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HLEG  
Foresighting the New Technology Wave

Converging Technologies –  
Shaping the Future of European  
Societies

*by Alfred Nordmann,  
Rapporteur*

Report

2004

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

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# Executive Summary

The European Commission and Member States are called upon to recognize 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 *CTEKS* as a specifically European approach to CTs, and to establish a CT research community.

These are the major finding 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 000 members of the group, chaired by Kristine Bruland and rapporteur Alfred Nordmann 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 challenge, 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 challenge by proposing a European approach to converging technologies: *CTEKS: Converging Technologies for the European Knowledge Society*.

## **THE CHALLENGE**

Information and communication technology was central to the transformation of life in the 20<sup>th</sup> 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 neuroscience 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 21<sup>st</sup> Century. If these various technologies each created controversy and anxiety, 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 HLEG 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.

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- *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 live 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 seductive 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 HLEG 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 be drawn to surrender 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 knowledge systems 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 destabilizing 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 countries.

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 *toward* a common goal. CTs always involve an element of agenda-setting. Because of this, converging technologies are particularly open to the inclusion

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of public concerns. Because of this, they can serve as a science policy to achieve the objectives, for example, of the Lisbon Agenda.

Agendas for convergence include “Converging technologies for improving human performance” or “Converging technologies for battlefield domination.” The HLEG does not recommend 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.”

Agenda-setting for CT researches is a research policy tool that along with the research programs creates a climate of investor and consumer confidence. It also supports the research community by exercising a catalytic effect and focuses creative energy. It invests science and technology R&D with social imagination by providing a broader vision.

## RECOMMENDATIONS

The HLEG offers 20 complementary and integrated recommendations towards the implementation of *CTEKS*. They call for

- preparatory actions in FP6 program calls to allow for the establishment of *CTEKS* as a thematic priority for European research;
- a WiCC (“Widening the Circles of Convergence”) initiative to establish a *CTEKS* research community, to develop proposals for CT research agendas, to provide mechanisms for public participation and an integrated social science perspective (*Begleitforschung*);
- research on the prospects and limits of CTs, especially in the areas of basic cognitive science, evolutionary anthropology, economics, technology-supported rational decision and control structures, and science studies;
- a “EuroSpecs” research process to propose, discuss, and recommend normative design specifications for *CTEKS* applications, giving Europe a leading role in the global discussion and negotiation of an international “code of good conduct” (including restrictions on military CT research and expanded mandate for ethical review of research proposals);
- a European Empowerment Campaign KEY 2020 that provides a forum for educational initiatives, idea competitions, and public debates to develop visions for the contribution of key technologies to *Knowledge Europe Year 2020* – along with other educational and outreach initiatives to foster social imagination for multi- and interdisciplinary research;
- an international survey of legal and regulatory frameworks to prepare for novel challenges posed by CTs, with a view toward a proposal of European standards,
- a societal observatory of national, European, and international CT research to study social drivers, economic and social opportunities and effects, ethics and human rights dimensions, serving as a clearing house and platform for communication between research community and public constituencies;

- criteria for *CTEKS* agenda setting: promotion of local solutions that foster natural and cultural diversity; engineering *for* the mind rather than *of* the mind; CT-based solutions need to always be balanced against low-tech or no-tech alternatives provided by voluntary action, cultural change, incentive structures, or legislation;
- an expanded foresighting methodology to include vision assessment, “hindsight for foresight,” and upstream, real-time technology assessment.

# 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 fertilization, genetic screening, more targeted pharmaceuticals and genetically modified crops. Nanotechnology researchers manipulate individual atoms, develop improved materials and aim to miniaturize 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 miniaturization, 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.

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## 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.)

*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.<sup>1</sup> 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 (‘nanomanufacturing’), integration at the macro-micro-nano interface and interdisciplinary (‘converging’) R&D.”<sup>2</sup>*

## FORMATION AND CHARGE OF THE EXPERT GROUP

The European Commission first drew attention to CT initiatives in the June 2003 issue of the *Foresighting Europe* newsletter. It featured a report about two NBIC (Nano-, Bio-, Info-,

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<sup>1</sup> “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., prop. 5, p. 2.

