NBIC: Converging Technologies

Some shots by: Mahmoud Mokhtari

- Long Shot: Institutes Projects and Products
- Medium Shot: Concept Generation and Diffusion
- Close Up: Nature and Future

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definitions of the scope of converging

- Nanotechnology: Technology related to features of nanometer scale (10^{-9} meters),
- Biotechnology: The application of science and engineering to the direct or indirect use of living organisms, or parts or products of living organisms, in their natural or modified forms.
- Information Technology: Applied computer systems – both hardware and software, including networking and telecommunications.
- Cognitive Science: The study of intelligence and intelligent systems, with particular reference to intelligent behavior as computation.

Implications of converging new technologies

1. Revolutionary tools and products,
2. Everyday human performance, such as work efficiency,
3. accelerated learning, and increase of group performance,
4. Changing organizations and business models, policies for reshaping the infrastructure, setting priorities for R&D planning, and other societal relationships;

research fields affected by or driving the development of convergence

- The clustering exercise resulted in eight areas:

1. Neuroscience and brain enhancement,
2. Physical enhancement and biomedicine,
3. Synthetic biology,
4. Human-machine interfaces,
5. Sensors,
6. Pattern recognition,
7. Computer-based modelling of the world,
8. Robots and intelligent software and devices.

Converging NBIC Knowledge and Tools

- convergence of computer science and genomics, and the evolution of microelectronics to nanoelectronics; both of these trends have been greatly aided by converging technologies.
- Nanofabrication has enabled the development of sensors and devices for biomedical applications.
- A very recent example of things that may come is a “genetic hard drive” that encodes digital information in DNA to produce a memory much denser than is possible with traditional technologies.

Converging NBIC Knowledge and Tools

- The open-source AFNI package (a set of C programs for processing, analyzing, and displaying fMRI data) is an example of widespread application of tools of information technology in biotechnology.

products and capacities

- pharmaceutical genomics; neuromorphic technology; regenerative medicine; biochips with complex functions; multiscale molecular systems;
- electronic devices with hierarchical architectures; software for realistic multiphenomena and multiscale simulations, processes, and systems from the basic principles at the nanoscale;
- new flight vehicles using biomimetics; and quantitative studies with large databases in social sciences.

products and capacities

- universal databases; cognition and communication developments; cloud computing; human–robotics systems; mind-cyber-physical systems;
- platforms for unmanned vehicles; the space program; the research program on fundamental particles (Higgs et al.);
- the birth of entirely new disciplines such as synthetic biology, quantum communication, nanophotonics, and nanofluidics; and the integration of biomedicine with physics and engineering.

Advances in NBIC Tools

- **Nanotechnology** provided new capabilities to "see" at the nanoscale.
- Our ability improved to probe single-charge, single-spin, spin excitation, and bond vibrations at the atomic scale.
- Coupled with these new capabilities were advances in atomic- and molecular-level simulations.

Advances in NBIC Tools

- Advances in synthesis and fabrication such as new techniques for soft lithography, development of synthesis and separation strategies for monodisperse nanomaterials (e.g., nanocrystals and quantum dots) and macromolecules, and progress in self- assembly, directed assembly, and molecular recognition,
- Advances in electronics, optics, photonics, plasmonics, and nanomaterials and metamaterials are leading to new applications in biomedicine, energy, and information technology.

Advances in NBIC Tools

- **Biotechnology** transformed agriculture and medicine, and more recently, synthetic biology.
- Dramatic advances in the capabilities and speed of DNA/gene sequencing.
- Three-dimensional tracking (at the single-molecule level) of protein motors, enzymes, liposomes, and other bio-nanostructures is now possible.
- Optical technology shows promise for parallel, remote control of neuronal activity with high spatial and temporal resolution.

Advances in NBIC Tools

- **Information technology** advances in global deployment of fiber and wireless communications systems, in computing speed and memory capacity.
- The increasing use of parallel programming software has been an important factor in harnessing the power of today's multicore processors.
- data mining: the acquisition of data becomes essentially free due to advances in nanoelectronics.
- Increasingly powerful search engines have had great impact.

Advances in NBIC Tools

- **Cognitive science:** noninvasive brain imaging, such as positron emission tomography (PET), magnetoencephalography (MEG), electroencephalography (EEG), and functional magnetic resonance imaging (FMRI)
- Deep brain stimulation electrodes, transcranial magnetic stimulation (TCMS), direct current brain stimulation (DCBS), and optogenetic approaches.
- cellular imaging: fluorescent probes (voltage-sensitive and calcium indicator dyes) and optical stimulation and inhibition of neural activity.

convergence–divergence

- The convergence phase consists of analysis, making creative connections among disparate ideas, and integration.
- The divergence phase consists of taking these new convergences and applying them to conceptual formation of new systems; application of innovation to new areas; new discoveries based on these processes; and multidimensional new outcomes in technologies, and products.

convergence to “smart phone”

- in “cell phone” platform: a wide range of technologies including high-frequency communications and packet switching protocols (for connections to global networks); materials science and nanotechnology (for CPUs, data storage, touch screens, antennas, etc.); and cognitive science and human–computer interface technologies (for the user interface) converged to create the “smart phone” about a decade ago.

