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Editors

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Governing Future Technologies

Nanotechnology and the Rise of an Assessment Regime

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Introduction: Governing Future Technologies

Mario Kaiser, Monika Kurath, Sabine Maasen, and Christoph Rehmann-Sutter

1 The Rise of an Assessment Regime

Unlike any other field before, nanotechnology has been the object of unprecedented "assessment hype." Immediately after former U.S. president Clinton announced the National Nanotechnology Initiative in 2000, a high-level workshop took place at which scholars from the humanities and social sciences, politicians, and representatives from the nanoscience community discussed societal implications of nanotechnology.[1] Since then, numerous countries such as Switzerland (Baumgartner et al. 2003), Germany (Paschen et al. 2003), and the UK (Royal Society & Royal Academy of Engineering 2004) have mandated their technology assessment institutions to author reports on the hazards and risks of nanotechnology.

Beside these governmental initiatives, actors from other social domains responded as well: nongovernmental organizations (NGOs) with an environmental focus such as the Action group on Erosion, Technology and Concentration (ETC Group 2003) and Friends of the Earth (Miller 2006), think tanks such as the International Risk Governance Council (Renn and Roco 2006) or DEMOS (Kearnes et al. 2006), and reinsurance companies (Munich Re 2002; Swiss Re 2004) – in spite of pursuing different objectives – have all contributed to promoting risk awareness and the regulation of nanotechnology. Furthermore, academic fields, such as science studies[2] and applied ethics,[3] also have begun to concern themselves with nanoscience and nanotechnology, which we will refer to here as NST.

Starting with the Human Genome Project, the idea that novel technologies should be accompanied by deliberations of the ethical, legal, and social issues (ELSI)

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[1] The report of the same name was published by Roco and Bainbridge (2001).

[2] Regarding science studies, cf. Baird et al. (2004), Hayles (2004); Nordmann et al. (2006), Rip (2006) and Schummer and Baird (2006).

[3] Regarding applied ethics: Allhoff and Lin (2008), Bachmann (2006), Berne (2004), Best and Khushf (2006), Ebbesen et al. (2006), Grunwald (2004), Khushf (2004) and Nordmann (2007).

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involved became important.[4] In the case of NST, a new acronym has emerged (NELSI), which testifies to the fact that ELSI considerations have become an inseparable part of this emerging technology.

> Because the stakes are higher for nanotechnology, because it is being touted as the transformative technology of the 21st century, and because it already touches so many industries and sectors of the economy, the exploration of NELSI on a broad and public scale is central to nanotechnology's success (Center on Nanotechnology and Society 2008).

For nanotechnology, in particular, the intensification and diversification of different assessment rationales and approaches has gained such magnitude that to refer to applied ethics *or* technology assessment *or* reinsurance companies in isolation would miss a unique point of importance: the emergence of what we suggest should be conceived of as an entire *assessment regime*. Despite the different organizations, methods, and actors involved in the evaluation, deliberation, and regulation of emerging technologies, they all adhere to an overarching scientific and political imperative: innovations are welcome if they are evaluated not only for technical and scientific soundness and feasibility but also for safety, justice, and sustainability, as well as for issues such as consumer desirability.

The "assessment regime" as a whole is concerned with those evaluation aspects that are regarded as crucial for the social acceptability of novel technologies. Each approach to assessment entails two dimensions: information (knowledge) and deliberation (values). Information is required for comparing nanotechnology to preceding technologies, in particular, with respect to their unintended consequences (David and Thompson 2008). Deliberation, on the other hand, refers to checking for a new technology's ethical or legal implications and its social robustness.

For most lay people, the latter aspect is pivotal: making sense of NST is inseparably linked to acceptable values. Thus, social scientists are being asked to examine the "values lying behind the ways people make sense of nanotechnology" (Gaskell et al. 2005), explore "public perceptions about nanotechnology" (Cobb and Macoubrie 2004), or reflect on issues such as "equity, privacy, security, and environmental impact" (Schulte and Salamanca-Buentello 2007). This task, however, is by no means confined to the academic discourse – on the contrary:

> [T]he concept of "acceptability" is no longer the province solely of experts; [it] is a "polygamous marriage with business, politics and ethics" (Power 1997: 5).

For instance, the EU Commission has decided "to involve powerful NGOs (for example, Greenpeace) to attract a broader audience to dialogue" (EU Commission, cited in Wullweber 2008: 40). As this kind of participation has occurred more regularly, working toward the acceptability of a technology has become a task that is

[4] The U.S. Department of Energy (DOE) and the National Institutes of Health (NIH) devoted 3–5% of their annual Human Genome Project (HGP) budgets to ELSI initiatives. The discussions accompanied the Human Genome Project even though the whole ELSI program was criticized as a mere "afterthought" with a blurry mandate and dismissed as a "welfare program for ethicists". These comments were made by Troy Duster, former chair of the ELSI Working Group at the National Center for Human Genome Research (NCHGR), to Francis Collins, who succeeded James D. Watson as director of the NCHGR, respectively. Cf. Marshall (1996).

sui generis deeply entrenched in the *making of* the technology altogether: it has opened up a discursive space attracting various actors and enabling them to shape the technology in question by way of articulating their own views, values, principles, or goals. Taken together, the pursuit of "acceptability" has given rise to the proliferation of an overarching assessment regime. It turns acceptability from a regulatory idea into a regulatory practice, a political project even.

Most importantly, acknowledging the existence and role of an assessment regime means accepting that the landscape of governance[5] is shifting, with new problems and actors coming to the fore. Notably, policy researchers, focused on science, technology, and innovation, as well as politicians have recently realized the importance of public deliberation of key technologies. ELSI, in particular, is regarded as a social innovation capable of overcoming (supposed) resistance against emerging technologies and improving their governance.

At this point, we step back and consider how ELSI is entrenched in the governance of key technologies, particularly with regard to NST. This broad view requires a careful examination of how regulatory strategies incorporate and interpret the concept of acceptability to develop the relationship between science and society. In fact, nanotechnology's emergence has entailed specific transformations in the political and epistemic spheres as well as in the ethical dimension.

- In the *political domain,* we have witnessed an increasing demand for *democratization of science and technology*. With the emergence of nanotechnology, however, participation and dialogue have been intensified and integrated in governance structures so that we now talk about "hybrid governance." Speaking back to science (Nowotny 2003) assumes the possibility of getting *involved in* governing NST.
- The *ethical dimension* is opened by recognizing the responsibility and accountability of science toward society. With the advent of nanotechnology, however, ethical deliberation has become a chief element in the politics of emerging technologies so that we now speak of "ethopolitics" (Rose 2001). Ethical concerns of individuals, groups, or institutions are increasingly connected with ideas of *good governance* of NST.
- Finally, the *epistemic dimension* is about a turn from *knowledge* to *innovation* or, in other words, from *supply* to *demand*. Thus, the emergence of a new mode of knowledge production explicitly includes extrascientific actors at virtually all stages of generating novel technologies. With the advent of nanotechnology, we observe an epistemic shift from manufacturing "socially robust knowledge" to the fabrication of "sustainable innovations".

The analytical distinction of these three dimensions should not obscure the close and complex connections between them: Political techniques and instruments

[5] Whereas *government* indicates a body of formal authority aimed at implementing duly constituted policies, *governance* suggests the processes and manner in which power is exercised by both formal and informal institutions (Rosenau 1992: 1–4).

always require knowledge for conceptualizing the problem to be regulated as well as for justifying their deployment. Likewise, the concrete ways in which knowledge is produced in the epistemic dimension greatly depends on what is valued as genuine or important in the ethical dimension.

The shifts that can be observed in all three dimensions (individually as well as combined) underline a central hypothesis of this book. Rather than being *ornamental* to technology development, in the case of nanotechnology the assessment practice in all three dimensions seems to have become an *integral* and *active* part of emerging NST. In many identifiable ways, they influence the strategies and the research practices in this field.

Let us briefly look at each of these dimensions of an assessment regime in turn. They all offer a choice between a pair of options: democratization *or* hybrid governance, ethics *or* ethopolitics, socially robust knowledge *or* sustainable innovations. Mostly, however, we find combinations of both. More often than not, the latter is supported and legitimated by the former.

1.1 The Political Dimension: Democratization or Hybrid Governance?

Beyond science policy, the idea to democratize science relates to broader aspects, such as a shift in democracy theory from a conventional representative model to participatory and deliberative models. For representatives of public administration, this shift entailed early on the prospect of overcoming the dual challenge of optimizing the economic and social impact of technology *and* the potential of public involvement in decision-making (Kloman 1974). By showing that scientific expertise in decision-making either neglects other kinds of relevant knowledge or transcends its domain of competence, historians and sociologists of science have drawn attention to a legitimacy problem of science policy (e.g. Jasanoff 1990, 1997; Smith and Wynne 1989; Nowotny 2003). To overcome it, they have pleaded for a democratization of science policy as well. For political scientists, in turn, democratization is seen as a cure for the political passivity and distrustfulness of the (non-)voting citizens. By actively involving the latter, more active forms of citizenship and democracy are expected to emerge, such as, for example, “technological” (Frankenfeld 1992) or “ecological citizenship” (Dobson and Bell 2005) and “strong” (Barber 1984) or “deliberative democracy” (Cohen et al. 1989). As a consequence, institutionalized technology assessment gradually incorporated democratic instruments into the traditional technocratic tool box, producing new models of technological citizenship.

Thus, participatory methods in technology assessment have been worked out as a micropolitical effect of democratizing science (Durant 1999; Joss and Bellucci 2002) – the instruments ranging from consensus conferences and citizen juries to public hearings and scenario workshops. On a macropolitical level, however, democratization has become almost synonymous with governance of science and technology. Probably the best-known example for the convergence of democratization and governance is the white paper “European Governance” (CEC 2001), along with related working documents such as “Science, Society and the Citizen in Europe” (CEC 2000). In these and similar proposals, the dialogue between science and society and the notion of governance are not just linked but conceptually depend on each other: no dialogue without governance, no governance without dialogue.

Whether such a “politics of talk” (Irwin 2006) really affects and changes the traditional governmental structures remains an important question. However, we do not agree with the allegation that it is *just talk*. First, the semantics of governance and dialogue have inspired many actors and institutions, many of which are only loosely tied to government. Moreover, it creates real institutions, like the think tank *International Risk Governance Council*. By inventing new participatory strategies like “upstream engagement”, DEMOS could firmly establish itself as an active player in the governance of nanotechnology as well. In addition to such highly visible institutions, governance activities occur in a variety of other arenas: in small workshops, in which scholars from the social sciences and humanities closely interact with nanoscientists, in working groups put together for a report, and in both local and multinational efforts to mount initiatives like “nanologue” (Nanologue 2006).

Obviously, nanotechnology is full of governance(s), ranging from micropolitical exercises of participatory technology assessment to macropolitical strategies on a supranational level. The EU’s Sixth Framework Program, which allocated research funds for generating “knowledge about citizenship, democracy and new forms of governance”, was such an example. More generally, the emerging type of socio-political governance involves science, politics, the media and the public sphere, the market, as well as society in general. Concepts of collective or participatory governance are meant to describe a shared set of responsibilities (Kooiman 2003: 5). These tasks meet several key functions: supporting the transformative impact of new technologies, advancing responsible development that includes health, safety, ethical, and social concerns, encouraging national and global partnerships, and commitments to long-term planning. Such frameworks explicitly include principles of good governance, most notably the participation of those who are affected by the new technologies, transparency of governance strategies, responsibility of stakeholders, as well as effective strategic planning.

All these different levels, institutions, and settings, in which governance is announced, expected, or exerted, constitute a loosely coupled network of governance(s). Referring to this network as “hybrid governance” accounts for the diversity of the governance strategies involved, their different instruments, rationalities, and aims. At the same time, however, all actors operate based on concepts such as *accountability*, *transparency, responsibility, prudence, effectiveness,* or *open dialogue,* which account for a flexible unity of hybrid governance. This can be illustrated with the white paper on nanotechnology issued by the International Risk Governance Council. The council claims that its governance framework is unique because it distinguishes different forms of risks, ensures the early participation of all stakeholders, including civil society, and because it implements the principles of

> good governance, including participation, transparency, effectiveness and efficiency, accountability, strategic focus, sustainability, equity and fairness, respect for the rule of law and the

> need for the chosen solution to be politically and legally realisable as well as ethically and publicly acceptable (Renn and Roco 2006: 35).

The case of nanotechnology thus demonstrates that the ideal of a democratization of science and technology and its multiplying effects have given rise to an assessment regime, operating *on*, *with* and *by* hybrid governance.

1.2 The Ethical Dimension: Ethics or Ethopolitics?

Especially, the debate over human embryonic stem cells leaves the impression that the deliberation of novel technologies primarily rests on ethics: politicians around the world were asked to follow their conscience rather than party discipline; ethical councils mushroomed on national and regional levels; and concepts of human dignity and sanctity of life suddenly extended beyond philosophical seminars and became publicly contested issues.

We call that change in the framing of the problem an *ethicization* of technology controversies.[6] With the rise of bioethics in the 1970s and the powerful support it received from the ranks of the Human Genome Project ELSI program, ethical deliberation has become one of the dominant frameworks for assessing future technological and scientific developments, foremost in the realm of biomedical technologies. By way of this ethicization,

> "laws and regulations are losing importance in the shaping of medical and scientific developments. Instead, new institutionalizations and representations of conversation, confession and negotiation rituals become increasingly central in government technologies" (Gottweis 2005: 120).

However, ethicization also covers the change from a language of calculable risks to a language of uncertainty, in which emotions, trust, and morality gain in importance. With respect to policy-making, strategies of expertise, according to Gottweis, are complemented by strategies of conversation and confession that do not focus on proof but rather on credibility (cf. ibid.).

In nanotechnology, however, it seems that the traditional risk framework has reclaimed much of its lost terrain. Mundane risks such as the possible toxicity of nanoparticles seem to have exceeded ethical problems as raised by the issues of human enhancement, at least in current debates. However, does this mean that ethicization has come to an end?

The expansion and dissemination of notions like accountability, sustainability, fairness, or transparency, through which governance has created plausibility for

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[6] The term *ethicization* was developed by sociologists to say that science, technology, and academic research has not only become economized, commercialized, and instrumentalized in a knowledge society but also encounters intensified ethical assessment (ethicization) (Stehr 2005). Adapting this concept to science and technology controversies, other STS scholars argue that "ethicization" leads to new rationalities at the interface of science, politics, and society, involving technology assessment and science governance as well; Bogner (2005) and Maasen and Weingart (2005).

bottom-up modes of governing, indicate that ethics still plays an important role. For the time being, it might have retreated from the thematic level but in no way from a procedural one. Here, ethical concepts assume even more functions and roles: the production of a "nano code" of conduct, for instance, should not only provide a framework for establishing public confidence; it is also a "response to a perceived lowering of respect for the scientific profession in recent years and aims to restore the high standing that scientists had in society barely fifty years ago" (Pitkethly 2007: 5). Ethical principles like fairness, non-strategic action, or veridicality also play a crucial role in legitimating participatory settings, which give participants a safe forum to articulate their sentiments, hopes, fears, or anxieties. Finally, the (often hidden) task to ethically justify one's political maneuvers has even led transhumanists to explain their attitudes and actions in terms of ethics, as the website of the Institute for Ethics and Emerging Technologies shows (IEET 2008).

On these grounds, Nikolas Rose (2000, 2001) has suggested that we live in an ethopolitical age where issues as diverse as crime control or emerging technologies are problematized in a similar way in terms of ethics. Not only in the life sciences, as Rose suggests, but also in other areas (NST and converging technologies, in particular) we notice extremely value-driven debates about technoscientific developments, always coupled with economic imperatives. In this perspective, the emerging assessment regime based on democratizing science and technologies co-evolves and interacts with the "ethicization" of emerging technologies. It shows in the

> ways in which the ethos of human existence – the sentiments, moral nature or guiding beliefs of persons, groups, or institutions – have come to provide the "medium" within which the self-government of the autonomous individual can be connected up with the imperatives of good government (Rose 2001: 18).

In addition to the "autonomous individual," the current deployment of ethics, however, has found further objects that are required to live up to the expectations of good government or rather good governance: businesses, firms, and corporations. All these entities are "required" to "voluntarily" follow particular codes of conduct. In fact, the ethical vocabulary (introduced earlier to define hybrid governance) not only hints at new ways of governing but also at new attributions of accountability. With regard to regulatory issues, accountability encourages "self-regulation". Self-regulation is highly welcomed as a novel "regulatory approach," one that replaces the tradition of "intervening states prescribing a policy which clearly indicates allowed and forbidden behaviour" (Führ and Bizer 2007: 327).

The case of nanotechnology thus illustrates that it is precisely the ethicization of science and technology and its multiplying effects that have given rise to an assessment regime that justifies itself in terms of ethopolitics.

1.3 The Epistemic Dimension: Socially Robust Knowledge or Sustainable Innovations?

The past few decades have seen a cascade of new proposals for conceiving the interplay of "science and society." A fundamental change in this relation was observed in a transition of knowledge production from “mode 1” to a “mode 2” (Gibbons et al. 1994). Science policy under the notion of “public understanding of science” was based on the idea that science takes place in a space that in a certain way is external to society, as research is conducted according to its own agenda, methodological principles, and its own quality assessment. Associated with the emergence of the idea of mode-2 knowledge production, new policy imperatives such as “public engagement” have led to reconceiving science as internal to society. Thus, society has switched from a passive end-user to an actively participating jury in knowledge production. Herein, society calls for good science – “good” defined as “socially robust knowledge” (Nowotny et al. 2001; Nowotny 2003).

In the example of NST, expectations continue to shift, and it seems that society has moved even more upstream. In current knowledge politics (Stehr 2005), the idea of social robustness seems to have been passed by the demand-driven (as opposed to supply-driven) side of knowledge production. In parallel, science policy has increasingly turned its attention to innovations and to systems of innovations (SI). What once began as a framework for “national systems of innovations” (Freeman 1987; Lundvall 1992) nowadays has gained credibility as the SI approach (Edquist 1997, 2005), which has been introduced to national governments and even to international organizations such as the OECD or the EU. The strength of this approach is to be found in its encompassing and interdisciplinary perspective, in its emphasis on the role of institutions and organizations, and in its capability to include both product and process innovations. In this vein, accounts of SI do not target technological innovations but instead look at the social conditions that enable and sustain them. Consequently, corresponding approaches aim at managing and improving the fundamentals of technology innovation and diffusion. These objectives may be achieved by changing the funding conditions in favor of excellence, by redefining teaching and learning processes at universities in favor of transferable skills, or by modifying policy environments in favor of (hybrid) governance.

Most interestingly, public engagement has become a major focus of SI research and policy, too. Within this context, however, the philosophy undergoes a significant change from knowledge to innovation. Once again, nanotechnology seems to be a case in point, as this field has enabled the articulation of increasing demands for sustainable innovations – demands that soon might outpace the ideal of socially robust knowledge.

In fact, striving for sustainable innovations in nano- and other technologies brings about a new quality in the science-society relationship. Society defines the ethical, social, or legal criteria that knowledge production has to take into account, even as it marks out the concrete directions that guide the development of *solutions*, i.e. innovations. While issues of social or ethical acceptability so far acted more or less as demarcations within which research and development had to be carried out, science and technology are now bound to take issues of desirability more seriously.

> Innovation does not automatically lead to societal progress, as is implicitly assumed in *technology push*-oriented policies. This assumption is an inheritance of the enlightenment; i.e., the belief that science will automatically lead to a better quality of life. The push for sustainable development needs an approach towards innovation that can be characterised as

> *society pull*: the society has to decide which (balance of) economical, ecological and social goals are to be met. Society pull can be organised by developing shared perspectives for the future, which are inspiring for public and private policy-makers and investors (Vollenbroek 2002: 215).

This exemplifies all the mentioned changes that have affected the object of science policy: from supply to demand, from knowledge to innovations, from technology push to society pull, from acceptance to desirability, and, in this vein, from ethical, legal, and social implications to economically, ecologically, and socially sustainable goals.

The case of nanotechnology thus illustrates that it is precisely the call for socially robust knowledge and its proliferating effects that has given rise to and legitimizes an assessment regime that increasingly aims at the production of sustainable innovations.

2 Assessing the Assessment Regime

In reviewing the changing conditions under which emerging technologies are deliberated and evaluated in their political, ethical, and epistemic dimension, a range of new policy offerings can be observed, particularly with regard to NST. These new policy trends range from requests for a "governance of sustainable socio-technical transitions" (Smith et al. 2005) or a "sustainable governance of emerging technologies" (Wiek et al. 2007) to petitions for a "responsible corporate governance" (Kuhndt et al. 2004) or for "an ethics of knowledge policy" (Von Schomberg 2007).

These new policies testify to the fact that the notions, practices, and institutions of hybrid governance, ethopolitics, and sustainable innovation have prepared the ground for the emergence of an assessment regime. Particularly, the interplay of these three domains has tied the heterogeneous set of deliberating, reflecting, and governing actors into a coherent framework: futurologists, ethicists, consulting firms, technology assessors, think tanks, NGOs, natural scientists, technicians, social scientists, transhumanists, and citizens all feed into the emerging assessment regime in its pursuit of reflecting and governing the acceptability of future technologies.

Traditional ELSI can no longer be seen as mere lip service for democratizing science, neither does it automatically lead to good or better governance of science. From a descriptive perspective – instead of a normative one – ELSI can be seen as having become part of hybrid forms of governing innovative technologies, thereby involving the moral sentiments of individual and collective actors and putting the responsibility on them for bringing about sustainable innovations. Therefore, it is high time for ethicists, scholars of STS, and those involved in technology assessment to critically review the political, ethical, and epistemic conditions that led to the "sustained innovation" of an assessment regime.

Speaking of an assessment regime as a social phenomenon opens up opportunities to see all-too-common things differently. As a general leitmotif, the contributions in this volume share the methodological aim of challenging the "standard view" of technology assessment, reflection, or deliberation. Reflecting on the ethical, legal, and social implications of a new technology helps us to maximize positive and minimize negative effects as best and as early as possible: it is all about reducing environmental and social risks, improving preparedness, creating mutual understanding about the ethical limits, and more. Seen from this perspective, however, such activity is perceived as merely secondary to technology developments. Against such a view, the book advances the thesis that the assessment regime is not additive to but *constitutive* of the formation of novel technologies – either with regard to technology development proper or with regard to the societal context in which the technology is about to be embedded. The papers collected in this book draw a multifaceted picture of such interactions between nanotechnology and the assessment regime.

What is the nature of these interactions? In the first issue of *Nature Nanotechnology*, Toumey (2006) described the rise of public deliberation – in our words: the assessment regime – and the birth of nanotechnology as a coincidence:

> Nanotechnology comes to public attention at an interesting time. The question of the role of the lay public in science policy has recently matured into a series of arguments and approaches, and nanotechnology is often thought of as a test case for experiments in democratizing science today. There is nothing about atoms and molecules that makes nanotechnology more suitable for this than other technologies: this is a historical coincidence, not a scientific result (Toumey 2006: 6).

We agree with Toumey in that there is nothing specific concerning NST that should attract so much assessment activities. We disagree, however, with Toumey's conclusion that the rise of NST and its impact on science policy is nothing but a historical coincidence. The importance of science and technology for today's knowledge societies (NST being a case in point) as well as the growing prominence of democratizing technology assessment both coincide such that the latter has become an integral part of generating future technologies. The articles in this volume explore different aspects of this thesis.

The first part assembles papers devoted to the question as to how particular organizations (research and testing institutes) as well as particular scientific disciplines (crystallography and toxicology) have selectively appropriated nanotechnology (Martina Merz; Monika Kurath; Christian Kehrt and Peter Schüßler). The patterns of adaptation are multifarious. In one case, a scientific discipline (crystallography) takes such a critical stance that it almost refuses to become "nano," although its objects of research as well as its methods seem to be nano proper at first glance. In contrast to this, scientific communities that are involved in assessing and testing technological products, such as in the field of toxicology, are not only more receptive to nano but take it as an opportunity to induce organizational as well as epistemic changes that even affect the identity of the relevant community. Concerning these transformations, it seems that assessment actors may approach nano more easily, as nano allows redefining what assessment "really" means.

The second part places emphasis on the symbolic and material linkages that bind science and society together either in the form of images, visions, or video games.

In different ways, they all connect to the assessment regime (Joachim Schummer; Christopher Coenen; Andreas Lösch; Colin Milburn). By playing the role of mediators, futuristic images of nanotechnology allow for deliberation across the boundaries of science and economy. As they are shaped by popular discourse as well, they exhibit dynamics similar to those that have also marked the deliberation of dangers and risks of nanotechnology. Like images, visions for the future have structuring effects on what we may and should regard as ethical or societal implications. Moreover, as a means of representation they allow even contested actors to enter the ELSI debate and to shape the future according to their views. Video games, however, open up a new way of becoming familiar with future technologies and their societal implications. By playing them, we get in touch with the world of tomorrow in a bodily way.

The third part explores the interactions between nanotechnology and the assessment regime (Arie Rip and Marloes van Amerom; Armin Grunwald and Peter Hocke; and Mario Kaiser). In more detail, it links up to the normatively relevant discussion as to whether and how different forms of deliberation, such as technology assessment or ethical discourse, have framed nanotechnology. As we cannot expect direct and intended relations between the domains, all contributions elaborate concepts and models through which the framing effects become visible. While two papers focus on past events by highlighting the shift in deliberation from scenarios like *grey goo* to risks, one article reacts to the ways the assessment regime is bound to anticipate the future of nanotechnology.

The fourth part takes up the challenge of critically reviewing the ELSI landscape in a broad view (Alain Kaufmann et al.; Risto Karinen and David Guston; Christoph Rehmann-Sutter and Jackie Leach Scully). In contrast to the fifth part, however, it does so in a normative perspective. Consequently, the papers reflect the current status of ongoing assessment efforts. They pay close attention to deficits and shortcomings mostly of their own scientific disciplines. To overcome them, they see the hypothesis of a co-evolution and co-production as induced by the assessment regime not as an empirical fact but as a normative ideal that we should strive for by means of public participation *plus* specific other instruments: "proper expertise processes" in the first, "anticipatory governance" in the second, or a sort of procedural ethical questioning in the last case.

The fifth part distances itself from normative reasoning by trying to shed a descriptive light on the assessment regime (Alfred Nordmann and Astrid Schwarz; Matthew Kearnes; Sabine Maasen). All the chapters here are concerned with the puzzle as to how nanotechnology could unfold a kind of noncoercive coercion to participate in the ELSI and assessment endeavor. The non-oppressive force of seduction, the expansion of governance as "government without politics," as well as new roles of and chances for intellectuality are deployed to explain why the "politics of talk" could gain so much credence, thereby leaving talk *behind* politics. In doing so, all contributions testify to the ambivalences with which the assessment regime is saddled.

Rethinking nanotechnology in the context of the concerned organizations, disciplines, symbolic and materialistic linkages, interactions, and deliberative efforts reveals the emergence of an assessment regime in science and technology. It opens up a rich framework of incremental, ambiguous, and dynamic developments that goes far beyond assessing technology implications on a broader scale. Rather, by its emergence, the assessment regime not only shapes future technology developments by a hybrid mode of governance and predominantly ethopolitical considerations but also frames technology in society by enforcing knowledge production guided by the idea of sustainable innovation.

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Part I
Going "Nano": Opportunities and Risks

The first part of this book assembles papers that address the opportunities and risks of appropriating nanoscience and nanotechnology (NST) in organizations and in scientific disciplines.

In her contribution, *Martina Merz* analyzes organizational dynamics and in what way they account for the emergence of scientific fields. She argues that NST can be mobilized as a resource to reposition a research institute in a situation of crisis. As a case, she reflects on the Swiss national materials science and technology research institute Empa, whose shift to the nanoscale is interpreted as an organizational response to its insufficient degree of scientification as perceived by decision makers. Merz demonstrates that the appropriation of NST "solves" this problem at different levels simultaneously. First, the association with nanotechnology's "economy of promises" grants scientific respectability to an organization and symbolically lifts its scientific reputation. Second, in the case of Empa, it enabled the testing institute to adjust the borders between its service (testing) and research (science) activities. Third, the organization makes use of nanotechnology as a topical area to promote itself as "a mediating instance between heterogeneous target groups." She concludes by saying that these moves, individually and together, help to frame and continue the debate over what exactly is NST.

Monika Kurath focuses on the strategies and rationale that actors of the assessment regime use to negotiate questions about identities, boundaries, and potential technology implications in NST. Those strategies lead to transformations within the concerned science and technology fields. Analyzing the case of toxicology, she argues that the delegation of the risk assessment of NST to toxicology initiates new possibilities of reconstructing identities for toxicology as an academic discipline. While those in the field see the opportunity to get involved in basic research, the field may not entirely abandon its tradition as a testing, regulatory-oriented science. Jumping on the bandwagon of cutting-edge research could allow the classical testing sciences to undergo scientification and to dissolve the tension between research and testing.

In their article, *Christian Kehrt and Peter Schüßler* study how nanotechnology is received in crystallography in terms of "boundary objects" such as nano-instruments or nanoscale research objects. This allows Kehrt and Schüßler to draw a distinction between scientists who remain within the boundaries of their discipline and *defensively appropriate* nanotechnology from those scientists who were forced to leave their disciplinary identity in order to explore new methods and realms of knowledge. Although the latter scientists may have new opportunities to explore molecules without asking whether they belong to biology, chemistry, or physics, they face a fragile and uncertain situation because they can no longer refer to the secure domains of the disciplines they left behind. For Kehrt and Schüßler, this disciplinary uncertainty is the main reason why scientists from different disciplines preemptively promote a new nanoidentity.