<sup>2</sup> “Communication from the Commission: Towards a European strategy for Nanotechnology,” COM (2004) 338, section 3.1.1., p. 10.

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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."*<sup>3</sup>

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 HLEG 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 challenge, 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 dual challenge 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 dual challenge 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.**"

The HLEG's report shows how this expanded vision can serve to shape 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 harmonize with the values of diversity, social justice, international security, and environmental responsibility.

### **THE WORK OF THE EXPERT GROUP**

The HLEG 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.<sup>4</sup> Its work was oriented by ten guiding

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<sup>3</sup> *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.

<sup>4</sup> See the HLEG's Terms of Reference that are included as Annex 000 to this report.

principles which included commitments to realism, integrated assumptions, ethics and sustainability.<sup>5</sup>

The wide range of concerns which seem likely to arise in the process of developing CTs were reflected in the composition of the HLEG 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 HLEG 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 emphasizes 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.

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 to 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

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<sup>5</sup> They are included in Annex 000.

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. 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.

The Conclusion summarizes the challenges of CTs and offers 20 recommendations for immediate action in the context of a medium-term strategy.

# 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,

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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 realization 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 organized 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.”<sup>6</sup>
- 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

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<sup>6</sup> Mihail Roco and William Bainbridge, eds., Arlington, June 2002.

system integrity and disease mitigation – nanotechnology, ecological science, biotechnology, information technology and cognitive sciences.<sup>7</sup>

- A third example was suggested by Stig Omholt of the Agricultural University of Norway. It repeats the pattern: “Converging technologies for salmon-productive aquatic environments – bioinformatics, environmental science, systems theory, salmon genomics, production biology, economics.”<sup>8</sup>
- More examples of CT research were considered by the HLEG. It recommends as a possible flagship project: “Converging technologies for natural language processing – information and nanotechnology, linguistics, cognitive and social science” (see box for further examples).

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 HLEG.

## 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.*<sup>9</sup> 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 realization of desirable architectures at the micro- and macroscale. Instrumentally, nanotechnology enables biotechnology by developing new imaging techniques, probes and sensors. It contributes to the

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<sup>7</sup> Raymond Bouchard, *Bio-Systemics Synthesis; Science and Technology Foresight Pilot Project*, Canadian National Research Council, June 2003, p. 8.

<sup>8</sup> Presentation at the Norwegian Research Council, May 5 2004, and personal communication. Omholt first proposed a 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.”

<sup>9</sup> Note that the term “(enabling) knowledge system” can be replaced everywhere by “technology-enabling scientific knowledge.”

### THREE SAMPLE FLAGSHIP RESEARCH PROJECTS

***Converging technologies for natural language processing:*** The Europe of 25 nations with mostly different natural languages (NL) faces exorbitant problems of communication among individuals and institutions. Any substantial progress in a technological support for 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 challenge includes the different modes of written as well as acoustic NL understanding systems, written and spoken NL generation systems, and translation systems. (see Annex 000, 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 biomimetic technologies, by integrating photovoltaics 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 neighboring buildings and urban infrastructure at large by exploiting its own specific capabilities that are determined by its location, structure, and material make-up.

- miniaturization demands of information technology. Also, nanochips and nanosensors 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 organization. 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, biomimetics and the investigation of cellular motors can enable nano-info R&D in nanorobotics.
  - 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

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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 maximizing benefit and minimizing 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 their support and diffusion. Philosophy, cultural studies, and ethics do so by providing 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.

### **3. LIMITS OF CONVERGENCE**

This 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 seems to expand the power of the others.

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&T decision-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 technical 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 environmental 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-organization and to make materials with novel properties has led at least one reinsurance company to question the insurability, for example, of nanoparticles.<sup>10</sup> It appears that genuine novelty can be attained through complex processes of self-organization 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-organization and whether these theories can be technically useful for creating genuine novelty.
- From the above one can highlight the role of cognitive science. 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. Especially the US approach to NBIC convergence may have embarked on such a course, because it envisions cognitive enhancements that are to engage complex and ill-understood cognitive processes. CT research must therefore include a study of the limits of such an approach. In order to avoid bad public investments, cognitive science research must be supported, and an assessment of its achievements and limits should determine when and 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 socialization 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.
- 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.