“smart phone” divergence into many applications

- This is now diverging into thousands of applications from social networks to controlling groups of very inexpensive miniaturized satellites, and many other examples, too many to list, affecting virtually every aspect of our society. These impacts in turn have profound implications for and secondary impacts on areas as diverse as national security, education, and cognitive science.

nanoscale

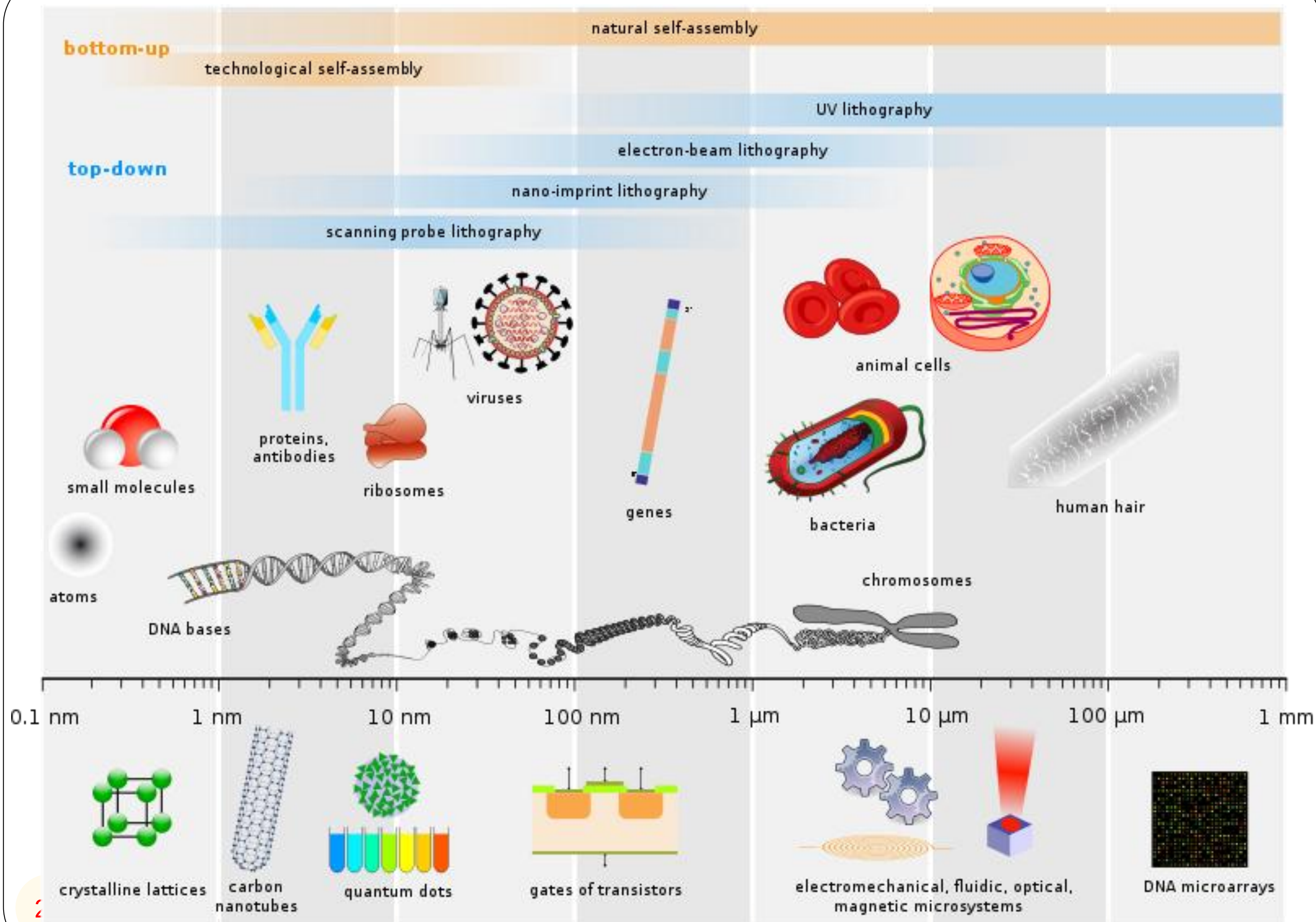
- convergence at the nanoscale is happening because of:

1. the respective use of the same elements of analysis (i.e., atoms/molecules in nanotechnology or bits/parts in information technology),
2. and of same principles and tools,
3. our ability to make cause-and-effect connections from simple components to higher-level architectures.

- In both nano and information realms, the respective phenomena/processes cannot be separated, and there is no need for discipline-specific averaging methods.

nanoscale

- Conventionally defined as the size range from 1 to 100 nanometers,
- the nanoscale is where complex molecules form, where the building blocks of living cells are structured, and where the smallest components of computer memories and processors are engineered.
- many of the key structures of the vast human nervous system exist at the nanoscale, such as the vesicles that store neurotransmitters, the gap between neurons across which those neurotransmitters flow, and the pigment molecules in the eye that make vision possible.



natural self-assembly
bottom-up
technological self-assembly
UV lithography
electron-beam lithography
top-down
nano-imprint lithography
scanning probe lithography
proteins, antibodies
viruses
animal cells
small molecules
ribosomes
genes
bacteria
human hair
atoms
chromosomes
DNA bases
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
crystalline lattices
carbon nanotubes
quantum dots
gates of transistors
electromechanical, fluidic, optical, magnetic microsystems
DNA microarrays

nanobio

- much biotechnology today – and increasingly more in the future – is a variant of nanotechnology.
- Organic chemistry does not necessarily depend upon biology, because the term refers to a broad class of complex molecules that need not have been produced by living organisms.
- Synthetic biology and engineering of nanobiosystems are recently introduced terms. Because both nanotechnology and biotechnology often deal with complex molecules.

nanoinfo

- Modern information technology is based on microelectronics, which is rapidly evolving into nanoelectronics.
- As a first step, computer chips have become nanoscale thin, and this very thinness gives them unique electric properties.
- The current advances on nanolayers with special insulation or conducting properties will evolve to three-dimensional nanostructures and devices and may lead to replacing the information carrier from electron charge to new carriers such as electron spin, photon, or quantum state.

cogno

- Of the four NBIC fields, cognitive science is the least mature,
- This is a multidisciplinary convergence of cognitive and perceptual psychology, linguistics, cultural anthropology, neuroscience, and artificial intelligence aspects of computer significantly in the development of cognitive science, even though many sociologists and political scientists study the formation and transmission of knowledge, belief, and opinion.