Reinventing a Laboratory: Nanotechnology as a Resource for Organizational Change

Martina Merz

1 Introduction: Scientific Fields and Organizations

Science studies have unduly neglected questions of specialty formation and disciplinary differentiation in recent times. As a novel, highly dynamic research field, nanotechnology[1] provides science studies scholars with a welcome incentive and new test case for reconsidering these issues from fresh angles.[2] This paper will promote attention to organizational change as one such new angle to explore science dynamics.

The reason for the as-yet insufficient conceptualization of disciplinary dynamics seems to lie in the historical development of social studies of science itself. While processes of institutionalization of emerging scientific specialties were high up on the agenda of *institutionalist* science studies in the 1970s (cf. for an overview Lemaine et al. 1977), the advent of *constructivist* social studies of science in the 1980s was accompanied by a disinterest in disciplinary structures in favor of attention to specific local research settings and a micro-analysis of scientific practice (cf. for an overview Merz 2005). Early institutionalist analyses, with their focus on paradigmatic change and disciplinary formation on the one hand, and laboratory studies, with their interest in experimental practice, skills, and instrumentation on the other hand, did not go well together.

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[1]"Nanotechnology" is employed in this text as a synonym for both nanotechnology and nanoscience. This choice is motivated, first, by a preference to increase readability and, second, based on the understanding that the distinction between the two is a matter of contention and negotiation in the concerned communities.

[2]A number of investigations have begun to chart out the shifting disciplinary configurations related to nanotechnology: for scientometric investigations cf. e.g. Heinze and Bauer (2007), Leydesdorff and Zhou (2007), Meyer and Persson (1998), Schummer (2004), and for observation studies cf. Kurath, in this volume, Kurath and Maasen (2006), Schüßler and Kehrt, in this volume, Vinck et al. (2006).

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The gap between scientometric analyses of disciplinary dynamics in the institutionalist tradition and observational analyses of scientific practice and culture in the lab studies tradition prevails still today. What these two approaches do have in common, however, is that they largely neglect the organizational level of analysis, albeit for different reasons. While scientometric inquiries predominantly focus on the level of the scientific community through its publication and citation patterns, investigations into "epistemic cultures" (Knorr Cetina 1999) have mostly disregarded issues of dynamics and change, being more interested in the defining features of established knowledge cultures and their differences.

Historians of science do provide some accounts of organizational change and discipline formation, albeit mostly with a focus on outstanding scientific laboratories such as CERN or EMBL.[3] Organizational studies, in turn, mostly focus on the level of universities or research institutions at an agglomerate level, with no particular interest in the question of disciplinary dynamics. In contrast, the focus here will be on one of the many middle-sized labs in which nanotechnology thrives today: Empa, the Swiss Federal Laboratories for Materials Testing and Research.

This chapter proposes to take the issue of *organizational dynamics* into consideration in order to more adequately account for the emergence of scientific fields. It starts out from the notion that the epistemic makeup of nanotechnology (research objectives, epistemic practices, objects, instruments, etc.) and its institutional arrangements (research institutes, collaboration networks, etc.) are both open to negotiation and mutually dependent. Scientific activities in the field of nanotechnology take place within very different organizational frames. For a research institute to establish a dedicated nanotechnology program, new activities must be reconciled with fundamental characteristics of the organization. The central thesis of this article is that a research institute can mobilize nanotechnology as a resource to reposition itself (e.g. in a situation of crisis) and that, at the same time, this mobilization plays a part in framing and nourishing the ongoing debate over the definition and character of nanotechnology. In a situation such as the present, in which nanotechnology's subject matter and orientation are a matter of contention and its institutional forms have not stabilized, the term nanotechnology is employed strategically in discourses of science policy, of public and private research endeavors, and of different deliberation platforms. Scientific organizations are active participants in this arena, in which various actors and societal dynamics determine the contours of nanotechnology.

To probe into these issues, a case study is examined in the context of Swiss publicly funded nanoscale research.[4] In the focus of attention are the materials science and technology research institute Empa and its nanotechnology research activities. The institute will be introduced by way of a historical sketch (cf. Section 2). Its shift to the nano-scale is then interpreted as an organizational response to the repeated call for its increased "scientification". Since the uptake of nanotechnology research

[3]Cf. Hermann et al. (1987), Hermann et al. (1990), Krige (1996), and Krige (2002).

[4]Methods include document analysis (e.g. annual reports of Empa) and ethnography (drawing, at this stage, especially on informal conversations and first phases of participant observation).

activities alone (cf. Section 3) does not solve the perceived problem, the institute, in addition, attends to the problematic image of testing by rethinking this central activity (cf. Section 4). Finally, the institute pursues yet another strategy to position itself as a modern science-based research organization by actively engaging in the public understanding of nanotechnology and in research on nanotechnology's social and environmental implications (cf. Section 5). These moves, individually and together, bring about organizational change and simultaneously participate in shaping nanotechnology (cf. Section 6).

2 Formation and Crises: History of a Testing Institute

In Switzerland, as in other European countries, the late 19th century was characterized by intensifying industrialization and the construction of large-scale infrastructure in transportation (e.g. bridges, trains) and other sectors (e.g. electricity). The development engendered the need to systematically monitor and test the quality of the materials used (e.g. building materials), and thus led to the formation of "scientific material testing as a new experimental discipline" (Burri 2005[5]). Testing activities targeted, for example, the carrying capacity of bridges or the danger of transporting dynamite (ibid.).

A "materials testing machine" was constructed in 1852 to test for the strength of construction materials against rupture, torsion, and folding. It was acquired with the financial assistance of the Swiss federal government, which also funded a "pavilion" to house it. The machine, with its concrete setup and equipment, did not yet meet the requirements of systematic scientific testing. This changed when, in 1880, the Federal Institute for Testing Building Materials[6] (the precursor of Empa) was founded.[7]

With the machine as the institutional trigger for the Federal Institute, the coming decade witnessed an expansion of both the institute's machine park and the building materials it tested. After a decade of existence, the institute was entrusted with its first major topical assignment: to investigate the cause of the spectacular collapse of the iron bridge across the river Birs. Constructed by Gustav Eiffel, the bridge failed when a train passed, resulting in numerous casualties. The final testing report created an occasion for the institute's first director, Ludwig Tetmajer, to promote the institute as both a public testing site and a technical experimental station (Burri 2005).

In its early years, the Federal Institute for Testing Building Materials already displayed three main characteristics that were to guide the institute throughout its

[5]Quote translated by the author (MM).

[6]Original German name: *Eidgenössische Anstalt zur Prüfung von Baumaterialien*.

[7]For the history of Empa, also see Empa (2005) and the Annual Reports of Empa, which are available for download for the years 1970–2006 at http://library.eawag-empa.ch/empa_annual_report.html (20-03-08). For the wider socio-historical context of science and research in Switzerland, cf. Gugerli et al. (2005) and Honegger et al. (2007).

history: First, its central determination by and irrevocable entanglement with the issue of testing[8]; second, its institutional integration into the ETH (Eidgenössische Technische Hochschule) Domain, which today comprises the two Swiss Federal Institutes of Technology (ETH Zurich and EPF Lausanne) and four federal research institutions; and third, its hybrid identity that combines testing and experimental research. All three characteristics will prove relevant to the specific account of how Empa has taken up nanotechnology in recent years (cf. Sections 3, 4 and 5).

Over the years the testing institute enlarged its activities. It no longer tested only building materials but also other materials such as combustibles, textiles, and yarns. Organizationally, the change was accomplished by taking in other testing facilities. The Swiss Federal Fuel Testing Institute joined the original institute in 1928, and the Control Agency for Cotton Yarn followed in 1937 (cf. Empa 2005). The ensuing name change of the institute led to an explicit mention of the tests' fields of application: industry, construction, craft.[9] At that time, the abbreviation "Empa" was already in use. The institute held and still holds locations in Dübendorf (near Zurich) and St. Gallen. A third location in Thun was established in the 1990s.

In the late 1980s, Empa underwent a major organizational reorientation, which brought about a new orientation toward research. The Empa "Strategy 88" was implemented under the leadership of a new president in 1989. According to the mandate, testing and research were to acquire equal weight in the organization's activities.[10] The upgrading of research was put into practice, and it became visualized and symbolized through the institute's new name: Federal Institute of Material Testing and Research.[11] The new "strategic business units" of Empa consisted of testing and advice, research and development, and knowledge distribution including teaching (cf. EMPA 1988: 17).

For its research and development activities, Empa cooperated with industry, universities, and polytechnics; its testing assignments were commissioned by industry and public administration. It positioned itself strategically at the interface of industry and academic science. Intensifying the research activities according to Strategy 88 went hand in hand with a reduction of routine testing assignments, a development that was put into practice over the next decade. During these years, Empa also enhanced its international reputation and was widely solicited for its materials testing expertise at home and abroad.

Throughout the 1990s, scientification was enforced as a continuing project. It received a further boost in the wake of the ascent of New Public Management,

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[8]The German verb "prüfen" seems to have a wider lexical content than the English verb "to test". The former also covers activities such as examine, review, investigate, inquire, and scrutinize.

[9]The new name now read "Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe".

[10]Empa is not the only testing institution that changed orientation throughout its history. The German "Bundesanstalt für Materialforschung und –prüfung" (or BAM), for example, was founded in 1871 under the name "Mechanisch-Technische Versuchsanstalt". It saw its research orientation invigorated in the late 1980s, which then induced a change to the current name in 1987.

[11]In the German original: Eidgenössische Materialprüfungs- und Forschungsanstalt.

which called for flexible, functional and lean organizational structures. At the same time, performance indicators were introduced in the Swiss public service, a strategy promoted also by the ETH Board for the institutions of the ETH Domain, among them Empa.

Spelled out in 1997, its four-year plan for the period 2000–2003 envisioned Empa to be, by the year 2003, "one of the leading technology institutes in the fields of materials, systems and environmental technology" (Eggimann 1997: 2). However, the performance indicators (monitoring the number of peer-reviewed publications, Ph.D. students, professors, etc.) cast doubt on the progress made to reach this plan's goals and rendered explicit the concerns of insufficient scientification: In the eyes of the decision makers, i.e. Empa's directorate and the ETH Board, Empa was still too little scientifically minded and, in contrast, too close to application. This translated into the contention that the organization's activity profile was too narrowly identified with (material) testing as a service task. Thus, Empa was and still is under pressure to remodel itself as a cutting-edge and high-profile research institution. This situation led Empa to draw on nanotechnology as a resource for organizational change.

3 Shift: Addressing the Nano-Scale

The reorganization of a research lab does not occur in a void but in the context of an organizational field (DiMaggio and Powell 1983). For Empa, the most proximate organizational environment was (and still is) the ETH Domain to which it was formally attached. The challenge for Empa consisted of defining its position in such a way that it complemented ETH Zurich, EPF Lausanne, and the other labs in the ETH Domain (in the sense of not duplicating their activities and orientation), while at the same time amplifying its degree of scientification. It thus had to maneuver a fine line between following other research labs in their uptake of nanotechnology as a research orientation and identifying a unique way to position itself in this novel field. The following will illustrate how the organization established a dedicated nanotechnology research program and how this allowed Empa to address its perceived problem of insufficient scientification.

3.1 Economy of Promises and Performance Indicators

Perhaps the most palpable benefit to an organization that adopts nanotechnology is related to nanotechnology's image as a scientifically challenging, economically promising, future-oriented, high-tech field of research and development. Strengthening its nanotechnology activities enables an organization to tap into nanotechnology's "economy of promises"[12] and, through this, to improve its image in terms of scientification geared to key future technologies.

[12]The notion "économie des promesses" is more commonly used in French language and has been applied to the case of nanotechnology, e.g. in the report Fondation Sciences Citoyennes (2006).

The second respect in which nanotechnology may support an organization's scientification has to do with the research field's formats of scientific output, especially its publications. If, as is the case within the ETH Domain, scientific output is exclusively assessed in the form of publications listed in the Science Citation Index (instead of monographs, edited volumes, book chapters, etc.), then nanotechnology research fares well in the evaluation. Its publication formats and practices are congruent with those of the scientific disciplines tracked by that database, according to which the performance measures have been modeled. When considering the wide spectrum of expertise and disciplines within Empa's research activities, nanotechnology research could thus be expected to produce a higher creditable scientific output than the average field of expertise.

This argument extends also to the provision of prestigious third party funds (e.g. from the Swiss National Science Foundation), which are more readily available to key scientific fields. And it extends to the number of Ph.D. students, which again gives nanotechnology a competitive advantage because it is a burgeoning field in comparison to other domains of expertise. Measuring performance by the mentioned indicators thus privileges nanotechnology, which benefits organizations such as Empa. This dynamic endows the powerful lure of an "economy of promises" at least partially to the organization that has adopted nanotechnology.

The two rationales suggest that a stronger involvement in nanotechnology research may be conducive to an organization's increase in scientification (for further rationales of Empa to engage in nanotechnology, cf. Section 4 and 5). But to begin with, the uptake and integration of nanotechnology in a research organization requires that certain organizational pre-conditions be met. In the case of Empa, the favorable conditions were present, above all, because of its long-term involvement in materials research on the micro (and nano) level, including the availability of the respective expertise and technical equipment.

3.2 Organizational Alignment: Recruitment, NANO 1 and NANO 2

To put into practice a shift to the nano-scale, the organization combined a number of measures.[13] In a first step, Empa implemented the dedicated program NANO 1 (2000–2003) to build up the EMPA Center of Competence in Nanotechnology, with the aim of establishing a test facility for producing nanoparticles and dedicated instrumental infrastructure. Two laboratories, "nanotech@surfaces" and "Surfaces, Coatings, Magnetism", were specifically designed for this purpose. Besides assembling the lab infrastructure, development of personnel is a key element in building up organizational expertise at the nano-scale.

[13]To avoid misunderstanding it should be noted that Empa continued to pursue other research topics and activities in parallel to engaging in nanotechnology.

In 2001, physics professor and expert in materials research Louis Schlapbach was appointed as the new CEO of Empa. His expertise covered important areas of nanotechnology (e.g. nanoscopic properties of new materials and surfaces). In addition to being CEO, he was a full professor at the ETH Zurich, which intensified the ties between the two organizations and created new opportunities for scientific cooperation. In another key step, physics professor Hans Josef Hug, expert in atomic force microscopy (which is a standard experimental technique in nanotechnology), was recruited in 2004 from the University of Basel, while maintaining his affiliation with this university. At Empa, he headed the new laboratory for nanoscale materials science. The two professors also brought with them active participation in two National Centers of Competence in Research (NCCR), which are prestigious Swiss research networks: for Schlapbach, in the NCCR "Materials with Novel Electronic Properties" network, and for Hug, in the NCCR "Nanoscale Science" program. Nanotechnology research brought about a considerable increase in publication output, which resulted in yet more visibility of Empa's activities in this area.

The program NANO 2 (2004–2007) contained four thematic modules covering research and development of novel materials, processes, and devices based on nanoscale features. The first module emphasized the development and operation of advanced scanning force microscopy, other new measurement strategies, and "nanofactory tools". The second module focused on nano-electronics and photonics. The third module made use of and advanced the organization's nanopowder pilot production to produce and investigate nanostructured materials (e.g. polymer/ceramic nanocomposites) and coatings. Finally, the fourth module aimed at creating organic nanostructured surfaces, for example, including biological material in functional systems. In particular, NANO 2 devoted special emphasis to the bottom-up approach in nanotechnology.

The internal reorganization toward a stronger involvement in nanotechnology was realized through a number of measures: Empa established new organizational structures (e.g. departments, laboratories, teams, a user laboratory cf. Section 4), recruited personnel predominantly from the academic realm, and redistributed personnel and resources within the organization to strengthen nanotechnology to the detriment of routine testing assignments, some of which were outsourced.

In one important respect, Empa was more flexible than universities when establishing its organizational units. The typical disciplinary structure of university research and teaching obliges universities to filter nanotechnology involvement through the lens of disciplines (cf. Stichweh 1994: Chap. 1). In contrast, Empa did not have to accommodate disciplinary peculiarities to the same extent. The possibility of sidestepping team-formation according to disciplinary homogeneity resonates with nanotechnology's image of being multi- and interdisciplinary. At Empa, nanotechnology research did indeed spread out across scientific specialties, and this cooperation brought together research and methodology from different disciplines.

4 Differentiation: Strategies to Rethink Testing

Its new involvement in nanotechnology assisted Empa in positioning itself as a modern research organization. Yet, this development did *not* single-handedly resolve the organization's other problem: the problematic image of testing. Testing seemed to resist scientification because of its irrevocable ties to the notion of service. Service, on its part, is symbolically associated with a notion of science and technology that lacks autonomy and is controlled by public administration and the economy. Sciences that traditionally suffer from a small "refractive index" (Bourdieu 1997, cf. also Bourdieu 2004) are less likely to follow their own autonomously generated research goals. Testing sciences are an example: their degree of autonomy from politics or the market is low. As a result, it is more difficult for organizations in these sciences to "refract" extrinsic exigencies (e.g. of a political, regulatory nature) and constitute their scientific agenda independently.

While materials testing, in principle and practice, encompassed a wide spectrum of Empa's activities situated between the poles of fundamental science and service assignments, the service aspect predominantly determined its image. Empa pursued a multifold strategy to address this problem. On the one hand, it reacted to the notion that a strong testing and service orientation is incommensurate with a modern research organization by *reducing and devaluing testing* (cf. Section 4.1). On the other hand, it met the challenge of preconceived notions of testing and service by *reinterpreting and repositioning* them to its advantage in two different ways (cf. Section 4.2 and 4.3). These three strategies are discussed in more detail below.

4.1 Reduction and Devaluation of Testing

The first strategy to address the negative image of testing consisted of aligning Empa with other high-profile research laboratories. This was accomplished by reducing the number and the extent of routine testing activities. The upsurge of dedicated nanotechnology research also assisted in rendering routine testing less visible within the context of the organization's overall research profile.

In addition, the association of Empa with testing was addressed at a symbolic level by reconsidering, once again, the organization's name. The new name-change, in line with the earlier trend to emphasize research, now took place within the frame of corporate design and corporate wording. The modification, made in 2005, involved three steps. First, the slogan "We research and test for you"[14] that accompanied the Empa logo on the official letterhead was no longer used. Instead, the logo was supplemented by the byline "Materials Science and Technology". Second, the acronym "Empa" was only spelled out in documents of judicial significance. This means that, with few exceptions, the previous name "Federal Institute of Material

[14] In the original German: "Wir forschen und prüfen für Sie".

Testing and Research" disappeared from view (in English and German).[15] Third, the term no longer appeared in all capital letters, as "EMPA"; instead, only the first letter was capitalized. This move turned the four letters from an acronym (EMPA) into a name (Empa), which resulted in yet another way of purging testing from the organization's label. The relabeling brought the notions of science and technology to the fore at the expense of "testing".

4.2 Reinterpretation and Repositioning of Testing

A second strategy to counteract the negative image of testing – and which Empa pursued in parallel to the aforementioned strategy – consisted of revalorizing testing by reinterpreting and repositioning it. To establish this new approach, the organization participated in recent discourses on the assessment, regulation, and deliberation around issues of nanotechnology (cf. Introduction to this volume). In particular, it took up the discussion of potential environmental and health risks of nanotechnology, which it then used as a resource to identify a new research program.

The starting point was the understanding that synthetically produced nanomaterials, some of which are now produced at an industrial scale, may have adverse effects on human health or the environment. Such effects are controversial and discussed heatedly among scientists. The debate has also raised considerable public interest. Empa entered the debate by establishing its new laboratory "Materials-Biology Interactions" with the aim to investigate the reaction of biological systems to synthetic materials (especially, nanomaterials). The group engaged in nanoparticle safety research under the leadership of the renowned toxicologist Harald Krug, a professor whom Empa recruited from the Forschungszentrum Karlsruhe as the laboratory's head in January 2007. Since this research included the testing for adverse health and environmental effects of nanomaterials, establishing the new laboratory can be interpreted as a move to reposition testing by focusing it on a new target of considerable public interest. Such testing activities were accompanied by Empa researchers supporting and monitoring the debate on safety and risk of nano-sized materials on a national level. Within the organization, the nano-safety research at the new laboratory was embedded both in Empa's nanotechnology research program and in the program "Materials for Health and Performance". It also cooperated with Empa's Technology and Society Lab, which, among other topics, engaged in risk analysis and technology assessment of nanotechnology.

Its involvement in nano-safety research allowed the institute to establish a more positive image of testing by associating it with environment, health, and safety

[15]The strategic renaming of research laboratories is common practice. Another case is the European Organization for Nuclear Research, CERN. The name was originally derived as an acronym from the French "Conseil Européen pour la Recherche Nucléaire" while CERN is today commonly referred to as the European Laboratory for Particle Physics (CERN 2007).

(EHS) initiatives and risk discourses of a key technology of the future. This translated into portraying Empa as a modern organization that seriously considered the issue of public accountability (cf. Dowdle 2006). At the same time, the move was consistent with the organization's emphasis on fostering its scientific reputation: Nano-safety research as conducted at Empa fulfilled all standards of high-profile research in contemporary natural science (concerning procedures, methods, publication practices, etc.). In addition, also Empa's activities in technology assessment and risk analysis met these requirements. This was the result of a deliberate policy to implement standardized performance measures (cf. Section 2) and of an employment strategy that privileged holders of advanced academic degrees (Ph.D., habilitation).

Finally, the engagement in nano-safety research had an effect also on how the organization framed nanotechnology: where different research perspectives on nanotechnology are organizationally integrated, assigning importance to nano-safety research participates in defining what nanotechnology is.

4.3 Re-Valorization of Service

The organization's third strategy to counter the criticism of insufficient scientification consisted of promoting a novel organizational form of service that followed a recent trend. During the past ten years, Swiss universities and the Federal Institutes of Technology have established a number of "facilities", "platforms", and "service labs" that specifically target research in micro- and nanotechnology. These units provide scientific and technological equipment and expertise (different forms of microscopy, specimen preparation, micro- and nanolithography, characterization, etc.), the corresponding expert personnel, and dedicated work environments (e.g. clean rooms). They offer their services to academic researchers as well as to industrial partners. In cooperation with the Competence Centre for Materials Science and Technology (CCMX), Empa established the Swiss Scanning Probe Microscopy User Laboratory (SUL), which provides analytical services and access to equipment, such as a variety of different scanning probe microscopes. Empa referred to the SUL explicitly as a "service lab for materials analysis on the nanoscale" and promoted it with a reference to its history and service tradition:

> With the SUL we extend one of Empa's crucial traditional roles – namely to provide highest-level services and training to industrial and academic partners in the field of nanotechnology. (Hug 2007)

The SUL allowed Empa to identify with its service tradition while simultaneously sanitizing the service notion by associating it with a newly established academic mode of service provision. This new approach was promoted and, thus, symbolically authorized by universities and the Swiss Federal Institutes of Technology.

5 Integration: Shaping the Contours of Nanotechnology

As discussed above, Empa not only advanced "traditional" nanotechnology research; it also fostered research into EHS dimensions of nanotechnology, for example, by establishing activities in the area of nano-safety. These measures aimed at reframing the organization and its image. As a side effect, they also affected the public debate on nanotechnology, albeit in an indirect way. In addition, the organization also contributed to forming the contours of nanotechnology as perceived by different audiences in a more direct way. Two recent initiatives illustrate how the research organization actively engaged in shaping the public understanding of nanotechnology.

5.1 ELSI, EHS, and Finance: The Case of the NanoConvention

Empa organized the NanoConvention as one of its first initiatives to shape the public image of nanotechnology and of the organization conjointly. This public event took place first in 2006 and again in 2007, with the motivation and the setup of both events similar each year. The focus here is on the two-day event that took place in the notable Kursaal Bern in late June 2007. The event attracted some 300 participants from heterogeneous social and professional backgrounds: scientists both from academe and industry, business executives, government officials, invitees of a major Swiss bank that acted as the main sponsor of the event, interested citizens, etc. The presentation program – plenary speeches mixed with parallel sessions of shorter contributions – was accompanied by an exhibition of a few companies that displayed nanotechnology products, such as bicycle frames fortified by carbon nanotubes, neckties made of stain-resistant nano-coated textiles, and the like. Empa CEO Louis Schlapbach spelled out the rationale for the event in his welcome message, as follows:

> to strengthen the Nano-Dialog beyond the boundaries of any discipline, and to offer a vehicle for fascinating talks and discussions by bringing together movers and shakers from science, industry, the insurance and financial businesses, politics, the administration and society. And once again we are able to offer national and international speakers of the highest caliber. (Schlapbach 2007)

Speakers from the US, China, Japan, and Europe covered a wide range of perspectives on nanotechnology, which Empa – in the event's announcement – organized under the three labels "Nano Fascination", "Nano Innovation", and "Nano Safety". Graphically, the labels were represented as three distinct views on the same geometric structure, reminiscent of a buckyball. The topics covered in the presentations ranged from the scientific underpinnings of nanotechnology to issues of innovation in the chemical industry or food sector, from health and environmental risks to the finance sector's readiness to engage in nanotechnology and, finally, from philosophical to sociological debates on the relations between technology and society. In this case, deliberation of the societal dimension was not reduced to EHS or economic aspects, as so often happens in science and policy discourses on nanotechnology. It also included considerations of the ethical, legal, and social implications (or ELSI), exemplified by the keynote lectures of both the philosopher Peter Sloterdijk and a prominent STS scholar.

By staging the NanoConvention as described, Empa, as illustrated by its CEO's message above, situated and configured both the organization and nanotechnology.

On the one hand, the event reinforced the public image of Empa as a *mediating authority* that is positioned between different communities and stakeholders and brings them into contact and "dialog". As a mediator, the organization at the same time assumed the role of integrator of the different perspectives.

On the other hand, the proposed integration of perspectives had consequences for the underlying notion of nanotechnology: nanotechnology appeared here in a packaged conglomerate form, as something that could be turned around and around, viewed from different angles, quite like the buckyball in the event's logo, to reveal its scientific, economic, environmental or societal nature. The conveyed image of nanotechnology was that of an embedded and integrated technology, which incorporated discourses of assessment and regulation – both ELSI and EHS – in as much as discourses of "nano fascination" and "nano innovation". This discursive shaping of nanotechnology allowed Empa to present itself as multivalent – its activities and interests covering various scientific perspectives on nanotechnology – and, as a result, rendered Empa unique. The image of nanotechnology conveyed through the NanoConvention appeared to be even more inclusive than the one the organization exhibited in its nanotech research: While Empa specifically promoted EHS research but only tentatively acknowledged the ELSI activities of its Technology and Society Lab as "nice to have", EHS and ELSI (besides economic) themes were assigned the same importance at the NanoConvention.

5.2 *Public Understanding of Science: The Case of NanoPubli*

A second initiative that affected the public's image of nanotechnology was Empa's participation in NanoEurope. This annual fair of nanotechnology in St. Gallen took place for the third time in September 2007. Empa was responsible for organizing and running the accompanying event NanoPubli. In contrast to NanoEurope, which catered to expert participants from academe and industry, NanoPubli targeted the general public – more specifically, "a young and technically interested public", as the program stated – and participation was free of charge. The focus of the 2007 event was on "nanotechnology in everyday life"; its aim was to "involve the consumers as early as possible in the discussion about 'nano' and inform them in a transparent way about this fascinating and forward-looking technology" (Rüedi 2007).[16] Involving the public translated into a program that combined lectures, hands-on experience for the visitors, a poster session that illustrated projects of

[16]Quote translated by the author (MM).

Empa researchers, and exhibits of nanotechnology products by companies. The leading Empa nano-toxicologist and his collaborators turned the main lecture into a show that combined factual information on slides with an experimental demonstration that rendered the novel properties of nanoparticles (e.g. their reactivity) more tangible to the audience.

In this case, Empa's mediation activity consisted of education, communication, and entertainment. As an initiative in the public understanding of science, NanoPubli followed a "deficit model" (Wynne 1991), educating the public at the same time about nano-sized particles and approaches of toxicological risk analysis. The public understanding of nanotechnology that the research organization promoted was therefore clearly one of *scientific* understanding. "Scientific" in this context referred to knowledge and expertise from the (natural and engineering) sciences, including the life science foundation of toxicological risk analysis. It did not refer to the knowledge base of ELSI considerations that draw on the social sciences and humanities.

The contours of nanotechnology seem to fluctuate as they are outlined by way of Empa's various science communication activities: including or excluding EHS, ELSI, or other aspects of nanotechnology depending on a variety of factors. Yet in general, it seems that the organization shares a wider and more inclusive understanding of nanotechnology than that promoted elsewhere. One may hypothesize that this wider understanding correlates with Empa's identity as a go-between, as a mediator between worlds and communities.

6 Conclusions

In this article Empa has been reflected upon *as a case*, as a specific example of how a research organization identifies with selected characteristics of a novel research area (nanotechnology), how it transforms and implements them according to organizational idiosyncrasies. In this case, one important motivation for strongly engaging in nanotechnology was the organization's insufficient degree of scientification as perceived by decision makers. The uptake of nanotechnology "solved" this problem at different levels simultaneously. First, the association with nanotechnology's economy of promises symbolized and warranted a high degree of scientific respectability. Second, it enabled the testing institute to readjust the relation of service (testing) and research (science) by applying strategies ranging from reducing and devaluing testing, revalorizing testing by repositioning it toward a new target (i.e. nano-safety), and promoting a novel form of service (i.e. a user laboratory). Third, the organization made use of nanotechnology as a topical area to promote itself as a mediating instance between heterogeneous target groups, e.g. science, politics, economy, public.