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

### **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 encyclopedias and dictionaries, to maps of every city in the world, they include the “Open Mind Common Sense” data base and can be customized to include data-bases of expert knowledge. Demand is high for this long-anticipated consumer product. 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 information.

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

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 recognizes 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.

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## 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 particularly 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 prioritizes 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.

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, information and communication infrastructure, energy, or environment. They will generate calls for abstracts and lists of invitees for *CTEKS* conferences that are organized 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 coordinate the effort, establish and maintain a directory of associated researchers, *CTEKS* projects, and institutional resources. Expanding on the EU’s “technology platforms” on photovoltaics, AIDS research or nanoelectronics, WiCC initiatives and resulting *CTEKS* programs

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will bring together a variety of public and private stakeholders, they will integrate social scientists and ethicists.<sup>11</sup>

## 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:

- *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 toward miniaturization in information technology, toward molecular engineering in nanotechnology, toward 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: It no longer has the character of care for a nature that needs to be preserved but becomes instead accountability for the surroundings that we have temporarily created.
- *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 realized 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.
- *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

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<sup>11</sup> Regarding the proposed technology platform for nanoelectronics see (000 exact reference) “Vision 2020: Nanoelectronics at the Centre of Change,” EC, Report of the High Level Group, June 2004.

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 organizational 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 characterized 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 recognized in the European context. In order to provide a context for the development of CTs, the HLEG identified four scenarios for Europe in 2020. Subgroups explored what *CTEKS* means 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.<sup>12</sup>

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* 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 toward shared goals. The novelty of *CTEKS* is therefore that they explicitly answer to the European agenda for the 21<sup>st</sup> Century – they are a science policy tool for the implementation of the Lisbon Strategy which was predated 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.”*

#### **1.1. European Objectives.**

The promise of *CTEKS* is that they can be geared toward these tasks. In particular, the *Millenium Declaration* identified the needs

- 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,
- to work for a more open and stable international economy that benefits also people in less favored parts of the world,

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<sup>12</sup> For the reports of these subgroups see Annexes 000-000.

- to create capabilities for managing international crises and providing humanitarian assistance.<sup>13</sup>

What best recommends *CTEKS* as a science policy tool for the achievement of European objectives is the fact that it 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."<sup>14</sup> In the case of enabling technologies and their convergence, roadmaps can be developed only for targeted areas of R&D.

### **1.2. Research for 2020 Europe.**

The scenario method was used by the HLEG to identify robust research interests for the development of CTs. Four developed scenarios compare Europe in 2020.<sup>15</sup> 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 prioritizes economic growth, while the latter focuses on social cohesion. In the pursuit of economic growth, "Global Capitalism" represents an increasingly homogenized 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, information and communication infrastructure (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.<sup>16</sup> The five topical areas can therefore serve to frame agenda-setting for *CTEKS*

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<sup>13</sup> 000 provide exact reference, refer also to Article 3 of the Draft Constitution.

<sup>14</sup> "Communication from the Commission: Towards a European strategy for Nanotechnology," COM (2004) 338, section 3.1.4., p. 11.

<sup>15</sup> refer to Annex 000 (*Scenarios Workshop Output*).

<sup>16</sup> refer to Annex 000, p. 000 (SIG 1 report).

researches. Within these broadly defined topical areas, research should serve to further the European objectives of the Millennium Declaration and Draft 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.

### **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.<sup>17</sup>

*CTEKS* are a science policy tool also for adapting the existing research infrastructure to the goals of the ERA. In particular, they 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.<sup>18</sup>

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

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<sup>17</sup> “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.”

<sup>18</sup> 000 provide exact references, 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

economic policies, cultural resistance and support, complementarity with established technologies, and many other factors.

### **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 sizable 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 11) 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 customized 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.

The move towards 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 and steel manufacturers alike are shifting from the manufacture and sale of products to the development of diagnostic tools or solutions that integrate the entire life-cycle of technology-based responses to consumer-specific needs. The provision of pharmaceutical agents or bulk material is subsidiary to the creation of such targeted solutions.