cogno-nano-bio-info

- Clearly, neuroscience and artificial intelligence tie cognitive science to biology and to information science,
- links to nanoscience are also visible on the horizon, both through the emerging understanding of the functions of neurons on the nanoscale and through new nano-enabled research methodologies for studying the brain and human-tool/machine interaction.

cogno-nano-bio-info

- Nanotechnology and information technology are enablers, as well as creative fields in their own right, giving other branches of science and technology new powers.
- Biotechnology and cognitive science directly concern the human body and mind and have the greatest possible implications for human physical and mental health.

enabling technology and knowledge systems

- 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.

enabling technology and knowledge systems

- the social and cognitive sciences have accumulated considerable knowledge about social interactions, effective communication, etc. To the extent that this scientific knowledge is implementable in engineered systems, it can also enable far-reaching technological developments.
- An important step in the history of CTs was the 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.

enabling technology and knowledge systems

- Converging technologies are enabling technologies and knowledge systems that enable each other in the pursuit of a common goal.
- What goals should be set for enabling technologies and knowledge systems to converge upon?

enabling technology and knowledge systems

- nanotechnology:
- Conceptually, enables other technologies by providing a common framework for all hardware-level engineering problems. Everything that consists of molecules can, in principle, be integrated with each other. An understanding of properties at the nanoscale allows for the realisation of desirable architectures at the micro- and macroscale.

enabling technology and knowledge systems

- nanotechnology:
- Instrumentally, enables biotechnology by developing new imaging techniques, probes and sensors.
- It contributes to the miniaturisation demands of information technology.
- Also, nano-chips and nano-sensors are set to enable advances in the new world of bioinformatics.

enabling technology and knowledge systems

- biotechnology:
- Conceptually, enables other technologies by identifying chemical-physical processes and algorithmic structures in living systems that are traced to their material basis in cellular and genetic organisation.

enabling technology and knowledge systems

- biotechnology:
- Instrumentally, enables nanotechnology by providing mechanisms of cellular recognition and targeted transport.
- It promises to enable information technology by developing, for example, the foundations for DNA-based computing.
- Also, bio-mimetics and the investigation of cellular motors can enable nano-info R&D in nano-robotics.

enabling technology and knowledge systems

- information technology:
- Conceptually, enables other technologies through its ability to represent ever more physical states as information and model processes with a variety of computational methods.

enabling technology and knowledge systems

- information technology:
- Instrumentally, information technology provides the computing power which is essential to the research process in all technical disciplines.
- It enables nanotechnology through precision control of patterning and intervention.
- It enables biotechnology by providing the means to model complex processes and thereby solve difficult research problems.
- Also, simulation software can enable nano-bio R&D in environmental monitoring.

enabling technology and knowledge systems

- social sciences and humanities:
- Conceptually, can enable science and technology in a variety of ways. Familiar examples include game-theoretical strategies for maximising benefit and minimising cost, models for the representation of economic and other forms of exchange, patterns of gestalt recognition in human perception or by machine intelligence,

enabling technology and knowledge systems

- social sciences and humanities:
- Instrumentally, they offer techniques of probabilistic reasoning and statistical inference, methodologies for qualitative research, or an understanding of the social dynamics of the creation and diffusion of technological innovation.
- Economics and the law enable technology R&D by shaping the incentive structure for its support and diffusion.
- Philosophy, cultural studies, and ethics provide orientation where new technologies disrupt traditional ways of life.

enabling technology and knowledge systems

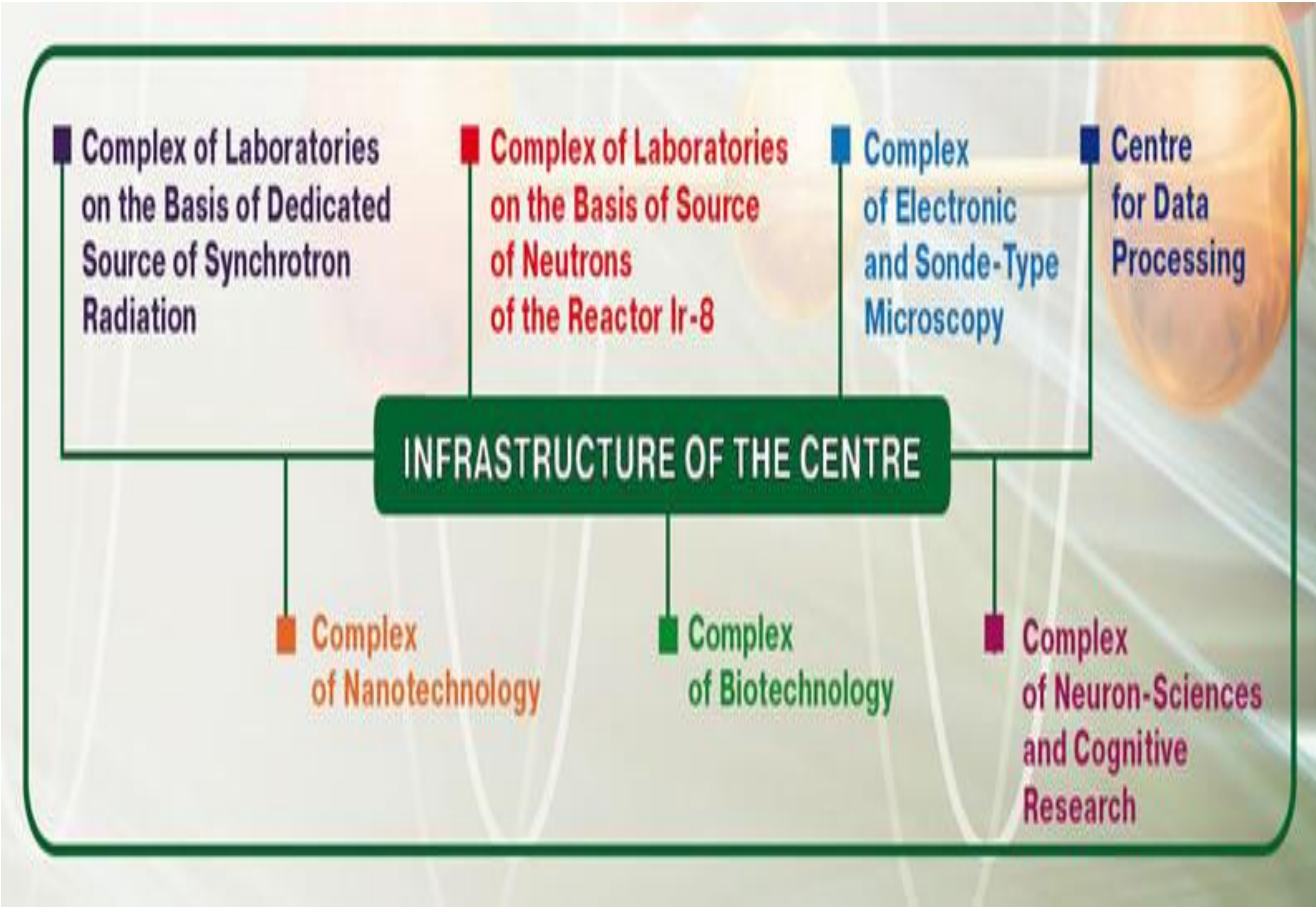
- Nanotechnology and cognitive science, information technology and the social sciences are needed not only to enable each other but also to inform each other about present and in-principle limits of convergence.