For this organization, the mobilization of nanotechnology was a means to reposition itself as a modern science-based research organization. But why was this move so successful in this particular case? The successful engagement with a cutting edge technology such as nanotechnology surely relies to an important extent on the prior predisposition and present accessibility of the pertinent expertise, apparatus, manpower, and research culture. Its tradition of materials research enabled Empa to address objects at the nano-scale and thereby latch onto nanotechnology's reputation. However, in addition, the organization's focus on testing opened up yet another venue for Empa to present itself as modern and forward-looking.

In a context in which science policy actors and funding agencies increasingly promote and enforce the inclusion of studies on ethical, environmental, and health aspects of science and technology in research projects on new technologies (especially in the case of nanotechnology, cf. Introduction to this volume), a research organization that complies with these external desiderata assumes a modern appearance. For Empa to incorporate nano-safety research as an integral component of its testing activities was expedient in this regard. The in-house integration of research on nanotechnology *applications* and nanotechnology *implications*, on the one hand, positioned Empa ably in the wider environment of research institutions (Swiss Federal Institutes of Technology, universities, laboratories, etc.). On the other hand, it accommodated discourses of assessment and deliberation to expert (i.e. natural science) discourses within the research context and, as such, affected how nanotechnology is shaped as a research field. Interestingly, the moves to foster scientification and to implement assessment activity were pursued hand in hand; they did not present complementary solutions to the organization's image problem but came as a package. This result was achieved by opting for EHS-type assessment research of high scientific reputation in the form of nano-safety research, environmental risk analysis, and the like.

Yet another organization-specific factor that accounts for the success of the testing laboratory to reinvent itself through nanotechnology consists of the traditional permeability of the organization's boundaries toward public administration and industry. This permeability, which is closely related to the small "refractive index" of its main activity, materials testing, accounts for the organization's ability to act as a mediator between heterogeneous communities, stakeholders, and professions. To stage itself as a mediator, the organization exploited the prior existence of a public controversial debate that, in the case of nanotechnology, had formed very early on. Its strategy was to tap into heterogeneous discourses and shape them by way of juxtaposing and mediating between contrasting perspectives under the authority of scientific "disinterestedness" (Merton 1973). The staged public debate then became a platform for the organization to present itself as *both* scientific and accommodating with respect to public concerns.

The bundle of strategies that Empa employed to reinvent itself by way of nanotechnology is a selection from a broader repertoire of possible solutions to related organizational problems. Science studies research on how this broader repertoire may be described and how it might vary from one technology to another is only just beginning. However, one may safely assume that the specific bundle of strategies is played out, in each case, against the background of an organization's history, image, and reputation, as well as of its organizational field; in the case of Empa, it played out against its background as a service institution and an organization that addresses and delivers to heterogeneous stakeholders and environments. Thus, one may hypothesize *path dependence*, analogous to that observed in technology development. In particular, it can be expected that other testing institutes follow alternative development paths in their orientation (or lack of orientation) toward nanotechnology.[17] Then again, research laboratories or university institutes may also turn to nanotechnology to address other organizational problems than that of insufficient scientification (e.g. its insufficient appeal to junior scientists). This assumption makes a comparison of case studies appear very promising.

Finally, the above observations bring up the more general question of why certain research organizations jump on the bandwagon of nanotechnology while others resist doing so. Recent investigations have raised similar questions with respect to scientific specialties such as toxicology or crystallography.[18] What are the rationales of research organizations (or scientific fields) that act as "nano deniers" or "nano makers"? Under what conditions and in which situations are these rationales played out in different, perhaps contradictory ways? Such questions call for in-depth and comparative investigations in science studies. What this article has tried to render plausible is the argument that to study the emergence of nanotechnology (or another research field for that matter), it neither suffices to restrict attention to the level of the scientific community nor to the local knowledge production context. A combination of these with an interest in specific research organizations and issues of organizational change may contribute to a closer understanding of the underlying dynamics of specialty formation and disciplinary differentiation.

7 Epilogue

In the most recent annual report of the ETH Board, Empa was honored specifically for its research on carbon nanotubes. The group of Oliver Gröning, head of the laboratory "nanotech@surfaces", was credited as being one of the leading teams worldwide to do research on emission properties of carbon nanotubes and their usability as efficient electron sources for Field Emission Display (FED) or miniature X-ray tubes (ETH-Rat 2007: 24–27). In addition, Empa received explicit credit for its transformation from a "mere testing institution" into an institute that performs "top level international research" in addition to its habitual service tasks. Mission accomplished, one may think. Yet the task group Blueprint Empa 2010, appointed to reflect on the future development of the organization, has suggested adapting the performance indicators, which "focused too strongly on research" in the 1990s, in favor of more strongly crediting applications and service for other parties (ibid.: 37).

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[17] In contrast to Empa, the German "Bundesanstalt für Materialforschung und –prüfung" (cf. note 10), for example, has not taken up activities in the field of nanotechnology.

[18] Cf. Kurath, in this volume and Kurath and Maasen (2006) for a discussion of toxicology, Kehrt and Schüßler, in this volume, for an investigation of crystallography, and Bensaude-Vincent and Hessenbruch (2004) for an analysis of materials science.

Empa's reorganization, so it seems, has not come to an end. Nonetheless one may assume that nanotechnology, with its proclaimed capacity of bracketing fundamental science and applied research and development, will continue to provide a good orientation.

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Negotiating Nano: From Assessing Risks to Disciplinary Transformations

Monika Kurath

1 Introduction: Identity Discourses and Assessment Dilemmas

A variety of discourses have been negotiating both promising visions and adverse implications of emerging nanosciences and nanotechnologies (NST).[1] But the "nano" future facing the assessment regime is unclear. While many possibilities of NST still in the making are imaginable, as their impacts become more knowable the options for dealing with them will become restricted. NST thus present Collingridge's dilemma (Collingridge 1992) as we try to assess today what will appear tomorrow and have consequences the day after tomorrow.

As soon as potential implications of research and development fields are discussed, questions about characterization or definitions emerge. As almost all assessments of NST stress, knowing the identity of a scientific field is a precondition for further assessment.[2] Identity negotiation, including conjectured implications, can determine the future shape and implications of the negotiated scientific field (Schummer 2004: 3). As the nanosciences themselves have not given answers to open issues of identity and implications, the assessment regime first faces the simple question of what nanotechnology really is about. To cope with these uncertainties, the assessment regime uses different strategies and rationalities. These discourses of NST assessment also shape the nanosciences as an academic field and substantially frame disciplinary developments there.

This article aims at analyzing such transformation processes in the NST-related academic fields that are framed by the strategies and rationalities of the assessment regime in negotiating open identities and reflecting on potential implications of NST. A particular focus is held on the ways assessment strategies and rationalities

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[1]Nanoterminology has its own complicated history. Before the grey goo controversies in 2004, Drexler (1986) was usually referred to as the creator of the term, "nanotechnology"' (Drexler 1986); since that controversy, the first use of the term has been attributed to Taniguchi (1974).

[2]In addition to traditional technology assessment (TA), NST is assessed from a wide range of different perspectives. Therefore, the broader term "assessment" is used here instead of TA.

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have been re-reflected and co-produced in the related scientific fields, what impact they have on disciplinary developments, and in what way this initiates disciplinary transformations.

First, an overview is given of the assessment strategies and rationalities used in evaluating identities and potential implications of NST. This is based on a discourse analysis that focuses on relevant assessment reports of different institutions and organizations, as well as participant observation at conferences, workshops, and participatory events on risk assessment in NST. Following this overview, the transformation processes in the negotiated science and technology fields and the effects on their disciplinary developments will be analyzed. Empirically addressing the delegation of aspects of NST risk research to scientific risk research fields – here toxicology – the disciplinary identity and boundary questions that toxicology faces through this delegation will be analyzed.[3] Finally, ideas concerning how and why involvement in a cutting edge technology can lead to transformation processes in the involved academic fields will be discussed.

2 Strategies, Facing Problematic Identities

Compared to earlier technology discourses, we see not only an increase in and anticipatory establishment of assessment efforts in NST, but also the emergence of new rationalities becoming manifest in various assessment tools. In addition to traditional technology assessment (TA) approaches – as addressed by TA institutions, civil society organizations, industry, and researchers in the social sciences, humanities, and academic ethics – new rationalities have been established by foundations, councils, and think thanks. They distinguish themselves not only by following external orders, but by internally defining their subjects and goals, and communicating them through occasional interventions (see i.e. Kaiser 2006).[4] Hence, they are not acting from a well-defined national position or focus on given issues, but rather react to self-identified problems. The assessment regime as analyzed in this context covers institutions using both traditional as well as new assessment rationalities.

To make the still open identity of nanotechnology comprehensible and to cope with the dilemma of the uncertain implications, traditional and new assessment institutions are acting with different strategies, such as

1. Relegating the dilemma to the future
2. Evading the problem through definitions and representations

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[3]The empirical study was conducted as an individual project in 2005/2006 and consisted of qualitative interviews with German, Swiss, Dutch, and American toxicologists (Kurath and Maasen 2006a, b). The study was funded by the Cogito Foundation and the University of Basel, Switzerland.

[4]On traditional TA approaches see, e.g., Paschen et al. (2004), Royal Society and Royal Academy of Engineering (2004), Arnall (2003), SwissRe (2004: 83). Examples of new rationalities include the U.S. based Woodrow Wilson International Center for Scholars, the Swiss based International Risk Governance Council (IRGC), and the British think thank DEMOS.

3. Self-reflection within the social sciences and ethics
4. Asking the public
5. Delegating the problem to scientific risk research

Below, overviews of these five strategies will be given, with a deeper analytical focus on the fifth strategy, in which toxicology has turned out to be an instructive case to demonstrate how questions have been brought to the core of scientific disciplines and have produced uncertainty.

2.1 Relegation to the Future

NST are still surrounded by the future. The extent of this has been documented by a number of cultural and social-scientific analyses (Hayles 2004, López 2004, Milburn 2002). Ironically, representatives of the nanosciences not only affirm the critical diagnosis according to which nanotechnology is characterized by an inextricable "blurring of fact and fiction" (cf. Milburn 2002), they even promote it, and definitions and characterizations of NST are widespread on nanoscience research center websites. Such characterizations often focus on potential future beneficial applications of the technology. In several cases, quite futuristic scenarios have been drawn, such as that by the Center for Nanotechnology at the University of Washington, which announces that nanotechnology would turn science fiction into reality. Furthermore, it is often argued that NST will be able to offer cures for threatening diseases and in general make the impossible possible.[5]

Thus it is not astonishing that technology assessment reacts with the request to strictly separate speculation from fact. The chair of the Royal Society and Royal Academy of Engineering (RS&RAE) nanotechnologies working group, Prof. Ann Dowling, stresses that it is important to "separate the hype and hypothetical from the reality."[6] Further assessors, such as the European Academy, recommend distinguishing between "the merely speculative nature" of visions and "possible risks of nanoparticles" (Schmid et al. 2006: 14–15). But what effects attend this request for boundary work (Gieryn 1983) regarding what nanotechnology really is? What nanotechnology unifies at present is to a large extent clear: very little.

Considering this polymorphism and heterogeneity, one could be tempted to suggest that NST do not have an identity or unity at all, so that we should – according to a suggestion of Howard Lovy's nanobot blog – refer to nanotechnology as "nanoscale stuff."[7] However, this impression is only correct for the present. In negotiating the future, in particular by anticipating converging effects, the term

[5] This science-fiction orientation seems quite astonishing for a well-reputed academic research center, which is part of the American National Nanofabrication Infrastructure Network (NNIN), funded by the National Nanotechnology Initiative. See http://www.nano.washington.edu/index.asp (accessed on December 21, 2007).

[6] See the press release for the RS&RAE report: http://www.royalsoc.ac.uk/news.asp?year=&id=2147 (accessed on December 21, 2007).

[7] See http://nanobot.blogspot.com/ (accessed on December 21, 2007).

"nanotechnology," in the singular, is regularly used. Hence, difference between the unity and polymorphism of nanotechnology will be bridged by anticipating visions of converging effects. The argument of convergence appears in various assessment reports, e.g. that of Fleischer et al. (2004), who uses the terms "overlap" and "melting" in the context of the crossover to the nanoscale level. Frequently, these converging effects are attributed emerging features regarding the announced network of disciplines, which initiates new research approaches that transcend individual disciplines (see i.e. Laurent and Petit 2005).

In addition to referring to a potential future reduction of the current plurality of NST, the assessment regime also tries to make NST comprehensible through definitions or representations and materializations, such as consumer products already on the market.

2.2 Evading the Problem by Definitions and Representations

Hardly any research project description, strategy paper, technology assessment report, regulation manual, or media contribution lacks its own definitional approach for making the identity of NST comprehensible. A clear definition of a research field and its demarcation from external domains is seen as a necessary condition for the assessment of potential implications. As an example, the European Academy argues in its NST definition report that the term nanotechnology is less relevant for scientists than "reflection of the research process" by technology assessment and that here, first, the "object of reflection" ought to be defined (Schmid et al. 2003).

However, when it is asserted that NST are emerging, definitions acquire an ambivalent aftertaste. They leave compellingly undetermined whether the definition concerns the subject of NST themselves, or whether usage of the term "nanotechnology" is a given. Instead of describing NST, they prescribe the appropriateness of the term in a fashion such as that of the European Academy report: "In contrast to our definition, Nanotechnology is commonly also used for proceedings which would be better described by *scaling effects*" (Schmid et al. 2006: 13). Technically speaking, these definitions are not primarily forming real, but rather nominal definitions, in the sense that they normatively try to regulate and control the use of a term. The frequent use of "should" and "ought" stands for this normative/descriptive ambivalence as nanotechnology has to be understood. In addition, the definition also decides which implications to subsume under nanotechnology and which not. In this sense, the ethicist George Khushf, seeing the clarification of the term as a necessary precondition for the analysis of ethical implications, introduces an article with an elaboration on "how Nanotechnology *should* be understood" (Khushf 2004).

However, frequently enough the dilemma basically will be avoided. In this way, a distinct characterization of nanotechnology is set aside in favor of characterizing and visualizing the technology with exemplary consumer products or applications.[8] These examples simply *stand for* nanotechnology, without the term

[8] See for example the consumer product inventory of the Woodrow Wilson International Center for Scholars (http://www.nanotechproject.org/44 (accessed on December 21, 2007).

"nanotechnology" receiving further explication. Another example of representation and demarcation on the product level is the German controversy involving the bathroom cleaning aerosol Magic Nano. In this episode, soon after the product appeared to show adverse effects it was pulled from the market. The removal o Magic Nano also was accompanied by the argument that the product "did not contain any nanomaterials."[9]

2.3 Self-Reflection in the Social Sciences and Ethics

If the first two strategies largely deal with the unsettled identity of NST, the strategy of self-reflection relates more to facing the paradox of the asynchrony of technology shaping and its consequences. Observed mainly in ethical, legal, and social implication (ELSI) research, self-reflection involves critical reflection in the social sciences or humanities that has been initiated by the emergence of NST. In these domains NST compel such questions as, What can *we* learn from technology debate precedents? Do *we* need new concepts (independent of where NST lead us)? and What is *our* role in this debate? The fact "that the social and ethical implications of nanoscience and nanotechnology are difficult to anticipate" (Berne 2004) leads not necessarily to a more intensive analysis of NST, but rather to reflexive rethinking of subjects or disciplines. Examples for such disciplinary self-reflection are the establishment of new journals and magazines such as the journal *NanoEthics* and related edited volumes, and the initiation of related groups or schools, such as the Nanoethics Group.[10]

In addition to these discussions about disciplinary capacity, the necessity and inalienability of social and ethical reflections is emphasized in a variety of assessment reports (see e.g. European Commission 2004, or Royal Society 2004). A similar question is whether, faced with NST, an existing area of reflection should be expanded. These elaborate questions to a certain extent also reveal disciplinary deficits that extend beyond NST. Gaskell et al. argue, for example, that the debates on NST need a wider agenda that mainly focuses on the "ethical and societal aspects of technological innovation" (Gaskell et al. 2004).

2.4 Asking the Public

In the context of new rationalities and attributions in assessing the open identity and potential implications questions of NST, the public plays a major role.

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[9] See http://www.giz-nord.de/php/index.php?option=com_content&task=view&id=122&Itemid=85/ (accessed on December 21, 2007).

[10] On the journal *NanoEthics* see http://www.springerlink.com/content/120571/. The Nanoethics Group is a US-based academic researcher network that produced the edited volume *Nanoethics: The Ethical and Social Implications of Nanotechnolgy* http://www.nanoethics.org/.

The idea of public engagement is prominently recommended in almost every assessment and strategy report.[11] Most prominently among these, the RS&RAE (2004) report advocated more upstream public engagement, and an editorial in the science magazine *Nature* further emphasized this idea (Nature 2004, Royal Society 2004). Subsequently, in many western European countries and most prominently in Britain a range of NST-related engagement projects started, including the NanoJury, the Lancaster-DEMOS Nanodialogues, and the assessment of such projects by the Nanotechnologies Engagement Group (NEG) (Gavelin et al. 2007).

However, the role and function of public engagement remained somewhat unclear. Critical voices argued that the claim for public engagement is mere fashion and a fund raising strategy, rather than a real interest in citizens' opinions, and that the public engagement amounted to mere public information instead of true exchange (Rogers-Hayden et al. 2007: 127). Others said that there was more talk about dialogue and engagement than there was actual dialogue and engagement (Hagendijk and Irwin 2006). In addition, it was argued that engaging people in discussion prior to public discourse on a subject raises a paradox of participation: at the very moment when a science or technology field is new, and decision making agendas are relatively open and could be influenced, public perception of the field is lowest (Rogers-Hayden et al. 2007). By contrast, public awareness tends to be much greater when both the development agendas of science and technology and the principles for regulating them are further developed, but less malleable. This perception was shared by opinion polls that said the public is little interested in nanosciences and nanotechnologies at the moment (see, e.g., Gaskell et al. 2004, Kahan et al. 2007).

The prominent recommendation of public engagement in almost every NST assessment report, at a moment when the public perception of the field is low, suggests that asking the public might be a strategy to cope with open identity and implication questions by delegating them to citizens. Recommending public engagement could even stabilize technology development by allowing proponents to argue that the public has been involved. Some participatory projects even try to achieve identity by consensus, one example being the Swiss Publifocus Nanotechnology project, which issued a brochure with definitions as a basis for the public consultation.[12] In this respect, NST are not what they evoke, but rather what the involved actors broadly agree upon.

[11] Further examples of assessment reports supporting public engagement consist of Renn and Roco (2007), Schmid et al. (2006), Wood et al. (2007). On strategy reports see e.g., Commission of the European Communities (2005); Schierow (2008).

[12] The definitions of nanotechnologies in the brochure of the Publifocus Nanotechnologyof the Swiss Centre for Technology Assessment (TA-Swiss) were adjusted with central stakeholders in NST in Switzerland, which include public authorities, regulatory bodies, scientists, and food and reinsurance firms (Cerutti 2006).

2.5 Delegation to Toxicological Risk Research

In the delegation of the identity question and the uncertainty regarding potential implications to scientific risk research, toxicology turns out to play a major role. As a traditional testing science, toxicology analyzes particles and materials for toxicity. In particular, particle and inhalation toxicologists have analyzed small-scale materials such as those from combustion processes for decades (Kurath and Maasen 2006b). When risk research is wanted, NST turn primarily to toxicology.[13] This is comparable to the fourth strategy, in which ELSI research disciplines are involved in assessments. In both that strategy and the reliance of NST on toxicology, open NST questions initiate demarcation and identity-finding processes within these separate disciplines. The unique case of toxicology has turned out to be instructive by showing how outlying questions have been brought into the core of the scientific discipline and there produced uncertainty. This is not unusual. Traditional testing sciences have often been particularly concerned with the emergence of new technology. They see themselves confronted with the choice of whether to remain applied disciplines or use short moments of disciplinary openness, which occur in particular situations of technology emergence, to reconstitute themselves as basic research disciplines (see Merz, in this volume, Schüßler and Kehrt, in this volume). In toxicology's case, its studies were the first to describe nanomaterial-related adverse health effects. This has contributed to increased attention to and pressure on knowledge production in toxicology, which in turn has led to an identity shift or redesign within the field itself.

3 Transformation Processes in Toxicology

The establishment of a socially valued, cutting edge scientific field opens up both the possibility for certain academic disciplines to participate in innovative research questions, and sources of substantial funding. Within the field of NST, toxicology is contributing significantly to risk research through its epistemic and ontological tradition as a testing science. Because of its cognitive and institutional background in the investigation of bioreactivities of particles and materials, and its orientation toward externally given problem definitions, toxicology plays an important role in concrete statements on the health implications of nanomaterials, which are a basis for potential regulation.

The delegation of the vague identity and the uncertainty about potential implications of nanomaterials to toxicology is able to initiate processes in toxicology that are quite similar to the coping strategies of the NST assessment regime. The initially

[13] This commitment can be found in various assessment reports such as Arnall (2003), Commission of the European Communities (2005), Commisssion of the European Communities (2004), European Commission (2004), Paschen et al. (2004), Royal Society (2004: 85), Schmid et al. (2006), SwissRe (2004).

frugal demand upon toxicological risk research to investigate potential risks of nanomaterials leads to problematic questions about what NST *really* is, and in what way the toxicological community should enlist in NST. Should toxicology become a fruitful part of NST, or remain as a mere testing science, focusing on nano from a material testing perspective only? Still, in virtue of its tradition as a testing science toxicology initially acts as if it would analyze nanomaterials and their implications from an *external* perspective comparable to that of other assessment institutions acting as if they are not subsumed under the *virtual* nanotechnology.

The negotiation of NST by toxicology is organized along two principal axes of communication or conflict:

1. Concerning the investigative analytical scope, toxicology includes nanomaterials and focuses on the question of whether and how nanoparticles can be toxicologically understood as something new.
2. However, this negotiation of novelty is not simply an ontological problem. Rather, it leads to the center of the disciplinary self-conception of toxicology. Facing the challenge of NST, toxicology starts to rethink the relation between its scientific function and the societal expectations regarding its knowledge production.

How, then, does toxicology negotiate the terrain of NST and the dual question of ontological and disciplinary novelty?

3.1 The Significance of Doing "Nano": Negotiating Novelty

> For us, the term "nano" is old hat, we have been doing "nano" for more than 15 years—respectively work with ultrafine particles—although we did not know that this would be called "nano" later (Toxicologist 1, Germany).

Many inhalation or particle toxicologists speak in a similar, inclusion-strategic manner. They argue that by working with manufactured nanoscale reference particles for measuring health effects of the smallest environmental dust, they worked nanoscientifically before the term "nano" was established. As a reference for experience with the behavior and hazardousness of nanomaterials, they cite work with particles on the micrometer level and constitutive research on ultrafine environmental particles, for example, those resulting from combustion. Based on experience with bio-interactions of these particles, toxicologists infer the behavior of industrially manufactured nanoscale material.

> Our experience with ultra fine particles is of high importance for analyzing the risks of nanoparticles. Along with ultra fine particles, we began to use nano-test particles to investigate certain mechanisms (Toxicologist 3, Switzerland).

The transition from the ultrafine to the nano-scale often happens inconspicuously. Alongside research with ultrafine particles, similar experiments are repeated with selectively produced nanoparticles.

Self-evidently, against this background there is no challenge toxicology cannot take care of; after all, “nano” is old hat for it. However, simply equating *nano-technology* with *nanoscale material* seems to provoke irritations in the toxicology community. As will be demonstrated in subsequent citations, nanomaterials are expected to have specific characteristics. So, it is controversial whether the particular technological nature of nano is reduced by defining the investigated particles as a matter of size.

> When I’d like to talk of risks of nanotechnology and then come to know that only environmental particles are discussed and no nanotechnological materials, then something is wrong (Toxicologist 2, Germany).

Seen theoretically, it does not seem implausible to react to such inconsistencies or irritations with differentiation. In the field of toxicology, an attempt is made to solve inconsistency with a differentiation regarding the origin of nanoparticles:

> The term “nano-material” implies technical design and intentional manufacture. The size range of particular ultra-fine particles only coincidentally lies in the nanometer scale. Therefore, I would use terms like “combustion particle” or “environmentally relevant particle” for particles unintentionally released into the environment, and definitely not the term “nanoparticle” (Toxicologist 4, USA).

Institutionally, such suggestions for differentiation can receive additional support. Therefore, research projects for the investigation of health implications of industrially manufactured nanomaterials are generally more generously funded than those with particles resulting from combustion processes. Hence, interests are produced to broaden the research field of nanosciences, which means that to understand the analysis of environmental particles on the nanoscale level coincides with nanoscience. Last, but not least, the *bandwagon effect* also plays a role in this field, as the ability to subsume oneself under the less specific field of “nano” facilitates the acquisition of research funds:

> “Nano”: this is a fashion and naturally also a funding strategy. If I applied for research funding on ultra fine dust at the European Union, that would be old hat. It was already done in the 1970s and the 1980s. However, if I applied for funding for a project on the influence of nano-particles, then everything looks quite different (Toxicologist 1, Germany).

The differentiation, as should be apparent here, does not necessarily result from demarcating something as less scientific, as Gieryn suggests with his concept of boundary work (Gieryn 1983). Quite the contrary, differentiations can also be adopted to specify uncertainties internal to a discipline in such a way that, subsequently, new, well paid research possibilities can be generated. This means an increase of epistemic authority in the sense of an expansive boundary work (see Gieryn 1995: 15–17) to incorporate unexplored ontological domains by differentiations. However, the expansion is only successful when a continuum can be established between ultrafine dust and “nanomaterial”, which is able to retrospectively level the originally drawn differentiation as fashion.

The same differentiation of nanoparticles according to their “unintentional and intentional sources” (Oberdörster et al. 2005: 823) or their structure, “physically and chemically heterogenous” versus “precisely constructed and entirely synthesized”

(Kreyling et al. 2006: 544) can at the same time be used to protect against excessive research claims. Thus, not rarely, but subliminally, it is demurred that with too wide a conception of the term nanoparticle the investigation of effects of all smallest particles will be assigned to the field of nanosciences. In particular, the comparability of nanoparticles with health-adverse particulate matter marks a controversial territory.

> The fact that the particle size of particulate matter in the surrounding air comprises the area of synthetic nanoparticles can not be equated with their toxicity. Here, additional criteria play a role, like their chemical composition. Hence, the conclusion from particulate matter of the surrounding air to synthetic nanoparticles can not be carried out globally (Claus and Lahl 2006: 2).

While in the first case the differentiation of toxicology offers the possibility of expansion, it serves in the second case to restrict the field of expertise, and therefore to protect its future credibility. This differentiation therefore can, at first sight, serve to stimulate excluding processes of "expansion" as well as "protection of autonomy" (Gieryn 1995: 16).

As the fairly unemotional debate over the correct concept of nanoparticles demonstrates, more is at stake than the matter of a few nanometers. Rather, it is about specifying, denying, or, in contrast, establishing the novelty of nanotechnology within the field of toxicology. The difference between old and new is negotiated not least by the difference between intentionally manufactured material and passively accumulating particles. Regardless of how this "negotiation of novelty" (Hessenbruch 2004) might turn out, it is to be judged against the background of what toxicology scientifically dares: how far should it expand, and thus establish a continuum between old and new? How far should it exclusively engage in the new, which means the manufactured particles?

If options based on differentiations are at hand, they may be reconciled in a second step by a suggested compromise. This direction also takes the suggestion of a leading particle toxicologist in the US, Günter Oberdörster, to subsume both particle types – independently from their differentiation with "intentional" and "nonintentional," which at the same time corresponds to the separation of "technical" and "natural" – under the term "nanoscale particle":

> Therefore, I'd suggest the term "nano-scale particle" as a comprehensive definition for environmental particles within the nanometer scale (Toxicologist 4, USA).

"Nano," for most inhalation and particle toxicologists, is nothing new. It only subsumes their longtime work under a new term. This indicates a tendency of persistence in the disciplinary tradition. However, the irritations that NST is able to provoke in the field of toxicology reach even further than the question of to what extent toxicology dares to fill a field whose novelty is disputed. The negotiation of whether nano is old hat or new not only affects the research object of toxicology but also the discipline's own self-conception.

3.2 *The Significance of Being "nano": Reflections on Function and Expectations*

The emergence of NST initially leads to reflexive attitudes among representatives of the toxicological research community – on their focus, their mission, their lost chances, and last but not least, on their participation in science as a whole.

> In toxicology, we are only able to publish negative results. When we find positive, or rather no effects, we cannot publish them. When we discuss that a particular substance is not toxic, this is fine for society but bad for us as scientists, since we measure research quality based on output (Toxicologist 5, Germany).

In my view, such reflections focus not only on the science's habit of shaping its own objects. Such reflections comprise more than the question of whether a discipline could gain a new face by establishing a new journal. Additionally, these reflections are about new orientations and the reflexively customized identity of a discipline.

According to Luhmann (1992), reflections – when undertaken in single disciplines – orient themselves around two fixed points. First, they orient themselves to *performances* or *missions* that a *specific* science has to perform (Luhmann 1992: 635). In the case of toxicology, this means that it has to produce valuable knowledge regarding which substances are toxic and which are harmless. Such knowledge then can be selectively taken up by science policy or industry and built into their own decision-making processes. The second point of reference is given by the *function* of a particular science. And this function is for all sciences the same, namely to produce new truths.

The focus on the specificity of performances and the focus on the universality of function often generate a stress relationship that applies to toxicology. As toxicologist 5 mentioned in the interview, that testing a substance that proves harmless, which is in the interest of society, is *bad for the scientists*, since research quality is measured based on (published) output. It is precisely the socially expected function that is perceived in this self-assessment as a direct competitor to the scientific mission or performance. However, other disciplines also show such difficulties in their orientation. But for those that explicitly follow a regulatory-oriented social order – like ethics, toxicology, or recently also sustainability research – this option of closing ranks by positioning themselves as a less implication-oriented, yet more research-oriented basic science discipline is hardly possible.