Economic opportunities for *CTEKS* in Europe depend on technological potential, international markets, social attitudes, and European policies. Especially in the case of *CTEKS*, a laissez-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

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research funding for *CTEKS* but it also helps mobilize *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. Utilizing the *CTEKS* Tool.**

Each of the likely characteristics of *CTEKS* applications (see Part 1, Section 5) 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 homogenize and globalize the world, the *CTEKS* approach accepts European diversity as a challenge and the basis of economic opportunity. It therefore incorporates cultural and intercultural studies in the structuring of and translation between artificial environments.
- *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* prioritizes *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 miniaturization trends. In a separate document, one of the HLEG’s subgroups details this technological and clearly also economic potential (Annex 000/SIG4). – 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 (Annex 000/SIG1).
- *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, what seems to be necessary is creative adaptation. *CTEKS* is 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.

## **2.2. Need-Opportunity integration through CTEKS**

The discussion so far of the economic dimension has shown that *CTEKS* represents 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 disproportionately small private sector involvement that was identified, for example, in the EC’s Communication on Nanotechnology.<sup>19</sup>

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<sup>19</sup> “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

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* is 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 toward 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 scrutinized 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.”<sup>20</sup> 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 a knowledge space for parents. This knowledge

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with 66% and 73% respectively,” compare also European Commission “Key Figures 2003-2004” (2003), exact reference 000.

<sup>20</sup> 000 exact reference Spring Report 2004 on the Lisbon Strategy.

space may be filled with learning objects that are chunks of information such as documents, experts, experiences, contacts, web-seminars, lessons, or digital libraries.<sup>21</sup>

- *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 (see page 11). 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.”<sup>22</sup>

- *Energy*: Living conditions the world over are largely determined by access to drinkable water and energy. *CTEKS* fosters inclusivity by creating new energy technologies for the generation, transport, storage, and consumption 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 will be integrated in devices in a manner that emulates nature. The goal of

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<sup>21</sup> See Annex 000 (SIG 4), p. 10.

<sup>22</sup> 000 exact reference.

this research could be that within a century nearly all energy needs can be met by way of locally generated renewable energy.

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.<sup>23</sup> 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.

#### **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 materialize. Inversely, there is a societal risk

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<sup>23</sup> See Annex 000/SIG 1 report.

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:

The *Baja Beach Club* in Barcelona 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 size 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 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. Favourite 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 recognized 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* designates the European approach of setting an agenda for CTs that will draw together enabling technologies and knowledge systems towards common goals appropriate to Europe. In a previous section (Part 1, Section 5), four general characteristics of likely CTs as well as *CTEKS* applications were identified. Each of these represents economic and scientific opportunity (Part 2, Section 2.1.), 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 *CTEKS*, like ambient computing, 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

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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. 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.

The development of *CTEKS* applications requires vigilance. In as much as they involve the creation of artificial environments, an effort needs to be made to preserve transparency and as long as possible 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 version 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

### **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 recognized.

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?

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 CTs 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?

- *Specificity*: The precision and specificity of CT applications may have a destabilizing 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 destabilizing 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* provides 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 destabilizing 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 jeopardize the international law of warfare.

## 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 individualized 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.

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.

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### **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 organizations, 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 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 emphasizes 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."*<sup>24</sup>

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."<sup>25</sup> 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* expands on the

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<sup>24</sup> "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 3.1.1., p. 10.

<sup>25</sup> "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.

concept of “technology platforms” and thereby advances the EC’s policy goal to “improve the coherence of public research agendas throughout Europe.”<sup>26</sup>

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<sup>26</sup> 000 exact reference - 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 organization 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* researches 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 Part 2 above, Sections 1.3. and 1.1.). 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, Framework Programme 6 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. Mobilizing 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 characterization and placement on conceptual as well as geographic maps, connections and complementarities between various

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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 proposed collection and exploitation of existing knowledge for CTs is an ongoing project that cannot be concluded before the start of the *CTEKS* process. However, a prototype of the heuristic method needs to be developed and refined. This prototype “ConvergenceDiscovery” process 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 HLEG 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 scrutinizes 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 HLEG 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 toward implementation, time-lines, social costs and benefits. Finally, a normative assessment compares the proposed engineering solutions against political, regulatory, and laissez-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.**

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The HLEG's sample flagship research proposals (see page 13 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 HLEG therefore recommends that the EuroSpecs process serve also as a support action 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 an expert group. In a series of workshops, the group will propose or identify candidate norms and assess them for their in-principle defensibility and practical viability.

