Technoscience and Convergence: A Tranmutation of values?

Bernadette Bensaude-Vincent

Bernadette Bensaude Vincent
UPX. France

Technoscience and Convergence: A Transmutation of values?

Summerschool on Ethics of Converging Technologies
21-26 September 2008, Dormotel Vogelsberg, Omrod / Alsfeld, Germany

Technoscience is often perceived as an expression of the primacy of utilitarian values that would take over the field of pure and disinterested science. A number of scientists deplore that the age of science for its own sake is coming to an end (Lévy-Leblond, 2000). This common view expressed by active scientists is shared and developed by historians. In a paper describing technoscience as a cultural phenomenon, Paul Forman comes to a similar conclusion (Forman, 2007). He defines technoscience as a reversal of the values attached to science. Whereas modernity was characterized by the high cultural rank of science and scientists – " the primacy of science to and for technology" –, post-modernity is characterized by the primacy of technology over science along with a loss of confidence and trustworthiness of scientists. The modern assumption that scientific research would bring about not only knowledge but technological applications in addition, has been undermined in the 1980s, according to Forman. And he argues that science studies were integral part in the trend toward technoscience as they more and more identified science with technology.
I would like to discuss this interpretation on the basis of converging technologies. The label "converging technologies" applies to current research programs launched in various countries. More precisely I refer to the US program entitled *Converging technologies for improving human performances* (Roco, Bainbridge, 2002) and the European program *Converging Technologies for the European Knowledge Society* (EU HLEG, 2004.) They are especially relevant for testing the alleged take-over of science by technology, because science is not even mentioned in the titles of the program which focus exclusively on technologies. Should we consider these programmes as the confirmation of Forman's claim about the age of technoscience?
In a preliminary conceptual analysis I try to disentangle the notion of technoscience from the vague connotation of utilitarianism. Then in order to examine to what extent the views and values attached to converging technologies express a primacy of technology over science, it is useful to distinguish between converging technologies as national research programs and the daily practices of research in which technologies converge because the views and values that active scientists attach to their research may deeply not reflect the claims and values of policy makers. However I will argue that in neither of these cases is technoscience adequately described as a primacy of technology over science.

I Conceptual messiness

The compound term *technoscience* commonly used to characterize contemporary research is a vague notion, with a strong utilitarian connotation. It suggests that science is only valued as a means toward practical and utilitarian ends. In fact, utilitarian values are not essential in the technical definition of technoscience. The term was coined by a Belgian philosopher Gilbert Hottois in 1979: «Contemporary scientific research in which technology (the technological space and time surrounding us everywhere) is the 'natural milieu' of development as well as the prime mover ». (Hottois, 1984, p. 60-61)

Hottois points to a complex process of internalisation of technology in science: technology is embedded in scientific research i) as a milieu and ii) as a driving force:

i) Technology as a milieu of development means that science needs technology (instruments and artefacts) for its advancement. Instruments themselves become objects of investigation, a research area labelled "research technology" (Joerges B. et Shinn T. eds., 2001).

ii) Technology as a driving force can be understood in two different ways: science is is oriented towards technological applications (not necessarily for utilitarian purposes); technological advances open up new research avenues (e.g. the STM for nanotechnology).

In any case, far from being a by-product of scientific research, technology has been so much internalized in science that they become indistinguishable.

Technoscience deeply changed the traditional organization of scientific research. Its impact on the interaction between academia, industry, state and civil society has been well described and analyzed by science studies scholars (Gibbons et al, 1984, Nowotny et al 2001, Etzkowitz et al. 2001, Pestre 2003). Their use of such phrase as "new regime of knowledge production" suggests that knowledge is something that has to be processed and produced. This phrase emphasizes that knowledge (*epistemê*) requires a *technê*, an activity aimed at the production of individual devices or machines.