However, exactly these efforts can be observed in toxicology in the context of NST. It is not only a question of getting a safety study published in *Science* or *Nature*, but rather to transform toxicology into a product-oriented, pure science. The new issue is, as we will see below, the development of biocompatible particles or materials.[14] In that sense we can observe a tendency of scientization in the field

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[14]The development of biocompatible or bio-inert, and thus artificially designed, material that is not irritating to biological systems is an important research area within NST. The aim of this approach is to develop mobile targeted drug carrier systems on the nanoscale level. A nanoparticle is designed to transport and apply a therapeutic agent directly to the site of pharmacological action

of toxicology. Doing this is killing two birds with one stone. As a testing discipline, toxicology relies on its rich experience, of which it profits as a nanoscience by the development of biocompatible materials. Or, in the validation of the prominent Rice University environmental toxicologist, Vicki Colvin,

> The paradigm shift really is not seeing toxicology as a gatekeeper but seeing toxicology as a point of information that allows you to generate more biocompatible materials (Colvin after Monastersky 2004).

Hence, participating in the development of biocompatible materials enables toxicology's transformation from a regulatory-oriented into a research-oriented science. Several studies observe that traditional testing disciplines and institutions judge such transformation processes as desirable (see Merz, this volume).

In addition, the possibility of therapeutic use apparently aims at the new scientific character of toxicology. Importantly, so far, the aim of toxicology has been to test, not to heal.

> A positive approach is therapy. We will find out how a nanoparticle should be designed, and what surface properties it must have in order to not cause any reaction in the organism. If I created such a particle, I could load it with a medicament or equip it with receptors such that these would then be carried into the cells (Toxicologist 6, Germany).

In short,

> "Nano" offers an enormous potential for toxicology. For example, we are able to develop biocompatible particles (Toxicologist 4, USA).

While these attempts indicate a potential transformation of toxicology into a product-oriented basic research discipline, the negotiation of novelty addressed in the preceding section rather suggested a tendency of persistence in its disciplinary tradition. Therefore, our findings most likely indicate a development of "as well as": as a testing *discipline,* toxicology can rely on its rich experience, of which it benefits as a virtual *nanoscience* in the development of biocompatible particles.

4 Assessment Transforming Disciplines?

4.1 Toxicology as a Nanoscience?

The delegation of risk assessment to toxicology, recommended by various assessments, initiates new possibilities of reconstructing disciplinary identities. These concern the risks of particles on the nanoscale level to a lesser extent than the question of whether NST pose an opportunity or a hazard for toxicology as an academic discipline. These negotiations can be characterized by two tendencies:

(Kreuter et al. 2002). Toxicology has acquired a lead in knowledge from in vitro and in vivo studies of particular features and structures of material, which it is able to use for the design of bio-inert particles with minimal health effects (see Kurath and Maasen 2006a).

1. On one hand, toxicology reconsiders whether and how it should turn to new ontological domains. How can nanomaterials become integrated into its research tradition? The observed dominant strategy indicates expansive boundary work, together with maintaining the disciplinary research tradition.
2. On the other hand, toxicology poses questions of disciplinary self-conception regarding the way emerging NST offer the possibility of a paradigm shift from distanced outside observation as a traditional testing science to active participation as a basic research oriented discipline.

Both crucially challenge the relationship between provision of a service, the performance of which involves the identification of toxic substances and academic knowledge production, and function, the pursuit of an academic career and publication in highly ranked journals. Current attempts to solve this dilemma indicate that toxicology experiments with achieving a more basic-research-oriented disciplinary understanding. However, this has only become possible through the emergence of NST and the associated need for more related risk research, which brought toxicology from the unloved position of a tester to nearer the center of an emerging cutting-edge technology. Furthermore, not only were its testing capacities asked for, but its experience also was sought in the development of basic medical research.

The question of whether toxicology has become a part of NST has an ambivalent answer. Although toxicology sees an opportunity for actively getting involved in product-orientation, it is not prepared to entirely abandon its tradition as a testing, regulatory-oriented science.

Finally, toxicologist 1's statement that "nano" "is a fashion and naturally also a funding strategy" leads to another observation: the attraction that cutting-edge research focuses hold for all sorts of neighboring scientific disciplines. This phenomenon, also known as the bandwagon effect, has been observed within several big science projects and research focuses such as biotechnology, the Human Genome Project, and the US war on cancer (De Solla Price 1974).

4.2 Disciplines Assessed

A variety of assessment discourses and institutions face the rather diffuse identity of NST and the difficulties of assessing potential risks that are captured by the Collingridge Dilemma. They are challenged by the difficult questions regarding where NST are located, of whom it consists, and how its potential impacts could be assessed in visions of the future, in definitions, in reflections, in the dialogue with the public, or in the delegation to scientific risk research.

The assessment regime that delegates the open questions about implications to scientific – or in this case toxicological – risk research produces two consequences in the related fields. First, answers to the health-implication question are being analyzed. In parallel, the related attention toxicology achieves by providing answers to a widely hyped and highly rated and funded technology provides a moment of openness, vulnerability, and change. An incremental process of demarcation and identity-shaping opens the possibility for transformation and increasing prestige in the academic hierarchy. The case of toxicology instructively stands for the recursive relationship between nanotechnology, its assessment, and the existing system of scientific disciplines. In other words, nanoscience can only emerge or condense by its specific negotiation within particular disciplines.

For the tension in classical testing science disciplines between academic prestige and completing the task, the emergence of a cutting-edge technology functions as a welcome transmitter. Therefore, we can speculate whether or not technologies in contrast to sciences are better able to bridge the separation between performance and function at all. What argues for this speculation is, first, that technologies, in contrast to academic knowledge, are less concerned by a loss of authority (Luhmann 1992: 632). Second, looking at technologies, function widely coincides with performance. Hence, the provision of new technological artifacts instead of new truths is as accessible in science as in other domains of society.

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"Nanoscience is 100 Years Old." The Defensive Appropriation of the Nanotechnology Discourse within the Disciplinary Boundaries of Crystallography

Christian Kehrt and Peter Schüßler

While public representations of nanotechnology in the media, political agendas, and forecasts have garnered attention, the scientific community's relationship to the so-called nanodiscourse has not yet been examined in depth. Questions, which social groups can be identified, who is taking part in this discourse, and who is excluded are still underrepresented. In order to establish this new field of research and innovation, scientists try to actively shape and appropriate the discourse on nanotechnology (Hård and Jamison 1998: 1–16).[1] Even scientists who do not explicitly identify themselves as nanoscientists have to take a position and react to the prospect of a future technology that promises radical innovation, stimulates research projects, and receives large amounts of funding.

As Cyrus Mody pointed out, the "transformation of a grand discourse into local practice is one of the most interesting parts of the nano phenomenon" and requires further analysis (Mody 2004b: 132). Joachim Schummer demonstrated that in the field of nanoscience and nanotechnology (NST), disciplinary traditions and restraints "pose strong barriers to interdisciplinarity" (Schummer 2004: 18). Consequently the question arises as to how scientists are able to transcend disciplinary boundaries. What reasons motivate scientists from different disciplines to identify themselves as nanoscientists; what strategies help them to forward nanoscience within the institutional setting of their disciplines? Our thesis is that only by locating themselves in a new discursive framework are scientist able to go beyond institutional boundaries and identify themselves as "nanoscientists."

NST takes place within a heterogeneous research landscape of different disciplines, institutions, and traditions. However, it is not at all clear whether these

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[1] By discourse we mean those written and spoken ideas that structure the public opinion and open up new spaces of possibilities (Lösch 2004: 195).

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new areas of knowledge will be unified into a new discipline. A discipline can be defined by the very boundaries that distinguish it from other disciplines, as well as by extrascientific social systems, influences, and interests. These boundaries are defined by a specific scientific community; certain methods; a defined body of knowledge; and an institutional setting with clear career patterns as well as traditions, hierarchies, and values that determine the identity and social position of its members (Stichweh 1979: 83). Disciplinary boundaries are transgressed in daily experimental practice, but cannot be ignored when scientific results are discussed and scientists' careers pursued. Disciplines can impose strong restraints for scientists who want to explore new realms of knowledge and no longer share a disciplinary identity.[2] In the case of nanotechnology, what conflicts occur when new methods and approaches are pursued that go beyond the established disciplinary boundaries?

The concept of "boundary objects" allows us to examine the limits and possibilities of NST as they are constructed by scientists taking part in the nanotechnology discourse (Gieryn 1999: 5–6, Star 2004: 70). The appropriation of boundary objects, such as scanning tunnelling microscopes or nanobjects in the dimension of less than 100 nanometers, takes place in different contexts that may in fact conflict with each other and imply different meanings. That's why we distinguish scientists who remain within the boundaries of their discipline and *defensively appropriate* nanotechnology methods from those scientists who were forced to leave their disciplinary identity in order to explore new methods and realms of knowledge. These nanoscientists have new opportunities to explore and "play around" with molecules without asking whether they belong to biology, chemistry, or physics. But they face a precarious and uncertain situation because they can no longer refer to the secure domains of the disciplines they left behind. That's why scientists from different disciplines actively promote a new nanoidentity. Our explanation is that they are in need of new symbolic capital as long as there is no new nanotechnology discipline that unifies and institutionalizes nanotechnology approaches within the differentiated system of disciplines.

In our case study, we examine how crystallographers appropriate nanotechnology. They have a long tradition of working at the nanoscale. However, crystallographers do not necessarily see themselves as nanoscientists. While some tend to remain within the boundaries of their discipline, others orient themselves towards transdisciplinary, nanoscientific communities. First, we describe the institutional situation of crystallographers in Germany. Then we ask how they position themselves within that new framework of NST.[3] Do they embrace the new opportunities promised by this discourse, do they defend their traditions, or do they take an

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[2] We understand these nanoscientific practices as forms of transdisciplinarity in difference to interdisciplinary projects, where scientists and engineers from different backgrounds work together on the basis of their original disciplinary expertise and identity (Klein 1990: 66; Gibbons et al. 1994: 168; Klein 2001; Schummer 2004: 11; Russel et al. 2008: 461).

[3] We conducted 15 interviews with members of the crystallographic section of the Ludwig-Maximilians-University Munich geosciences department.

opportunistic stance, profiting from the "nanohype" without actively identifying themselves as nanoscientists? Finally, we look at the discursive strategies used at the Munich Centre for Nanoscience (CeNS) to connect Munich scientists under the "nanoscience" title.

1 Strong Traditions and Weak Positions in Crystallography

Crystallography focuses on the structural determination of crystals by X-ray diffraction (Law 1979: 279). It can be defined by a set of founding myths, key figures (Max von Laue, W.H and W.L. Bragg, Paul Peter Ewald), methods (X-ray diffraction), journals (*Acta Crystallographica, Zeitschrift für Kristallographie*), prizes, and associations of crystallographers (German, European, International Union of Crystallographers) that basically unite the field.

The founding myth of modern crystallography is the discovery of X-ray diffraction in 1912, when Max von Laue found out that the pattern on a photographic plate could be related to the regular atomic crystal structure (Schirrmacher 2007: 125). The modern community of crystallographers using this method was established in the first half of the 20th century. As early as 1962, Paul Peter Ewald, one of the key figures in Munich's Sommerfeld School (the school of thought led by Arnold Sommerfeld), published the book *50 Years of X-Ray Diffraction* (Ewald 1962). X-Ray diffraction provided the tools to establish a specific body of knowledge about the periodic structure of crystal lattices. Its results are reported and updated in the *International Tables of X-Ray Crystallography* (Norman and Lonsdale 1952).

From this perspective, crystallography fulfils almost all requirements of a discipline and definitely has identifiable disciplinary boundaries. Nevertheless, crystallographic methods are applied in almost all branches of the modern sciences. In this sense, crystallographers describe their culture as cross-disciplinary (Schulenburg 2002, Fischer 2001, Hahn 1990). "Since crystallography provides the professional knowledge about the laws of atomic structure of matter, it bridges all those branches of the sciences that deal with the solid or liquid state of aggregation of matter" (Jagodzinski 1965: 24).

Although the basic method of X-ray diffraction is applied in many fields, the institutional situation of crystallography in Germany poses some constraints on crystallography as a discipline. In the 1960s, the Munich crystallographer Prof. Heinz Jagodzinski, Fritz Laves' student and a leading figure in the realm of disordered-structure determination of crystals (Fehlordnungskristallographie), wrote an influential memorandum for the German Research Association (DFG). His *Denkschrift* lead to a modernization and intensification of crystallographic research. Even then, crystallography's traditional affiliation with mineralogy seemed restrictive, missing the manifold possibilities that the field's methods could offer to biology, chemistry, and physics (Jagodzinski 1965: 5, 24). However, these optimistic visions from the 1960s were not fulfilled. Looking back at the evolution of his field, the 90-year-old Heinz Jagodzinski commented on the current position of crystallography in Germany: "Here I am a little sad that crystallography in Germany still is not as good as I had once imagined, one has to openly admit that."[4] In his opinion, classic crystallography is not innovative enough, whereas marginal and new fields such as surface crystallography or the determination of crystal imperfections have close and fruitful links to other disciplines. In reconsidering his memorandum from the 1960s, Jagodzinski concluded that it promoted structural analysis but did not succeed in establishing a central field: "As a specialty and basic method, crystallography is widespread; as a discipline, it has its difficulties."[5]

In the aftermath of the German reunification in 1990, when the German Association of Crystallography (*Deutsche Gesellschaft für Kristallographie*) was founded, a spirit of renewal emerged within the German crystallographic community.[6] But ten years later, at the turn of the millennium, crystallographers found themselves in a lethargic or even frustrating situation. Contrary to their self-perception as a broad, cross-disciplinary, and basic specialty, their institutional situation in Germany has to be characterized as marginal (Fischer 2001). Obviously, crystallography is struggling with its identity and future. In 2001, the steering committee of the crystallographic union formulated a public call: "without crystallography there will be no new materials and no medication!" (Paufler and Depmeier 2003: 5). Crystallographers condemn the fact that important academic chairs are vacant. This situation is due to the reorganization of earth science departments and the marginalization of mineralogy.

If we look at the number of crystallographic professorships, the traditional adherence to mineralogy is still visible. The majority (65%) of the 66 chairs of crystallography in Germany are institutionally located in the earth sciences.[7] The remaining chairs are almost equally distributed between physics (14%), chemistry (9%), and research centers and institutes outside of the university structure (*ausseruniversitäre Forschungszentren*) such as the Max Planck Institutes (12%). Among these 66 professors of crystallography in Germany, only 7 have visible links to the nanosciences. Which means that they use the "nano"-prefix in order to label their institutes and research groups.

The fact that there are only a handful of professors that explicitly made the move toward the nanosciences highlights our observation that, on the one hand, a close relation to the nanosciences exists and, on the other hand, most crystallographers prefer to remain within the traditions and boundaries of their discipline. The majority of these crystallographic chairs with a direct nanoscience focus can be found within physics departments.

One of these physicists is Peter Paufler, a well-known crystallographer from the GDR School of technologically oriented crystallography and former head of the

[4] Interview Prof. Heinz Jagodzinski, 8.12.06.

[5] Interview Prof. Heinz Jagodzinski, 8.12.06.

[6] Interview with Prof. Heinz Schulz, 16.2.07, head of the new German crystallographic association at that time; Deutsche Gesellschaft für Kristallographie, http://www.dgkristall2.de/, (23.09.08).

[7] These data were obtained through a list of crystallographic chairs in Germany by the Union of German Crystallographers. We thank Fabian Ochsenfeld for this survey.

German Association of Crystallographers. Paufler is publicly perceived as a scientist in the realm of nanotechnology.[8] He rose public interest in nano-reserach with his *Nature* contribution on the discovery of nanotubes in the famous metal blade of the Damascus Sword (Reibold et al. 2006, 286). This rather small side note in *Nature*, published under the heading "brief communications," was spread in the media as well as within the scientific community as "nano-news." With descriptions and headlines like "Modern technology found in old materials," "Nanotechnology enables Damascene sword," "Nanoblade," etc., this story helped publicize nanotechnology and combine crystallographic research and innovation at the nanoscale with older and more familiar topics like Damascene steel.

This story is a good example for how nanotechnology attracts the interest of a larger audience and how different scientific communities can relate to this nanoscientific discovery. The nanotubes discovered by crystallographers are boundary objects appropriated by different actors: the several scientific communities that work with nanotubes, the local museum of the city of Bern in Switzerland (Berner Historisches Museum), and a larger public that is more interested in the history of the sword than in nanoscience. Nevertheless, it remains an open question whether scientists like Peter Paufler, a classic crystallographer, explicitly share the radical visions of Nanosciences and Nanotechnologies (NST) that lead into the realms of molecular engineering, or whether these scientists remain within the boundaries of their discipline. These different ways of appropriating nanotechnology boundary objects will be discussed in the following sections.

2 Discursive Limits at the Nanoscale

Considering the precarious institutional situation of crystallography in Germany, in conjunction with its tradition of research and innovation at the nanoscale, the question arises why the majority of crystallographers do not embrace nanotechnology wholeheartedly. In the following, the mutual perception and position of crystallographers and nanoscientists is investigated. How do self-proclaimed nanoscientists see their neighbors in crystallography, and how do crystallographers relate to their "nanoscientific" colleagues? A closer look at the institutional setting of a crystallographic university section and its nanoscientific research branch will show that there is a close relationship between crystallographers and nanoscientists, but also fundamental differences in their appropriation of the nanodiscourse. Our chosen case study is the Institute of Crystallography at the Ludwig-Maximilians-Universität (LMU) München, which is affiliated with the Department of Earth and Environmental Sciences (see Fig. 1). It consists of five research groups. The majority of these groups do classic crystallographic research in terms of crystal structure determination.

[8]With the help of electron microscopes, Paufler and his team determined that these nanotubes are filled with "*Zementit*," a mixture of iron and carbon, that explains the material's special strength.

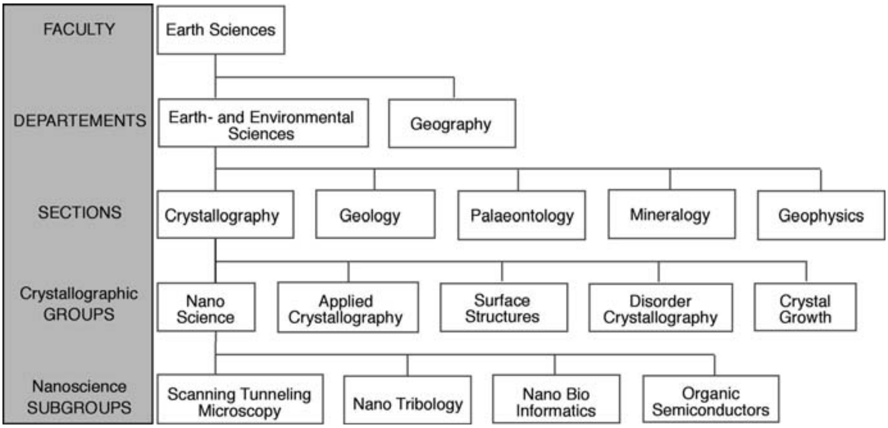

Fig. 1 Organigram of the LMU Institute of Crystallography with its nanoscience subgroups

However, the nanoscience group, led by Prof. Wolfgang Heckl, cannot be understood solely in terms of its formal affiliation with the Institute of Crystallography. Its main research topics are described as "nanomanipulation," self-assembly, and Scanning Probe Microscopy (SPM) development in the fields of "NanoBioScience," "NanoGeology," "NanoTribology," and "NanoBioInformatics."

Heckl's nanoscience subgroups at the crystallographic institute are not, as it might seem from an outside perspective, a crystallographic research group doing nanoscience, in the sense of Paufler's work. As our interviews show, the members of the Heckl group do not identify themselves as crystallographers. Although they conduct their research at the Institute of Crystallography, they are in terms of contacts and cooperation more closely networked with the Munich Center for Nanoscience (CeNS) than the institute's traditional crystallographic groups. These nanoscientists do not regard their institutional affiliation with the Institute of Crystallography as a necessity, but rather as a coincidence. When one scientist was asked if he felt at home in the institute, the researcher replied, "Yes and no. I think that we could just as easily be affiliated with Physics."[9]

This contingency seems to be characteristic for nanoscientists who, on the one hand, adhere to a new field of research and, on the other, still have to work within older institutional settings.[10] Despite these institutional affiliations, there is little cooperation between crystallographers and nanoscientists. At most, the nanoscientists ask their crystallographic colleagues to do quality control on their research, whereas joint research projects do not exist.

The Heckl group systematically explores processes of molecular self-organization aimed at technological innovation. Comments from a member of the

[9] Interview, nanoscientist A.

[10] The actual nanoscience laboratories are still located at the Institute of Crystallography.

group illustrate this as follows: "An essential principle of this assembling mechanism is the so-called self-assembly of molecules, which aggregate because of their chemical interaction. When I have understood this principle, I can deduce from it in order to build still higher dimensions."[11] This idea of "scaling up" as a means of creating molecular nanosystems is at the core of NST visualizations. In this regard, the Heckl group's nanoscientists try to do research, for example, on the origin of life, in order to understand how basic building blocks of matter self-assemble into higher-order complexes. According to Heckl, nanotechnology aims at "the technological control of the smallest functional entities, for example as they exist in biological systems" (Heckl 2004).

While Heckl avoids concrete statements about future technological applications, in the public arena he still tries to make his ideas plausible to a larger audience by using simple images and analogies. In a television report on nanotechnology, he employed the example of a microwave to explain the future vision of a "nanowave."[12] In this thought experiment, basic components such as carbon, nitrogen, hydrogen, oxygen, trace elements, and water are put together atom by atom until they are transformed into a cutlet (*Nanoschnitzel*).

This TV presentation of nanotechnology is an example of how scientists try to promote the idea of molecular engineering with its unlimited possibilities for technological innovation. "There is a vision of the distant future that one day it will be possible to create whatever we dream of, like a *deus ex machina*, using molecular components and atoms. We would like to have a machine: the vision is that small active units assemble themselves. They do it in countless nanofactories without human aid. Through them, every desired material, every substance required would be put together atom by atom, molecule by molecule" (Heckl 2005:843).

These *visions* represent some of modern society's core desires. They promise to transcend the age of silicon and assure abundance, progress, and growth. Nanoscientists want "to start with basic building blocks of matter, atoms and molecules, and then step by step construct the desired functional entities" (Heckl 2004, 130). Alfred Nordmann (2006: 20) calls this a "system of building blocks" (Baukastensystem). According to Heckl, this process can be observed in nature, which makes his audience see this process as "organic" and "natural," even though it is technology in the lab. In a newspaper interview, he declared: "I am convinced that this will be realized. I do not want to answer the question when this will happen. I do basic research, I am interested in effects. We have to make the future, not predict it" (Heckl 2000: 94). Compared to these far-reaching future prospects, nanoscientists are still at the level of basic research.

In contrast to their self-perception as a field leading to future technological innovations, nanoscientists regard crystallography as an antiquated field that should

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[11] Interview, nanoscientist A.

[12] Television report of *Bayerisches Fernsehen "Faszination Wissen – Das Nanoschnitzel. Vision und Wirklichkeit in der Nanotechnologie*" (first aired 23.10.03).

be more open to newer scanning probe methods. In this sense, one nanoscientist we interviewed sees a chance for his crystallographic colleagues to learn from nanoscience and to "direct this classic crystallography one step into modernity."[13] NST, with its specific applications of scanning probe microscopy, represents definite progress in this direction. In our interviews, nanoscientists showed themselves to be fascinated by the unlimited possibilities of simultaneously mapping and manipulating on a molecular and even atomic level, while crystallography with its questions and methods is perceived as outdated, in contrast to the completely new possibilities in nanoscience. One nanoscientist declared: "At our institute, there are exciting things because nanotechnology is an exciting new field, where a lot of research has to be done. You can achieve a lot of results the world has been waiting for."[14]

Crystallographers, however, reject this perception of their discipline and often react annoyed in regard to the distinction between "forward-looking" nanoscience and "antiquated" crystallography. They blame nanoscientists for constructing this difference for science policy reasons. A crystallographer of the institute criticized the ignorance of nanoscientists as follows: "This [distinction] is used by certain scientists, sometimes unconsciously, because they don't know better, but sometimes completely consciously in order to direct funding into the right channels."[15]

To counter a backward image, crystallographers refer to the continuous extension of their methods and the ongoing development of their research. In our interviews, they emphasized that their specialty is still expanding and improving diffraction methods and that crystal structure analysis is possible at an increasingly higher resolution: "The identification of such molecular structures, well, that has been done for 100 years now. It has just become more precise."[16] They claim that several methods used in crystallography had already achieved a higher resolution than scanning probe methods long ago, for example, transmission electron microscopy (TEM): "Today there are high-resolution transmission electron microscopes that can produce magnificent images of the interface between two crystalline materials. And in my eyes, this is nanoscience."[17] Another crystallographer also explained further: "It is a misunderstanding that proponents of this new [nano-] method maintain that now structures can be determined that were not accessible before."[18]

Crystallographers apparently perceive nanoscience and scanning probe microscopes from a different perspective, which is closely linked to the history of their field as described above. We were repeatedly confronted with our interview partners' conclusion that there is nothing really new about the possibilities of scanning tunnelling or atomic force microscopy. Crystallographers don't turn against

[13]The interview transcriptions have been translated from the original German. Interview, nanoscientist B.

[14]Interview, nanoscientist B.

[15]Interview, crystallographer A.

[16]Interview, crystallographer B.

[17]Interview, crystallographer B.

[18]Interview, crystallographer C.

nanoscience per se, but rather against the claim that nanoscientists generate fundamentally new knowledge. They appropriate scanning probe methods in a defensive way as they integrate them in the history of their field: "Certainly you can see things with it that you couldn't see as well before. Otherwise the method would not be utilized. But it isn't an outrageous breakthrough. Monomolecular layers on surfaces have been workable long before."[19] This statement shows that crystallographers refer to a single aspect of NST, namely the size of structures, which can be represented by high-resolution scanning probe methods.

Yet, from a nanoscientist's point of view, this argumentation by crystallographers is limited. As we have seen above, nanoscientists do not simply identify themselves by the mere reference to the dimension of scale. According to the definition of one Munich nanoscientist we interviewed, an object has to have dimensions under 100 nm in at least two aspects, in order to be characterized as "nano." The leader of a nanoscientific subgroup of the institute said: "It is something that is in more than one dimension smaller than 100 nanometers, simply in order to exclude thin surfaces or similar technologies. So for me a thin surface coating is, as such, not nanotechnology and second, there has to be a new effect in these small dimensions that in bigger scales is not there."[20]

Furthermore, for nanoscientists, scanning probe methods not only allow them to generate images but also to manipulate single molecules and atoms, as one nanoscientist explained: "It is more than just a matter of scale. 'Nano' describes the size and then you need a whole array of different instruments in order to get there."[21] For him, the passage into the nano-world is not only made possible by images: "You can take this needle and move these samples. You can push and pull. You need an arm somewhere that can enter into the nanoworld. That is not just creating images."[22]

Nanoscientists want to disclose radically new technological possibilities and follow visions of molecular self-assembly and control. The difference between these nanoscientists' understanding of the term "nano" and the crystallographers' definition becomes clear with one interviewed crystallographer's rejection of this fundamental concept: "I wouldn't say that it necessarily has to do with the manipulation of matter. If I explore matter with high-resolution methods, this can be nano."[23]

As the interviews clearly show, crystallographers can easily relate to nanoscale dimensions as well as to specific nanoscience instruments by including them in their discipline's tradition. We understand this appropriation of the nanotechnology discourse as a defensive strategy, considering that the new and highly visionary nanoscience approach, the search for molecular building blocks, scaling up, and self-organization as technologically relevant processes do not really characterize

[19] Interview crystallographer C.

[20] Interview nanoscientist C.

[21] Interview nanoscientist A.

[22] Interview nanoscientist A.

[23] Interview crystallographer B.

crystallographic research. Taking these differences into account, one can clearly say that the term “nano” refers to different phenomena.

The nanoscale dimension and the methods of scanning probe microscopy can be understood as boundary objects (Star and Griesemer 1989). Bowker and Star (1999: 297) define them as “those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. [. . .] Such objects have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation.”

In the context of our case study, this means that although crystallographers and nanoscientists work at the nanoscale and use scanning probe techniques in fundamentally different ways, they both can participate in nanodiscourse. For crystallographers the term “nano” simply denotes a dimension of scale, where they can produce high-resolution pictures of molecular structures with the help of diverse methods. For nanoscientists, the nanoscale delineates a field of research and innovation at the dimension of atomic and molecular particles, where new and so far unknown physical properties and effects will be adapted in future nanotechnologies. From the perspective of crystallographers, scanning probe microscopy is only one of several methods that determine crystal structures on the nanoscale, while for nanoscientists scanning probe methods constitute a new and promising way to manipulate atomic and molecular structures – methods that are needed for nanotechnological innovations. For these scientists, “nano” has to be explained by its highly visionary contents and radically new technological possibilities, whereas crystallographers refuse such a visionary “nanoidentity.” These new nanoscientific realms of possibilities and identities are forged by a local transdisciplinary network that will be discussed in the following paragraphs.