Early discussion of these 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 it was envisioned in the EC's Communication on Nanotechnology.<sup>27</sup>

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 researches.**

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).

- 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.

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<sup>27</sup> "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 5, p. 22.

## 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 expand and 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 destabilize 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 or physical capabilities in order to remain competitive in the labor market. At the very 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 of counter-technologies ought to be included with technology R&D.
- Just as knowledge of the human genome must not be privatized, 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 patented and privatized.
- 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.

- 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.
- US and EU 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.”<sup>28</sup> 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.

These supporting researches need not await the establishment of *CTEKS* as a thematic research priority. Since they afford important background knowledge for the design of *CTEKS* research, they should begin immediately.

## 2. RESEARCH INFRASTRUCTURE

The research infrastructure for *CTEKS* research has to be created along with *CTEKS* itself. The HLEG’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.

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<sup>28</sup> Mihail Roco, „Broader societal issues of nanotechnology“ (*Journal of Nanoparticle Research*: 5, 2003, 181-189, p.189. – Compare “Communication from the Commission: Towards a European strategy for nanotechnology,” COM (2004) 338, section 000.

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 HLEG welcomes that a process will be launched in preparation of the next Framework Programme.<sup>29</sup>

### **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 up 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.”<sup>30</sup>*

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. The office also promotes *CTEKS*

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<sup>29</sup> “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.

<sup>30</sup> (000 exact reference) Research in the Financial Perspectives 2006-2013: Commission Proposals (February 2004).

research within the EU by negotiating strategic sites for vertical *CTEKS* interventions that cut across work programs.

The move from WiCC initiative and prototype development to *CTEKS* research programs corresponds to the creation of an “innovation network.” An innovation network is a new form of organisation within knowledge production and has three major implications.

- Innovation networks are important 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 characterized 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. By this, innovation processes are fed with new extensive technological opportunities which otherwise would not exist, or whose existence would at least be delayed.
- Innovation networks provide a reward structure for creative and entrepreneurial engineering that seeks to integrate economic opportunity with public good.

Member states can take a leading role in developing prototype *CTEKS* proposals and innovation networks.

## **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 HLEG therefore recommends that Member States should be invited to participate in a European Competition for Centers of *CTEKS* Excellence.

## **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 optimize 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* researches therefore cannot simply embark on an interdisciplinary project. Interdisciplinarity has to begin with cognitive scientists criticizing 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 requires stable professional and institutional relations in an atmosphere of respect.

### **2.3. Measuring *CTEKS*.**

Since there is no *CTEKS* research community before the WiCC initiative, investment in this initiative must precede measures of national and international CT funding levels, publications, and patent applications. This is one way in which *CTEKS* presents a new challenge for the allocation of R&D resources. Instead of generating artificial measures through creative keywording and re-labeling ongoing research activities, a more appropriate way to measure *CTEKS* research must be found.

The characteristic feature of *CTEKS* is that it gives extant researches a particular unifying direction, namely their convergence towards a common goal. Since the various contributing

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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, while appropriate measures of the *CTEKS* programs themselves are provided 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 assessed. These assessment measures will include considerations of transformative or disruptive effects, economic, social, and environmental significance, and public response.

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.

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. 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 mobilized to integrate historical knowledge with on-going assessments of current developments regarding the creation and diffusion of new technologies.

#### **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.

#### **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 conceptualize 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 compartmentalization toward the synergy of various natural and social sciences.

### **3. RESEARCH GOVERNANCE**

*CTEKS* requires 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 recognized 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 inclusion 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.<sup>31</sup> 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.

#### **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 HLEG 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 with such questions as the applicability of patents, the definition of the commons, and the allocation of intellectual property rights in multidisciplinary collaborations.

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.

#### **4. FORESIGHT FOR EUROPE**

The *CTEKS* challenge is to recognize 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, customized solutions, alternative technological approaches, etc. As it compares itself to the economies of developing countries, Europe sees that its wealth creates

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<sup>31</sup> "Communication from the Commission: Towards a European strategy for nanotechnology," COM (2004) 338, section 5, p. 22.

an obligation toward 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 and continued economic as well as cultural exchange.

As a science policy tool in pursuit of the Lisbons 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* researches.