However the notion of technoscience has never been adopted as an official label for research departments or agencies. It is not a neutral, descriptive term. Rather it is a polemical notion. From the outset, it was coined by Hottois against the "linguistic turn" that dominated both the analytic and the hermeneutic traditions in order to alert philosophers that by confining themselves to the analysis of language and logic they were blind to the dramatic changes going on in the world around them (Hottois, 2004, p. 173-187). The term retains a polemical stance whether it is used by Heideggerians to criticize the thoughtless modern science and its will to mastery, or by Bruno Latour to debunk the myth of the purity of science. "I will use the word technoscience from now on, to describe all the elements tied to scientific contents no matter how dirty, unexpected or foreign they seem" (Latour 1987, p. 174). In Latour's terminology technoscience means something quite different from the primacy of technology over science or from the importation of techniques within science. Latour uses this compound term to refer to all kinds of hybrid entities of humans and non-humans, of nature and society, The term takes a very loose meaning in which the ideas of heterogeneity and mediations prevail. In his effort to stress the alliances between heterogeneous actors involving humans and non-humans, science, nature, society, economics and politics, Latour not only deconstructed the myth of "pure science" but he later symmetrically cast doubts on the concept of technology. Technologies do not exist as such, there is nothing such as objects or artefacts or element of technology, because one cannot separate units from the various combinations in which they are engaged (Latour, 1999).

To summarize the notion of technoscience is not a neutral term describing the current regime of scientific research. It has been used by historians, social scientists and philosophers to emphasize so many diverse features that the only stable connotation is the break with modernity or at least modern mythologies.

In considering the case of converging technologies (CTs) this paper may provide a more precise characterization of what is meant by this compound term. This case suggests that technoscience is not just a mixture in various proportions of two ingredients. Rather it is something different from both science and technology that reconfigures the views of human action on nature.

II- Converging Technologies as Programmes

The phrase "converging technologies" (CTs) was introduced in 2002 by an American report that promotes the convergence of nano, bio, and information technologies and the cognitive sciences for improving human performance. Two years later in 2004 convergence was taken up as a research program by the European Commission but it was assigned a different goal: CTs for the European knowledge society. Without entering into a detailed comparative analysis of the two programmes I will just try to identify the values underlying these programmes in order to examine whether or not they confirm the primacy of technology over science. It is not an easy task because the NBIC report is not a consistent research programme. Rather it is a collection of essays on various topics written by workshop participants who do not necessarily share values. However the Executive Summary and the Overview which introduce the papers are full of bold claims and grand visions.

1) At first glance CTs may seem to comply with Forman's view of technology overtaking science. The NBIC initiative promised a variety of wonderful technological applications ranging from nano IT devices to fuel cells and solar cells, targeted drug delivery systems, prostheses, and above all smart implantable devices to enhance human capacities develop mind-machine and direct mind-mind communication. Most of the applications envisioned are visions of a remote future and belong to the genre of techno-utopia. Here is precisely a major feature of technoscience: futuristic visions and grand narratives about the future of mankind are no longer banned from scientific literature. They flourish under the cover of roadmaps. Planning the future with roadmaps could indicate a technocratic management of scientific research. In reality the promises of the NBIC report are just "visions" rather than genuine roadmaps for a development of converging technologies. As pointed out by many commentators they are meant to attract investors and sponsors. Henry Etzkowitz even argued that the national nanoinitiative was an attempt by the physical sciences to find a new basis for public funding, following their relative eclipse by the biological sciences. (Etzkowitz in Roco, Bainbridge, 2001, p. 121-128). Technological visions and alleged social needs are brought to the front stage as means to provide a social basis for funding science.

2) However the sequence "science drives technology" is never questioned. Although it focuses on applications the NBIC initiative still relies on the linear model. Remarkably within the 4 components of the NBIC programme there is only one science: Cognitive Science. And it is assigned a leading role of providing new ideas whereas the three other components just play executive roles. As a workshop participant, W.A. Wallace, put it:
"If the Cognitive Scientists can think it
the Nano people can build it
the Bio people can implement it,
and the IT people can monitor and control it" (Roco, Bainbridge, 2002, p. 13)

The ambition of the editors of the NBIC initiative was to foster a new era of science. After centuries of fragmentation of science into disciplines now the time has come for a new Renaissance based on a holistic vision embracing nature and society.
"The sciences have reached a watershed at which they must combine in order to advance most rapidly. The new renaissance must be based on a holistic view of science and technology

that envisions new technical possibilities and focuses on people" (Roco, Bainbridge eds, 2002, p. 2) .

