Routledge
Taylor & Francis Group

Knots and Strands: An Argument for Productive Disillusionment

ALFRED NORDMANN

Darmstadt Technical University, Darmstadt, Germany

This article offers a contrast between European and US-American approaches to the convergence of enabling technologies and to associated issues. It identifies an apparently paradoxical situation in which regional differences produce conflicting claims to universality, each telling us what can and will happen to the benefit of humanity. Those who might mediate and negotiate these competing claims are themselves entangled in the various positions. A possible solution is offered, namely a universalizable strategy that aims to disentangle premature claims to unity and universality as in the case of the greater "efficiency" of nanomedicine. This is the strategy by which Science and Technologies Studies (STS) can analytically tease apart what it has helped produce and sustain in the first place. The virtues and limits of this strategy are briefly presented, deliberation and decision-making under conditions of productive disillusionment recommended.

Keywords: *converging technologies, disentangling entangled concepts, European and US approaches to research and development, nanotechnology, Science and Technology Studies (STS)*

I. INTRODUCTION

Science is a cosmopolitan enterprise as witnessed by international journals, conferences, and collaborations of the scientific community. And where scientific research is dedicated to innovation, invention, even product development, this happens within an increasingly globalized economy. In light of this, it is not at all obvious that so-called world regional differences, e.g.,

differences between the United States and Europe, should influence far more than details of policy and regulation but should influence what "nanotechnology" or "converging technologies" are. While we would expect, for example, that there are different national approaches to questions of nuclear power or global warming, we would be surprised to find out that "physics" is defined differently in Europe than in the United States. As opposed to "physics," however, "nanotechnology" and "converging technologies" are defined by what they can do, by what problems they might solve, or what challenges they pose. If expectations serve to define a research enterprise, these expectations and definitions can obviously take shape in national and world regional contexts.

Where regional perspectives play a decisive role in the configuration and development of research and development, it is worth exploring the significance of these differences. In particular, I would like to pursue how philosophical discourse advances or reflects these differences, or how it is entangled in them. To this end, I begin with a brief survey of U.S.-American and European approaches to converging technologies and to a range of associated issues. Having noted these differences, I will then ask how we might deal with them and, in particular, how philosophy, ethics, or social science might help us deal with them.

II. NBIC-CONVERGENCE AND C*TEKS*

"Converging technologies" were first defined as NBIC (nano-bio-info-cogno) convergence for improving human performance in a report co-sponsored by the National Science Foundation and the U.S. Department of Commerce (Roco & Bainbridge, 2002). It was answered by a European definition according to which "converging technologies for European knowledge societies (C*TEKS*)" arise from an explicit agenda-setting process — the convergence of enabling technologies (not limited to NBIC) results only when these technologies begin enabling each other in the pursuit of a set common goal (HLEG, 2004).[1] The difference between these two approaches has been subject to considerable analysis (e.g., Baird, 2004; Berthoud, 2005; Cameron, 2005; Coenen, Fleischer, & Rader, 2004; Fontela, 2006; Grunwald, 2006, 2007; Laurent & Petit, 2005; Saage, 2006).[2] In terms of process and policy it illustrates fairly well extant accounts of the difference between the United States and Europe, in part because such accounts informed the process and entered reflexively into the articulation of European as opposed to U.S.-American identity (notably the work of Sheila Jasanoff, 2003, 2005). Philosophically, the difference can be stated most succinctly by spelling out the credo that underwrites each of these reports.

The credo of NBIC-convergence and subsequent proposals for human enhancement technologies is this: We need technological innovation to

realize human potential. In contrast, the credo of *CTEKS* is: We need social innovation to realize technological potential.[3] On the first of these assumptions or commitments, converging technologies continue, perhaps accelerate, an ongoing trend. Humans have always tended to overcome physical and mental deficiencies with the help of technology and technology has always helped to promote the full development of human capabilities and aspirations. There is thus a kind of progressive force that drives technological progress. By way of technology, human evolution continues and might even become subject to human control. While this view is expressed not only in the United States (Gehlen, 1965), historians of technology have found it to have cultural resonance especially in the United States: It marries the ideal of liberated, emancipated individuals with a conception of transcendence, if not manifest destiny (Hughes, 2004; Noble, 1999).

In contrast, the notion that we need social innovation to realize technological potential takes the concept of "enabling technologies" seriously to the point of denying that there is a continuous trajectory of technological development. Instead, new technologies are seen to emerge from the interaction of technological capability, social conditions and cultural appropriation (Bijker, Hughes, & Pinch, 1993; Feenberg, 2002; Oudshoorn & Pinch, 2005).[4] Technological development is therefore viewed as inherently political and open to social shaping. The greater and more vaguely described the technological capabilities are — as is the case for nanotechnology and the convergence of enabling technologies — the greater the opportunity for social imagination to discover non-stereotypical areas of application. Instead of producing transcendence, however, this political process remains ambivalent in that the expansion of power and control is accompanied by new dependencies, new kinds of ignorance, new problems even of human or ecological survival.

On the U.S.-American conception, the convergence is already "out there," propelling us forward on the path of all technology towards improved human performance. There is no shaping but perhaps some steering, evaluating, countenancing, or preparing to be done. To be sure, there are political differences on how to assess, steer or promote this development (Coenen, 2006), but NBIC-convergence is unanimously taken as reality-in-the-making.

On the European conception, in contrast, we find ourselves in a situation where various enabling technologies and many pressing societal issues (global warming, obesity, water and energy supply, etc.) challenge us to institute converging technologies as a means of gearing emerging capabilities towards common goals. In principle, improving human performance might be one such goal, but pilot *CTEKS* initiatives advocate converging technologies for enabling the information society, converging technologies for clean water active aging.