Kurchatov Center of Converging NBIC

- It concentrates at interdisciplinary development and researches.
- The complex of mega facilities is the experimental base of NBIC centre: dedicated synchrotron radiation source, neutron research reactor IR-8 (both facilities are equipped with a wide range of analytical and technological stations to carry out researches in the area of materials science, nanobiotechnology, medicine, etc.).

Kurchatov Center of Converging NBIC

- There are also advanced laboratories of high-resolution electron and probe microscopy, genomic and proteomic research, cognitive sciences.
- The Centre has a complex of molecular-beam epitaxy facilities and multi-purpose modular nanotechnological system NanoFab.
- Data processing and storage is fulfilled in the supercomputer data processing centre


Complex of Laboratories on the Basis of Dedicated Source of Synchrotron Radiation
Complex of Laboratories on the Basis of Source of Neutrons of the Reactor Ir-8
Complex of Electronic and Sonde-Type Microscopy
Centre for Data Processing
INFRASTRUCTURE OF THE CENTRE
Complex of Nanotechnology
Complex of Biotechnology
Complex of Neuron-Sciences and Cognitive Research

MIT Institute for Soldier Nanotechnology

- 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.

MIT Institute for Soldier Nanotechnology

- 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.

MIT Institute for Soldier Nanotechnology

- ISN research is organized into five Strategic Research Areas (SRAs):

1. Lightweight, Multifunctional Nanostructured Materials
2. Soldier Medicine — Prevention, Diagnostics, and Far-Forward Care
3. Blast and Ballistic Threats - Materials Damage, Injury Mechanisms, and Lightweight Protection
4. Hazardous Substances Sensing
5. Nanosystems Integration: Flexible Capabilities in Complex Environments

Biodesign Institute at Arizona State University

- planned 75,000 square meters of shared research space, housing centers that span biomedicine, nanotechnology, and bioinformatics.
- Large, open lab spaces, shared by multiple investigators, are enclosed in glass.
- Facilities are clustered around an open hall that forms a natural interaction space.
- The labs themselves are designed to be as flexible as possible, with mobile benches and facilities that are readily moved to accommodate new projects.

Biodesign Institute at Arizona State University

- 26 tenured faculty members work in one or more of 11 research centers at the Biodesign Institute Their faculty tenure homes include the School of Life Sciences; Physics, Chemistry, and Biochemistry; Electrical, Computer and Energy Engineering; Biological and Health Systems Engineering; Sustainable Engineering; Computer Informatics and Decision Engineering; Engineering of Matter, Transport, and Energy; and Medical Bioinformatics.

Biodesign Institute at Arizona State University

- An additional 32 research faculty members have institute appointments.
- The centers are supported by 140 research staff,
- Nearly 100 graduate students,
- 40 postdoctoral fellows,
- Nearly 100 undergraduates are involved in Biodesign Institute research projects.

Artificial Hand Project

- researchers at Lund University in Sweden:
- 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. 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.

Cognitive Computing

- There is a biologically inspired research agenda to build cognizant systems, i.e., software and hardware that compete with (rather than attempting to replicate or simulate) the architectures, algorithms, and processes used in brains for data processing to extract meaning.
- The goal is to build systems that can be taught rather than programmed, and that can autonomously learn how to respond to unanticipated events in an uncertain and changing world.

IBM brainscale simulation project

- IBM projects that a human-scale simulation, running in real time, would require a dedicated nuclear power plant, whereas the power dissipation in the human central nervous system is on the order of 10 W.
- Continuing to do computations in the conventional way will not lead us to brainscale simulation because it will be limited by power consumption.
- Nanoelectronics today and its projected evolution will enable enormous computational capability.

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Converging Technologies- USA Viewpoint

- The US Government refers to convergence as NBIC and envisions that the mastery of the nano-scale domain will ultimately amount to the mastery of all of nature.
- At the molecular level, there exists a “material unity” so that all matter- life and non-life is indistinguishable and can be seamlessly integrated.
- The goal of NBIC is to “improve human performance,” both physically and cognitively.

Converging Technologies- USA Viewpoint

- A "new renaissance" of science based on unity: "Convergence of diverse technologies is based on material unity at the nanoscale and on technology integration from that scale.
- Science can now understand the ways in which atoms combine to form complex molecules, and how these in turn combined according to common fundamental principles to form both organic and inorganic structures.