Interestingly the holistic vision is said to rely on the unification of science and technology which itself relies on four key principles: i). material unity at the nanoscale, ii). NBIC transforming tools, iii). hierarchical systems, and iv) improvement of human performance.

i). What is called "material unity at the nanoscale" is typically a reduction of technology to the old view of technology as applied science: understanding nature principles in order to use them in the making of artefacts.

"Science can now understand the ways in which atoms combine to form complex molecules, and how these in turn aggregate according to common fundamental principles to form both organic and inorganic structures. Technology can harness natural processes to engineer new materials, biological products, and machines from the nanoscale up to the scale of meters" ibid p. 2)

ii). NBIC transforming tools do not exist: they are future tools that will be generated as a result of the synergy between previously distinct disciplines. In short, the inner dynamics of science is still viewed as the main cause of technological advances.

iii). The linear model is also at work in the third "key principle":

"Developments in systems approaches, mathematics, and computation in conjunction with work in NBIC areas allow us for the first time to understand the natural world and cognition in terms of complex, hierarchical systems. Applied both to particular research problems and to the overall organization of the research enterprise, this complex systems approach provides holistic awareness of opportunities for integration, in order to obtain maximum synergy along the main directions of progress" (Ibid. p. 3)

iv). The fourth key principle still mentions the sequence "science drives technology". However it is more disruptive because it undermines the traditional view of technology.

"NBIC convergence can give us the means to deal successfully with these challenges by substantially enhancing human mental, physical, and social abilities. Better understanding of the human body and development of tools for direct human-machine interaction have opened completely new opportunities. Efforts must center on individual and collective human advancement, in terms of an enlightened conception of human benefit that embraces change while preserving fundamental values." (ibid. p. 3)

Indeed improvement has been a traditional goal of technology often rooted in the notion of mankind as a perfectible species. However in an evolutionary perspective it is usually aimed at transforming the environment for the purpose of adaptation. The novelty of the NBIC program is that technologies are aimed at transforming human nature itself. The goal is the augmentation of human capabilities and modification of human body and mind by technological means. For some proponents of the NBIC program it includes a possible "reconstruction of man", or even the creation of "posthuman" beings.

The goal ascribed to CTs is a major point of divergence between the US and EU views of converging technologies. While the EU High Level Expert Group shared the US enthusiasm for the convergence they expressed doubts and criticisms about the technocratic vision and the individualistic values promoted by the US report. The phrase "Converging Technologies for the European Knowledge Society" reflects a deliberate attempt to formulate a European vision for converging technologies, in contrast to the US-program of NBIC convergence; to render CTs more compatible with the aims of the Lisbon Agenda and European values. The HLEG rejected the perspective of human enhancement in favour of more democratic ideals. CTs were acclimatized to the European context.

3) Here is a striking feature of CTs. They consciously claim to engage society in the process of technological innovation. Both the NNI and NBIC initiatives included SHS research on the

societal implications of technologies from the very beginning upstream rather than downstream. This proactive strategy is described in two different ways: Whereas the NBIC report (Roco-Montemagno, 2004) uses the phrase "co-evolution of converging technologies and societies", by contrast the EU report uses the phrase "co-construction of CTs and knowledge society". The US program suggests a bio-naturalization of society and culture. A number of the papers collected in the first NBIC report favour a programme of extensive reduction with elimination of all boundaries between nature and culture. The acclimatization of CTs to European values on the contrary is based on the assumption that technology can be socially and culturally constructed through negotiations.[1] Although the EU version of CTs reflects different philosophical choice, it also assumes that it is a co-construction of technology and society. Nordmann, who wrote the CTEKS report, emphasizes the process of co-construction of Europe and of converging technologies in the context of the European Commission's Sixth Framework Program (Nordmann, 2008). He even argues that converging technologies provided a testing ground for European identity and for socio-constructivism as well[2]. In other term CTs are described as a grand experiment.