This comparison of U.S. and European definitions of "converging technologies" leaves us in a paradoxical situation. On the one hand, it speaks very clearly to different cultural perspectives and thus to a kind of parochialism on both sides. On the other hand, neither perspective views itself as parochial but claims universality. The U.S.approach relies on an anthropological or evolutionary view of technological development as a whole and might appeal for that to the European anthropologist and philosopher Arnold Gehlen (1965). NBIC-convergence claims only that a new chapter is beginning in a grand historical narrative. And similarly, I have defended "the European approach" as all but regional:

> The science-based development of technology is rooted in a tradition of truth-seeking, criticism, and enlightenment, the same tradition that produced the political constitutions not only of the U.S. and Europe. The critical recognition [by the *CTEKS*-approach] of limits of feasibility, the creation of spaces for political deliberation and agenda-setting, the expectation of societal benefit from public investment hardly reflect regional commitments but are valued in all parts of the world. The question is only whether these commitments prevail in the formulation of sound science policy. (Nordmann, 2006, p. 6)

This paradoxical situation spells trouble for attempts to discover and develop a way of dealing with this difference. For it would appear that the relevant philosophical principles and historical assessments are already entangled with the two positions.

III. REGIONAL CLAIMS TO UNIVERSALITY

Lest one should think that U.S. and European approaches part company only on the contentious issues of "improving human performance," the following incomplete survey indicates the range of questions where a similar paradox might arise (see also Schummer, 2006a, b).

1. In June 2004 began an international dialogue on the responsible development of nanotechnology (Meridian Institute, 2004). At the first meeting representatives of the European Union proposed an "international code of good conduct" for nanotechnology research. The report from the meeting reflects that this proposal encountered reserve, if not resistance. It issued in the suggestion that one should first develop a common nomenclature that includes a definition of "human dignity."[5] Also, the demand to publicly share all knowledge regarding the implications of nanotechnology was to require balancing against intellectual property rights. In this case of an ongoing political negotiation, any kind of

meaningful settlement will presuppose a full accounting of the conflicts of interests, including a view of the risks posed by a failure of settlement. What is lacking at this point is not the common definition of a term, but a clear appreciation of the underlying conflict where proponents of an international code are reminded that the very proposal of such a code reflects a specifically European agenda.

2. There appears to be widespread agreement that ethical concerns need to be included in the early stages of nanoscience and converging technologies research and development. However, beneath this apparent agreement lurk different motives and widely divergent conceptions regarding the role of ethics. To be sure, most everyone wants to get away from a merely regulatory framework in which ethical criteria are brought in as gatekeepers to monitor only end products. Especially among technological visionaries, quite a different role for ethics is envisioned. On their account, we should expect inevitable revolutionary changes from nanoscience and converging technologies and should therefore prepare ourselves for these changes. However, ethical norms usually express traditional values and the value of traditionalism. A speedy change of traditional attitudes is therefore needed and requires that ethicists are brought on board early on.[6] The assumption that ethicists can be turned into early adopters of nanotechnology is an example of what Sheila Jasanoff calls hubris in attempts to politically manage potential resistance (Jasanoff, 2002). The opposing attitude of humility looks to ethics for precisely the opposite reason, namely in order to buy time for reflection and to mobilize the cultural resources that will allow for local adaptations of technological agendas and avoidance of uniform global diffusion. Economically speaking, the former attitude serves to protect near-term corporate advantages, while the latter attitude wants to first secure a stable environment that will facilitate economic and technological development. Here then, ethical reflections find themselves framed in political and economic schemes and must begin by questioning their assumed position of political autonomy and the very possibility to transcend the regional frame with claims to universality.

3. Most programmatic presentations of nanotechnology and technological convergence emphasize their environmental benefits. Even before one subjects such claims to the required scrutiny, one can discern a fundamental disagreement regarding the very conception of nature. In many publications, nature is likened to an engineer who assembles living organisms from atoms and molecules. On this conception, we need not worry about the basic environmental friendliness of a technology that obviously adheres to nature's own principles. However, since these principles are the eternal and immutable laws of nature, this amounts to a thin and ahistorical conception of nature — that of the physicist. It is thin because it hardly constrains technology at all. Everything in the realm of

physical possibility would thereby belong to the realm of technical possibility and ecological permissibility. But the laws of nature are indifferent, of course, to the existence of human life. In contrast, a thick or substantial conception of nature views it not as a particularly brilliant nanoengineer, but as the singular process that evolved a biosphere to which we find ourselves peculiarly well-adapted. This, of course, is the evolutionary biologist's or ecologist's conception of nature. On this conception, nanotechnology is attuned to nature only as long as it meets special conditions and safeguards what has evolved on this planet. Again, the principles at stake are already entangled in the selective appeal to equally plausible and general conceptions of nature — ecologists will obviously favor theirs, physicalist proponents of nanotechnology theirs, and the difficulty is compounded if in some regional contexts the ecological concerns have more weight than in others.[7]

4. Assessments regarding economic opportunities or societal risks often express conflicting assumptions and will be interpreted differently by different parties. For example, claims regarding the efficiency of nanomedicine can refer to the medical notion of individualized treatment, the scientific notion of root cause and targeted intervention at the cellular level, and the policy consideration of cost-effectiveness (Nordmann, 2007). Similarly, economic predictions tend to conflate substitution processes in existing industries and the creation of genuinely new products or systems; they tend to neglect the elimination of labor in areas of maintenance and repair. Policies for research and development sometimes assume that nanotechnological advances will appear wholesale on store shelves as so-called tradable goods. This assigns the development to global market forces and consumer choices. It systematically underestimates the challenge and opportunities of locally instituting infrastructural technical systems. These systems are non-tradable and their economic importance (like that of software) comes from the problems they solve and the practices they enable, from the need to maintain and upgrade them, from derivative tradable goods that operate within such a technical environment. Finally, the consideration of societal risk is framed within different temporal horizons. Some limit themselves to short- or medium-term risks from new materials, medical devices, and the like. Others insist that the prospect of molecular manufacturing, for example, or of spiritual machines ought to be included in the consideration of emerging risks.[8] By the same token — and this completes the cycle — it belongs to the very definition of nanotechnology and the convergence of technologies whether they include radically new devices and procedures in a distant future or whether they incrementally improve or build upon existing technology.