Converging Technologies- USA Viewpoint

- Technology can harness natural processes to engineer new materials, biological products, and machines from the nanoscale up to the scale of meters.
- The same principles will allow us to understand and, when desirable, to control the behaviour both of complex microsystems, such as neurons and computer components, and macrosystems, such as human metabolism and transportation vehicles.

levels of convergence

- *Three successive levels of convergence* have been described by U.S. Government-sponsored studies:

1. in the late 1990s moving into the 2000s, *nanotechnology* provided integration of disciplines and technology sectors of the material world building on new knowledge of the nanoscale,

levels of convergence

2. in the 2000s, converging *nanotechnology, biotechnology, information technology, and cognitive* (“*NBIC*”) *technologies*—starting from basic elements, atoms, DNA, bits, and synapses, as well as a system approach—led to foundational tools that integrated (both horizontally and vertically) various emerging technologies into multifunctional systems,

levels of convergence

3. moving into the 2010s and beyond, *CKTS* (also referred to as “beyond-NBIC” or “NBIC2”) is integrating essential human activities in knowledge, technology, human behavior, and society, distinguished by a purposeful focus on supporting societal values and needs.

from multi- to trans-disciplinarity

- The vision is to go beyond multi-disciplinarity to trans-disciplinarity.
- Multidisciplinary research adopts tools and techniques from many disciplines to provide innovative solutions to problems.
- Transdisciplinary research transcends disciplines through transformative interactions that change the evolution of disciplines and create new fields at the intersections of disciplines.
- Instead of ad hoc solutions to problems, general frameworks are created.

Converging Technologies-European View

- The European Commission report proposed Converging Technologies for the European Knowledge Society (CTEKS), envisioning different research programs that address specific problems such as "CTs for natural language processing" or "CTs for the treatment of obesity."
- CT applications offer "an opportunity to solve societal problems, to benefit individuals, and to generate wealth," they also pose "threats to culture and tradition, to human integrity and autonomy, perhaps to political and economic stability."

Converging Technologies-European View

- Unlike the original, more openended, and unabashedly optimistic conceptualization of NBIC put forth by the original American report, CTEKS “prioritizes the setting of a particular goal for CT research” but also calls for “an awareness of their potential and limits”.
- to introduce the social sciences and the humanities as significant participants and players within the European approach, thereby allowing representatives from these fields a voice in setting the converging technology research agenda and determining the acceptable boundaries for inquiry.

Convergence of knowledge and technology for the benefit of society (CKTS)

- CKTS builds on previous stages of convergence, beginning with the integration of disciplines at the nanoscale, followed by convergence of nanotechnology, biotechnology, information, and cognitive (NBIC) technologies.
- convergence between emerging NBIC technologies and the essential platforms of human activity (technology, human-scale, Earthscale, and societal-scale platforms),

Convergence of knowledge and technology for the benefit of society (CKTS)

1. nanotechnology: convergence of many formerly separate scientific and engineering disciplines (biology, chemistry, condensed matter physics, materials science, electrical engineering, medicine, and others) when applied to the material world, based on growing understanding of atomic and nanoscale structures.
2. NBIC: connecting emerging technologies based on their shared elemental components such as atoms, DNA, bits, and synapses, hierarchically integrated across technology domains and scales.

two related but separate types of convergence

- two related but separate types of convergence:

1. scientific convergence consisting of the cooperation and cross-fertilisation of different scientific disciplines working on a common topic,
2. technological convergence, meaning the use of the findings from different disciplines in specific applications and products of technology.

two related but separate types of convergence

- In the former area, the US NBIC report and the EU CTEKS concept make very different propositions for scientific convergence:
- While the NBIC report argues for a common basis of all science at the nanoscale, the CTEKS concept makes a strong case for interdisciplinary cooperation between existing disciplines. While this does not exclude the possibility of true convergence to form new scientific disciplines or sub-disciplines, this is not an essential element of the CTEKS concept as understood by CONTECS.

two related but separate types of convergence

- It appears that convergence takes place at the level of doing things and constructing things, not necessarily at the theoretical level. Convergence thus seems to aim at the building of entirely new structures, or objects, or artefacts, or devices.
- Technological convergence might affect the way scientific knowledge is produced and contribute to recent trends towards new forms of "technoscience", an issue which deserves closer attention.

two related but separate types of convergence

- One question that arises in this context is whether some sort of new field with a permanent status which might evolve into one or more new scientific disciplines or sub-disciplines is being created or whether it will be something that will disappear once the different projects have been finished.
- There is also the issue of encouraging people to work in interdisciplinary fields, since it currently seems that working in interdisciplinary teams in academic biographies is seldom rewarded or acknowledged as a scientific achievement.

two related but separate types of convergence

- The philosophy of science has made strong efforts to differentiate between several kinds of interdisciplinary research.
- Schmidt (2008), found at least four types of interdisciplinary research enabling integration:

1. Theoretical,
2. methodological,
3. problem orientated,
4. object orientated.

two related but separate types of convergence

- Examining these four types of interdisciplinary in relation to the concept of technological convergence Schmidt concludes that CT is based on a weak understanding of interdisciplinary, which he terms “object-oriented” interdisciplinary.
- According to his analysis there is no theoretical or methodological framework or paradigm that is able to transcend the different fields of research in CT.

two related but separate types of convergence

- The fact that interdisciplinary integration has not yet taken place can be shown by looking at the interdisciplinary rate (IR) in publications. The IR shows how many authors from different disciplines contribute to a specific publication.
- There is growing evidence that this rate in CT is not higher than in other fields of research, meaning that research and development is still very fragmented in CT.

two related but separate types of convergence

- Two considered factors (size and aim) are not sufficient for convergence: Using size as common basis, there are so many different objects of research that can be analysed that interdisciplinary integration becomes almost impossible.
- On the other hand, the technological aim, e.g. the end that can be reached with the technology is not concrete enough for a stimulation of interdisciplinary research.