To sum up, the CTs official initiatives do not really subject science to technology. Rather they generate a holistic vision embracing nature and society. They even reinforce the attractive power of science by two powerful means: i) connecting research to grand narratives and futuristic visions; ii) social monitoring of scientific and technological choices. Technoscience thus clearly means that scientists no longer work in their ivory tower and that the public has to be engaged in science.

Finally technoscience as seen through the prism of CTs transforms the world itself into a laboratory. No longer there is a clear boundary between purified laboratory spaces where scientists could control natural phenomena and an open social space where complex phenomena occur which are never fully under control. The world itself becomes a laboratory for a grand scale experiment engaging the future of the earth of humans and life itself.

III Convergence in practice

What is exactly the status of these official reports on CTs. Indeed they have largely commented by social scientists but their impact seems rather limited. Neither of them was followed by funding initiatives. Although the NBIC-report was issued by the NSF, it did not define a true research programme. A second workshop organized in Los Angeles in 2003 published in the *Annals of the New York Academy of Science* expands the scope of CTs to society education and business and provides samples of research topics illustrating the NBIC convergence, most of them being related to neurotechnology (Roco Montemagno 2004). However even when they are authored by scientists who enjoy high reputation, these papers do not look like standard scientific publications. Rather they belong to a hybrid genre in between propaganda, ideology and science.

The gap between such initiatives and actual research practices may well be an additional characteristic feature of technoscience. At least, such is the impression resulting from a number of interviews conducted in various academic laboratories engaged in bionano

---

[1] The phrase "ontological politics" became fashionable among experts of the CONTECS report. "Ontological politics are the processes, practices, discussions, struggles and contentions whereby the existence and character of entities are defined, constructed and brought into being. Ontological politics help define the focus and targets for CT".

[2] Nordmann argues that the EU CTs program was a kind of reification of Sheila Jasanoff 's programme of "technology of humility" in contrast to the US "technology of hubris". (Jasanoff 2002 and 2005)

research. The hypothesis certainly requires closer investigation of the relations between science policy guidelines and daily laboratory life. But a huge number of scientists working in nano, bio, IT and cognitive science never have never about NBIC or CTEKS.

When looking at the views and values underlying research practices through publications and face to face interviews with scientists, one does not get a clear and uniform worldview. Unsurprisingly researchers working in the same area keep their personal views or and ethos. However as they share linguistic practices and metaphors, and instruments, they also share a number of tacit assumptions about nature, about science and technology.

Three major features come out from a study of nanobiotechnology in academic laboratories.

1. Fundamental science is still highly valued.

Most scientists interviewed had never heard about the NBIC program and even less about its European equivalent, the CTEKS. And they just laugh when they hear they are supposed to work for human enhancement or for knowledge society. Most of them claim they are working to advance knowledge in their discipline rather than working for designing technological devices. Even scientists who enter in industrial partnership or build their own start-ups or spin-offs to develop their inventions claim that their objective is to better understand how natural system work. For instance Christian Joachim, a physicist from CEMES in Toulouse is designing molecular machines (molecular wheel-barrow among others) with the idea of testing quantum mechanics. Thanks to the Scanning Tunnelling Microscope and Atomic Force Microscope, instruments that allow to visualize and manipulate single molecules scientists are now in a position to challenge Dirac's and De Broglie's view of the quantum world. For a number of scientists who jumped in the bandwagon of nanotechnology, the grand visions and promises of policy makers are just hype and rhetoric. They claim that they are using nanotechnology for pursuing strictly cognitive purposes.