Though incomplete, this survey shows how sensitive nanotechnology and technological convergence is to competing cultural or philosophical

attitudes and historical assessments. This sensitivity owes to the very construction of these research endeavors and needs to be understood before one can find a way to negotiate these differences and evaluate technological convergence.[9]

IV. ENTANGLEMENTS

"Nanotechnology" is a common label for a heterogeneous collection of research projects and visions. The proposed convergence is to be enabled by nanotechnology and — as we have seen — its definition remains contested or is subject to deliberate agenda-setting. When we ask about the glue that holds these terms together, what applies to nanotechnology holds even more so for converging technologies, namely that it requires work to maintain the unifying power of these concepts.

This work is not performed by researchers who formulate new theories, train graduate students, edit disciplinary journals, establish and articulate a paradigm. It is performed for the most part by advocates and activists, visionary policy makers, scientists when they speak to the public or argue for future funding — and by philosophers, ethicists, social scientists.[10] The work consists in devising broad and flexible definitions that can accommodate the multiplicity of current and envisioned research agendas (Nordmann, 2007).

From the early days of nanotechnology, that work also consisted in producing credibility for a visionary research program by drawing attention to its transformative, potentially dangerous implications. Eric Drexler's Foresight Institute and the National Nanotechnology Initiative have this much in common: Both encouraged philosophers, social scientists and ethicists to reflect on societal impacts on the principle that "if it has social impact, it must be real." This principle has since been extended by the so-called Center for Responsible Nanotechnology and the Institute for Ethics and Emerging Technologies. In order to follow their invitation to engage fascinating ethical issues, we must accept the premise of the reality of molecular manufacturing or of a transhumanist future.

Philosophers, social scientists, and ethicists have thus been recruited to do some of the work that is required to convince a larger audience that "nanotechnology" and "converging technologies" are meaningful concepts. To be sure, this work has been genuinely productive: Nanotechnological research collaborations have been energized by it and agenda-setting for the convergence of enabling technologies may stimulate innovative developments.

More importantly for present purposes, however, the conceptual, even philosophical work that is done to define "nanotechnology" and "converging technologies" renders these sensitive to cultural influences, traditional

values, etc. In other words, the principle "if it has social impact, it must be real" implies that the reality of nanoscience and converging technologies is shaped by the different ways in which their supposed social impacts are envisioned, approached, and discussed.

Another way, then, to characterize "nanotechnology" as a common term for heterogeneous research projects is to call it an entangled concept: Like a ball of thread, it draws together many ideas and visions, many institutions and contributing disciplines, and many actors from a variety of backgrounds (researchers, promoters, policymakers, stakeholders, humanities and social science scholars). It is therefore worth showing with greater detail how social scientists, philosophers of science, and ethicists are entangled in nanotechnology or more generally in enabling technologies and their convergence. Seeing how this entanglement is at risk of becoming a deadly embrace, we can also see a way out: The main contribution of philosophers, social scientists, and ethicists at this point is to disentangle the knot they are helping to create, disentangling themselves and the issues at hand, liberating the research heuristic and science studies analyses from their deadly embrace, thus allowing for more creative, less stereotypical work by all concerned.

V. FROM SCIENCE WARS TO LOVE FEST

To appreciate just how deeply social science and philosophy are implicated, it is worth reminding ourselves that not long ago the so-called Science Wars marked a profound alienation between Science Studies scholars and the technological and scientific research communities. The Science Wars began when physicist Alan Sokal exposed the apparent fraudulence of much contemporary philosophy and social studies of science by cleverly parodying a "deconstructionist" Science Studies approach to quantum mechanics (Ross, 1996). This was to call into question any attempt to relate scientific accomplishments to the cultural contingencies of laboratories, research institutions and societies at large.

According to Sokal, science, social science, and philosophy should all be speaking truth to power in the tradition of Galileo and the Enlightenment. However, if "truth" is deconstructed as being relative to very particular, possibly subjective conditions, it can no longer confront power but becomes bound up with it. If we followed the path of STS, Sokal argued, we would have to accept that the establishment of truth is itself an exercise of power. Rather than offer an Archimedean platform for critique, scientific truth would appear to be nothing but cultural prejudice or societal interest in the guise of objectivity.[11]

These Science Wars seem all but forgotten when philosophers, social scientists, and ethicists are invited to reflect upon the emergence and

convergence of novel technologies. This is not surprising, however, since even the current love fest is informed by the Science Wars. While it may have appeared scandalous to argue that chemistry, biology, or physics are political constructs, no one would deny this for nanoscience and the convergence of enabling technologies. Indeed, the latter owe their very existence to an understanding that emerges from the work of historians and philosophers of science and technology, namely that political constructions do not undermine, but can actually advance the production of objective knowledge. In other words, the hitherto suppressed Science Studies findings about societal and cultural contingencies now serve as an openly acknowledged point of departure.

More particularly, the work of Science Studies that was criticized by Sokal attempted to show that science does not simply study nature but refashions it in the course of its investigations. While this remained unacknowledged in the traditional scientific claims to objectivity, the National Nanotechnology Initiative made its entrance with the programmatic headline "Nanotechnology — Shaping the World Atom by Atom." Here the world does not appear as a given object of research but along the constructivist lines of Science Studies it is considered as subject to technoscientific shaping (Nordmann, 2004).

At this point, we encounter again the paradoxical situation where parochial cultural perspectives can each make claims to universality. The recognition of the contingencies that go into and come out of nanotechnological and related research supports rather different approaches. First, one might conclude that Science and Technology Studies (STS) are harmless and inconsequential when they show how such research programs are constructed, and thus that they firmly belong to the present and inform an envisioned future. Indeed, standing at the interface between science and society, STS helps articulate the cultural dimensions and thus the timeliness of nanotechnology research programs.