3 Networking a New Identity

The Center for NanoScience (CeNS) in Munich is the main actor in the local nanodiscourse.[24] It provides a platform for exchanging ideas across disciplinary boundaries. Furthermore, it offers the opportunity to address extrascientific, economic, and public issues that now have a huge impact on the allocation of resources. CeNS was founded in 1998 as a rather small and flexible local network of Munich

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[24]It is characteristic for the Munich research landscape that activities in the realm of NST are university-based. More than two-thirds of all publications in this field stem from the two major universities LMU and *Technische Universität*. Only a small part is published by the semiconductor industry, which has a strong tradition in Munich. We counted 1251 nonscientific publications from the Munich area for the period 1997–2006. The publications were identified by the term “nano” in the title or abstract. The data stem from a survey of publication activities based on the Science Citation Index.

scientists. At the time, the U.S. National Nanoscience Initiative was starting up, and a series of nanoscience centers was established in Germany with the support from the national government (*Bundesministerium für Wirtschaft und Technologie*; Bührer et al. 2002: 80–82). CeNS, however, is only indirectly related to this national nanoscience initiative. It follows a rather anti-institutional and bottom-up strategy to make new ways of thinking and communication within a local scientific community possible. It coordinates approximately 200 Munich scientists that share a certain "nano-identity." CeNS organizes workshops, seminars and conferences, publishes "nano-news," and presents these results and scientific achievements to a larger audience.

One of the key figures of the Munich nanoscience network, Prof. Jörg Kotthaus, who has been working in the realm of semiconductor microstructures for more than 30 years, took the opportunity to create CeNS with his colleagues from the physics department in the year 1998.[25] This local association of scientists does not have a huge budget and has no research facilities or infrastructure: "It is a center without a building, without a long period of construction: it is a virtual center, so to say. Where scientists try to find new ways beyond their disciplines" (Rubner 1999: V2/10). Its main equipment is a LCD projector, a poster printer, and a webpage. It is located in a single room with one scientific manager in an old physics building in the city's center, whereas the ideal of a high-tech campus of the 21st century more aptly describes the new science buildings in Martinsried and Garching, outside of Munich (Hessler 2007: 196).

This local network of Munich nanoscientists has a rather virtual, hybrid, and even paradoxical character. It is supported by scientists that look for new horizons and transdisciplinary communication while they continue to work within the institutional setting of their disciplines. Scientists, for example, who work at the crystallographic department, but who do not share crystallographic methods and traditions, try to find a new identity together and symbolic shared resources. From a disciplinary perspective, they have a fragile identity (see Kurath, in this volume). By relocating themselves in a nanoscientific network, they turn their marginality resulting from the insecurities of a transdisciplinary orientation into a vanguard position and promote their research as future-oriented and innovative, ultimately leading to new technologies.

This step into an ambiguous new space between and beyond disciplines can be identified as boundary work. As Monika Kurath and Sabine Maasen (2006: 415) have shown in the case of toxicology, the reference to a rather vague nano-identity helps to transgress disciplinary restraints and traditions. CeNS thus provides a discursive framework that allows scientists from different venues to go beyond their disciplines without completely leaving or denying them: "How can we build a structure that can be a spontaneous, interdisciplinary instrument, without immediately provoking dissent? Because, a really big problem indeed is – in case you

[25] 1988 he already formulated the idea of a laboratory for research at the nanoscale (Nanostrukturlabor).

want to work interdisciplinarily – the fact that there are disciplines," Kotthaus commented.[26]

CeNS resembles a "club" of scientists based on a free and rather loose association with little formal and juridical weight. Gerd Binnig, according to his self-image, understands CeNS as a "space for mavericks" (Burtscheid 1999) that he allegedly missed during his time as leader of the IBM Munich physics group in the early 1990s.[27] Kotthaus also sees CeNS as a "subversive institution."[28] This attitude of working "outside" of academic disciplines, as well as the self-image of being creative and radically innovative by simply "having fun"[29] and following unorthodox paths, seems to be characteristic for the new *habitus* of nanoscientists and their "strategies of seduction" (see Nordmann and Schwarz, in this volume). Younger scientists in particular might be attracted to this kind of network, and given the opportunity to exchange ideas and get into contact with other colleagues from different disciplines and countries.

In opposition to crystallographers, Kotthaus (a physicist) does not refer to the Nobel Prize–winning discovery of X-ray diffraction in 1912 to locate himself within an old tradition of crystallography. For him, the Laue story shows rather that radical scientific discoveries were made by young scientists without merit who were in close, local contact.[30] Thus this new and informal network offers new freedoms and possibilities of interaction between and beyond the established disciplinary boundaries, without needing to locate these research endeavours and results within the existing institutional framework. In this sense, CeNS was clearly created from the perspective of local research experiences and the needs of scientists who wanted to explore new and – from a disciplinary perspective – rather unfamiliar terrain. This can be illustrated by the fact that some physicists who used to work in the field of semiconductor physics have started to combine classical semiconductor methods and instruments – such as molecular beam epitaxy or vacuum chambers that are usually located in a clean room – with methods and materials that stem more from the field of chemistry and biology, such as fluorescence resonance energy transfer (FRET) or DNA techniques. This hybridization and fast realization of approaches that bring together knowledge and expertise from different disciplines is made possible through such a local, transdisciplinary network.

Obviously Kotthaus and his colleagues in Munich preferred a small and flexible organization. The idea of CeNS is to absorb and react more quickly to new questions and trends in the scientific community. The image CeNS wants to have is one of local excellence and creativity in a globalized world: "CeNS brings scientists from various disciplines together in a joint effort. The excellent working conditions attract prominent researchers from around the globe," according to the organization's

[26]Interview, Kotthaus, 19.12.06.

[27]For a good description of Binnigs' attitude and *habitus*, see Chapter 3 of Mody 2004a.

[28]Interview, Kotthaus, 19.12.06.

[29]Interview Prof. Kotthaus, 19.12.06.

[30]Interview Prof. Kotthaus, 19.12.06.

website.[31] Despite its focus on basic research, as indicated by its name "Center for NanoScience," CeNS promotes the technological and economic promises of nanotechnology (Bögel 2001: 50). It wants to support spin-offs and lead to "new ways of information processing, to new materials with highly desirable properties and to new techniques for medical diagnostics, to mention just a few possibilities."[32] CeNS presents local spin-offs as results of the interdisciplinary and creative atmosphere supported by CeNS.[33] Indeed, CeNS shares the view that nanotechnology with "its wide interdisciplinary scope is likely to be the key to innovative technologies in the 21st century."[34] It relates to the public nanodiscourse and highlights the future importance of this new field. Yet CeNS avoids radical visions**,** such as formulated by Eric Drexler, who authored the sci-fi scenario of self-assembling nano-bots that would reduce the planet to "gray goo" (Drexler, 1986).

In this sense, CeNS strengthens a rather loose and general definition of nanotechnology. It thus pursues a double strategy: the rather indefinite and broad definition of NST has the advantage of offering a wide array of opportunities for scientists from different disciplines, while, in fact, the majority of the CeNS members have a background in physics. At the same time, the promotion of a "nanoidentity" distinguishes CeNS members, e.g. nanoscientists from the Heckl group, from their crystallographer colleagues, who do not have this symbolic capital at their disposal as long as they see themselves as crystallographers working within the framework of their discipline.

In our interviews, CeNS is always held up as an example when the question arises as to whether nanoscience is an interdisciplinary field. CeNS members agree to share their instruments and equipment. Nevertheless, it is doubtful whether they really cooperate in their daily laboratory practice. Thus, cooperation at CeNS does not take place at the level of concrete common research projects. Rather it provides new freedoms and new opportunities for scientists who want to identify themselves as nanoscientists. CeNS also helps scientists to explain what NST is to a larger public and to researchers who do not actively work in that field. CeNS members promote nanoscience in the media and try to establish the CeNS brand in the field of science, industry, and technology.[35] This is a second important function of this local network, as it allows scientists to address extrascientific economic, political, and social issues that do not come from the scientific disciplines but from society at large. These media and science policy issues nevertheless play an increasing

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[31] About CeNs: http://cens.de/About_CeNS.23.0.html (8.3.2007).

[32] About CeNs: http://cens.de/About_CeNS.23.0.html (8.3.2007).

[33] "The creative and unorthodox atmosphere within CeNS efficiently helped to create concepts for and incubate young nano-technological companies: the spin-off companies attocube systems, Advalytix, ibidi, Nanion Technologies, Nanoscape, Nanotools, Nanotemper and Neaspec currently employ about 120 mostly young scientists and technologists, working primarily on nano-biotechnological tasks." http://cens.de/ (19.9.2008).

[34] About CeNs: http://cens.de/About_CeNS.23.0.html (8.3.2007).

[35] http://www.muenchner-wissenschaftstage.de/content/e5/e29/index_ger.html, (8.3.2007).

role, and they are reintroduced into scientific disciplines because today's knowledge production depends more and more on extrascientific resources.

Scientific results such as CeNS members' papers, dissertations, prizes, and patents, as well as spin-offs of small nanotechnology firms, are identified as CeNS activities, although they were produced within the traditional institutional framework of physics or chemistry departments.[36] This peculiar rejection of and at the same time reliance on the university that sponsors CeNS can be illustrated with a little anecdote: The CeNS email address is paid for and provided by LMU, which, contrary to the university's usual policy, does not appear in the address. In this sense, CeNS pursues an intelligent marketing strategy by playing a very successful game of scientific policy-making with minimal resources. CeNS' apparent success on the discursive level of science and technology policy is mirrored in last years' Munich excellence initiative, when German universities competed for money and the prestigious status of an elite university. A "nano-excellence" cluster – Nanosystems Initiative Munich – could be established in Munich using basically the main leading researchers and ideas that created CeNS.[37]

4 Conclusions

As our case study shows, there are two ways of appropriating nanotechnology. Whereas nanoscientists working in LMU's crystallographic department participate in the nanodiscourse to open up a new field of research, most crystallographers do not see themselves as nanoscientists and remain at a certain distance. Yet their closeness to the nanosciences in terms of the objects under investigation, their methods, and also their institutional situation forces them to take a position. They do not deny nanotechnology's methods or results, but they remain within the boundaries and traditions of their discipline. They use a rather broad and general definition of nanotechnology as a matter of scale. They also understand the scanning tunnelling microscope or the atomic force microscope as instruments that reveal the nanoscale. Therefore the dimensions of scale and scanning probe methods can be understood as boundary objects that enable crystallographers as well as nanoscientists to relate to the nanodiscourse. However, there is a second and more specific understanding of nanotechnology that is shared only by those scientists that define themselves as nanoscientists. They explicitly relate to far-reaching future visions of molecular engineering based on self-organizing building blocks and orient their daily laboratory practice to a program of technological innovation. These nanotechnological visions separate scientists who identify themselves as "nanoscientists" from those who *defensively* react to the nanodiscourse.

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[36]http://cens.de/CeNS_Annual_Reports.76.0.html, (8.3.2007).

[37]Interview, Kotthaus 19.12.06; Nanosystems Initiative Munich (NIM): *LMU Pressinformation 13.10.2006 Entscheidung im Excellenz-Wettbewerb LMU ist Spitzenuniversität*; http://www.nano-initiative-munich.de/, (15.11.07).

Considering crystallographers' institutional situation with their strong traditions and specific methods, the integrative function of a nanoscience center like CeNS becomes clear. It helps scientists who left the disciplinary boundaries of crystallography behind to find new ways of communicating and to shape new perspectives and identities (Mody 2004b: 129). These scientists are facing, on the one hand, new possibilities to "play around" with molecules. On the other hand, they find themselves in an insecure, indeterminate, and tenuous transdisciplinary situation (see Kurath, in this volume).

CeNS thus pursues a double strategy to make nanoscience credible. It reproduces common topics of a broad and rather unspecific nanodiscourse, in order to benefit from the nanohype. Furthermore, it offers symbolic resources to stabilize the identity of all those scientists who follow transdisciplinary nanoscientific research projects and thus lose contact with their disciplines. The "nanoidentity" as made possible through reference to CeNS gives the opportunity to gain financial support and scientific acceptance. By actively appropriating and shaping the nanodiscourse in the interest of Munich scientists, CeNS demonstrates to the public that nanoscientists' actual research projects are future-oriented without risking the claim of being utopian or unscientific.

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Part II
Making Sense: Visions, Images, and Video Games

The second part of this book elaborates on how science and society are mediated by images, visions, and even video games. In doing so, these mediators embody societal implications in one or the other way.

Joachim Schummer demonstrates that the frequent reference to a supposed "convergence" of disciplines (nano-bio-info-cogno-socio) in the nano-realm is a powerful conceptual tool for connecting the present to the future. This connection may be a surprise, because convergence cannot act as a predictive instrument, just as convergence cannot serve as an empirically based description of current developments in the landscape of scientific disciplines. Instead, convergence incorporates and organizes a wide range of interests and also of concerns about the divergence of the scientific disciplines and the dissociation of scientific progress from the real problems of societies. Therefore, convergence has been very influential in the formation of the US National Nanoscience Initiative (NNI) and the mobilization of funds from different sources at an unprecedented scale. As an example Schummer shows that Roco and Bainbridge's 2002 report on *Converging Technologies* (NBIC report), highly stresses "enhancement" of the human organism and herein overlaps with the "transhumanist" movement.

Like Schummer, *Christopher Coenen* focuses on visions of converging technologies as well, but explores their historical origins. In his perception, he argues, we have witnessed a shift of focus in the overall ethico-political discourse on science and technology since the 1990s. This shift from actual technoscientific innovations and short-term visions to far-reaching projections had been on the horizon of various twentieth-century debates on innovations, yet with the advent of nanotechnology, the perceptions of such areas as artificial intelligence research, genetics, and space research have converged. Coenen identifies these fields' common focus on the enhancement or augmentation of human capabilities as a factor that has enabled the convergence of these technological ideas. Such transhumanist concepts have not only informed the politics of nanotechnology, but also the deliberation and reflection on its ethical, legal, and social implications.

Andreas Lösch, in his contribution, analyzes how mass media have covered futuristic visions. While in the 1990s science fiction images of nanotechnology in a remote future frequently were controversial topics, these images disappeared after

2004 and have were replaced by potential applications of nanotechnology in the near future. Using the concept of "defuturization," Lösch argues that with the increasing economic impact of a new technology such as nanotechnology, futuristic visions are replaced with potential applications closer to the present. With an eye toward the assessment regime and by reference to the contributions of Rip and van Amerom as well as of Grunwald and Hocke (both in this volume), Lösch speculates on a similar defuturization in experts' debates on the ethical, legal, and social implications (ELSI) of "nanotechnology."

Colin Milburn inventively approaches "nano-visions", as encoded within video games. By interacting with simulated nanotechnologies in the present, whether with a consumer videogame console, a laptop computer, or a research laboratory, gamers and scientists alike are learning how to play with real nanotechnologies, now and in the future. "Playing nanotechnology" does not only entail the manipulation of molecules, as Milburn shows, but also the anticipatory engagement with the ethical and societal implications of that technology. As mere digital representations, computational nano-things acquire physical and social dimensionality though ongoing acts of speculation – exploratory, economic, and imaginary—into the burgeoning multiverse of synthetic worlds and "realistic nanoworlds." With the divide between computer-simulated atoms and conventional atoms thereby diminishing both epistemologically and ontologically as the nanotech era looms increasingly closer, it would seem that any lingering difference between the two is, by now, really only a very small matter.

From Nano-Convergence to NBIC-Convergence: "The Best Way to Predict the Future is to Create it"

Joachim Schummer

1 Introduction

Since nanotechnology has been touted to bring about the next industrial revolution,[1] the talk about nanotechnology has considerably shifted towards the future. Given the notorious fuzziness of the concept of nanotechnology, various actors have employed the future to define the field by reference to its future "societal and ethical implications" (Schummer 2004c). Sometimes the futuristic ideas of nanotechnology become so removed from the present research which scientists call nanotechnology that it is difficult to see any connection. In order to bridge the gap between the present and the future, various tools have been developed, including prognostic tools of technology foresight and assessment as well as conceptual tools that conceive of technology as process rather than as products or states. In this paper I analyze another powerful conceptual tool for connecting the presence to future: the concept of convergence and its use in US reports on nanotechnology.

It would seem that the concept of convergence was first employed in the so-called NBIC report, which suggested the convergence of nanotechnology, biotechnology, information technology, and the cognitive science for improving human performance (Roco and Bainbridge 2002). However, as I argue in Section 2, the concept and its various rhetorical uses to connect the present to the future were already fully developed in the early science policy idea of nanotechnology as nano-convergence. Section 3 examines how the tool was transferred to the idea of NBIC-convergence by widening the scope of technologies and by stating the explicit goals of human enhancement. My procedure simply consists in analyzing the meaning of various sentences, such as convergence did, does, can, will likely, will necessarily, should, and ought to happen, which all appear in the reports. I argue that in all these modes

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[1] "Supporting the Next Industrial Revolution" has been the motto of the US National Nanotechnology Initiative since its launch in January 2000. The term "nanotechnology revolution" goes back to a book co-authored by Eric Drexler (Drexler et al. 1991) which further developed his specific vision of molecular nanotechnology.

M. Kaiser et al. (eds.), *Governing Future Technologies*, Sociology of the Sciences Yearbook 27, DOI 10.1007/978-90-481-2834-1_4,

the talk of convergence is a more or less encrypted form of stating and attributing goals. Section 4 examines more systematically why the concept of convergence is such a flexible rhetorical tool by analyzing the teleological nature of the concept. In conclusion I argue that the science policy induced shift towards deliberating the future poses various new challenges to STS, of which analyzing the talk of convergence is but one example.

2 The Rhetoric of Nano-Convergence

2.1 Convergence-as-Fact

In early 2000, the National Science and Technology Council, Subcommittee on Nanoscale Science, Engineering, and Technology (NSTC/NSET) asked the National Science Foundation (NSF) to organize a workshop from which a report should be produced on the *Societal implications of nanoscience and nanotechnology* (Roco and Bainbridge 2001). Mihail C. Roco, Director of the then freshly established National Nanotechnology Initiative (NNI), and William S. Bainbridge, then Director of NSF's division for social and behavioral sciences, became in charge of the project. They promptly organized a workshop in September 2000 and published the report in March 2001. Their Executive Summary starts with the remarkable claim:

> A revolution is occurring in science and technology, based on the recently developed ability to measure, manipulate and organize matter on the nanoscale — 1 to 100 billionths of a meter. At the nanoscale, physics, chemistry, biology, materials science, and engineering converge toward the same principles and tools. As a result, progress in nanoscience will have very far-reaching impact (ibid.: 1).

On behalf of the NSF and NNI, Roco and Bainbridge suggested here that, because of some unspecified recent scientific achievements, almost all the science and engineering disciplines were converging toward the same principles and tools. They argued that this convergence itself was a true revolution, which, in case of further progress, would also lead to far-reaching societal impacts. However, the two components of their revolution claim, the convergence of disciplines and the recent scientific developments that would have induced the convergence, remain questionable. In lack of further specification, we may only speculate about what they had in mind.

The "recently developed ability to measure, manipulate and organize matter on the nanoscale" (ibid.) could mean many different abilities or only one. To be sure many of the mentioned disciplines have in the past decades further developed their synthetic capacities in the nanoscale, including combinatorial chemistry, stereoselective synthesis, chemical vapor deposition, recombinant DNA technology, lithography, and so on. However, they have done that permanently during the 20th century, and it is questionable how such diverse developments should suddenly bring about the convergence of the disciplines. It is more likely that Roco and Bainbridge referred to scanning probe microscopy (SPM), which had been developed since around 1980 and indeed had very soon been widely adopted by many science and engineering disciplines. However, that technique has been widely used only as an analytical tool to analyze surfaces, rather than to “manipulate and organize matter on the nanoscale” (ibid.). Other analytical tools developed since the first half of the 20th century, like x-ray diffraction, nuclear magnetic resonance, and various spectroscopies, were equally adopted by many disciplines, which in the same period enjoyed further disciplinary divergence rather than convergence. It seems therefore that Roco and Bainbridge referred to the discovery of the late 1980s that one can also scratch on crystal surfaces with the tip of an SPM and that, under extreme conditions, one can move with the tip single surface atoms. While electrical engineers still explore that approach as an alternative to IC lithography, it has never yielded the slightest promising results as an effective engineering approach to “manipulate and organize matter” in any other discipline up to today. Thus it is more likely that Roco and Bainbridge referred to some envisioned future science rather than to the actual science and technology practice as they pretended to do.

Similar to the obscure tool, it remains unclear what they meant by convergence of the science and engineering disciplines toward the same principles. Obviously they were not willing to repeat the standard physicalist reductionism story and thus did not refer to the axioms of quantum electrodynamics or the particles of particle physics. Instead, as their Introduction to the Report makes clear, they were referring to the “basic building blocks” of the world by which they meant “atoms and molecules”. However, our present concepts of atoms and molecules originate from early 19th-century chemistry. While these concepts indeed enjoyed extraordinary success during the entire 20th-century and became used in any natural science and engineering discipline other than software engineering, there is no evidence of any recent disciplinary convergence in that regard. For instance, physics owes much of its modern identity to its quest for the “basic building blocks” in sub-atomic particles, from baryons and hadrons (e.g. electrons and neutrons) to quarks and strings, and there is not the slightest evidence that physicists are suddenly giving up that idea. In biology, dropping the simplistic idea of molecular building blocks in favor of systemic and informational approaches led to the split of molecular biology from biochemistry in the mid-20th century, again with no indications of a recent return. Materials science established itself as an independent discipline since the 1970s by carving out research fields from chemistry and physics, and they show no inclination to reverse the history. While all the disciplines still use terms such as “molecule”, the meaning of these terms have diverged rather than converged, because they developed their own models and theories that provided new disciplinary meanings to the terms (Schummer 2004b). The increasing lack of common principles might be regrettable, if one prefers stronger interdisciplinary research collaboration, but it nonetheless remains a history of science fact.[2]

[2]As a funding agency the NSF itself represents this paradox: On the one hand, its organization is divided into disciplinary directorates that distribute money to the corresponding classical disciplines (except for the biomedical science for which the NSF is not responsible!), and the bigger the

I conclude therefore that Roco and Bainbridge had little to no evidence for claiming a sudden revolution in the recent scientific development based on the convergence of the disciplines because of some new synthetic tools or common principles. Their claim is an incidence of describing the desired future convergence as if it were a fact of the presence or recent past. The rhetorical topos is well known. They suggested that there was no need to question the goal of convergence because it had already happened.

2.2 Convergence-by-Higher-Necessity

Shortly after the NNI was established, the National Research Council (NRC), an agency of the private National Academy of Sciences, was commissioned to review the efforts of the NNI up to then. To that end the NRC established a committee consisting of representatives from academia and private business. In their report of 2002, they made another remarkable claim about the convergence of disciplines:

> Nanoscale science and technology are leading researchers along pathways formed by the convergence of many different disciplines, such as biology, physics, chemistry, materials science, mechanical engineering, and electrical engineering (National Research Council 2002: 2, similar on 16 and 47).

At first glance, the claim appears similar, if not identical, to the claim made by Roco and Bainbridge a year before. However, the context in which that claim appears makes unmistakably clear that the NRC committee assumed just the opposite. Indeed, they argued at length that there was insufficient interdisciplinary collaboration between the disciplines, which meant that in the actual research practice there was anything else than convergence of the disciplines. And so, as one of their ten main recommendations, the committee suggested as a remedy to "provide strong support for the development of an interdisciplinary culture for nanoscale science and technology" (ibid.: 3).[3] Indeed, a scientometric study of the cross-disciplinary research collaboration in all major nanotechnology journals makes clear that, while each of the classical disciplines has embraced the nano-label, they all do their own "nanotechnology" with no remarkable degree of interdisciplinarity (Schummer 2004a).

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organization grows, the more disciplinary subdivisions emerge. On the other, there are increasing efforts to support interdisciplinary research, including special programs for "cross-cutting research", an "Office of Multidisciplinary Research", the recent inclusion of the "transformative research" criterion in proposal evaluations, and, last but not least, the share of the NNI budget administered by the NSF (see www.nsf.gov). Indeed, the whole nanotechnology movement epitomizes the science policy intention to break up the disciplinary funding structure against the long-term historical trend, such that the talk of convergence is only the latest rhetorical step in that direction; see also note 3.

[3]This recommendation has been translated into NSF's nanotechnology funding policy which mainly supports interdisciplinary research centers for a limited period. It is questionable however if that policy has any long-lasting effects, once the center funding stops (Schummer 2007a).

While Roco and Bainbridge, contrary to all evidence, talked of convergence as if it were a fact of the presence, the NRC committee employed a subtler rhetorical means, which is worth analyzing in more detail. The phrase "Nanoscale science and technology are leading researchers along pathways formed by the convergence of many different disciplines" (ibid.: 2) suggests first that there are some mysterious agents at work that are leading researchers and which are called "nanoscale science and technology". It further suggests that there are predetermined pathways for each of the disciplines, and that the mysterious agents only help the disciplines find their proper way to their own predetermined destiny. And the common destiny of the disciplines is, of course, convergence. How can we make sense of such a mysterious story in an official report? I suggest that there are two intertwined readings.

On the one hand, the story expresses the metaphysical view of technological determinism. In this view, the development of science and technology follows a predetermined pathway towards the goal of disciplinary convergence. The mysterious agents called "nanoscale science and technology" are but ideas that capture the "proper" goal of the disciplines and thus help researchers find their predetermined pathway. As a metaphysical view, technological determinism is the most naive idea about science and technology development that disregards virtually anything we know about their social dynamics. As a rhetorical figure, however, which incidentally resonates with the Christian eschatology, it provides strong guidance to the extent that any alternative way appears unnatural, i.e. contrary to the predetermined natural course of events.

There is also a more mundane reading of the mysterious story. Given that the story appeared, and indeed frequently appears, in science policy contexts, the mysterious agents called "nanoscale science and technology" could be nothing else than governmental agencies – here, the National Nanotechnology Initiative, which actually represents all the federal research-funding agencies in the US. In this reading, the agencies are unhappy with the disciplinary structure of science and technology because disciplines tend to focus on idiosyncratic academic problems instead of dealing with problems of general societal concern. Thus, they might have decided that future funding must increasingly be channeled to research that disregards disciplinary boundaries. In this reading, the goal of convergence is equivalent to breaking up the disciplinary identities, and the NNI is but a helping meta-agency that leads researchers "along pathways formed by the convergence".

Both readings are intertwined in the sense that the metaphysical reading and its rhetorical effect help convince scientists of following the goals of the political agenda.

2.3 Convergence-as-Opportunity

Another popular way of framing the convergence of disciplines is by pointing out the extraordinary opportunities that the convergence will open up to society. Indeed, almost the entire report on *Societal implications of nanoscience and nanotechnology* (Roco and Bainbridge 2001) consists in praising nanotechnology because of the unprecedented health, wealth, security, and so on that it will bring to society. While pointing out opportunities has become standard language in science and technology reports, it is not very clear what it actually means and what its implicit message is. It is a specific way of talking about the future that is clearly distinguished from the previously discussed formulations of convergence-as-fact and convergence-by-higher-necessity.

Opportunities are more than mere possibilities or feasibilities. Before pointing out the opportunity of something, the reports always assure us that this something is technologically feasible in principle. A recurrent phrase is, "It can be done. It is only a matter of time." As a rule, the only obstacles or "challenges" that are mentioned are social rather than scientific obstacles, e.g. insufficient funding, unfocused research efforts, lack of interdisciplinary collaboration, and so on. Thus, because opportunities presuppose technological feasibilities, they are possibilities whose realization depends only on social factors.

Moreover, opportunities are well-selected possibilities. No report provides a list of all technologically feasible possibilities, and hardly any report provides several possibilities as options to chose from.[4] Instead, the reports usually list many opportunities that can altogether be seized by the same possible technology, once the social obstacles are overcome. The criteria for selecting possibilities as opportunities are exclusively social criteria. A possible technology is an opportunity only because it is said to meet the goals of society. And since the opportunities are not offered as options to chose from, depending on one's personal preference, the talk of opportunities expresses a very determined view of what the goals of society actually are, what society expects from scientists.

The talk of opportunities of a possible technology, or of the possible convergence of technologies, thus turns out to be rather about society than about technology. In a cryptic manner it criticizes society because of its irrationality: Because of social obstacles, society is unable to achieve what it actually desires. If addressed specifically to scientists and engineers who are unwilling to converge, the talk of the opportunities of convergence has a clear moral message: You are not doing your duty, what society expects you to do.

Like convergence-by-higher-necessity, convergence-as-opportunity is a cryptic form of talking about goals and norms, about what should or ought to be done rather than about what happens or what are possible options.

3 NBIC-Convergence

3.1 From Nano-Convergence to NBIC-Convergence

When Roco and Bainbridge published their 2002 report on *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and the Cognitive Science* (Roco and Bainbridge 2002, in the following

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[4] A notable exception is the European response to the NBIC-report (Nordmann 2004).

also called "NBIC report"), they seemed to imply that nanotechnology already existed as a discipline that is ready to converge with other disciplines. The "revolution" of nano-convergence they had claimed only a year before, according to which "physics, chemistry, biology, materials science, and engineering converge toward the same principles and tools" (Roco and Bainbridge 2001: 1), appeared to be no longer a matter of the present or future, but a matter of the past. I assume, however, they had simply changed their mind about the scope and arrangement of the disciplines that should converge and about the goals of convergence. Indeed, the idea of nanotechnology in NBIC-convergence was no longer the original idea of nanotechnology in nano-convergence, because it was now deprived of its original biological and engineering components and became largely a proxy for materials science, chemistry, and physics. Thus, rather than letting one convergence follow after the other, they widened the scope, regrouped the disciplines that should converge, and formulated the specific goal of human enhancement. It should be noted that the idea of NBIC convergence was not new but already discussed by the Interagency Working Group on Nanoscience, Engineering and Technology (IWGN) when they prepared the launch of the NNI. For their 1999 report on *Nanotechnology Research Directions* (NSTC/IWGN 1999), the IWGN, which was chaired by Roco, hired as Public Affairs Consultant John Canton, who entertains a website called futureguru.com, to provide a visionary look into the future of nanotechnology. Indeed, Canton provided the template of what later would be called NBIC-convergence:

> The convergence of nanotechnology with the other three power tools of the twenty-first century – computers, networks, and biotechnology – will provide powerful new choices never experienced in any society at any time in the history of humankind (Canton 1999: 179).