I am well aware that it is not possible to infer general conclusions from a few individual cases. The opinion of dozens of French academic scientists does not reflect the general scientific opinion. However it seems that the resistance among academic researchers against teleological research (not just goal-oriented but driven by a finality like human enhancement) cannot be minimized. In their perspective these finalities or social interests are an excuse for legitimating their research in the public arena. As Sacha Loeve put it "impure science" (non-disinterested science) is as much a myth as "pure science". (Loeve, 2008, p. 117)

2. Nature artificialized

If technology can help advance science, if the design of artefacts can shed a light on how nature functions it is because the boundary between nature and artefact is blurred. Here is in my view the essential assumption underlying the notion of technoscience and catalyzing the convergence of technologies.

To be sure blurring the boundary between nature and artefact is not novel. For centuries chemists have made and reacted artificial molecules in their laboratories in order to understand the composition and behaviour of natural substances. Knowing and producing are never separated in chemistry : the cognitive purpose and the technological interests are intertwined. Knowing through making is a typical strategy of laboratory sciences. It is not specific to what is now called technoscience, or we should say that chemistry has always been a technoscience.

However a more specific feature is the attention to functions and processes. It is a quite general attitude today to consider natural entities as functional units capable of performing interesting tasks. Atoms, molecules, micelles, DNA, proteins, and neurons are described as

machines or devices. The ultimate constituents of inorganic and organic systems are considered as machines or devices performing specific operations.
This new approach to nature was initiated and developed by the juxtaposition of science and engineering in the study of materials. The creation of a new discipline Materials Science and Engineering in the 1960s, gathering under one single umbrella such diverse things as cement, ceramics, paper, metals, wood, polymers, semiconductors etc prompted interdisciplinary collaborations and a new conceptual framework. (Bensaude-Vincent 2001). What is a material in general? Materials are usually defined as « substances having properties which make them useful in machines, structures, devices, and products ». A material is a substance which is useful or of value for human purpose. It combines natural science and humanities, physical and chemical properties are viewed as responses to social demands, civilization, industrial or military interests. The core notion here was "design". New materials had to be designed with novel properties for specific and high-performances in space and military programs. Their structure has been processed to perform a specific task. The focus of process was added to the traditional linear sequence structure, properties, functions and a systems approach replaced the old linear model. This engineering approach reconfigured the intellectual space and brought together fundamental disciplines such as quantum physics, solid state physics and chemistry, thermodynamics, and metallurgy, electrical engineering or chemical engineering.

3. Epistemic anthropomorphism

Merging Science and Engineering encouraged a new epistemic attitude.
In order to characterize this attitude let us go back to the origins of modern science. As it is well-known the scientific revolution deconstructed the Aristotelian view of nature as a teleological system. It has often been pointed out that the mathematization of natural phenomena (as illustrated by the laws of falling bodies) rest on the assumption of a leverage point outside the universe from which universal laws could be edicted. Hannah Arendt in particular insisted that it was the merit of modern science to consider humans as just outside observers of the universe (Arendt, 1954)
Moreover nature had to be "disenchanted", deprived of its meaning and lisibility for humans. The core assumption underlying the mathematization of physics and the mechanization of the world was that the natural necessity was universal, immutable and inexorable. As Galileo used to say "nature is inexorable" (Hamou, 2008). The book of nature is neither written in a human language nor in a language that could provide answers to our questions. Unlike the Bible, the book of nature is not addressed to us, it is not written for us. She is indifferent to our prayers, to our projects, and even to the knowledge we get of her. "Nature has no obligation with regards to humans and has signed no agreement with them" (quoted by Hamou, 2008, p. ?).
By contrast technoscience encourages an anthropomorphic representation of nature fostered by the individuation of molecules and proteins. Although it is not exactly a re-enchantement of nature since nature remains deaf to human prayers, technoscientists are so to speak engaged with individual natural entities.
The convergence between nanoscience and biology is nurtured by two different assumptions i) that nature works as an engineer, ii) that nature is plastic.
i) nature is an engineer who designed along the geological and biological evolutions a number of "devices", to achieve specific functions. Although scientists and engineers are unable to ascribe a definite function to each part of each "natural device", nature is a reservoir of astute and ingenuous devices. Molecular biology encouraged this view by the adoption of the program metaphor for the genetic code. Nowadays all the constituents of living cells are