Alternatively, one might mobilize and render consequential specific STS findings about innovation and diffusion, about public resistance to new technologies and their adaptation to social contexts through intellectual and practical appropriation. STS could thus inform research policy and help shape science-society interactions, for example by encouraging public participation in agenda-setting for the development of technologies.

As great as the difference between these alternative understandings of STS may be, in one important respect they come to the same: Alan Sokal is proven right by this newfound mutual understanding between science and Science Studies. Nanoscience — if it is a science at all and if its primary interest is to seek truth — does not continue the tradition of Galileo, Darwin, Freud, or Einstein and it does not speak truth to power. It is not set up to challenge established theories or popular misconceptions but draws on a rich toolkit of existing theory and calibrates it to the complexities of the

nanocosm. Indeed, one might argue that the emerging technologies call for scrutiny by normative philosophy of science as well as normative ethics. These would critique, for example, the collusion of nanoscience with industry, government and the military.

However, to offer such a critique is not why STS was invited to reflect on societal implications of nanoscience and converging technologies. Instead, by accepting the invitation, STS scholars are for the most part accepting Sokal's judgment of their trade. Few philosophers of science ask hard questions regarding the quality or reliability of nanoscientific knowledge,[12] even fewer ethicists adopt a clearly normative stance towards the implicit presuppositions of nanotechnology research (but, see Dupuy, 2005), and at this point it would appear a virtually insurmountable task for STS scholars to justify or critique public investment in nanotechnology.[13] In these respects, the mutual admiration of the two communities of nanoscale research and Science Studies may turn out to be a deadly embrace. The fresh opportunities and new-found ability to talk to one another about societal dimensions and public concerns tempts all parties to believe that they are already rehearsing novel science-society interactions — even though the public at large remains uninvolved and many uncomfortable questions do not get asked.

VI. DISENTANGLING ENTANGLED CONCEPTS

The preceding diagnosis exposes the several challenges faced by STS scholars and all those who seek to clarify or negotiate the competing claims made on behalf of nanoscience and emerging technologies. First, they have to recognize and acknowledge how they themselves are entangled in the construction of the emerging technologies, for example, what role they play in defining nanotechnology and perpetuating its treatment as a unified technology that appears unified precisely because of its ethical or societal implications.

The second challenge is to escape the deadly embrace, at least as far as it goes.[14] Also, conditions have to be created and the issues prepared for a fruitful negotiation of different policies and practices with regard to nanoscience and converging technologies, including the differences, say, between U.S.-American and European approaches. And finally, one must find a way to engage these issues ethically.

To meet these various challenges all at once, I recommend the strategy of disentangling entangled concepts. While it undermines premature claims to universality, this strategy is itself universally applicable. It seeks to tease apart and isolate the various strands that have become entangled as alliances were formed, disciplines merged and support built for the emerging technologies. As the knot is disentangled, philosophers and social scientists

become aware of how they have themselves become entangled in it. They elude the deadly embrace as far as it goes: Refusing claims of unity that gloss over significant cultural or disciplinary differences, the disentangling approach remains appreciative of all that went into the formation of the knot and seeks to preserve the integrity of the strands. Though it does not refuse nanotechnological and convergent developments altogether, it exhibits them individually, allowing for differentiated discussions that bring to light differences of approach.

Without applying ready-made ethical categories, this finally satisfies two measures of ethical appropriateness:

1. In its pursuit, disentangling requires sensitivity, care, tact, or "*Fingerspitzengefühl*" — it teases the threads apart without destroying them; and,
2. it renders nanotechnological questions amenable to public debate in a way that is answerable to experts and stakeholders in the field while empowering broader publics.

The strategy of disentangling thus aims to destroy mystical conceptions that get in the way of public deliberation, while at the same time preserving the heuristic and creative potential of nanotechnology and visions of convergence.

Where these desiderata come into conflict, philosophical analysis or political principle have to resolve the conflict case by case. Reconsider, for example, the various conceptions that are conflated in the rhetoric of efficiency in respect to individualized nanomedicine. As was mentioned already above, claims regarding the efficiency of nanomedicine refer simultaneously to three different notions and thus entangle them — the medical notion of individualized treatment, the scientific notion of root cause and targeted intervention at the cellular level, and the policy consideration of cost-effectiveness. The common term forges an alliance between scientists, the medical profession, and health policy makers.[15] This alliance, one might argue, is good for nanotechnology research and development even if the conflation of meanings does not stand up to scrutiny.

Accordingly, it might appear that to disentangle the different meanings of "efficiency" may turn out to be bad for nanotechnology and society — if, for example, this has the effect of disillusioning policy makers, funding agencies, and the public at large. Here, the decision to disentangle owes to the principle that honesty is, quite literally, the best policy. Indeed, the work of disentangling the three disparate claims to efficiency may render nanomedical research more secure and better integrated than does the perpetuation of a vaguely unifying rhetoric. In the place of the false expectation of cost-effective nanomedicine, disentangling makes room for an explicit commitment to cost-intensive health care that is good for medicine

and wealth generation. Rather than construe medical practitioners as beneficiaries of nanotechnological advances (a technology push towards greater treatment-efficiency), it helps strengthen a patient-oriented pull that integrates nanomedicine in a larger therapeutic context. Finally, the reductionist appeal to causal efficacy at the molecular level can now be balanced against anti-reductionist insights from a variety of scientific disciplines like genetics, evolutionary anthropology, social linguistics.[16] In other words, the strategy of disentangling the entangled notion of "efficient nanomedicine" does not constrain research but opens a rich arsenal of resources and ideas, allowing for a more sustained and productive engagement among the various stakeholders. By liberating nanomedical research from the narrow stereotype of efficiency it effects a productive disillusionment for public policy, the health-care system, and the research community alike.