I assume therefore that the political success of the NNI, i.e. that all disciplines were jumping on the bandwagon and attaching the nano-label to their mono-disciplinary research, encouraged Roco and others to consider nano-convergence only a test phase, a preliminary step towards the bigger project of NBIC-convergence.

3.2 The Ideas and Articulations of NBIC-Convergence

Unlike the reports produced by the IWGN and NNI, the NBIC-report is not an official document commissioned by any governmental agency; instead, it is based on a workshop sponsored by the NSF and the Department of Commerce and conducted by Roco and Bainbridge. However, it is composed exactly like an official report, with contributors from government, academia, and the private sector; an executive summary with recommendations to governmental agencies; and, last but not least, it is co-edited by the director of the NNI.

The central idea of the report is to orientate the research of all the disciplines involved towards the goal of enhancing certain human capacities, including physical, intellectual, and social capacities. For instance, physical enhancement includes new sensory abilities through electronic sensor implants, exo-skeletons or bullet-proof armors that support physical strength, robotic war fighter systems, and measures to "control the genetics of humans" (Roco and Bainbridge 2002: 5), etc. Intellectual enhancement includes transportable super-computers, brain-computer interfaces, and a "hierarchical intellectual paradigm" (ibid.: 6) for understanding the world. Social enhancement includes brain-to-brain interfaces for better communication, new management principles based on an atomistic understanding of human culture, and a new unified educational paradigm.

Apart from nano-, bio-, and computer-technology, a field called "cogno science" should also be involved according to Roco and Bainbridge. That seems to include such diverse things as cognitive psychology, neurophysiology, software engineering, sociology, ethology, and so on, in so far as these disciplines are committed to a systems theory approach or to what Canton in 1999 called network thinking.

How was the NBIC-convergence idea articulated? If one ignores the numerous other authors, Roco and Bainbridge provided three different versions in the NBIC report. In their "Executive Summary" they chose the "convergence-as-opportunities" version. That is, they did not claim that NBIC-convergence was already happening, but pointed out that, because of some recent scientific achievement, now would be the best time to start with. They argued that, if the disciplines converge towards the enhancement goals, these goals could be achieved within 10–20 years. And, of course, as they did before in their *Societal implications of nanoscience and nanotechnology* report, they praised the goals as unique opportunities to society that ought not to be missed out because they would bring unprecedented health, wealth, power, security, and so on. In the manner of an official report, they concluded, on behalf of all workshop participants, with the recommendation of "a national R&D priority area on converging technologies focused on enhancing human performance" (ibid.: xii).

In his own workshop paper on "Coherence and Divergence of Megatrends in Science and Technology" (Roco 2002), Roco chose two further versions. At first, he employed the "convergence-by-higher-necessity" theme. He started with identifying six "megatrends", which not incidentally comprised the NBIC field, and which he called (1) Information and computing, (2) Nanoscale science and engineering, (3) Modern biology and bioenvironmental approaches, (4) Medical sciences and enhancement of the human body, (5) Cognitive sciences and enhancement of intellectual abilities, and (6) Collective behavior and systems approach. Then he claimed that the "megatrends" 1–4 were naturally converging: "The nano, bio, and information megatrends extend naturally to engineering and technology, have a strong synergism, and tend to gravitate towards one another." (ibid.: 82) In order to harvest the full synergy of this "natural" convergence focused on "human development", he argued, one needs to consider the full scope "from individual medical and intellectual development to collective cultures and globalization" (ibid.: 83). From that he reasoned that the remaining two "megatrends" must be integrated as well. The teleological argument here seems to be that the "natural" goal of the deterministic convergence is better met by integrating the other two trends. Then, after a lengthy review of the NNI and his own role therein, Roco made a sharp turn and pointed out the need of strong political guidance: "Professors do not leave their students to do everything they like in academic research. On the contrary, if a research project goes well, more resources are guided in that direction. This idea should be held true at the national level, where there are additional advantages such as synergistic and strategic effects." (ibid.: 94)

It seems that in practice Roco has always, from nano-convergence to NBIC-convergence, followed the idea of convergence-by-creation, according to his slogan "The best way to predict the future is to create it" (ibid.: 94). Although the NBIC-report was no official report and although no official report has ever been commissioned by the NNI on the NBIC issues, it eventually found its way into the official science policy agenda of the US. In the *Supplement to the President's FY 2007 Budget* for the NNI, where all agencies have to explain their activities, the NSF states:

> Special emphasis will be placed on research in the following areas: [...] Merging science and engineering at the nanoscale: the convergence of nanotechnology with information technology, modern biology, and social sciences will stimulate discoveries and innovation in almost all areas of the economy. (NSTC/NSET 2006: 5)

3.3 The Friends of NBIC-Convergence

The list of the human enhancement goals, to which most of our natural, engineering, and social sciences should be bound according to the NBIC-report, expresses the authors' particular normative ideas of what the ideal human being is, what kind of human capacities should be valued and deserve enhancement. In this picture of the ideal human being there is an almost complete lack of emotional, moral, and political capacities, while social capacities are reduced to the exchange of information, obedience to a kind of totalitarian order, and the removal of disagreement by unified indoctrination. What is particularly valued instead are physical strength and invulnerability, extraordinary sensory abilities like infrared night sight, and the ability to process large amounts of information in short time.

It is no coincidence that this image of the ideal human being almost exactly matches the capacities expected from the perfect soldier in combat. Indeed, many of the enhancement examples are explicitly taken from the military area, like armors that support physical strength and robotic war fighter systems. Moreover, a whole section of the NBIC-report is devoted to "National Security", with representatives from all major military agencies. For instance, Michael Goldblatt from the Defense Advanced Research Projects Agency (DARPA) explained the military interest in human enhancement as follows:

> With the infusion of technology into the modern theater of war, the human has become the weakest link, both physiologically and cognitively. Recognizing this vulnerability, DARPA has recently begun to explore augmenting human performance to increase the lethality and effectiveness of the warfighter by providing for super physiological and cognitive capabilities (Goldblatt 2002: 337).

The summary of the military workshop section explains why NBIC-convergence is particularly important to that end. For instance,

> Applications of brain-machine interface. The convergence of all four NBIC fields will give warfighters the ability to control complex entities by sending control actions prior to thoughts (cognition) being fully formed. The intent is to take brain signals (nanotechnology for augmented sensitivity and nonintrusive signal detection) and use them in a control strategy (information technology), and then impart back into the brain the sensation of feedback signals (biotechnology) (Roco and Bainbridge 2002: 329).

Another example is genetic or biochemical engineering of the human body:

> Non-drug treatments for enhancement of human performance. Without the use of drugs, the union of nanotechnology and biotechnology may be able to modify human biochemistry to compensate for sleep deprivation and diminished alertness, to enhance physical and psychological performance, and to enhance survivability rates from physical injury (ibid.: 329).

The NBIC-projects raise numerous ethical issues, including those of the intended human experiments on brain-machine interfaces, genetic/biochemical engineering of humans, the erosion of basic human rights of soldiers, and the erosion of human responsibility (see e.g. Schummer 2007b). What is more important in the present context, however, is that the military seems to be the driving force behind the move from nano-convergence to NBIC-convergence.[5] That might be economically justified by the fact that the Department of Defense has had the largest share of the NNI budget thus far. However, binding the community of natural, engineering, and social scientists in an allegedly humanistic vein to a human ideal that is modeled after the perfect warfighter, as Roco did, is a severe intrusion of military values into civic society.

Roco found further support for his move from nano-convergence to NBIC-convergence in a techno-religious movement called transhumanism.[6] Again that is no coincidence, because his co-editor and NSF fellow Bainbridge is an influential leader of the transhumanist movement. Transhumanists strive for salvation from world-immanent suffering in a transcendent, so-called post-human, state through step-wise technological transformations. One step is the removal of diseases and aging and the perfection of the human body through some wondrous nanotechnology and genetic engineering. Another step consists in connecting their brains to computers to reach "super-intelligence" and in connecting their brains with each other to reach a harmonious "cyber-society" network. In the perfect transhumanist world, their minds have been completely removed from their bodies by being "uploaded" to computers to live the happy life of software.

NBIC-convergence meets the needs of transhumanists because it employs the community of scientists for their specific religious goals. Indeed the NBIC-report includes most of the central features of human enhancement that transhumanists

[5]Note that the only official NBIC-report was prepared by RAND's National Defense Research Institute for the National Intelligence Council (2001).

[6]See Schummer (2004c), Schummer (2006), Coenen (2006), Coenen, in this volume.

consider as steps towards their salvation. That the military and transhumanist religion here form a strategic alliance might appear strange, but it is hardly an incident that they focus on the same ideas. It is more likely that both have been inspired by the same enhancement ideas that have been circulating for decades in the science fiction literature under the names of cyber punk, post-cyber punk, and, more recently, nano-science fiction (Schummer 2009). Under the heading of nanotechnology, and by the help of the military and transhumanists, these ideas have now become part of the official science policy agenda in the US. The convergence-as-opportunity talk was successful in passing off the specific interests of the military and transhumanists as the proper goals of the society at large.

4 Analysis: Convergence as a Teleological Concept

In the previous sections I have analyzed the various uses of the concept of convergence in US reports on nanotechnology. It has turned out that the concept is an extremely flexible rhetorical tool to speak about the future, to encrypt goals, and to attribute specific goals to others. In this section I examine the concept of convergence itself to understand the conceptual feature that makes it such a powerful rhetorical tool. I argue that, with the exception of describing the past, convergence is a teleological concept that is about goals and norms rather than about possible facts.

The term "convergence" describes a process over time in which several elements, which are originally at a distance from each other in a certain dimension, move towards each other in the same dimension. As a historical phenomenon, convergence is measurable if the elements are clearly defined and retain their identity over time and if the distances between the elements are measurable at any time. When all the distances between the elements continuously decreased over a certain period and became zero at a certain point, convergence is a plain historical fact. However, neither for nano-convergence nor for NBIC-convergence, any effort at measuring the process of the recent past have been made or commissioned by those who have claimed the recent convergence of disciplines.

Imagine such a measurement would have been made and that it would indicate that the distances between the disciplines, in a certain dimension, have continuously decreased in the recent past, without yet becoming zero, however. Imagine further, that this is not an artifact by the growth of the disciplines in the respective dimension, according to which the intermediate spaces between the disciplines have been filled while the disciplinary centers remained at their former distances. What could we follow from such a move? One could argue that this move is the beginning of a convergence process and that we are currently in the middle of that process. However, any such convergence claim about the recent past and presence is based on anticipating the future, because the move is only part of a convergence process if the convergence will actually be completed. Now one could argue that the past trend allows predicting the future convergence by extrapolation. Although such predictions are frequently made, particularly for the stock market, and at first glance appear plausible by analogy to mechanics, they are usually nothing but guesses without epistemic justification. The reason is that any meaningful prediction of the future by extrapolation from the past requires knowledge of the dynamical features of the system, that is knowledge of the driving forces. Without reasonable assumptions about forces, such predictions are but arbitrary guesses, in mechanics as well as elsewhere.

The dynamics of disciplines do not occur in a mechanical system, but in a complex social system in which human beings rather than billiard balls are the acting and interacting agents. If there are any equivalents to mechanical forces in that social system, then these are the intentions, desires, and goals of the scientists. Therefore, any meaningful, i.e. non-arbitrary, prediction of the inherent, undisturbed dynamics of disciplines must be based on assumptions about the intentions, desires, and goals of the scientists both individually and collectively, i.e. on assumptions of what scientists want to do in the future and how individuals interact with each other to form collective goals that translate into actions. It follows that whoever makes any meaningful prediction of a future disciplinary convergence, as an undisturbed process, actually makes the claim that disciplinary convergence is the collective goal of the scientists in the present and near future. Again, neither for nano-convergence nor for NBIC-convergence, any systematic efforts at understanding the individual and collective goals of scientists have been made. Therefore any predictions of the inherent convergence of disciplines in the future are but arbitrary guesses. And because describing the recent past and present as part of a convergence process depends on anticipating the future, any such descriptions of the recent past and present are equally arbitrary guesses.

Now imagine that the future convergence is not considered an undisturbed process of the social system of scientists, but a process that is to be controlled from the outside by science policy. In this case, "convergence" describes neither a possible fact of the past nor the collective goals of the scientists in the present, but a current science policy goal of where the social system of scientists should move to in the future. More precisely, it is a science policy goal about controlling the current collective goals of the scientists. If a science policy maker, in this case, speaks about convergence, then he speaks first of all about his own goals. If he makes predictions about the future convergence of disciplines, then he speaks about his own power in the present and near future to control the collective goals of the scientists. If he actually has the power to impose his goals, then the alleged prediction about science becomes true in the future because of his power rather than because of his predictive capacities.

However, the power of science policy to control the *social* system of scientists is largely confined to two factors: money and language. By setting funding priorities on projects that require interdisciplinary collaboration, science policy can provide incentives for interdisciplinary projects or temporary networks and centers, hoping that they transform into more stable institutional forms (Schummer 2007a). The influence of this factor is limited by the amount of available money and competing funding sources. The other, more direct way is to convince the scientists to make the science policy goals their own goals. That usually requires an explicit normative debate about goals, about what each party actually wants for the future, about common understandings, differences, and possible compromises. Such a debate has never happened, however. Instead, science policy makers have used the concept of convergence to mask their own goals (as in convergence-by-higher-necessity, see Section 2.2), to articulate the alleged goals of the scientists (as in convergence-as-fact of the recent past, present, or future, see Section 2.1) and the alleged goals of society (as in convergence-as-opportunity, see Section 2.3). Since the concept of convergence allows you to talk about your own goals without explicitly stating them and about the goals of others without providing evidence that anybody actually subscribes to these goals, it is a perfect tool to avoid public debate about goals, norms, and values. Whether the rhetorical strategy proves successful or backfires, remains to be seen.

The previous analysis allows drawing the more general conclusions that, with the exception of describing the past, the concept of convergence if applied to social systems in the presence or future is always a teleological concept. That is, any description of the presence or prediction of the future as convergence either attributes goals to the social system or expresses the author's own goals.

5 Conclusion: New Challenges for STS

The increasing impact of science and technology on the daily life of citizens and the increasing costs of publicly funded R&D both justify stronger political control and assessment of R&D, which require strategic planning of the future. However, the more power shifts from individual researchers to science policy makers, the more are independent critical studies of science policy required, particularly in a state when fundamental science policy decisions are made by administrators rather than democratically elected politicians. That opens up new areas for science and technologies studies (STS), with their traditional sharpness of analyzing science-society relations.

The present case study on the rhetoric of convergence illustrates the complexity of the task, which includes at least four major challenges for STS. First, when science policy makers develop new programs for the future, they usually start with historical narratives to show that their program is naturally outgrowing from the past, as the claims of the alleged recent convergence illustrate. Critical historical, including scientometric, studies are required to check the accuracy of those claims. Second, science policy ideas are frequently encapsulated in sophisticated rhetoric of book-long reports, as I have illustrated with the various uses of "convergence". Systematic analyses of the rhetorical topoi, including their specific uses and contexts, are required to unravel and criticize their messages. Third, because science policy programs are about future science and technology, they come in a great variety of future talk, including visions, promises, wishes, predictions, predictions of predictions, feasibility and opportunity statements, scenarios, guesses, and teleological concepts, like convergence. We need a systematic conceptual, epistemological, and sociological understanding of these various ways of pointing to the future, including their rooting in the presence and their cultural traditions, in order to understand what they are actually about, to analyze their social dynamics, and to critically assess their claims (see also Grunwald 2006). Fourth, science policy is, like policy in general, about agenda setting and goals, which frequently come, as the example of convergence talk illustrates, in various cryptic forms. We need rhetorical analyses to decode these goals and to identify those who actually hold these goals; and we need sociological and ethical analyses to assess if these goals are socially and morally acceptable.

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Deliberating Visions: The Case of Human Enhancement in the Discourse on Nanotechnology and Convergence

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1 Nanotechnology and the Convergence of Visions

A new concept of "converging technologies" (CT) evolved mainly out of activities within the US National Nanotechnology Initiative (NNI), which were strongly tied to the ethical and societal implications of nanotechnology. It became more widely known after the publication of a workshop report entitled "Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science" (Roco and Bainbridge 2002), and the fields are now abbreviated NBIC. The workshop, held in December 2001, was sponsored by the US National Science Foundation (NSF) and the Department of Commerce (DoC), and was attended by high-level politicians, scientists, and representatives of government institutions and private corporations. It was the starting point of what is called the NBIC initiative, whose status is controversial but which was, nevertheless, often seen as a major US research and development (R&D) policy activity. Its other workshops and publications (e.g. Roco and Montemagno 2004, Bainbridge and Roco 2006) have received less attention, but CT initiatives subsequently started elsewhere too (cf. Rader et al. 2006). While claiming a nearly all-encompassing character for the NBIC fields and their ethical and societal implications, the NBIC initiative emphasized the "human enhancement" aspect by means of biotechnology (e.g. genetic engineering), information and communication technology (e.g. visionary "strong" artificial intelligence and new portable and miniaturised devices), and neurotechnology (e.g. new brain-machine interfaces). The nanosciences and technologies are seen by the key actors in the debate as fundamental enablers and a kind of bracket for most of these fields of science and technology (S&T).

In several ways, the issue of CT appears to be a perfect example of how early activities related to ethical and societal issues are crucial in an emerging area of R&D. Building on the use of the term "nanotechnology" as a scale-oriented, catch-all notion for R&D activities in various fields, several promoters of nanotechnology,

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mainly in the US, introduced the concept into the official international discourse on S&T (Schummer, in this volume). The main drivers of the international debate on convergence have been science managers, experts in the fields of the ethics of technology, technology assessment, science and technology studies, or futurology, and various groups from civil society. Their positions range from highly visionary technofuturist projections, to several sceptical approaches, to dire warnings of cultural and political crisis or even a profane, technology-driven apocalypse. While the political conceptualisation of convergence reflected the international diversity of agendas, leading, for example, to the establishment of the CT concept in the European Union's (EU) R&D policy (mainly on nanotechnologies and nanosciences), the debate on convergence exhibits a clear focus, namely technologies that can be used for the enhancement or augmentation of human capabilities (human enhancement), for a massive modification of human bodies in terms of a possible "reconstruction of man", or even for the creation of "posthuman" beings.

Since the 1990s, at the latest, we have witnessed a shift of focus in the overall ethico-political discourse on S&T. This shift from actual technoscientific innovations and short-term visions to far-reaching visions (with strong claims about the future of Western societies) had been on the horizon of various twentieth century debates on innovations in S&T, which were also often influenced by "posthumanist" and other variants of technofuturism (cf. Coenen 2006, Coenen 2007). But with the advent of nanotechnology, far-reaching visions on such areas as artificial intelligence research, genetics, and space research have converged. The relevance of these visions in discourse on nanotechnology, which was most prominently expressed in the US 21st Century Nanotechnology Research and Development Act (2003), can basically be explained by two facts: The ideas and activities of Eric Drexler, which have played a central, albeit contested, role in the political formation of nanotechnology (cf. e.g. Milburn 2002, Rip and Amerom, in this volume), were developed in the context of the "strong" artificial intelligence tradition (moulded by Drexler's mentor, Marvin Minsky) and have numerous links with posthumanist technofuturism. Subsequently, Bill Joy, in his internationally widely discussed pessimistic essay on the future prospects of genetics, nanotechnology and robotics (Joy 2000), took up the visions of posthumanism and Drexlerian nanofuturism, thereby introducing them to a wider public. In this decade, enthusiastic adherents of posthumanist visions such as the transhumanists have done their best to popularise and mainstream these ideas, while many policy actors and scientists have tried to free nanosciences and technologies from them and Joy's nightmarish prognoses (Kaiser 2006, Rip and Amerom, in this volume).

The drivers of this convergence of visions have used "nanotechnology" (mainly in the somewhat mystifying singular) as the medium for establishing their ideas in the ethico-political discourse on S&T. After that they turned to the topics of "convergence" and "human enhancement", with the goal of creating a widely accepted, "technology-independent" framework for the articulation of their worldview in political and academic discourses (e.g. Sandberg and Bostrom 2006). What are the contours and historical roots of this worldview? And how did it come that the discourse on nanotechnology functioned as a kind of flow heater which has turned radical visions of "human enhancement" into a "hot" topic?

2 Après La Lutte: The Return of Posthumanism

At least in Europe, we are used to viewing our era as a post-utopian age in which we are also disillusioned about the prospects of S&T insofar as they are no longer considered unproblematic providers of instruments for societal progress. Remnants of social utopianism live on in science fiction and certain subcultures, but the overall impression is that we live *après la lutte* and that political utopianism disappeared from the stage together with the end of the Soviet Union. However, the technoutopian tradition still informs much of the recent visionary discourse on S&T, which blends highly individualistic visions of a reconstruction of man with ideas for a new social technology, to possibly become a powerful instrument in the post-9/11 world and the "war on terrorism".

The discourse on nanotechnology and convergence has served as a gateway for the introduction of a specific, posthumanist worldview into the ethico-political discourse on S&T. This introduction was in fact a re-introduction, shedding new light on this peculiar strand of the history of ideas on S&T and their societal future implications. The prominent role of posthumanist technofuturism in the discourse on nanoconvergence was accompanied by the resurfacing of ideas and issues known from earlier debates on artificial intelligence and, in particular, the idea of a very "strong" artificial intelligence that may become a partner of or even successor to mankind. Posthumanism can be defined as both a set of ideas and a sociocultural movement ("transhumanists", "extropians", "cryonicists", etc.), promoting ideas directed towards overcoming the physical and cognitive limits to the human condition. On the one hand, posthumanism focuses on actual means of "human enhancement" (such as psychoactive drugs) and, on the other, displays a strong interest in far-ranging visions in which a transformed human species, together or in confrontation with purely artificial posthuman entities, strives for goals such as individual immortality or the colonisation of outer space. Together with other futuristic worldviews, as well as with some mainstream positions in S&T and bioethics, posthumanism shares the hope that humanity will be able to replace "blind evolutionary chance by the self-directed re-engineering of human nature" (Mauron 2005: 67 f.). In some cases, it even extends this hope to the grand vision of a cosmic civilisation based on human-machine symbiosis which physically controls the universe (Kurzweil 2005).

Older intellectual traditions, such as the left-wing biofuturism and early posthumanism of the 1920s and 1930s (cf. Coenen 2007, Euchner 2005), apparently inform much of the science fiction and transhumanist discourses whose relevance for the overall discourse on CT (nanotechnology in specific) is often emphasised (Catellin 2006, Milburn 2002, Milburn, in this volume, Schummer 2004). On the other hand, some roots of posthumanism can be traced back to the influence and ideas of the author H.G. (Herbert George) Wells who was also a key figure in the literary tradition of science fiction (cf. e.g. Parrinder 1995). In the 1920s, "Wellsian" scientists, with strong liberal or Marxist leanings, provided visions of the future (cf. e.g. Bernal 1970, Haldane 1995) which were used as blueprints not only by today's post- and transhumanists, but also by generations of science fiction authors.

With the advent of nanotechnology, we have witnessed – in the form of a full-fledged worldview – the re-emergence of posthumanism in the overall discourse on S&T. The disciplines and interdisciplinary fields of research that contribute to this discourse – such as science and technology studies, technology assessment, and the philosophy of technology – have responded to this new challenge in diverse ways. Taken together, however, the reactions oscillated between astonishment and amusement, on the one hand, and horror and indignation, on the other. We may distinguish here several discrete challenges, impositions or even impertinences caused by posthumanism such as

- the "unwarranted attribution of defectiveness" (Nordmann 2007) to our bodies,
- misanthropic utterances, reminiscent of totalitarian ideologemes (cf. Weizenbaum 1995), such as comparisons of man and bacteria (Moravec 1992), by the immediate mentors of today's posthumanist movements,
- the hypostatisation of the ego, aiming at a digitalisation or "uploading" of the mind, a vision which culminates in a new spiritualism (Dupuy 2007) or solipsism (Euchner 2005),
- the "insouciance" of its predictions and the confidence that the changes posthumanists endorse will make for a better world, which might, quite the contrary, resemble Aldous Huxley's *Brave New World* (PCBE 2003),
- the "science-fictionizing of technoculture" (Milburn 2002, cf. RS/RAE 2004), and
- the unhesitating coupling of rather dubious visions of a new "social technology" based on a future social-cultural-neurotechnological-computational science and of life-style "enhancements" with political and military goals.

While the new posthumanism is a re-mergence of ideas known, for example, from the first third of the twentieth century, we have to be receptive for the differences between the early-to-mid twentieth century discourses on S&T and our current discourse on NBIC convergence. One important aspect is the integration of visions on artificial intelligence, genetic engineering, man-computer and brain-machine interactions, and other fields of R&D into a worldview which is promoted by the transhumanists, an organised sociocultural movement with political ambitions.

3 The Politics of Nanoconvergence and "Human Enhancement"

Seen politically, one notices that science policy makers in the US created a thematic network on convergence with strong transhumanist leanings. Taking advantage of the widespread political fuelling of highly visionary discourse on nanotechnology (cf. McCray 2005, Grunwald 2006, Lösch 2006, Lösch, in this volume, Nordmann 2003, 2007, Paschen et al. 2004, Schummer, in this volume) in the US and elsewhere, this network introduced hitherto marginal ideas on the future of S&T and humanity into the official discourse and accompanying activities on new technologies. Observers and critics have pointed to the quasi-religious fervour of some promoters of the NBIC issue, suspected a political strategy to conceal more "profane" interests in "human enhancement technologies" such as military ones, or interpreted the NBIC initiative as a tactical attempt to mobilise technoutopian dreams for political goals (cf. e.g. Coenen 2007, Schummer, in this volume). However, the apparently intentional integration of posthumanist perspectives and transhumanist actors into the core of the political discourse on nanoconvergence remains a strange phenomenon: Much "boundary work" had been done by the "nano community", and the US National Nanotechnology Initiative (NNI) in particular, to demarcate the field from Drexlerian nanofuturism (Milburn 2002, Kaiser 2006, Rip and Amerom, in this volume), but, subsequently, despite their close relationship with the NNI, the NBIC initiative in the US put ideas from the wider, posthumanist context of Drexlerian nanofuturism on the political agenda.

The key players in the NBIC initiative, which was highly active between 2001 and 2006, developed their concept of NBIC convergence at the end of the 1990s and early in this decade. In addition to two NSF officials, Mihail C. Roco, the main architect of the NNI, and the sociologist of religion William S. Bainbridge, these key players included the technology advisor James Canton and Gerald Yonas, the vice president and head of the Advanced Concepts Group of Sandia National Laboratories. Notable political backing for the initiative was long provided by the Technology Administration of DoC and the NSF's directorate. Initially, the initiative was also supported by the Defense Advanced Research Projects Agency (DARPA) of the Department of Defense, several representatives of other political institutions such as the National Aeronautics and Space Agency (NASA), and influential individuals such as the Republican politician Newt Gingrich. Other occasional or regular participants in the initiative were renowned natural and social scientists and humanists, some of them highly active in other activities related to the ethical and societal implications of nanotechnology. With regard to the inclusion of actors from civil society, it is notable that promoters of posthumanist ideas appear to have been progressively included in the activities of the initiative, while more critical perspectives and groups were either ignored or only taken into account at the beginning.

The NBIC initiative's program included the vision that "the human body will be more durable, healthy, energetic, easier to repair, and resistant to many kinds of stress, biological threats, and aging processes", and a view of a transformed civilisation looming on the horizon, in which advances in nanoconvergence will enhance sensory and cognitive capabilities (also "for defense purposes") and enable "brain to brain interaction" (Roco and Bainbridge 2002: 1, 5 f., 18–20). This might then lead to "wholly new ethical principles" that will govern "areas of radical technological advance, such as the acceptance of brain implants, the role of robots in human society, and the ambiguity of death in an era of increasing experimentation with cloning". Moreover, Roco and Bainbridge hoped that technological convergence would lead, hand in hand with "human convergence", to a "golden age" characterised by "world peace, universal prosperity, and evolution to a higher level of compassion and accomplishment". Humanity might then become something "like a single, distributed and interconnected 'brain'" or a "networked society of billions of human beings", possibly regulated with the help of "a predictive science of society" (Yonas and Glicken 2002), by applying "advanced corrective actions, based on the convergence ideas of NBIC" and an "engineering" (Bainbridge 2004) of culture. Some participants were impressed by the long-term potential for uploading aspects of individual personality to computers and robots, thereby expanding the scope of human experience and longevity (Roco and Bainbridge 2002: 86).