Converging Technologies-Environmentalist Groups

- The group refers to converging technologies as BANG, an acronym derived from bits, atoms, neurons and genes, the basic units of transformative technologies.
- The group warned that BANG will profoundly affect national economies, trade and livelihoods including food and agricultural production in countries of both the South and North.
- BANG will allow human security and health even cultural and genetic diversity to be firmly in the hands of a convergent technocracy.

the (convergence) concept diffusion

- There is currently little evidence of spectacular advances involving the complete NBIC quartet,
- so it might be more relevant to look at specific directions of convergence of pairs or trios of the technologies, like synthetic biology and neuroscience where there is most likely progress which could not have been achieved without convergence.
- Central impulses for convergence are coming from the field of neuroscience.

the (convergence) concept diffusion

- the term "converging technologies" referring to NBIC, emerged from the US National Nanotechnology Initiative (NNI).
- NBIC appears to have been conceived largely as a successor to the nanotechnology program with the aim of securing continued funding.

the (convergence) concept diffusion

- Interviews in the US indicate that the visions, such as the unity of science or radical human enhancement have not been taken at face value in the US.
- Most notably, there has never been any genuine national US policy or national debate on converging technologies and human enhancement as has frequently been assumed in Europe.

the (convergence) concept diffusion

- Scientists working in fields belonging to the converging technologies do not use the term and are sometimes even unaware that it exists.
- The term seems to have originated in the sphere of research policy, which raises questions about its use by policy makers and its discovery and adoption for strategic reasons by researchers.

normative or scientific driven concept

- What are scientific drivers of CT?
- Do researchers use the concept in their everyday work?
- What is the role of visions in the process of research and technology development?
- How is industry involved in the convergence process?

normative or scientific driven concept

- Is the concept actually being used as a guiding vision by researchers in their every-day work?
- it is not clear whether the convergence idea is something which has been invented by a few research planners, and gratefully adopted by the so-called "transhumanist" movement (that argues for radical "human enhancement" which might lead to a transformation of the human species), or something which has come out of the scientific community itself as a result of the observation of technological development and its organisational requirements.

normative or scientific driven concept

- As a result, convergence might be either a normative concept imposed on researchers by science politics or a science-driven concept embodying future requirements for collaborative research and technology development.
- In order to approach this question we made an attempt to determine the distance between the visions of the NBIC debate and actual developments in the relevant areas.

normative or scientific driven concept

- We propose employing assessments by experts of the distance between visions and realities as an indicator for the relevance of the concept,
- A greater distance, i.e. technological realisability at some remote point in the future, would make the use of convergence as a normative concept more plausible than its use in the frame of a science-driven concept.

normative or scientific driven concept

- Analysis of the visions and of cutting-edge research in the overlapping fields of nano, bio, info and cogno shows that scientific convergence is indeed under way in various fields.
- Multi- and interdisciplinary research and development seem to be the core of technological convergence.

normative or scientific driven concept

- Investigation on the application areas of NBIC has shown that the central fields of CT, such as neuro and brain enhancement, physical enhancement and biomedicine and - with some restrictions - also the relatively new field of synthetic biology, are characterised by the incorporation and combination of previously separate existing research fields by a process of technological convergence.
- Indicators are new potential applications, interdisciplinary co-operation and research projects. There is thus evidence of both scientific and technological convergence.

normative or scientific driven concept

- However, visions and cutting-edge research are considerably remote from each other in all eight fields.
- The gap is especially wide in the two human enhancement fields (brain enhancement and physical enhancement) and also in Synthetic Biology.
- In almost all of the remaining fields, the distance is not as significant and visions can be expected to turn into concrete applications in the not too distant future.

normative or scientific driven concept

- In neuroscience and biomedicine there is a strong focus on medical applications and improvements of existing treatments and therapies.
- In some areas such as Artificial Intelligence, convergence does not describe a new approach but includes an existing research field, which could profit from a more rigorous trans- and interdisciplinary approach as suggested by CT.

normative or scientific driven concept

- The cognitive sciences have always been interdisciplinary in nature and are characterised by the conventional benefits and problems of interdisciplinary work. The very label "cognitive sciences" implies that there is no true unity between the various disciplines in the domain.
- An interesting research question is whether there is any basis for the convergence of these disciplines into cognitive science (singular).

normative or scientific driven concept

- Are researchers in the labs actually and consciously working towards convergence?
- Some scientists reported in the interviews that they pay some lip service to the hype in order to receive funding money and that apart from that the concept does not matter in their daily work.
- However, we should not conclude that this actually is the case it might well be that the concept concretely guides them in one way or the other.

normative or scientific driven concept

- The research question therefore is to find out how the concept of convergence actually may motivate or guide researchers in the labs and what difference it makes in their daily work and in the results of their research.

normative or scientific driven concept

- We also found that the concept has not yet reached the level of being relevant for enterprises and industry. Although there are some approaches in the research labs of large firms in the biopharmaceutical or biomedical area that could be termed "technological convergence" and some interest in new processes of convergence on the part of bio and infotech firms,
- the NBIC concept itself has not yet triggered specific investments and has not yet fuelled expectations in the corporate world.

in scientific-driven (Not-Normative) vision of convergence

- Established, "real" SSH is reluctant to enter the discussion on convergence. The idea of interdisciplinary work seems nothing new to established SSH researchers.
- Far-reaching visions of convergence which imply fundamental changes in society are met with scepticism. But if SSH researchers join the debate, they are mostly occupied with defending existing positions for example in the "free-will" debate with neurotechnology or by maintaining integrity and the so-called oversight function of SSH.