While this is not the place to provide further examples of disentangling in action (see Bensaude-Vincent, 2004; Nordmann, 2007), it should be possible to briefly map out the likely effects of pursuing this strategy. In regard to the science behind nanotechnology and the convergence enabled by it, it encourages a skeptical attitude of believing less and, instead, asking questions about the limits of understanding and control at the nanoscale — and it thus should also encourage methodological reflection on invention and innovation within given limits of knowledge. In respect to democracy and attempts to democratize technological development, it redirects public discourse from speculation about possible futures towards participation in agenda-setting processes — if enabling technologies are open to shaping, publics can learn (as in the health-care arena) to formulate specific demands for technologies that promote environmental remediation, renewable energies, global equity etc.

In respect to questions of risk, the strategy of disentangling does not aim to provide assurances but to foster public deliberation on hazard-benefit trade-offs — thereby fostering also a kind of vestedness in technological development when some unknown risks are willingly accepted in order to achieve clearly defined potential benefits. In regard to funding, this strategy undermines the notion that one should globally subsidize the promise of industrial innovation, but considers funding for application-oriented research as a targeted investments for expected returns.

VII. LIMITS OF METHOD AND METAPHOR

To the foregoing list must be added the effect of pursuing disentanglement in regard to the very notions of nanoscience and technological convergence. Here, the attempt to disentangle entangled concepts appears all but impossible, if only because it construes these concepts from the get-go as

mere products of entanglement that lack unity. The very metaphors of entanglement and disentangling may not be adequate, however, if it turns out that there are powerful principles that unify nanotechnology and the nano-enabled convergence of technologies. That there might be such a unity was suggested by the report on NBIC-convergence:

> The architecture of the sciences will be built through understanding of the architecture of nature. At the nanoscale, atoms and simple molecules connect into complex structures like DNA, the subsystems of the living cell, or the next generation of microelectronic components. At the microscale, cells such as the neurons and glia of the human brain inter-act to produce the transcendent phenomena of memory, emotion, and thought itself. At the scale of the human body, the myriad processes of chemistry, physiology, and cognition unite to form life, action, and an individual capable of creating and benefiting from technology. Half a millennium ago, Renaissance artist-engineers like Leonardo da Vinci, Filippo Brunelleschi, and Benvenuto Cellini were masters of several fields simultaneously. Today, however, specialization has splintered the arts and engineering, and no one can master more than a tiny fragment of human creativity. We envision that convergence of the sciences can initiate a new renaissance, embodying a holistic view of technology based on transformative tools, the mathematics of complex systems, and unified understanding of the physical world from the nanoscale to the planetary scale. [. . .] People will be able to acquire a radically different instinctive understanding of the world as a hierarchy of complex systems rooted in the nanoscale. (Roco & Bainbridge, 2002, pp. 11, 16)

To be sure, once nanoscience has become a scientific discipline that studies structure-property relations and the complex dynamics of self-organization at the nanoscale and once this science of complexity provides the paradigm also for the convergence of technologies, it can no longer be disentangled into separate strands that are knotted together only by abstract definitions in terms of scale-dependent properties or by general discussions of societal impacts and industrial revolutions. Inversely, the strategy of disentangling the knot is appropriate just as long as it works.

This leaves us with a final disagreement, however. Instead of disentangling premature claims to unity and universality, shouldn't one foster the new renaissance and the holistic or unified view of the physical world from the nanoscale to the planetary scale? Behind the prospect of such an unification slumbers the age-old utopian dream of an entirely new, less alienated, more integrative way of doing science. If this dream is ever to be realized, this might be the time to constructively engage with just those scientific visionaries who advance it in the report on NBIC-convergence. No one pursues more vigorously than George Khushf this experiment of constructive engagement with the aim to take these visionaries by their word and promote as far as it

will go the transformation of the traditional scientific enterprise (Khushf, 2004ab, 2006). There is no reason why "disentanglers" should interfere with this experiment rather than watch it with cautious skepticism.[17]

I began by describing a situation where claims to universality have become entangled in parochial knots of promises and projects. I recommended the method of disentangling such knots as a universally applicable strategy that prepares for public scrutiny and debate the isolated strands of particular nanotechnological research programs and of particular agendas for the convergence of enabling technologies. We have now seen, however, that this method is not impartial in regard to the inherent unity of nanoscience or the convergence of enabling technologies.

While we are waiting and seeing whether such inherent unity will emerge eventually, we are in the meantime well served to disentangle premature claims that are made regarding the power of enabling technologies to globally transform our lives. This includes an acknowledgment of the fact that the technosciences do not speak truth to power and do not challenge traditional ways of conducting research. Though they encourage teamwork among disciplines, they do not establish a fundamental re-organization of the disciplines. Indeed, there is nowhere as of yet anything like a nanotechnological revolution, scientific, industrial, or otherwise. And all this is good news for democratic societies that are called upon to collectively negotiate and appropriate technological developments and that therefore rely on evolutionary, rather than revolutionary developments.[18]

While some nanotechnological applications may have tremendous implications, particular nanotechnologies can and should be dealt with one at time. Overall, then, the goal of disentanglement expresses a strategic faith in productive disillusionment. It bets on the notion that creative innovations are forged in the heat of public debate, that social innovation is required to make the most of the tools provided by enabling technologies. By the same token, the strategic optimism recommended here warns against expecting too much from nanoscience and the convergence of technologies, warns against creating a monster in our midst or mythical entities that are amenable neither to rational debate nor to political choice.

NOTES

1. A third definition was developed in Canada where the convergence is crafted in an expert road-mapping process that seeks to match emerging capabilities to defined fields of problems (Bouchard, 2003). A synthesis of the various approaches has been developed in Spain (Fontela, 2006).

2. Since the author of the present paper served as *rapporteur* for the European expert group and drafted the C*TEKS* report, he should leave to others the assessment of that report. As to the perceived need to "answer" the American NBIC-proposal, a German policy document must stand for others: "American visions are strongly oriented towards capabilities for optimizing the human being, and there is a danger that these visions diffuse into a Germany that lacks a developed science policy position of its own. Such a conception of the human being will find little acceptance in Germany. This might lead to a

loss of the opportunities that can potentially arise from the convergence of advanced technologies. As an alternative to this, there must therefore be a broadly conceived public debate on a science policy which is compatible with the German mode of innovation and system of values and which clearly sets itself off from discussions in the United States" (Giesecke, 2004, compare European Commission, 2003).