described as machines: Ribosomes are assembly lines, myosins are motors, polymerases are copy machines, proteases and proteosomes are bulldozers, membranes are electric fences, and so on.
Again the use of technological metaphors to describe nature is not novel. Modern science was based on a mechanistic view of nature that implied a designer or clock-maker. Today biologists generally agree that living systems are the product of a blind evolution rather than of design. Here is precisely a major characteristic of technoscience: nature is no longer the creation of a designer who assembled all the functional units into a big machine. Rather it is a collection of small devices or functional schemes without central design. Nature is thus a toolkit or a warehouse of functional devices. For instance synthetic biology aims at collecting all the building blocks in a library of independent and interchangeable parts, which is named a "Registry of Standard Biological Parts".[3] Then synthetic biologists will be able to repair or re-engineer living organisms to make them suitable for social or technological needs.
ii) a second assumption is the plasticity of nature. Generally speaking nanomedicine, and neurotechnology aimed at correcting or improving human performances thanks to sensory substitutes or enhancers assume the plasticity of the brain and of the body. More specific to the converging technologies is the assumption that the access to the nanoscale opens indefinite opportunities to amend or reengineer natural systems. When you can visualize and manipulate the building blocks of nature - atoms, genes, neurons (cf Little Bang) - you can redesign natural systems just as a *demiurgos* shaping the world from scratch. To paraphrase Feynman's famous words, one could say that "all is plastic at the bottom". The assumption underlying a number of current researches is not even modern rather it is reminiscent of the "*per minima*" strategy of early modern alchemists. Just as alchemists sought to transmute lead into silver and gold by reducing their mixts into the "minima naturalia", modern alchemists are striving to build new artefacts from the building blocks. Just as Daniel Sennert reduced metals to their primitive state (*reductio ad pristinum statum*) –in order to recover a more noble mixt later on, technoscientists aim at seizing the ultimate units of matter or to get as close as possible to the supposed origin of organisms because they contain all possible futures. Totipotent stem cells may stand as the paradigmatic object of this quest of the Graal. The building blocks, the primitive state are supposed to open up unlimited possibilities for a free play of creativity. The notion of a totipotent blocks is extremely attractive but it soon raises the issue of control of their uses out of the laboratory.
This changing view of nature brings about ethical concerns. Whereas in modern science scientists as outside observers of an inexorable universe did not have to worry about the consequences of their investigations on the future of mankind (Arendt 1968), technoscientists are now engaged in a kind of game with natural entities. Each move in this cosmic game can entail tremendous consequences. Scientists thus have a number of obligations not only with regards to their fellow humans but to nature as well.

To sum up this section current research practices in converging technologies clearly proceed from an engineering approach to nature. However the focus on functions and processes, the assimilation of the building blocks of nature to devices and machines and of nature itself to an engineer do not inhibit basic research. Technoscience is not devoid of great cognitive ambitions. Rather technology is embedded in science. Moreover nanotechnology and CTs can hardly be considered as technologies in the traditional sense. As Alfred Nordmann argues, technology has traditionally been conceived of as a management of human limits, with tools

[3] The design of the site of the Registry for standard Biological parts full of Lego and cogwheels eloquently reveals the mechanical model of life underlying the project http://parts.mit.edu/registry/index.php/Main_Page access October, 30 2007

and machines being designed as extensions of our organs. By contrast technoscience opens up "a space of unbounded possibility" and a free play with potentialities.

With all their different agendas the various programmes and practices of CTs do not suggest a primacy of technology over science. Rather they change the meaning of science and technology as well by directing them to the enhancement of cultural values and inscribing them in grand visions. CTs reconfigure the notion of technoscience as a triple utopia:
It is a techno-utopia relying on the mythical figure of the unbounded Prometheus
It is a scientific utopia rejuvenating the search for the philosopher's stone capable of fulfilling all promises.
It is a social utopia, a grand-scale collective experimentation testing new techniques of management of nature, of technological inventions and citizens. Both science and technology are engaged in a collective experiment that also includes human societies and cultures, the present and future generations as well as the earth itself.