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NBIC initiative

1. Mihail C. Roco – a National Science Foundation (NSF) officer and "architect" of the US National Nanotechnology Initiative (NNI)
2. William S. Bainbridge, another NSF officer, a professional sociologist of religion

- who has been responsible since the 1990s for projects at the interfaces of social, behavioral and economic sciences and information technology research.

NBIC initiative

- The NBIC initiative's programme includes the vision that "the human body will be more durable, healthy, energetic, easier to repair, and resistant to many kinds of stress, biological threats, and aging processes“
- A view of a transformed civilization forthcoming on the horizon, in which advances in nanoconvergence will enhance sensory and cognitive capabilities

NBIC initiative

- also "for defense purposes" and enable "brain to brain interaction".
- This might then lead to "wholly new ethical principles" that will govern "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".

NBIC initiative

- Moreover, the editors hope that technological convergence hand in hand with "human convergence" will lead to a "golden age", characterised by "world peace, universal prosperity, and evolution to a higher level of kindness and completion".
- Humanity might then become something "like a single, distributed and interconnected 'brain'" or a "networked society of billions of human beings"– possibly regulated with the help of "a predictive science of society“.

NBIC initiative

- Bainbridge has acted as the link between the initiative and organized transhumanism, at least since 2003, and himself published very distant visions of an interstellar, posthuman civilization, and an overcoming of death by technical means.
- Bainbridge writes: "we can agree that the planet Earth should remain a shelter for traditional humanity, living in a variety of low-tech societies in what technophiles would call a everlasting Dark Age. … The modest will inherit the Earth, but the bold will go elsewhere".

Critics of the initiative

- Critics of the initiative: US conservatives, American and European academics and technology experts, EU research policy officials, ecologists, leftists, Christian laymen and theologians, and European natural scientists and engineers,
- Critics reacted by pointing out the proximity of the NBIC visionary programme and initiative to transhumanism, science fiction and rather dubious research fields, such as "memetics";
- ideas of US military and cultural supremacy furthered the impatience, in particular in Europe.

Posthumanism

- A very prominent, albeit partly veiled ideological feature of the discourse on CT is the influence of posthumanism on the ethico-political discussions about convergence and related visions (such as "human enhancement").
- Posthumanism can be defined as both a worldview, with roots mainly in the early-mid 20th century, and a movement ,"transhumanists", promoting this worldview, which is directed towards overcoming physical and cognitive limits on the human condition.

Posthumanism

- If we sum up the core features of the posthumanist worldview, we may better understand the role it plays in the ontological politics of convergence,
- Early Western posthumanism saw science as "man's gradual victory, first of space and time, then of matter as such, then of his own body and those of other living beings, and finally the subjugation of the dark and evil elements in his own soul“.

Transhumanism

- Transhumanist philosophers argue that it is possible and desirable for humanity to enter a transhum phase of existence in which humans are in control of their own evolution. In such a phase, natural evolution would be replaced with deliberate change.
- in Hnshumanist thought, humans attempt to substitute themselves for God, implying as it would, that "man has full right of disposal over his own biological nature".

Report on the 2005 Interests and Beliefs Survey of the Members of the World Transhumanist Association

Which of these best describes your religious or spiritual views?

	2003			2005		
	Non-US	US	Total	Non-US	US	Total
Secular, atheist	**65%**	**63%**	**64%**	**61%**	**62%**	**62%**
Atheist	34%	26%	30%	30%	31%	30%
Agnostic	11%	16%	14%	15%	16%	16%
Secular humanist	10%	10%	10%	9%	9%	9%
Other non-theistic philosophy	10%	10%	10%	7%	7%	7%
Religious or spiritual	**20%**	**31%**	**26%**	**22%**	**26%**	**24%**
Spiritual	3%	6%	4%	6%	6%	6%
Protestant	1%	2%	1%	3%	4%	4%
Buddhist	2%	5%	3%	2%	3%	2%
Religious humanist	2%	3%	3%	2%	3%	2%
Pagan or animist	2%	3%	2%	2%	1%	2%
Catholic	2%	3%	2%	2%	2%	2%
Unitarian-Universalist	1%	3%	2%	1%	3%	2%
Hindu	3%	1%	2%	2%	0%	1%
Other religion	1%	3%	2%	0%	1%	1%
Jewish	0%	1%	1%	1%	1%	1%
Muslim	2%	1%	1%	1%	0%	1%
Raelian	0%	0%	0%	0%	1%	1%
Other/DK	**15%**	**6%**	**10%**	**16%**	**11%**	**14%**
None of the above	11%	4%	7%	12%	9%	11%
Don't know	3%	3%	3%	5%	2%	4%

naturalistic trends

- To 'naturalise' a domain is to make it clear that it belongs to nature, and thus that it can be accounted for with the sole help of the natural sciences.
- CT carries strong naturalistic trends,
- CT deploys tools from the natural sciences in attempts to understand and/or change the human realm or condition, on either the individual or the social level.

naturalistic trends

- The idea which to a large extent drives CT is that by uncovering the formal or structural properties of certain phenomena, one reveals an essential feature of their ontology.
- in the case of thought, for example, there may be no *essence* hiding behind informational structure,
- This opens up an entirely new way of conceiving the 'moral sciences', making them accessible to a whole slew of methodologies belonging or akin to the natural sciences, without (necessarily) endangering their mental and social dimensions.

naturalistic trends

- Naturalism seen as a threat to free will, CT may appear to add insult to injury, siding with deterministic doctrines and attempting to impose new, partial or total, modes of determinism.

Humanities concerns in NBIC

1. if convergence of Nano-, Bio-, Cognoscience in combination with Information Technology is a real possibility, i.e. if the promised technologies come into reality;
2. what intended or non-intended consequences could derive if those technologies come into being;
3. how those potential consequences could be judged by ethical standards;
4. if it is possible to influence, control or stop such a technological development.