3. I borrowed this second credo from a programmatic presentation by Josephine Green of Philips (at a September 2005 European Commission, Directorate Research conference on Key Technologies in Brussels). Green took it to express the favorable conditions for technical research and development in Europe.

4. The belief in a single trajectory of technical progress is underwritten by folk historiography such as simple extrapolations of "Moore's Law." In contrast the second approach is grounded in history and social studies of technology, especially the microsociological studies of recent decades.

5. The European proposal was formulated in advance of the meeting: "Common shared principles for R&D in nanotechnology could be embodied in a voluntary framework (e.g. a "code of good conduct") to bring the EU together with countries who are active in nanoscale research and share our commitments to its responsible development" (European Commission, 2004, p. 22). The response to the proposal is reflected in the report on the international dialogue:

> Such a code of conduct could include: a commitment from institutional authorities to use public funds for R&D of nanotechnology in a manner that protects the integrity of mankind; the constitution of a high-level advisory board to give advice concerning among others, risk prevention; and a commitment to treat knowledge on the impacts of nanotechnology a public good and share this information. This language, however, led to questions about how to define human dignity and how to reconcile the desire to share information with intellectual property (IP) protection, and led to the suggestion that the international community needs a common nomenclature. (Meridian Institute, 2004, pp. 7f.)

6. Compare the following passage from the NBIC report:

> 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. Human identity and dignity must be preserved. (Roco & Bainbridge, 2002, pp. 18f.)

Davis Baird comments on this passage that "[s]ome people are likely to be suspicious about how genuinely open NBIC is to ethical debate" (Baird, 2004). Jean-Pierre Dupuy paraphrases pointedly: "The major impediment is ethics, that is, our current ethics, conservative and overcautious. The report looks forward to a possible radical change in ethics, akin to a transformation of civilization, thanks to which 'the acceptance of brain implants, the role of robots in human society, and the ambiguity of death' will conform to new principles" (Dupuy, 2004, p. 134).

7. Implicit in the discussions of converging technologies is a similar difference of conception regarding human nature. Some define the human being in terms of its potential and aspirations. They suggest that nanotechnology will help humans overcome their current limitations and realize their potential. In contrast, the Enlightenment tradition conceives the human being as essentially imperfect and frail but nevertheless fully human (autonomous, rational) and therefore neither capable nor in need of "improvement." This concerns, in particular, mortality as a defining moment of the human condition. Similarly, the following three assessments of sensor networks for environmental monitoring require analysis. The first response will stress the environmental benefits of the new technology that allows us to quickly diagnose environmental stresses and to take appropriate steps. The second response will highlight possible harm and ecological imbalance introduced by the nanoparticulate sensors themselves; it will view them as a potential hazard to environmental and human health. The third response will point to the danger of relying on a technological remedy rather than address underlying causes; in particular, it will express the worry that belief in an all-powerful technological fix will diminish our attitude of care toward the environment and encourage carefree, wasteful consumption. The shared commitment to sustainability and environmental protection is thus accompanied by a fundamental difference of sensibilities. While this difference has to be made explicit, the misleading appearance of an "either-or" might

also be diffused. Perhaps, the best way to adopt or appropriate such sensor networks is by acknowledging and acting upon all three points.

8. The so-called Center for Responsible Nanotechnology complains, for example, that the report on nanotechnology by the Royal Society and Royal Academy of Engineering (2004) does not include visions of molecular manufacturing. More recently, a report on risk governance set out to fuse the different temporal "frames" (Renn & Roco, 2006; compare Renn 2005).

9. Accordingly, the following is an implicit argument for the notion that a methodological, philosophical, sociological understanding of nanoscience and converging technologies prepares the ground for ethical and societal deliberations. Compare also note 4 above. This is reflected in the fairly large number of Science Studies scholars who have been involved from the beginning in discussions of societal implications of nanotechnology (as opposed to the preponderance of applied ethicists in debates of biomedical technologies): Davis Baird and collaborators in the United States (the first NSF-funded research group on philosophical and societal dimensions of nanotechnology), Arie Rip and collaborators in the Netherlands, Brian Wynne and collaborators in the UK, Hans Glimell and Sven Ove Hansson and each of their collaborators in Sweden, Jean-Pierre Dupuy and Alexei Grinbaum in France, Joachim Schummer, myself, and others in Germany, etc. The recognition of the importance of Science Studies also speaks through the following appeal by Mihail Roco:

> An appeal is made to [. . .] initiate societal implications studies from the beginning of the nanotechnology programs, and to communicate effectively the goals and potential risks with research users and public. By this message, we try to encourage various research and funding communities 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. (Roco, 2003, p. 189)

10. David Berube's book on "nanohype" can be read as telling the background stories on this (Berube, 2005).

11. To be sure, Sokal did not plead for a naive trust of science and technology but allowed for a critical, scientifically informed stance also toward the institutions and practice of science.

12. Such questions are subject of a research group at Bielefeld University's Center for interdisciplinary Studies (ZiF) in 2006–2007. Looking at "Science in the Context of Application" it asks questions about control vs. understanding in simulations, about the robustness of knowledge claims that are validated by interested actors, etc.

13. Joachim Schummer (2005) has raised the issue of distributive justice in research funding. Though the difficulty of such a task is universally acknowledged, this difficulty does not justify or explain the absence of debate on the subject.

14. This is not the place to review the various strategies that have been proposed and that are being practiced. George Khushf and Davis Baird pursue a strategy of "constructive engagement," Joachim Schummer recommends the role of "neutral mediator," and Mickey Gjerris maintains as a minimal standard for any real conversation between science and its publics that among possible outcomes is a resounding "no" to any proposed nanotechnology. Of course, these three strategies and the one proposed in this paper by no means exhaust all the possibilities.