Although Roco has on several occasions denied any affinities or connections with transhumanism, suspicions of a hidden transhumanist agenda within the initiative came up early. There is now a great deal of evidence of direct connections, such as the invitation extended to several leading transhumanists to contribute to the initiative's latest publications (including an article on a kind of transhumanist "policy of alliances", Hughes 2006). In 2006, Bainbridge was a keynote speaker at an important transhumanist conference (Bainbridge 2006), presenting his eclectic worldview (cf. Coenen 2006), renewing his offer of strategic cooperation, and polemically criticising the US government. Moreover, he addressed the audience as "the heroes of the future" and emphasised the need for a vital transhumanist movement. Although generally more cautious, Roco has been cited in an online article about "human enhancement" aspects as follows:

> One of the objectives of NBIC is maintaining and enhancing the everyday human performance. This may include improving sensorial capacity when aging, increasing group work productivity through better communication, and using implant devices and neuromorphic human-machine interfaces. We see a future where we will focus on improving human performance rather than improving technology and the machines themselves. In this direction, main areas of focus will be improvement of human physical capabilities, learning, various intellectual capabilities, sensorial abilities, communication, and group creativity. (...) We plan to replace parts of our bodies with artificial materials and devices. However, I am not saying that we will turn humans into robots. We treat ethical and legal concerns responsibly, respect individuals, and maintain an appropriate level of individual privacy (Yamashiro 2004: no page numbers).

How did the NBIC initiative handle ethical and societal issues and which role did pertinent expertise play? First, the polarisation between the various critics and the promoters of "human enhancement" and posthumanist visions was intensified by the initiative both actively, by the transhumanists involved (e.g. Bainbridge 2005, Hughes 2006), and indirectly, by avoiding a substantial and continuous dialogue with its most outspoken critics. Secondly, the diversity of standpoints that characterised the initiative as a whole was not reflected in the editorials and texts of the key players. The rare references to substantial NSF-funded research on broader societal and ethical implications of the nanofields had largely ornamental character, and the integration of these aspects in the numerous pertinent publications of Roco and Bainbridge was mainly restricted to re-wording. The NBIC initiative can therefore be characterised as a construct in which the core policy actors not only set the agenda for activities on ethical and societal issues, but largely produced their own main outputs. Indeed, the contributions of other groups in the US appear, at least until 2007 and with only few notable exceptions, to have been no more than ornamental.

Certainly, this development cannot be explained by the influence of individual key players alone, but must be looked at in the wider political context. The initiative's focus on "human enhancement" was facilitated by the fact that several institutions were interested in deliberations on this topic with regard to convergence: DARPA used the opportunity to promote some of their pertinent, cutting-edge research projects; the foresight think tank of Sandia National Laboratories introduced its ideas on the future role of the NBIC fields in a global security context; and the Technology Administration of the DoC included posthumanist and "human enhancement" aspects in its nanoconvergence strategy of "hype and hope". The NSF's interest in the convergence issue may have been motivated by the hope to consolidate and continue its mainly NNI-related increase in relevance, compared to other funding agencies. The strategy underlying the NBIC initiative and other NSF activities was to bring in biotechnology and cognitive science:

> Converging Technologies was originally conceptualized as a successor to NNI (. . .). It is also a potential joint successor of NNI and ITR (Information Technology Research initiative), as the latest projects funded under ITR would indicate. ITR and NNI provide the technological "push" with broad science and engineering platforms. Realizing the human potential, "the pull", would include the biotechnology and cognitive technologies. (Roco 2006: 13)

In the heyday of the convergence concept in US R&D policy (2003 and 2004), "human enhancement" played a noteworthy role, at least at the level of programmatic statements. Within the NSF the emphasis on it largely stemmed from the activities of the NBIC initiative. In addition to influencing nanorelated funding, it started to play a role in the NSF's activities in the social and behavioural sciences, which include the cognitive sciences. At the Technology Administration of the DoC, various aspects of "human enhancement" and posthumanism were strongly emphasised, including ethical and political challenges arising from them. The Technology Administration also discussed visions and new possibilities of NBIC-enabled "human enhancement" as recently as 2006, one year before its elimination, and with a focus on the economic potentials of "neuroenhancement" (Cresanti 2006). DARPA which took part in the first activities of the NBIC initiative has long been conducting research on various "human enhancement" technologies. The agency also reportedly invited a bioethicist to talk on the development of brain implants and related worries about mind control (Moreno 2006: 181).

However, the most visible political effort to situate "human enhancement" among the most important ethico-societal aspects of nanotechnology was its integration in the 21st Century Nanotechnology Research and Development Act (Public Law 108–153, signed into law on December 3, 2003), in the context of a "Responsible Development of Nanotechnology". While not referring to the concept of convergence, Congress exacted "that ethical, legal, environmental, and other appropriate societal concerns, including the potential use of nanotechnology in enhancing human intelligence and in developing artificial intelligence which exceeds human capacity" are considered during the development of nanotechnology. These two and several other points (including questions concerning the feasibility of nanofuturist core visions and defensive technologies) were mandated to be investigated in two studies to be undertaken by the National Research Council (NRC) within the framework of the triennial external review of the national nanotechnology program. However, the experts of the NRC decided to largely exclude the issues of cognitive enhancement and super-human artificial intelligence from their study. In the preface of the review, they counted the latter and "similar topics" to "the more futuristic aspects of nanotechnology (. . .) popularized in science fiction" (NRC 2006: x). The topic of "human enhancement" played no role in the rest the study, with one notable exception: The NRC had invited two experts on NELSA, both recipients of NSF grants in the NNI context, to a workshop on the "Responsible Development of Nanotechnology" (held in 2005). They delivered the two speeches (NRC 2006, 165–169) within the session "Defensive Technologies, Human Enhancement, and Ethical Issues", in which representatives of military research institutions also took part. One of the speakers was the philosopher George Khushf, who has been playing an active role in the NBIC initiative since 2003, often pleading for us to overcome of the polarisation of the enhancement debate and for the systematic integration of broad philosophical and sociological expertise into the convergence processes. The other invited expert, Rosalyn C. Berne, discussed the ethical aspects of military research funding in nanotechnology.

The involvement of these two ethicists in the reviewing process of US nanotechnology activities is only one example of what appeared to be the changing role played by research and expertise on ethics and societal aspects in the formation of nanotechnologies and CT in the US. An important element of this change was the tendency for more such experts to tackle the issue of "human enhancement" visions, based on nanoconvergence and neurotechnology in particular, and not to leave it largely to the key actors of the NBIC initiative and their transhumanist allies. Even before this, Khushf (2005) had characterised the new "human enhancement technologies" and related visions, both of which are based on convergence, as "stage-two" and "more radical" enhancements compared with the topics discussed in the early enhancement debate (such as doping in sport, cosmetic surgery and smart drugs). New and apparently revolutionary developments that are now emerging or expected in the future indicate that there will be major changes in S&T and medicine. Examples include the ideal of a "self-aware evolution" ("the capacities to engineer directly the next stages" of evolution by "genetically altering existing living systems or through direct creation of artificial life"), the strong interest in "human–machine hybrids" (Humanity 2.0), and "medical enhancements" (from therapy to the enhancement of "normal function" and the introduction of "new capacities that humans never had before"). Khushf argued that, even "if we wish to contest the optimistic tone or to argue with the background assumptions or 'transhumanist' goals", everyone should recognise "the kernel of truth in these kinds of claims". In his view, science has brought us to a point where the radical project of re-engineering ourselves moves out of the realm of science fiction and into the realm of scientific fact. Khushf used the visions and techno-scientific background of the NBIC initiative in the US, which he characterised as a "representative policy initiative", to illustrate the "new stage" of the enhancement debate. He sees “second stage” enhancements as multifunctional, altering how we approach disability, providing “radically new capacities”, enabled by a convergence of multiple kinds of technology, and developing at an accelerating rate. In view of the “initial stages of human experimentation, not just in medical arenas, but also in industry and military”, he remarked that these new “human enhancement” technologies will not just be “like a new gadget, even a highly influential one like computers”, but make possible radically new forms of human interaction. And with this, they may “alter the rules of post-hoc ethical and policy reflection”. In Khushf’s view, this is the key component, because many of the enhancements “will be of such a kind that those who control them may have capacities to manipulate directly the rules of social engagement” in ways we now might consider unfair. These possible “kinds of radical shifts in power and control” should, therefore, “be explored in tandem” with the development of the technologies.

How does this discussion of the more visionary and nanoconvergence-related aspects of “human enhancement” fit into the political “landscape” and timing of activities on the ethical and societal implications of nanotechnology? And what about interrelations with older and other “human enhancement” debates? The NBIC initiative had largely ignored the relevant bioethical research on this topic (e.g. Parens 1998) and the issues of political control and manipulative uses of NBIC technologies. Excluding the work of some enthusiastic libertarian or transhumanist promoters of cognitive enhancement, neuroethical issues of “human enhancement” were only given a cursory glance in the initiative’s publications, or not touched on at all. Leading neuroscientists took part in the initiative’s activities, including one researcher (Nicolelis 2002) on brain implants who conducted a much publicised DARPA-funded project, but their fields of research were not substantially discussed from an ethical perspective. Again, we may notice that the specific handling of broader societal and ethical issues in the framework of the initiative led to lag and a lack of preparedness on the part of the experts. Almost completely excluded was ethical reflection on the military uses of “human enhancement” technologies: Visions of an enhancement of soldiers’ performance were developed by the NBIC initiative, by the DARPA and by other military R&D institutions, for example with regard to implants or new means to counter the effects of sleep deprivation and traumatic experiences. If these would be realised, “human enhancement” technologies may be used in the context of the duty to obey. We would then have to deal with a “mandatory enhancement”, a highly significant ethical topic, also with regard to established practices and new ideas for the treatment of aggressive criminals.

However, the issue of “human enhancement” was often circumvented or depreciated as transhumanist or science fictional within the original core of the emerging field of accompanying research on nanotechnology and convergence. Taking into account that the US funding of this research appears to be rather weak against the background of the NBIC initiative’s visions, we may assume a “structural overloading” of the non-affirmative activities and research accompanying the formation of the converging nanotechnologies. At least with regard to the US, the “thorny” issue (STOA 2006) of “human enhancement” was, above all, part of the playground of policy actors and activists with close personal or intellectual affinities to transhumanism. The related accompanying research (such as Khushf 2005) and activities occasionally delved deeper into the diverse ethical, historical and political aspects of this issue (cf. Coenen 2005), but they came late and, in fact, only accompanied the highly visible political activities on NBIC convergence.

The NBIC initiative, while far from having realised its goal to become a major official R&D policy activity, has not only triggered other, less visionary and largely non-posthumanist conceptualisations of CT (e.g. at EU level), but also contributed to the establishment of the new posthumanism as well as to the re-evaluation of "human enhancement" as a central topic in the discourse on S&T. The posthumanist "charging" of nanotechnology and the NBIC visions served to fuel the debates on new and visionary forms of enhancement. Subsequently the interest of the transhumanists and technofuturist promoters of NBIC convergence shifted from nanotechnology to brain research and new or visionary neurotechnologies (cf. e.g. CSPO/ACG 2006, Sandberg and Bostrom 2006).

4 Shortcomings and Obstacles in the Deliberation of Visions

With regard to CT, the hypothesis appears plausible that the topic of accompanying research and activities has turned into a new meta-field of S&T. Some qualifying, specifying, and summarising remarks, however, seem appropriate here. On the one hand, "nanotechnology" and, in particular, "CT" appear in part to be new political labels for R&D activities that were formerly assigned to other fields of S&T. The above hypothesis may therefore only be asserted for the new and "hyped" fields that are constructed politically. To stress the relevance of their ethical and societal implications might be understood to be predominantly motivated by the goal to gain attention and attract public and private funding for specific areas of R&D. To clarify this, one would have to examine, for example, the relative relevance to scientists of such "hyped" fields compared to the synergies from the confluence of other areas of R&D that is more strictly driven by S&T. On the other hand, a closer look at the political construction of the convergence issue reveals that the accompanying research on ethical and societal issues needs to be viewed in context, such as with regard to the timing of activities, their political relevance, the drivers who set the agendas, and wider societal issues. Such a closer look provides evidence of the decisive role that major funding institutions have played in setting the agenda (Schummer, in this volume) and even in determining the goals and major contents of activities related to ethics and societal aspects. The contribution of individuals within these institutions has been so substantial and determinant that overall these activities appeared to largely reflect the strategic priorities of these institutions, or even their personal ideological inclinations. While there is some evidence that the contributions of academic and other non-government actors to the debate are increasingly losing their ornamental character, there are also counter-tendencies.

Besides the rather precarious and under-reflected role of accompanying activities and research on ethical and societal issues of nanotechnology and CT, we may identify other shortcomings in the deliberation of nanotechnology- and convergence-related visions. Without a systematic integration of a historical perspective on posthumanism, including its interrelationships with the utopian tradition, we may be doomed to reproduce the ethico-political deliberations on S&T which took place in the first half of the twentieth century. Great parts of the new debate on "human enhancement" and posthumanist visions have already run out in a sterile, show-like confrontation of quasi-religious transhumanist visions and equally speculative warnings of cultural decline and moral hubris (cf. Coenen 2007). The new posthumanism may turn out to be a fading fashion, but there seems to be a potential for cyclical returns of immortalism and interplanetarism within the dialectics of the utopian and the technofuturist. An analysis of the debate on convergence and on radical visions of "human enhancement" may therefore contribute to the reconstruction of the changing roles that the posthumanist worldview has played in twentieth and twenty-first century debates on future prospects of science, technology and their societal implications.

There are also obstacles to the further deliberation on converging technologies and sciences and the related visions: In an evaluation of the US nanotechnology policy, the statement was made that the assessment of "the more futuristic aspects of nanotechnology, such as the use of nanotechnology in developing artificial intelligence, and similar topics popularized by science fiction, would be premature and speculative at best" (NRC 2006). While it is often and, in our view, rightly emphasised that futuristic aspects have to be tackled here and now because they shape our views of the world and humanity, there is indeed a two-sided danger associated with these issues. Deliberation on far-ranging visions may serve the interests of different groups (ranging from policy makers, military research groups and business representatives to ethicists and futurists to certain protest groups) and even structurally benefit posthumanist and other futurist perspectives and organisations. The latter already offer alternative expertise on foresight and ethics that is quite firmly grounded in the academic world and would probably win any competition for the production of the most imaginative and dramatic future scenarios. Particularly with regard to "human enhancement" by means of converging technologies and sciences, the discourse on assessment, regulation, and deliberation also must be problem-oriented and evidence-based to be relevant. As has been recently stated,

> there is nothing wrong with public debate of human enhancement technologies (. . .) where such visions provide a backdrop for society to reflect upon itself. However, if the point is to demonstrate foresight or to debate the ethics of technologies that converge at the nanoscale, claims about human enhancement are misleading and serve only to distract us from comparatively mundane, yet no less important and far more pressing issues (Nordmann 2007: 43).

One may argue that activities related to the ethical and societal aspects of nanotechnology and convergence should be deemed exceptional phenomena caused by specific political and cultural factors. Alternatively, they can be seen as examples of general tendencies that are driven by emerging and converging fields of S&T. These tendencies have been, for example, interpreted as a "science-fictionizing of technoculture" (Milburn 2002) and as a further increase in contingency (Grunwald

2007), caused by the technologically intensified dialectics of tradition-dissolving emancipation and new needs for societal and individual orientation. Real, but also imagined transgressions of the boundaries between the naturally grown and the artificially made (cf. Habermas 2003) obviously have a strong public appeal. Political and commercial strategies will most probably continue to build on that, often taking the form of activities on ethical and societal issues. Ethics as the reflection on morality, together with the social sciences and the attempts to “bring in” stakeholders and the public, can potentially act as counterweights to such strategies. In this particular sense, such deliberation and research on broader ethical and societal aspects may play a constitutive, non-ornamental role in the formation of future fields of S&T, transcending their accompanying and often even lagging character.

As we have argued, nanotechnology has not only been shaped by posthumanist visions, but the references to it have helped to modernise an important, albeit often neglected tradition of ideas on future technologies and societies. Originating from the discourse on nanotechnology and building on its characteristics, the debates on convergence and “human enhancement” have opened up a discursive space in which the deliberation on visions has become the main medium of a new overall debate on S&T on normative grounds. But what happened to nanotechnology in turn? With “human enhancement” being either the skeleton in the closet or a peripheral aspect of the discourse on it, we may ask whether nanotechnology, as an established field in R&D policy and academic discourse, still needs futuristic visions and, if so, what kind of visions could serve its needs. It is still possible that nanotechnology will be damaged if the mainstream of the “human enhancement” debate flows into other discursive contexts (such as the discussions on brain research and neurotechnologies), because nanotechnology functioned from the outset as a “flow heater” with regard to highly visionary or contested prospects of S&T. If, however, the further maturing of the field, based on a more sober and concrete concept of convergence, proceeds together with the development of realistic visions of S&T and their future applications, the topic of “human enhancement” may also have to play a role in it. It would then not be reduced to science fictional cyborg visions, but encompass the whole range of man-artefact interactions which might “enhance human performance”. That all of these interactions have to be reflected on against the background of different concepts of perfectibility goes without saying (Knorr Cetina 2004). A historically informed and more participatory deliberation on visions might then realise its potentials.

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Visual Dynamics: The Defuturization of the Popular "Nano-Discourse" as an Effect of Increasing Economization

Andreas Lösch

1 Introduction

In 2004 the popular informational brochure *Nanotechnology conquers markets* (BMBF 2004a) from the German *Federal Ministry of Education and Research* (BMBF) diagnoses:

> Often described as the technology of the future, nanotechnology is attracting growing interest worldwide. Its distinguishing feature is that it gives rise to new functionalities solely as a result of the nanoscale dimensions of the system components—functionalities that lead to new and improved product properties. ... Dawn has already broken on a new era characterized by the dynamic growth of nanotechnology; the challenge ahead is to set the course of future funding and to direct the breakthrough. ... The dialogue on innovation and technology assessment will be actively pursued in order *to give objectivity* and thus direction to the partially critical *public discussion* about the opportunities and risks associated with nanotechnology (ibid.: 4–5, emphasis A.L.).

Which public discussion is addressed in this recommendation? Which subject of the popular "nano-discourse" does this call for objectification focus on?

If we look into the popular "nano-discourse" in mass media up until 2004, we find that futuristic visions were controversial topics. During the period from the late 1990s on, the visions were often accompanied by futuristic science-fiction images (e.g. of nanorobots or submarines diving into the human body). After 2004, however, images of tiny nanomachines diving into the nanocosmos disappeared from the mass media.[1] They were replaced by scenarios based on contemporary research and

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[1]By "mass media publications" I mean popular science magazines, the business press, and daily and weekly newspapers. Popular "nano-discourse" signifies combinations and constellations between discourses of different societal origins – such as science, economy and politics – which are represented and arranged by the mass media. Sociological theories of the "knowledge society" (e.g. Weingart 2001) consider mass media debates to be a "general" forum in which discourses by "specific" public audiences – for example, discourses in politics, various scientific fields, investment and business sectors and finally journalism itself – are interlinked.

M. Kaiser et al. (eds.), *Governing Future Technologies*, Sociology of the Sciences Yearbook 27, DOI 10.1007/978-90-481-2834-1_6,

development that depict laboratorial, clinical or everyday applications and products improved or enabled by nanotechnologies. Corresponding to this visual *defuturization*, the popular "nano-discourse" focuses on discussions concerning calculable market-values of improved products containing nanomaterials and the potentially quantifiable risks of nanoparticles for human health and the environment.[2] Finally, let us assume that giving "objectivity" means focussing public expectations and concerns on economic market and scientific risk calculations of contemporary nanoproduct developments. This would mean, however, that the demand for objectification has come too late; today there is no "critical public discussion" which can or should be objectified. The form of objectification recommended in the quoted BMBF-brochure would imply exactly the phenomenon of defuturization which has already been observable in the popular "nano-discourse" since 2004.

With the concept "defuturization" I follow Niklas Luhmann, according to whom current descriptions of the future provide the space for exclusive options. There are several possibilities. Defuturization in Luhmann's sense means the reduction of these possibilities in current descriptions of the future on the temporal dimension (Luhmann 1982: 278–279). With "visual" defuturization I refer to a transformation in the visual patterns of the popular "nano-discourse". The visual patterns familiarize the discourse with the phenomenon "nanotechnology".

"Nanotechnology" (singular) signifies a "phenomenon" which can be considered a discursive effect of societal communication.[3] What is ascribed to "nanotechnology" might vary depending on the temporal constellations e.g. between the program-strategies of research politics, economic interests or the mass media's modes of gaining the public's attention. Various technologies and products – e.g. cosmetics, antibacterial surfaces, bio-sensors, tiny computer chips, functional food, cleaning products, or products merely labelled "nano", even if they do not contain any nanoparticles (such as "Magic Nano") – might nonetheless be considered "nanotechnology". The only condition of an internationally conventionalized and vague definition is: The products must be enabled via technological interventions in the size properties of < 100 nm in at least one dimension of the whole process of productdevelopment.

Visual images of the nanotechnological future (and their inscribed visual patterns of familiarization) can be regarded as the especially effective and functional means of communication in the popular "nano-discourse".[4] Based on case studies

[2]A similar form of defuturization is observable for the same period in the expert discourses on the ELSI-topics of "nanotechnology" (See Section 5 and Grunwald, Rip and van Ameron in this volume).

[3]To regard "nanotechnology" as a societal and a discursive construction is commonplace in Science and Technology Studies (STS) on nanotechnology (e.g. Fogelberg and Glimell 2003, Schummer 2004, currently Nordmann 2007, Lösch et al. (2009), see also Kaiser in this volume).

[4]Various STS studies already point out the constitutive function of visual images for the phenomenon "nanotechnology" in scientific and popular contexts (e.g. Hennig 2004, Nerlich 2005, Hayles 2004, Nordmann 2004). Most of them, however, do not concentrate on the temporal dynamics of image-communication.

on future images in different nano-discourses, I observed that such images – depicting nanorobots and micro-submarines diving through the nanocosmos – evoked a dynamic of communication in the popular "nano-discourse". Due to the specific polysemy of the futuristic images and their need for interpretation, the discourses are constantly "animated" to reprocess the references between the visual symbolic system and their different discourse-specific evaluations of current reality (Lösch 2006a, Lösch 2006b, summarized in Section 3.1.).

The central hypothesis is that the temporal dynamics of interpretative statements referring to the futuristic images in the popular "nano-discourse" between the late 1990s and 2004 set the stage for visual defuturization, which has been empirically observable since 2004. Furthermore, the phenomenon of visual defuturization – that is, the replacement of futuristic images with contemporary images – can be interpreted as an indication of increased economization of the popular "nano-discourse" (Section 4.1.). This phenomenon corresponds to a fundamental transformation in the visual patterns, and these visual patterns "familiarize" the discourses with the new "futures" of nanotechnologies (Section 4.2.). Since that shift, the dominant mode of familiarization is no longer "to recognize nano by looking into the future". The new mode is "to recognize the future by looking at the present market of nano-products". The transformation of visual patterns and the interpretation of this shift highlight the power of the images' mediality in the popular "nano-discourse" and in popular discourses regarding new technology in present societies.

2 Futuristic Images and Contemporary Images of the Future

In the popular "nano-discourse", two fundamentally different types of images of the future can be distinguished. Between the end of the 1990s and 2003, documents of the mass media preferred *futuristic images* as visualizations of the future, such as the image of a micro-submarine in a human artery (cf. Fig. 1).[5] Comparable with Armin Grundwald's definition of "futuristic visions" (Grunwald 2004, Grunwald 2006), this type of image depicts highly speculative visionary contents, as opposed to scenarios of guiding visions, which are, for example, used as planning tools in the industrial development and business sectors. Since 2004 we have observed a rapid disappearance of such futuristic images from publications in the mass media.

The other type of image of the future is frequently found in current informational brochures in German research policy – such as *Nanotechnology Conquers Markets* (BMBF 2004a) or *Nanotechnology: Innovations for the World of Tomorrow* (BMBF 2004b). These brochures are part of current PR-campaigns aiming to objectify the popular "nano-discourse". *Contemporary images of the future* are preferred

[5]This image of a mini-submarine in a human artery shows the prototype of a submarine in micrometer-scale. It was presented by the German company *microTec* at the World Expo in 2000. The company produced this image primarily to draw public attention to its products (cf. Moore 2001).

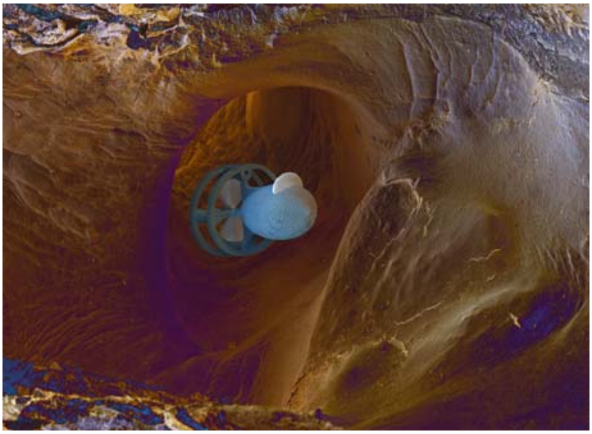

Fig. 1 Micro-submarine in an artery (Courtesy of microTec/eye of science/Focus)

Fig. 2 Clinical examinations in the future (Courtesy of Pictures of the Future, Siemens AG)

in an effort to mediate nanotechnology's future potentials to the public. These images of the future are closely linked to current scientific and technological product developments and societal application frameworks. One such image shows medical diagnostic equipment in a clinical examination room. The products shown are to be manufactured via nanotechnological system components (See Fig. 2).[6]

Before 2004, elements from such contemporary images of the future – e.g. representations of specific nanotechnological products and scientific experts in their working world – likewise were found in mass media documents. But they were not

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[6]This image was originally published in the Siemens Corporations' magazine Pictures of the Future (Zechbauer 2003). The research sector of Siemens produced this and similar images as a communicative tool for indoor planning purposes (See Section 3.2.).

used as a means of anticipating and communicating the future; rather, they were used primarily to represent the current state of nanotechnologies. Only after the visual defuturization, that is, only after the futuristic type of image was eliminated from mass media publications could these images represent both the future and the present of nanotechnology.

3 Empirical Observations and Analysis of the Images' Mediality

3.1 The Process of Visual Defuturization (Mass Media Publications)

Based on the analysis of documents published from the mid-1990s to 2006 in popular science magazines, the business press and in German daily and weekly newspapers, I have observed a general shift in the relationship between the textual argumentation regarding the futures of nanotechnologies and the futuristic portrayal of the images: Until approximately 2001, images of futuristic nanomachines (e.g. nanorobots and micro-submarines, cf. Fig. 1) were mostly presented as visual reproductions of possible future innovations. Starting in approximately 2002, the texts increasingly treat the images as metaphors for diverse future nanotechnological innovations in the medical-pharmaceutical area of drug delivery and drug targeting. These innovations are to be enabled by a new molecular construction of nanoparticles. For the period after 2004 I have observed a rapid disappearance of the futuristic images of nanomachines in mass media publications and now raise the following questions: Are the futuristic images disappearing because they have lost their function as a means of communication for the mass media? What does this visual defuturization imply for the constitution of the phenomenon "nanotechnology" in the popular "nano-discourse"?[7]

We can interpret the shift in the relationship between text and image as the result of a *past* communication between the various discourses. The dynamics of this communication can be explained via the discourse-specific processing of disconcerting information, which was triggered by each discourse's specific interpretation of the images' contents. For the discourse analysis of the observable variations in these textual image references I applied a systems-theoretical differentiation. Thus, I categorized statements in the texts according to the differentiation of social subsystems corresponding to their primary codes in scientific, economic and mass

[7] This section summarizes results of case studies on the mediality of images of the future in popular discourses communicating the future potentials of nanotechnologies. These case studies focused on the forms of mediating innovations in nanomedicine. Financial support for this research was provided by the German Research Foundation (DFG). The results are published more extensively in Lösch (2006a) for the mediality of the futuristic images and in Lösch (2009) for the medialities of the futuristic images in relation to contemporary images.

media discourses (e.g. Luhmann 1995). These statements produce analytically distinguishable relations or image references for each discourse between the symbolic system of the futuristic images and their discourse-specific evaluations of the current research and development of nanotechnology.[8]

Analytically speaking, we can categorize those image references which are based on the discourse-specific distinction "truth/non-truth" and which assess the feasibility of the depicted visions as being statements of scientific discourses (Luhmann 1992). Image references which are based on the distinction "market value/no market value" and which thus link the images to the marketability of depicted future products are categorized as belonging to economic discourses (Luhmann 1994). Finally, references relating to the novelty of the depicted artefacts according to the distinction "new information/old non-information" can be ascribed to statements of mass media discourses (Luhmann 2000). In their function as the discourses' shared means of communication, the images create "communicative spaces" which enable each discourse to refer to the pictorial elements flexibly in its own discourse-specific mode of meaning and knowledge production.

My case studies on the mediality of futuristic images in mass media publications reconstruct a kind of "genealogy" of this defuturization-process by means of a temporal periodization of image communication: The dynamics of the image references of the three discourses, which evolved from the late 1990s to early 2006, could be categorized into four distinct periods (See Table 1). The references to the images which scientific, economic and mass media discourses produced during their discourse-specific evaluations of the future potentials of current nanotechnological research and development varied in each of the periods. Based on these variations, communicative effects emerging over the course of time were empirically observable.

To summarize the research results, the *textual contexts* of the images in the four periods can be described as follows:

The first period (end of 1990s until mid-2000) is characterized by a mood of "starting up" in science and economy. The first possibilities of the transition from basic research to industrial application become apparent. The articles usually begin with a description of futuristic visions of nanorobots and micro-submarines which in the course of the article are contrasted by the description of market-oriented research plans on nanoparticles in the field of drug targeting (e.g. Müller 1998, Traufetter 2000).

The second period (mid 2000 to late 2001) is characterized by a disenchantment of economic expectations. Industrial nanotechnological breakthroughs were not realized as fast as one had expected. With the market-crash of the IT-branch,

[8]For the discourse analytical approach I applied the concept of discourse from Michel Foucault (cf. Foucault 1972). This method makes it possible to differentiate between statements of various discursive origins which are entangled in mass media documents. The combination of discourse analytical and systems theoretical approaches has an additional value over actor-theoretical and leitbild oriented approaches in comparable studies of vision assessment and the sociology of expectations (See Lösch 2006a, b).

