in mind that will help shape the relevance of the debate. In any a pluralistic society and culture such as Europe, it is rare that any single approach or philosophy applied to any reasonably broad subject matter can reign supreme at the cost of others. The different technical approaches demand it, as well as the panorama of policies which may be impacted.

Process

1. **Consistent and Integrated Reflections -** When working in reflective mode, frequent cross-referencing is needed to ensure a uniform and consistent approach in which diverse views can be captured. Convergence is the driver, Europe the context!
2. **Realism -** The US Key report is repeatedly criticised for containing a very wide ranging set of technology development assumptions.
3. **Inter-disciplinarity -** Whether Inter-, Multi-, Cross-, Trans- disciplinary approaches are relevant is still open. It is the coming together of technologies and the implication of that that is the object, not the technologies themselves.

(36) By "contextualised technology" we mean all technologies which improve productivity, competitiveness and working conditions, closely linked with identified needs of the society. That does not exclude in any way the new technologies, which can be suitable answers in certain cases, but that also stresses the improvement of competitiveness in economic sectors considered as "traditional".

Content

4. **Social Drivers of Change -** Social impact per se, and personal impact are the framework
5. **Education and Training -** There are many implications for all education, with the special demands converging technologies place on the traditional systems.
6. **Ethics -** in science is a wide area and still developing what is a European perspective. However, it is a key structural instrument in developing the ERA. The principle is the respect of ethics, support for their eventual development to meet new norms, and what that means for research into the evolution of ethics and norms and how they are inserted into research agendas.
7. **Sustainability** - with emerging technologies as a goal as an unambiguous gain for technology and society.

Context

8. **The European Dimension -** The issues to be discussed here need to be discussed in a Lisbon and European 25+ context. ERA, European policies and Europe's role in the global picture are the focus, building and complementing national deliberations where these exist. The new EC financial perspectives for beyond 2007 for the future framework programmes offer some early insight into possible structures.
9. **Pre-caution, Anticipation and Risk Management -** The guiding principle then on the reflections is that at each stage we need to consider what precautionary measures one can reasonably anticipate to ameliorate risk, build trust and offer scientists and society the safest way forward.
10. **Managing a Strategic Jump in Diversity -** The technologies here coincide in timescale with a key fact for Europe Enlargement from 15 to 25 to maybe then 30 States. This brings with it the biggest boost to S&T since the 1970's. Reflections on this moment in time are important, with an eye to the next scheduled round of enlargement and also the long term future of the EU S&T base.

Proposed structure of work

The core group is responsible for achieving a number of horisontal tasks dealing with issues of general relevance as well as those of co-ordination. A number of specialised sub groups are proposed to deal with specific "vertical" issues; applying guiding principles throughout. Individual contributions may be solicited (Hearings).

Workpackages foreseen for the core group focus

Common tasks foreseen for the group include:

1. Review of the State of the Art
2. Foresighting the New Technologies Wave - Scenarios
3. Quality of Life
4. Education and Competitiveness Impacts
5. Horisontal Issues

Special interest groups

SIG 1 Cool – Convergence for Quality of Life - Covering the convergence of social issues like ageing, social and demographic trends and convergence of biomedical visions of the future of QoL. The SIG adopted a workplan using the Calvert Henderson QoL matrices and questionnaire to the group.

SIG 2 CCC – Cultural Configuration of Convergence - The group will consider technologies and techniques that surround the emergence of converging technologies. It views ethical, legal, political discourses as interventions in the process of coming to terms with and directing the emerging convergence.

SIG 3 EE – Economic Effectiveness - What are the challenges and opportunities that NBIC poses for the economic effectiveness of Europe over the next 20 years? Social effectiveness will also be an issue, Europe tends to use more "total returns"; balancing the Lisbon objectives to including social cohesions.

SIG 4 – Society, Cognition, and Group Performance - Scientific Analysis and Technologies, like individual and distributed cognition, cognition and intelligence and their models, accumulation of knowledge in individuals as well as in groups, knowledge systems for support of individuals and groups, understanding the relation between local and global knowledge to support the development of technology for the area under consideration. Normative issues: like the relevant ethics involved in these technologies, risks to be taken into account in their development and deliberations about how they could evolve and be ameliorated, positive results coming out from such technologies such as enhancement of self-awareness and "happiness".

Dissemination starts with a conference inviting a much broader group of participants to open a debate on the conclusions and proposed actions for the research policy. This will be on 14-15th Sep. 2004, in Brussels.

Index to Report

European Commission

EUR 21357 – Converging Technologies – Shaping the Future of European Societies

Luxembourg: Office for Official Publications of the European Communities

2004 – 63 pp. – 21.0 x 29.7 cm

ISBN 92-894-8313-X