15. A European report on benefits and risks of nanotechnology provides one example of how these notions become entangled:

> The patient will benefit from this 'near patient' [Lab-on-a-Chip] diagnostic through an optimised therapy with fewer drug side effects. A targeted or personalized medicine reduces the drug consumption and treatment expenses resulting in an overall societal benefit by reducing the costs to the public health systems. [. . .] The overall drug consumption and side-effects can be lowered significantly by depositing the active agent in the morbid region only and in no higher dose than needed. This highly selective approach reduces costs and human suffering. (Nanoforum, 2004, 19f.)

16. For a somewhat more detailed presentation of this example see Nordmann, (2007).

17. The skepticism is underwritten by Jan Schmidt's critical analysis of the systems-theoretic claims in the report on NBIC-convergence. Instead of a radically new conception of integrated research he finds that behind these claims lurks a variant of the traditional reductionist program for the unification of the sciences (Schmidt, 2004).

18. Of course, some refer to the "digital revolution" as an example of a radical transformation of leisure, work, and social relations. This was not, however, a revolution. As fast as digital technologies developed, they were appropriated and contained within existing technical, regulatory, and conceptual schemes that resisted immediate transformation and slowed down the pace of change, allowing for users to modify trajectories of development and to ultimately define the various information and communication technologies.

REFERENCES

Baird, D. (2004, April 22). *Converging Technologies, Diverging Values? European and American Perspectives on NBIC*. Presentation at the AAAS Forum on Science and Technology Policy, Washington, DC.

Bensaude-Vincent, B. (2006). Two cultures of nanotechnology? *HYLE — International Journal for Philosophy of Chemistry*, *10(2)*, 65–82; reprinted in J. Schummer and D. Baird (Eds.), *Nanotechnology Challenges: Implications for Philosophy, Ethics and Society* (pp. 7–28). Singapore: World Scientific Publishing. [On-line]. Available: www.hyle.org, accessed May 17, 2007.

Berthoud, G. (2005, September 5–9). *The Techno-utopia of Human Performance Enhancement*. Contribution to the SAGW-Kolloquium Utopie heute, Swiss Academy of Human and Social Sciences: Gerzensee.

Berube, D. (2005). *NanoHype: The Truth Behind the Nanotechnology Buzz*. Amherst, MA: Prometheus.

Bijker, W., Hughes, T., & Pinch, T. (Eds.). (1993). *The Social Construction of Technological Systems*. Cambridge, MA: MIT Press.

Bouchard, R. (2003). *Bio-Systemics Synthesis: Science and Technology Foresight Pilot Project*. Ottawa: Canadian Research Council. [On-line]. Available: http://2100.org/Nanos/biosystemics-canada.pdf, accessed May 17, 2007.

Cameron, N. (2005). *Convergence and Divergence: European Union Responses to US Converging Technology Policy*. Contribution to the Converging Technologies Conference (NBIC 2005) in Hawaii.

Coenen, C. (2006). Der posthumanistische Technofuturismus in den Debatten über Nanotechnologie und Converging Technologies. In A. Nordmann, J. Schummer, & A. Schwarz (Eds.), *Nanotechnologien im Kontext* (pp. 195–222). Berlin: Akademische Verlagsgesellschaft.

Coenen, C., Fleischer, T., & Rader, M. (2004). Of visions, dreams, and nightmares: The debate on converging technologies. *Technikfolgenabschätzung — Theorie und Praxis*, *13*(3), 118–125. [On-line]. Available: www.itas.fzk.de/tatup/043/coua04a.html, accessed May 17, 2007.

Dupuy, J.-P. (2004). Assumptions and values of NSF report. In Foresighting the New Technology Wave — Expert Group, *State of the Art Reviews and Related Papers* (pp. 134f.) [On-line]. Available: http://ec.europa.eu/research/conferences/2004/ntw/index_en.html, accessed May 17, 2007.

Dupuy, J.-P. (2005, March). *The Philosophical Foundations of Nanoethics: Arguments for a Method*. Presentation at the Nanoethics Conference, Columbia, SC.

European Commission (2003). Converging technologies. *Foresighting Europe (Newsletter of the Science and Technology Foresight Unit, DG Research) 2,* 2–4.

[On-line]. Available: http://ec.europa.eu/research/foresight/pdf/foresight_news letter_02_en.pdf, accessed May 17, 2007.

European Commission (2004). *Communication from the Commission: Towards a European Strategy for Nanotechnology*. Office for Official Publications of the European Communities, Luxembourg. [On-line]. Available: ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/nano_com_en_new.pdf, accessed May 17, 2007.

Feenberg, A. (2002). *Transforming Technology: A Critical Theory Revisited*. Oxford: Oxford University Press.

Fontela, E. (2006). *Convergencia NBIC 2005: El Desafíol de la Convergencia de las Nuevas Tecnologías*. Madrid: Escuela de Negocios.

Gehlen, A. (1965). Anthropologische Ansicht der Technik. In H. Freyer, J.C. Papalekas, & G. Weippert (Eds.), *Technik im technischen Zeitalter: Stellungnahmen zur geschichtlichen Situation* (pp. 101–118). Düsseldorf: Schilling. English translation in R. Scharff and V. Dusek (Eds.), *Philosophy of Technology: The Technological Condition* (pp. 213–220). Oxford, UK: Blackwell.

Giesecke, S. (2004). Verschläft Deutschland die Konvergenz der Spitzentechnologien? *ips: innovation positioning system — Innovationspolitische Standpunkte, newsletter of VDI/VDE Innovation+Technik, November 2004*, 1. [On-line]. Available: http://www.vdivde-it.de/ips/november, accessed May 17, 2007.

Grunwald, A. (2006). Nanotechnologie als chiffre der zukunft. In A. Nordmann, J. Schummer, & A. Schwarz (Eds.), *Nanotechnologien im kontext* (pp. 49–80). Berlin: Akademische Verlagsgesellschaft.

Grunwald, A. (2007). Converging technologies: Visions, increased contingencies of the condition humana, and search for orientation. *Futures*.