Humanities concerns in NBIC

- CTs do raise many questions in the social realm, it is a question to what extent these are generic issues related to technologies and to what extent they are specific to converging technology.
- whether it makes sense to deal with all topics under the common umbrella of "convergence" or to tackle them separately, although a distinction should obviously be made.

Humanities concerns in NBIC

- Blurring the boundaries: Physiological enhancement blurs boundaries between what can be considered human and what can be perceived technical or artificial.
- Humans substitution: Technological convergence will contribute to the development of intelligent robots. In which ways can humans be substituted by robots?

Humanities concerns in NBIC

- Sharpening of social inequality: When technological implants enable humans to process information faster than possible rivals, the question is raised how social justice can be guaranteed.
- It can sharpen the contrast between different social layers insofar wealthier parts of the population will be able to afford technological instruments that will further improve their relative competitive position.

Humanities concerns in NBIC

- Neuroscience will give get new information about mental states and personality structures. Will this knowledge be used for marketing?
- When all processes of the brain can be observed and analyzed, will this change the guiding principles about whom and when someone should be punished?
- The existence of sensory implants improves possibilities of social control. It will be much easier to find out whether someone lies or not with much higher precision lie detectors.

Humanities concerns in NBIC

- In an age of neurocognitive drugs to enhance memory or attenuate it,
- who will decide what we can or can not remember? Who is to say what we
- may or may not actively seek to forget?

Humanities concerns in NBIC

- 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 and their publics, can learn from each other.

social sciences and humanities (SSH)

- mainstream SSH, especially in the 20^{th} century, insist on a more or less total autonomy from the natural sciences, often coupled with a militant conception of humanity requiring protection from the encroachments of natural science and its accompanying reifying technologies.
- Whether the sciences of man are *real* sciences, and whether, if so, they are or should strive to be indistinguishable from the natural sciences, is a venerable issue, as old as the social sciences and humanities (SSH) themselves.

social sciences and humanities (SSH)

- SSH research fields may contribute to a better understanding of the issues in the CT debate:
- *Research Policy Analysis*: e.g. the analysis of funding of CT; the role of international competition and cooperation; role of institutions and agencies; the strategic context of CT initiatives
- *Discourse Analysis*: e.g. analysis of relations between policy actors, business, technology experts, NGOs and sociocultural movements in the CT debate; new forms of governance; ontological politics of convergence.

social sciences and humanities (SSH)

- *Scientometrics*: e.g. relevance of concepts of convergence; inter- and transdisciplinary R&D
- *Sociology of Expectations in S&T*: e.g. relevance and role of visions; changing role of science in society
- *Philosophy and History of Science and Technology*: e.g. epistemological challenges; new modes of knowledge production; ontological status of CT developments; changing paradigms of science and technology

social sciences and humanities (SSH)

- *Ethics (Bio-, Nano-, Neuro-, Info-)*: e.g. distributive justice; human dignity; human enhancement and the topic of informed consent; free will.
- *History of Ideas*: e.g. changing conceptions of man-machine interactions; interrelations of utopianism, eschatology and technoscientific visions
- *Theology*: eschatological qualities of technoscientific visions; conceptions of human nature and of the conditiohumana

social sciences and humanities (SSH)

- *Anthropology*: e.g. man-artefact relations; trans- and posthumanism
- *Cultural Studies*: e.g. identity politics; R&D and science fiction; "posthumanist studies"; “cyborg studies (cybernetic organism)”
- *Disability Studies*: e.g. prosthetic technologies; human enhancement; ideology of ableism; cultural impacts of CT and the related visions
- *Technology assessment (including vision assessment)*: e.g. R&D Foresight; societal, legal and ethical aspects of CT;

social sciences and humanities (SSH)

- *Innovation analysis and economics*: e.g. innovation systems and CT; marketability of CT developments; benchmarking
- *Science and technology studies*: several of the above-mentioned topics and, for example, empirical analysis of processes of technoscientific convergence; participant observation and other approaches by social scientists and humanists; systemic approaches.

Future

- 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.
- One can expect that for every problem, someone may propose a more or less creative, viable or desirable technological fix.

the genuine challenge

- The central question will remain: Can we use NBIC convergence and evolution to resolve the grand challenges and the big problems that we either face today or will face in the future?
- This is the genuine challenge we need to meet to create sustainable and successful societies, industries, and economies. This should be the greatest challenge every leader in government and industry must be concerned about and working towards resolving every day.

the genuine challenge

- much of the world does not enjoy the same benefits as does the West.
- Is there a potential that the convergence of key NBIC technologies could alleviate some of these problems and accelerate people’s access to sustainable energy, abundant food, and pervasive communications?
- The social risks associated with not furthering the use of NBIC in sharing the wealth of innovations may destabilize global security in the future. The risks are too high.

References

- A. Nordmann (2004): *Converging Technologies: Shaping the Future of European Societies*, High Level Expert Group,, Luxembourg: Office for Official Publications of the European Communities, European Commission.
- J. J. Hughes (2005): “Report on the 2005 Interests and Beliefs Survey of the Members of the World Transhumanist Association”, World Transhumanist Association.

References

- W. S. Bainbridge and M. C. Roco (2006): Managing Nano-Bio-Info-Cogno Innovations Converging Technologies in Society, Springer.
- D. Andler et al. (2008): Converging Technologies and their impact on the Social Sciences and Humanities, CONTECS consortium.
- M. C. Roco et al. (Editors) (2013): Convergence of Knowledge, Technology and Society, Springer.

References

- ETC (2013): Converging Technologies: a Definition and an Overview of Some Different Viewpoints, ETC Group Report.
- R. V. Est et al. (2014): From Bio to NBIC Convergence, From Medical Practice to Daily Life, written for the Council of Europe, Comittee on Bioethics, Rathenau Institute.
- National Rerearch Center "Kurchatov Institute“ (2011): Kurchatov Center of Converging of NBIC Sciences and Technologies, Online: http://www.nrcki.ru/e/nbic.html