- 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 development, it addresses the intentions 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 toward the input of agendas, visions, and ideas, the history and pitfalls of foresighting itself become increasingly relevant. "Retroforesighting" might be used to reflexively explore how foresighting has shaped or failed to influence and anticipate the course of events.
- Finally, conceptions of freedom, morality, and human nature should be brought to normatively assess the visions that go into CTs or the philosophosphical 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.

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# Conclusion and Recommendations

Converging Technologies present equally significant opportunities and challenges.

- The citizens of Europe will benefit as *CTEKS* create advances in 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 for the satisfaction of pressing needs in Europe and the developing world.
- Citizens and governments shoulder grave responsibilities as they confront deeply transformative and potentially disruptive changes in the relation to nature, society and self. They will have to find their way between an obligation to steer the development of CTs and a sense of cultural and moral dislocation that is brought upon them by these pervasive technologies.
- Though they do not foster basic research for its own sake, *CTEKS* will have a catalytic effect on science and technology R&D and will therefore invigorate the scientific community.
- European competitiveness will benefit from *CTEKS* as knowledge-intensive customized technology solutions are marketed internationally. The socially inclusive agenda-setting process is an incentive for an increase in private sector research investment.
- *CTEKS* are 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 “Lisbon and Research” document. They strengthen the European Community by benefitting European citizens and by including them in the policy process.

In order to meet these opportunities and challenges, the present report developed a series of recommendations on:

- vision and strategy
- preparatory actions and support actions
- ethics and social empowerment

## **1. Vision and strategy: Establishing *CTEKS*.**

*Challenge:* To use the potential of CTs to develop ambitious research programs and advance European social, economic, and research policy goals.

*Recommendation 1:* The European Commission is advised to integrate CTs in FP6 program proposals to prepare for the establishment of *CTEKS* as a thematic priority for European research. This includes the development of flagship research proposals such as CTs for Natural Language Processing, CTs for the Treatment of Obesity, CTs for Intelligent Dwelling.

*Recommendation 2:* Member States are encouraged to promote the *CTEKS* process by developing prototype CT research initiatives through national foresighting activities and funding programs.

*Challenge:* To create a positive environment for the implementation and development of these research programs.

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*Recommendation 3:* Intensify and accelerate the “Lisbon and Research” process of encouraging the mobility of scientists, of developing regulatory and metrology standards for nanotechnology and other enabling technologies, of improving conditions for technology transfer and the management of intellectual property, of developing joint projects with developing countries.

## **2. Preparatory actions and support systems.**

*Challenge:* To swiftly create multidisciplinary communities of CT researchers for the development of scientifically feasible, economically attractive, and socially beneficial *CTEKS* proposals.

*Recommendation 4:* Implementation of the WiCC-initiative (“Widening the Circles of Convergence”): 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.

*Challenge:* To consolidate and support multidisciplinary CT research, allowing for focused and sustained technical developments.

*Recommendation 5:* Member States should be invited to participate in a European Competition for Centers of *CTEKS* Excellence. The winners of the competition will receive support from the European Research Council through the creation of high prestige visiting fellowships at these Institutes.

*Challenge:* To conduct the complementary and background researches that are necessary for the scientific, economical, historical and normative assessment of *CTEKS* proposals.

*Recommendation 6:* The assessment of the prospects and limits of *CTEKS* requires scientific research in cognitive science, evolutionary anthropology, economics, and philosophy. 1) Commission and Member States need to 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 potential and limits of “engineering of the mind”- approaches, and study of the effects on cognitive processes by technical environments such as video game culture. 2) 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. 3) 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. 4) 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.

*Recommendation 7:* A framework of norms and policy goals for *CTEKS* should be developed through the “EuroSpecs” research process. Economists, social scientists, philosophers, product designers and process engineers will together address normative questions regarding technology development. This will give Europe a leading role in the global discussion and negotiation of these issues towards an international “code of good conduct”. The interdisciplinary research process will develop prototypes for *CTEKS* agenda-setting processes and generate design specifications for CTs.

*Recommendation 8:* 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 will be moved upstream also through the consideration of anthropological dimensions and the promoting or retarding effects of public resistance in the shaping of CTs.