HLEG (High Level Expert Group, Foresighting the New Technology Wave). (2004). *Converging Technologies: Shaping the Future of European Societies*. Luxembourg: Office for Official Publications of the European Communities. [On-line]. Available: ftp://ftp.cordis.lu/pub/foresight/doc/ntw_report_nordmann_final_en.pdf, accessed May 17, 2007.

Hughes, T. (2004). *Human-Built World*. Chicago: University of Chicago Press.

Jasanoff, S. (2002). Citizens at risk: Cultures of modernity in the US and the EU. *Science as Culture*, *11(3)*, 363–380.

Jasanoff, S. (2005). *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton, NJ: Princeton University Press.

Khushf, G. (2004a). The ethics of nanotechnology: Visions and values for a new generation of science and engineering. In National Academy of Engineering (Ed.), *Emerging Technologies and Ethical Issues in Engineering* (pp. 29–55). Washington, DC: National Academies Press.

Khushf, G. (2004b). Systems theory and the ethics of human enhancement: A framework for NBIC convergence. *Annals of the New York Academy of Sciences*, *1013,* 124–149.

Khushf, G. (2006). An ethic for enhancing human performance through integrative technologies. In W. Bainbridge and M. Roco (Eds.), *Managing Nano-Bio-Info-Cogno Innovations: Converging Technologies in Society* (pp. 255–278). Dordrecht, The Netherlands: Springer.

Laurent, L., & Petit, J.-C. (2006). Nanosciences and its convergence with other technologies: New golden age or apocalypse? *HYLE — International Journal for*

Philosophy of Chemistry 11(1), 45–76; reprinted in J. Schummer & D. Baird (Eds.), *Nanotechnology Challenges: Implications for Philosophy, Ethics and Society* (pp. 249–286). Singapore: World Scientific Publishing. [On-line]. Available: www.hyle.org, accessed May 17, 2007.

Meridian Institute (2004). *Report of the International Dialogue on Responsible Research and Development of Nanotechnology*. Alexandria, VA: Meridian Institute, National Science Foundation. [On-line]. Available: http://www.meridian-nano.org/international.php, accessed May 17, 2007.

Nanoforum. (2004). *4th Nanoforum Report on Benefits, Risks, Ethical, Legal, and Social Aspects of Nanotechnology*. [On-line]. Updated version available: www.nanoforum.org, accessed May 17, 2007.

Noble, D. (1999). *The Religion of Technology*. New York: Penguin.

Nordmann, A. (2004). Nanotechnology's worldview: New space for old cosmologies, *IEEE Technology and Society Magazine, 23(4)*, 48–54.

Nordmann, A. (2006). *Shifting Grounds: From Tomorrow's People to Today's Challenges*. [On-line]. Available: www.philosophie.tu-darmstadt.de/fileadmin/phil/nordmann/NordmannShiftingGrounds.pdf, accessed May 17, 2007.

Nordmann, A. (2007). Entflechtung: Ein Vorschlag zum ethisch-gesellschaftlichen Umgang mit der Nanotechnologie. In F. Schiemer, A. Gazsó, & S. Greßler (Eds.) *Nanotechnologie und Nanowissenschaften: Chancen und Risiken.* (215–229). Berlin: Springer.

Oudshoorn, N., & Pinch, T. (Eds.). (2005). *How Users Matter: The Co-construction of Users and Technology*. Cambridge, MA: The MIT Press.

Renn, O. (2005). *Risk governance: Towards an integrative approach*. Geneva: International Risk Governance Council. Reprinted version (January 2006). [On-line]. Available: http://www.irgc.org, accessed May 17, 2007.

Renn, O., & Roco, M. (2006). *Nanotechnology Risk Governance*. Geneva: International Risk Governance Council. [On-line]. Available: http://www.irgc.org, accessed May 17, 2007.

Roco, M., & Bainbridge, W. (Eds.). (2002). C*onverging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science*. Arlington, VA: NSF/DOC. [On-line]. Available: http://wtec.org/ConvergingTechnologies, accessed May 17, 2007.

Roco, M. (2003). Broader societal issues of nanotechnology. *Journal of Nanoparticle Research*, *5*, 181–189.

Ross, A. (Ed.). (1996). *Science Wars*. Durham, NC: Duke University Press.

Royal Society and Royal Academy of Engineering. (2004). *Nanoscience and Nano-Technologies: Opportunities and Uncertainties*. London. [On-line]. Available: http://www.nanotec.org.uk/finalReport.htm, accessed May 17, 2007.

Saage, R. (2006). Konvergenztechnologische Zukunftsvisionen und der klassische Utopiediskurs. In A. Nordmann, J. Schummer, & A. Schwarz (Eds.), *Nanotechnologien im Kontext* (pp. 179–194). Berlin: Akademische Verlagsgesellschaft.

Schmidt, J.C. (2004). Unbounded technologies: Working through the technological reductionism of nanotechnology,. In D. Baird, A. Nordmann, & J. Schummer (Eds.), *Discovering the Nanoscale* (pp. 35–50). Amsterdam: IOS Press.

Schummer. J. (2005). Forschung für die Armen versus Forschung für die Reichen: Verteilungsgerechtigkeit als moralisches Kriterium zur Bewertung der

angewandten Chemie. In C. Sedmak (Ed.) *Option für die Armen: Die Entmar-
ginalisierung des Armutsbegriffs in den Wissenschaften* (pp. 605–626).
Freiburg, Germany: Herder.

Schummer, J. (2006a). Nano-Erlösung oder Nano-Armageddon? Technikethik im
christlichen Fundamentalismus. In A. Nordmann, J. Schummer, & A. Schwarz
(Eds.), *Nanotechnologien im Kontext* (pp. 263–276). Berlin: Akademische
Verlagsgesellschaft.

Schummer, J. (2006b). Cultural diversity in nanotechnology ethics. *Interdisciplinary
Science Reviews*, *31(3)*, 217–230.