References

Arendt Hannah (1968) *Between Past and Future. Eight Exercises in Political Thought*, new edition New York, Viking Press.
EU HLEG (European Union High-Level Expert Group "Foresighting the New Technology Wave") (2004): (Rapporteur: A. Nordmann): *Converging Technologies - Shaping the Future of European Societies*. Brussels.
Etzkowitz H., Leydersdoff L. (eds) 1998, *A Triple Helix of University-Industry-Government Relations: The future Location of Research?*, New York : Science Policy Institute.
Felt Ulrike ed. 2007 *Taking European Knowledge Society Seriously* Brussels: (rapport du Groupe d'experts sur Science and Governance) European Commission, Directorate General for Research.
Forman, Paul, 2007, « The primacy of Science in modernity, of technology in postmodernity and of ideology in the history of technology », *History and Technology*, 23, N°1/2, 1-152.
Gibbons, Michael Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott, Martin Trow, 1994, *The new production of knowledge - the dynamics of science and research in contemporary societies*, London: Sage.
Hamou Philippe (2008) "La nature inexorable" *Galileana*, forthcoming
Hottois Gilbert (1979)
Hottois Gilbert (1984) *Le signe et la technique. La philosophie à l'épreuve de la technique*, Paris, Aubier.
Hottois, Gilbert (2004) « La science moderne : entre valeurs modernes et postmodernité », conférence au Collège de France , 25-27 novembre 2004.
Jasanoff Sheila (2002) "Citizens at Risk: Cultures of Modernity in the US and the EU", *Science as Culture*, 11:3.
Jasanoff Sheila (2005) *Designs on Nature: Science and Democracy in Europe and the United States,* Princeton: University Press.
Joerges B. et Shinn T. (eds.) 2001, *Instrumentation Between Science, State and Industry* Dordrecht : Kluwer Academic Publishers.
Latour Bruno, 1987, *Science in Action,* Milton Keynes, Open University Press.
Latour Bruno, 1999, *Pandora's Hope. Essays on the Reality of Science Studies*, Cambridge Mass., Harvard University Press.
Levy-Leblond, Jean-Marc, 2000 "la technoscience étouffera-t-elle la science?" conférence de janvier 2000, éditée par la Mission Agrobiosciences, Conseil regional Midi Pyrénées http://www.agrobiosciences.org/article.php3?id_article=0903 (accès mars 2008)

Nordmann, A. (2007). Collapse of Distance: Epistemic Strategies of Science and Technoscience. (Danish Yearbook of Philosophy, 41, 2006, pp. 7-34)
Nordmann, A. (2008). Philosophy of Nanotechnoscience. in Harald Fuchs, Michael Grätzel, Harald Krug, Günter Schmid, Viola Vogel, Rainer Waser, and Mark E. Welland (eds.) Nanotechnology,Weinheim: Wiley)
Nordmann Alfred, (2008b) "The European Experimentation" *Osiris*, in print
Helga Nowotny, Peter Scott, Michael Gibbons, 2001 *Re-Thinking Science. Knowledge and the Public in an Age of Uncertainty*, Cambridge: Polity Press, ; trad. fr. *Repenser la science*, Paris, édition La découverte, 2003.
Pestre, Dominique, 2003, *Science, argent et politique*, Paris, éditions INRA.
Roco, M. and William Bainbridge (eds.) (2002) *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science*, NSF/DOC-sponsored report, Arlington.
[http://www.wtec.org/ConvergingTechnologies/]
Roco Mihaïl, Bainbridge William eds, 2001, *Societal implications of nanoscience and nanotechnology* Dordrecht, Boston, Kluwer.
Roco, M.C., Montemagno, C. (Eds) (2004): *The Coevolution of Human Potential and Converging Technologies* (Annals of New York Academy of Sciences 1013). New York: New York Academy of Sciences