*Recommendation 9:* Program calls and research policies of the Commission and Member States should foster standards of interdisciplinarity that go beyond planned or institutional collaboration. 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.

*Challenge:* To establish a monitoring and assessment system that is adequate to the potential of *CTEKS* and their specific mode of development.

*Recommendation 10:* A permanent societal observatory should be established for real-time monitoring and assessment of international CT research, including *CTEKS*. Building on the models of EITO (European IT Observatory) and the nanotechnology observatory, it should study social drivers, economic and social effects, ethics and human rights dimensions. The observatory should bring together a standing committee of social scientists and

ethicists who also participate in WiCC initiatives, Centers of *CTEKS* Excellence, and the EuroSpecs research process. The observatory establishes and monitors roadmaps and benchmarks in collaboration with *CTEKS* research groups. The social scientists and philosophers in the societal observatory represent policy and ethical perspectives while developing expertise in CTs.

*Recommendation 11: Begleitforschung* (“accompanying research”) should integrate social research in technological development. This promotes the consideration from R&D beginnings of the entire life-cycle of technology-based responses to socially identified needs. 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.

### **3. Recommendations on ethics and social empowerment.**

*Challenge:* To ensure the consideration of ethical concerns even as the discussion of norms for *CTEKS* development is only beginning through the EuroSpecs process.

*Recommendation 12:* A strict line must be drawn between military ambitions for CTs and their development in Europe. *CTEKS* R&D should be confined within the stated parameters of the “European Security Research Programme.”<sup>32</sup> In the context of international negotiations about codes of good conduct, CTs must not be allowed to undermine the Geneva Convention and international agreements on arms regulation. New agreements need to be pursued as necessary.

*Recommendation 13:* The mandate for the ethical review of European research proposals needs to be expanded to include ethical and social dimensions of CTs. Funding organizations in Member States are asked to take similar steps.

*Recommendation 14:* Agenda-setting for *CTEKS*-research should be guided by European standards. While some approaches to CTs promote an increasingly homogeneous technical culture, *CTEKS* are a tool for the development of local solutions that foster natural and cultural diversity. And while some approaches consider engineering *of* mind and brain, *CTEKS* is dedicated to engineering *for* the mind and improvements of the cognitive environment. Further standards will be developed through the EuroSpecs process.

*Challenge:* To prepare a regulatory process that is appropriate to CTs.

*Recommendation 15:* Comparative studies on legal, regulatory, and normative frameworks should be commissioned 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 toward a proposal

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<sup>32</sup> See “Lisbon and Research” section 4.3.2.

of European standards especially for CTs that are developed outside the *CTEKS* research process.

*Recommendation 16:* Drawing on new models and tools for public interaction and participatory research governance, transparent decision making processes need to be developed. Since *CTEKS* involves at its core collaborative agenda-setting, rational decision and control structures should be developed in a multidisciplinary, technology-supported and participatory framework. In particular, this concerns the application of the precautionary principle as the need for *CTEKS* R&D needs to be balanced against release of materials with untested novel properties – requiring new tools for the assessment of non-quantifiable and unknown risks. It also concerns investment in environmental technologies while maintaining an emphasis on environmental awareness and conservation. As a guiding principle, technology-based solutions need to always be balanced against low-tech or no-tech alternatives provided by voluntary action, cultural change, incentive structures, or legislation.

*Recommendation 17:* Since *CTEKS* produce mostly non-tradable technical goods, the question of intellectual property rights must be addressed proactively on an international level. In analogy to current discussions regarding computer operating systems, the boundaries between publically 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 questions regarding the applicability of patents, the definition of the commons, and the allocation of intellectual properties right in multidisciplinary collaborations.

*Challenge:* To empower citizens and consumers to understand, use, and control CTs and to maintain a sense of ownership.

*Recommendation 18:* Member States are encouraged to begin national discussions of CTs and the *CTEKS* perspective. This can begin with conferences that survey national CT research, contribute to the WiCC initiative and the development of prototype *CTEKS* research. Member States should also contribute to 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 19:* At secondary and higher education levels, CT modules should be introduced to synergize 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.

*Recommendation 20:* The WiCC office should establish an internet platform that affords the research community, various publics and special interest groups opportunities for exchange about relevant information regarding technological development and issues of science policy.