Table 1 Overview of the periods of image communication

Time period	Dominant image reference	Textual context
1. Start-up (late 1990s to mid-2000)	Feasibility of nanorobots	International research funding in nanotechnology; “Nanotechnology” as a central topic of the mass media
2. Problematization (mid-2000 to late 2001)	Market-damaging visions of nanorobots	Discussions about the market-crash of the IT-branch; Bill-Joy debate “Why the future doesn’t need us” in the mass media
3. Metaphorization (2002–2003)	Nanorobots as metaphors	Beginning of the risk-discussion concerning toxic nanoparticles; Michael Crichton’s novel “Prey”
4. Defuturization (starting in 2004)	Nanotechnology is the present	PR-campaigns of the BMBF and the EU; Increasing number of marketable nano-products

the problematization of nanotechnology is adopted as possible hype and mere fad. At the same time, as a result of the Bill Joy debate caused by the publication of his pessimistic vision *Why the Future Doesn’t Need Us* (Joy 2000) in the *Frankfurter Allgemeine Zeitung*, the articles problematize the possible negative effects of futuristic visions for the general public’s and potential investors’ view of nanotechnology (e.g. Knop 2000, Jung 2001).

The third period (2002–2003) is characterized by an increasing hope for the progress of nanoparticle research and the production of marketable products enabled by new nanomaterials (e.g. Waters 2003, Freise and Janich 2002). Nanoparticles are dubbed “huge market conquerors” (Knop 2003).[9] At the same time, the effect of the thriller *Prey* by author Michael Crichton, in which he depicts the catastrophic scenario of a swarm of nanorobots gone wild, is controversial with regard to the public’s conception of nanotechnology (cf. e.g. Crichton 2002, Saxl 2002, Heckl 2002). In this period, the debate between K. Eric Drexler and Richard Smalley over the feasibility of the production of nano-assemblers also reaches its peak (cf. Rip and van Ameron in this volume). Molecular nano-assemblers, really all complex nanomachines, are increasingly being classified during this time not only as fictional visions but also as powerful *metaphors* for the innovative potential of nanotechnology in general (e.g. Baum 2003, Haas 2003).

[9]In the following all quotes from German sources have been translated.

In the fourth period (starting in 2004), which coincides with the BMBF's call for the objectification of public discussion (BMBF 2004a: 5), the articles concentrate primarily on the discussion of the market value of already-developed products made of nanomaterials as well as their future improvements (e.g. Grotelüschen 2004). Much more than in the period before, during this time potential and unknown risks of nanoparticles for human health and the environment are discussed (See the interpretation of the Swiss Re intervention by Rip and van Ameron in this volume). A well-known and often quoted event in this discussion is the "Magic-Nano-Case" (e.g. Lindinger 2006, Bullis 2006). It is remarkable for this period that visions of nanomachines are no longer a central topic of the popular "nano-discourse" in the mass media.

The *dynamic of the image references* in scientific, economic and mass media discourses during these four periods could be reconstructed as follows:

1. From the end of 1990s until the end of 2001 *scientific discourses* interpreted the futuristic images of nanomachines as being representations of future innovations whose feasibility was said to be dependent on scientific and technological advancements, i.e. the nanotechnological development of suitable propulsion systems for miniaturized micromachines. In 2002/2003 the references in scientific discourses instead emphasized the fictionality of such visions. Finally, in the period since 2004 statements in scientific discourses have referred only to contemporary images by using them as evidence for current tangible development. Since the articles have concentrated mostly on the market value of already-developed products made of nanomaterial as well as their future enhancements, an evaluative distinction between the scientific feasibility and the fictionality of futuristic nanomachines has become superfluous for scientific discourses.
2. This modification of image references in scientific discourses on the temporal dimension can be interpreted as a reaction to the problematization of a market-damaging effect of nanorobot visions in *economic discourses* (starting roughly in mid-2000) which holds the popularization of futuristic visions of nanomachines responsible for investors' lack of interest. In contrast to current incremental innovations via improved products by nanoparticles, these visions are said to represent nanotechnology as a radical innovation whose future marketability is allegedly too uncertain and thus incite no interest among investors. In the metaphorization period (2002/2003), this assessment in economic discourses finally switches to an interpretation of nanotechnological developments in general as being hopeful steps on the way to marketable innovations of the future. Finally in the defuturization period (since 2004), statements of economic discourses refer to the contemporary images by assessing all current and future nanotechnological research as innovations with marketable potentials. The economic discourses' evaluative dichotomy of "market value/no market value" loses its meaning because the future of nanotechnologies is discussed solely as an extension of already-realized innovations whose market value has long been proven.

3. In the early period from the late 1990s until mid-2000 *mass media discourses* evaluated the futuristic images as representations of future microsystems that assumed an absolutely novel molecular design of atoms and molecules. In the metaphorization period (2002/03), their evaluation changed to an interpretation of the futuristic images as metaphorical depictions of nano-products – in the areas of medicine and pharmaceutical drug targeting – enabled by a totally new molecular construction. Only a short time before, in mid-2000, mass media discourses discussed the exact same research and product developments as the tried and true miniaturization of pharmaceutical ingredients but did not connect them to visions of nanorobots and mini-submarines as depicted by the futuristic images. In the defuturization period (since 2004), statements of mass media discourses suddenly refer to contemporary images in order to produce the typical discursive distinction between current, already produced – and thus old – "nanomaterials" and so-called new "nanomaterials" that are expected to be produced in the foreseeable future. The specific differentiation of the mass media discourses between "new information/old non-information" becomes nearly obsolete. All previous methods of material production with nanoparticles are now considered new molecular nano-design.

I observed that the statements in the various discourses concerning the potential of nanotechnologies *converge* in correlation with the elimination of futuristic images. This is the result of the dynamics in image communication over the course of time. Contemporary images, e.g. of nanotechnological applications and nanoproducts,have served as a kind of tool to calculate future nanotechnological developments. Before the elimination of the futuristic images, contemporary images had been used by the discourses solely as evidence for the first steps towards the future realization of complex nanomachines (scientific discourses), as the representation of current marketable products in contrast to the crazy nanomachines (economic discourses), or as depictions of traditional technology in contrast to the future novelty of nanomachines (mass media discourses).

3.2 *Defuturized Images at Work (Research Policy Brochures for the Public)*

It is easier to understand the replacement of the futuristic visions with calculations of the opportunities and risks of diverse nanotechnological product improvements and the corresponding visual defuturization if we look at the discursive and visual forms chosen by the German BMBF for their informational brochures to mediate nanotechnologies to the public. When reading the brochures, it becomes evident that the recommended objectification of public discussions (Section 1) implies the observed visual defuturization, and that this is caused by specific forms of linking nanotechnology very close to the present. According to the observations in mass media publications, however, the BMBF's recommendation must be viewed as a diagnosis of a currently ongoing transformation of the popular "nano-discourse" rather than a recommendation for future actions.

In the 2004 BMBF brochures – for instance, *Nanotechnology: Innovations for the World of Tomorrow* (BMBF 2004b) or *NanoTruck: Journey into the Nanocosmos* (BMBF 2004c) – German research policy seem to be striving for a defuturization of the popular "nano-discourse" in the name of scientific objectification. In reference to the futuristic visions of Michael Crichton's novel *Prey*, which presents a horror scenario of intelligent nanorobots running amok, the brochure *NanoTruck*, for example, emphasizes:

> According to the majority of expert opinions in science and industry, such horrific visions are absolutely unrealistic. Nevertheless, they cause public apprehension and fear. The BMBF therefore calls for the public dialogue regarding the risks of nanotechnology (BMBF 2004c: 38).

The brochure refers in its argumentation to the code "truth/untruth" in scientific discourses. It also states that the "discussion of nanotechnological risks – regardless of whether they are likely or futuristic – are relevant to all of society" (ibid.: 39). At the same time, however, we notice that it is not the futuristic visions, but rather the "possible negative effect of nanoparticles on human health [that] should be the focus of" public discussions (ibid.: 39). Thus, public discussions about the potential risks of nanotechnology which are shaped, according to the BMBF, by futuristic visions should instead focus on discussing the regulation of exposure to health hazards related to nanoparticles; these nanoparticles, so the brochure, should be measurable via toxicology in the near and foreseeable future.

This form of scientific objectification of evaluations via a close linking between current and future knowledge about risks of nanoparticles corresponds to a similar form of objectification in the discussion about future nanotechnological opportunities. For example, when the brochure *NanoTruck* describes the "benefits" of nanotechnology for "medicine and health", it doesn't distinguish between current application and future expectation. The "detection and curing of diseases in the early stages of development" (ibid.: 30) is listed as a current application. The detection of the "onset of diseases such as cancer ... at the molecular level" is called a "future vision" (ibid.). This and similar brochures published by the German BMBF constantly refer to "visions". But these "visions" are fundamentally different from the futuristic visions of nanomachines diving into the nanocosmoswhich were used by the media from the late 1990s into 2004).

How present and future are linked in this strategy for mediating "nanotechnology" to the public is evident again by means of the references of textual arguments to the images' contexts. In the brochure *NanoTruck,* for example, descriptions of *current* nanotechnological applications in the field of medicine and *future* visions are illustrated with both the photo of a computer or magnetic resonance tomograph (as shown in the background of figure 2) and a microscopic image of nanoparticles. The microscopic image is captioned: "Nanoparticles accumulate in cancer cells (visible on dark coloration)" (BMBF 2004c: 31). Whether the microscopic image is meant to represent future or current therapies that are enabled via special nanoparticles remains unclear in the textual description, which says: “Researchers are currently testing nanoparticles as a means of fighting cancer” (ibid.).

What nanotechnology is and what it could be is thus *extrapolated* from the present. The BMBF brochures visually convert this extrapolation of the future from the present via the use of contemporary images of the future oriented towards everyday scenarios. Thus, current application scenarios which are assumed to be familiar to most readers are used to derive future applications of nanotechnological products. The clinic scenario (See Fig. 2) that depicts a doctor and clinical staff evaluating diagnostic images is accompanied by textual descriptions of the future benefits of nanotechnology, thus bringing the relationship between present and future into perspective:

> Orange juice is sugary. Sugar causes cavities. Once again, nanotechnology is needed: toothpaste (*already exists*) contains nanodimensional beadlets made out of apatite and protein, also found in natural tooth material, which helps to restore the tooth. Moisturizer (*already exists*) contains zinc oxide nano-beadlets to protect against harmful UV-rays. The beadlets are made on a nanoscale and are thus invisible. . . . Medicine inside the body transports nanoparticles which are coated so that they adhere only to the source of the disease—“drug delivery”, to be direct on target. Similar tricks can be used to direct nanoscaled magnetic particles to the cancer’s metastasis which can then be warmed by an alternating electromagnetic field which destroys the tumor. . . . Clinical trials have *started* (BMBF 2004b: 34–35, emphasis A.L.).

In both the textual references and the images themselves it is almost impossible to distinguish between future innovations and currently manufactured nanotechnological products. The text must denote which current products, such as toothpaste and moisturizer, “already exist”, so that it is made clear that “nanotechnology” is also a technology of the future. Nearly everything still seems to be in a “trial” stage.

This type of extrapolating the future from the present and simultaneously “retropolating” the future scenario to the present has little in common with any mode of scientific objectification. It is rather a mode of *economic* calculation – e.g. of the future marketability of nanotechnologically improved products compared to traditional products which have already shown their market value in the present. These contemporary images of the future can thus be interpreted as a kind of economic calculation tool.

This insight is not astonishing if we consider that the future images used in BMBF’s 2004 brochures are taken from the *Siemens AG* magazine *Pictures of the Future* (e.g. Aschenbrenner 2003, Zechbauer 2003). According to the scenarios’ designers, the images serve Siemens’ research department as a “comprehensive overview of future technological development” with the aim of gaining “an overview of the technologies that will play a major role in the future.” According to the designers, the overview will enable the Siemens Corporation to “systematically track down new business opportunities” and allow the company to “communicate to people both inside and outside the company that Siemens is a visionary and innovative organization” (Eberl 2002: 4). The images will project “technologies and products of today into the future” via extrapolation (Eberl 2001: 5). At the same time, future scenarios will use the method of retropolation to “backtrack to the present from the "known" facts of the future scenario. This way, [it should be] possible to identify the kinds of challenges and problems that need to be overcome to get there" (ibid.).

The future images designed by Siemens are not depictions of visions. They are in-house planning instruments which are oriented towards current developments, resources, strategies and interests of the company. In the BMBF brochures, which are addressed to wide public audiences, these visual product and application scenarios seem to "abandon" their original business communication and mediation context. As I will explain in the following chapter, however, the scenarios are a kind of prototype for a new form of familiarization and its underlying visual patterns, which have become hegemonialized in the popular "nano-discourse" in the last few years. The evident phenomenon is visual defuturization.

4 Theoretical Interpretation of the Observed Phenomena

4.1 Defuturization as an Effect of Increasing Economization

The visual defuturization of the popular "nano-discourse" and the corresponding convergence of discursive expectations with evaluations of currently ongoing product-improvements correspond to the form of the mediating nanotechnologies in the BMBF-brochures of 2004. This form of mediating future possibilities seems to be a result of previous interdiscursive dynamics in the popular "nano-discourse" between the late 1990s and 2003. Thus the question arises: Are we to explain the phenomenon of defuturization as an effect of a shift in the dominant mode of familiarization – the mode by which certain discourses make themselves familiar with unfamiliar futures?

In the late 1990s *scientific* patterns of familiarization implicated the depiction of the nanocosmos as an open realm of possibilities on how to construct and use complex nanotechnologies. Mass media discourses assessed product developments as new due to procedures on the way to the future construction of nanorobots or other complex nanomachines. The popular "nano-discourse" thus became familiarized with future potentials of nanotechnologies via futuristic images of the nanocosmos which mixed science fiction motives with representations of the inner spaces of the human body.[10] This mode of familiarization seemed to work quite well until the defuturization period.

In the defuturization period, the popular "nano-discourse" is confronted with a broad and increasing number of already marketable and often well-known products – such as coated and fireproof surfaces, speedy computer-chips, capsulated drugs or cleaning products – which are now labelled as "nano".[11] In this period

[10] For the analysis of the interplay between images of the outer space and the inner space in the nanocosmos, compare Nordmann (2004+2007).

[11] For a currently updated list of products see e.g.: http://www.nanotechproject.org/index.php?id=44.

it is probable that patterns of familiarization via futuristic images of the nanocosmos be replaced by visual patterns linking nanotechnology closely to present time. Futuristic images are not needed to produce meaning for nanotechnology's futures if "nanotechnology" is already recognizable in present products and developments. The message of the familiarization pattern of the futuristic images – "recognize nano by looking into the future" – is no longer necessary for meaningful communication if the new message corresponds to the current situation of developing more and more "nano-products": "Nano is already everywhere and can be done now".

The production of meaning in *economic* discourses always relies on the identification of marketability of future technological developments (Luhmann 1994). This identification is much easier if the products are seen merely as improvements of similar or already tried and true products rather than technological revolutions or radical innovations. A corresponding situation was evident around 2004, as the popular "nano-discourse" focused strongly on the successes in the development of nanomaterials and nanotechnologically optimized products, such as cosmetics, fireproof surfaces, capsulated drugs and so on. All these products had certainly already been topics in the popular "nano-discourse" since the late 1990s; but before 2004 these product developments were interpreted as being the first steps towards the "real nanotechnology", which was considered to be the actual construction of complex nanomachines.

At the same time as the dominating patterns of familiarisation were being changed in the popular "nano discourse", German research policy declared its traditional focus on the funding of material improvements to its guiding vision in its PR campaigns; for many years, this focus has entailed financial support in concrete areas of nationally relevant product development (e.g. electronics, automobiles, optical industries, life sciences) (BMBF 2004a: 28–33). Although research policy seems to be a combination of science and politics when viewed from Luhmann's systems-theoretical perspective, it really consists primarily of politics (Luhmann 1992: 639). Similar to economic discourses, the typical pattern of familiarization of political discourses consists of linking the future as closely as possible to the present. According to the code of politics "to have power/to have none", discourses in research policy try to reinforce decisions concerning the shaping of the future during a legislative period (Luhmann 1988: 180). Concerning a "nanotechnology" which is "already everywhere and can be done now", it is of course much more attractive to make political decisions which will have evident effects during the legislative period than those which might not have any effect on the foreseeable future, e.g. the funding of basic research for complex nanomachines.

The political funding of applied nanomaterial research and the form of mediating nanotechnology to the public via means of objectification implies an elimination of futuristic visions from popular discourses. So, it reinforces the economic interests in nanotechnology and corresponds to their forms of *calculating* the future potential of a new technology. It was precisely the economic assessments of nanotechnology's future potential, however, that already disconcerted scientific and mass media discourses in mid-2000 (i.e. the problematization of the nanorobot-visions) and evoked the scientific discourses *metaphorization* of the nanorobot-visions. The outcome of these transformations in communicating the futures of nanotechnologies was the hegemony of the economic pattern of familiarization, evident since 2004 as an increased economization of the popular "nano-discourse". The empirically observable phenomenon is a visual defuturization.

In this sense, the scientific discourses' metaphorization of the futuristic visions (as of 2002) was incited by the problematization of these visions by economic discourses (in mid 2000) and so made the popular "nano-discourse" as a whole see "novelty" and the "future" in already-existing technologies, products and developments. Since 2004 "novelty" is always integrated with something "old"; the future is everywhere in the present.

The contemporary future images used in the 2004 German research policy informational brochures visualize precisely this pattern of familiarization in an evident way: "Hidden Wonders" is the title of a future scenario depicting applications of nanomaterials in everyday life, published originally in the Siemens Corporation's magazine *Pictures of the Future* (Aschenbrenner 2003) and reproduced in the BMBF-brochure *Nanotechnology. Innovations for the World of Tomorrow* (BMBF 2004b, see Fig. 3).

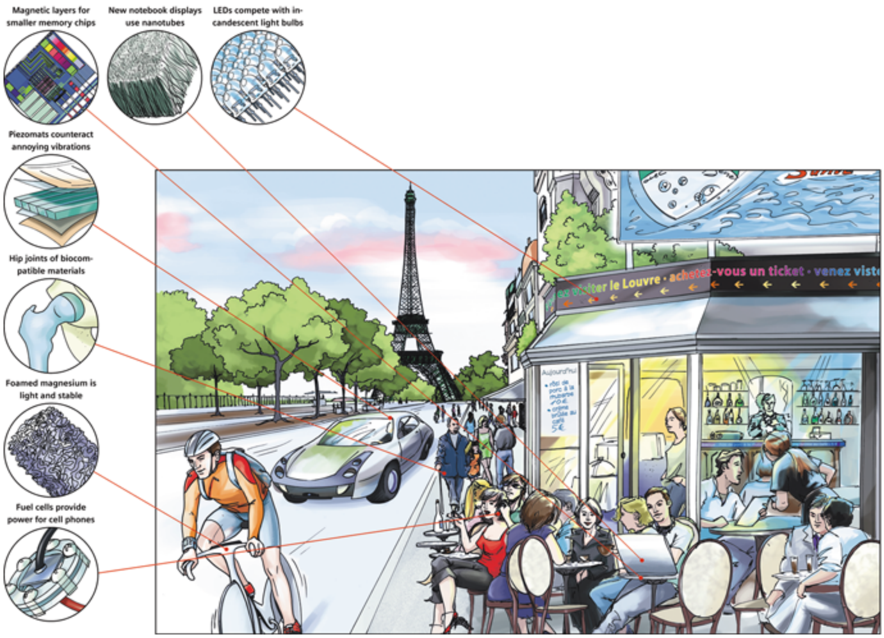

Fig. 3 "Scenario 2015 – Materials: Hidden Wonders" (Courtesy of Pictures of the Future, Siemens AG)

4.2 Images as the Powerful Drivers Behind the Familiarization Processes

Images are constitutive elements of the analyzed discourses; they are the discursive media (c.f. the concept of media in Luhmann 1992: 53–54). The specific depictions of the futuristic and contemporary or current images provide “loose linkings” between various elements of knowledge. From this ensemble of knowledge the different discourses produce “strict linkings” (ibid.) according to their discursive modes of producing meaning. The images are not only means *for* communication, they are constitutive means *of* communication on the material dimension of meaning. The images’ specific mediality becomes observable on the temporal dimension: the re-assessments of the future potential of nanotechnologies in the textual references of the different discourses to the images’ contents. In this sense the images constitute the phenomenon “nanotechnology” in a temporally “flexible” manner.

On the one hand, the images’ power is relative to their discursive context of use (c.f. Maasen et al. 2006, Mitchell 1986). On the other hand, this context – in our case the popular “nano-discourse” – is co-constituted by the discourses and the images, but differs depending on the visual patterns of the images. Dieter Mersch regards scientific images as “visual arguments” (Mersch 2006). My analysis extends this view from science to all societal domains in which images function as means of communication. Popularized images also serve as visual arguments of several discourses. Focusing on scientific images, Mersch makes a differentiation based on Hans-Jörg Rheinberger’s concept of “epistemic things” (Rheinberger 1997): He distinguishes between the visual image as *proof* and the visual image as *calculating figures* (ibid.: 97, similarly Sachs-Hombach 2003: 201–15). Both forms of visual images may be interpreted as modes of visualizing possibilities which enable relations between the discursive and the visual “worlds” (Deleuze 1987: 82). Both visual forms can be processed according to the modes of different discourses.

In the case of the futuristic images used in the popular “nano-discourse”, visualization functions primarily as an evident proof, e.g. for the feasibility or the fictionality of nanorobots in scientific discourses or for the novelty or tradition of the tiny machines in mass media discourses. In contrast, in economic discourses visualization is more important in its function as a figure for calculating the marketability and thus the market value of the depicted nanotechnological products and applications. Of course, visualization as a calculation is an important argument for science in the research context. In the popular “nano-discourse” science must provide evidence for the aims and potentials of nanotechnologies in a manner which is compatible with the rules of how the mass media usually presents science as a discovery of something genuinely new. In the context of the increased economization of the popular “nano-discourse”, it is thus not astonishing that contemporary future images replace the futuristic images of the undiscovered nanocosmos.

If we remember the original context of contemporary images of the future (See Figs. 2 and 3) we realize that these kinds of images are pictorial solutions of industrial calculation; they are, as the scenario designers point out, tools for industrial corporations to “systematically track down new business opportunities” by extrapolating “technologies and products of today into the future” and to “backtrack to the present from the “known” facts of the future scenarios” (Eberl 2001: 4–5). In contrast to the futuristic images, the contemporary or current images of nano-products and applications *hide* and *avoid* “wonders”. They have to make the future marketability of current investment-decisions evident. These images are the correlating visual pattern for the familiarization of nano-products in a period of increased economization of the popular “nano-discourse”.

Thus, the call for objectification in the BMBF-brochure *Nanotechnology conquers markets* (BMBF 2004a: 4–5) implies not only the replacement of futuristic nano-visions by economic (and not merely scientific) calculations of opportunities and risks. This recommendation corresponds to the fundamental time change of the visual pattern with which the popular “nano-discourse” familiarizes itself with the “future”. The futuristic images of nanomachines diving into the nanocosmos produced both: attention for the scientific discovery-projects by evident wonders of the nanocosmos *and* a new orientation via technologies at work in the nanocosmos (interpreted as a seductive invitation; see Nordmann and Schwarz, in this volume). The images serve the purpose of convincing the observers that there is an interesting new realm for research and that research is progressing successfully in that space. For the mass media they serve as evidence of a space in which the media can always detect any new information about nanotechnologies. After the image-shift, the dominant function of a visual pattern of familiarization is no longer to draw attention to and give orientation in an unknown space. Rather, the new pattern focuses on the familiarization of expected innovations via their economic calculation. The constitutive function of visual images to serve as a means of interdiscursive communication has switched from providing proof to enabling calculation. Economic calculation doesn’t like wonders: They have to exclude and hide the wonders.

5 Conclusion

The correlation between the increasing economization and the replacement of futuristic visions with expectations linking the future very closely to the present might be regarded as a standard phenomenon in the genesis of new technologies in modern societies. This familiarization process is a condition for successful societal implementation and thus for technological innovations in general. But the case of “nanotechnology” is especially remarkable for the following reason: when compared to other technologies like genetic engineering or information technology, “nanotechnology” represents a priori the result of interdiscursive processes. Depending on the temporal dominant discursive constellations, the multiple technological developments and products ascribed to “nanotechnology” can integrate non-existing future technologies and improvements on already-realized products, which would not be considered genuinely new if they were not also considered “nanotechnology”. Thus, in the case of nanotechnology one could observe much more frequent and closer couplings between discourses of different societal origins and a much stronger influence of the popular "discourse" – represented by the mass media – compared to previous cases of the shaping of new technologies.

In the interdiscursive field of "nanotechnology", the power of the visual patterns of images as a shared means of communication gets much more constitutional. The power of the images can no longer adequately be explained by differentiating the images solely on their original context of use – e.g. being merely scientific arguments in research contexts, being pure calculation tools for the in-house planning of corporations or being a means for popularizing science. The images combine all these functions in the constitutional popular "nano-discourse".

The phenomenon "nanotechnology" and the observed dynamics in its visual patterns of familiarization could be regarded as a prototype for the societal shaping of current new technologies in general. Nearly all new technologies are currently science-based technologies, that is, technologies developed in the context of societal application. The constitution of such technologies outside of heterogeneous communication in popular agendas is highly improbable. We could interpret the case of nanotechnology as guiding for the current era of economy, which accumulates profits by inventing the object of investment in a virtual manner. This invention depends fundamentally on discourses highlighting the new innovative subject in all of the older, already existing objects. Popular "technology-discourses" do this job quite well if they first put these wonders in the spotlight and then eliminate them at precisely the right time.

Furthermore it is remarkable that the corresponding defuturization and economization of the popular "technology-discourse" in the case of "nanotechnology" correlate with comparable dynamics in the expert-debates on the ELSI-topics of "nanotechnology". In the debates since the "Swiss Re intervention" in 2004 risk issues are no longer discussed in the context of futuristic visions of a revolutionary "nanotechnology". The risk discussion focuses ever more on the implications of the toxicity of nanoparticels in current nano-products and those expected on the market in the near future expected (See the analyses of Rip and van Ameron and Grunwald, in this volume). According to this shift, the assumed risks of "nanotechnology" are communicated as an important regulatory and investment issue, which requires the immediate development of an adequate regulatory framework and new modes of governance for embedding the current evolutionary developments and innovation processes of "nanotechnology". Among other new instruments of regulation, Codes of Good Practice – such as the *Code of conduct for responsible nanosciences and nanotechnological research* of the *European Commission* (European Commission 2008) – are expected to guarantee a responsible self-regulation of the development of new nanotechnological products, primarily by the industrial actors (c.f. Lösch et al. 2009).

Reflecting on both the defuturization of future expectations on "nanotechnology" of the popular "nano-discourse" on the one hand and of the ELSI-topics in expert discourses on the other hand, we can interpret the defuturization processes not only as a condition for an increasing economization by making the uncertain futures of "nanotechnology" calculable for investors; defuturization also seems to be a discursive tool for the production of “governable” nano-actors in industry and in the economy.

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Digital Matters: Video Games and the Cultural Transcoding of Nanotechnology

Colin Milburn

<<< NEW GAME SELECTED >>>
<<< LOADING >>>
"Please tell me the truth—are we still in the game?"/*eXistenZ*/1999/David Cronenberg/
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Virtually everywhere in contemporary discussions about the onrushing era of advanced nanotechnology, visionary scientists and technological forecasters rehearse the claim that reality as such will be rendered digital by this new technoscience. As nanotech theorist John Robert Marlow writes: "The coming Age of Nanotechnology might best be described as the Age of Digital Matter, for it will be a time in which it becomes possible to manipulate the physical world in much the same way that a computer now manipulates the digital ones and zeroes on its hard drive" (Marlow 2004). Masami Hagiya, a professor of molecular programming at the University of Tokyo, suggests that new nanotech methods are leading us into a world where "designing molecules and molecular systems is like programming electronic computers" (Hagiya 2004: 126). The nanoscientist K. Eric Drexler posits that nanotechnology, ultimately, "is about bringing digital control to the atomic level and doing so on a large scale at low cost. . . . This methodology, led by molecular simulation, will be at the heart of the engineering process that will lead us forward into this new world of technology" (Drexler 2004). J. Storrs Hall, a Fellow of the Molecular Engineering Research Institute and co-founder of the nanotech company Nanorex, has put it even more succinctly: "One way to sum up nanotechnology is that it will make matter into software" (Hall 2005: 271).

While such statements are characteristic of postmodern technocultures in which the computer serves as a primary conceptual tool and a privileged metaphor, they also indicate certain epistemic features of nanotechnology and the extent to which this forward-looking science comprehends our lived realities as increasingly orchestrated by computational processes and processors: codes, programs, hardware, software, wetware. Despite their figurative qualities, these claims are not purely tropological or rhetorical, for the researchers involved in such discussions are quite

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literal about their goals. For example, the multi-institutional nano project "Digital Matter?: Towards Mechanised Mechanosynthesis", which launched in 2008 under Philip Moriarty at the University of Nottingham, presents its agenda for "digital matter" – a concept whose suspension between metaphor and metonymy, virtuality and actuality, appears as an open question – to involve turning this point of interrogation towards a truly pointillistic future: "Computer-controlled chemistry at the single molecule level, a field very much in its infancy, represents arguably the most exciting and, to many, definitive example of the power and potential of nanotechnology. . . . Our goal is to programme the assembly of matter from its constituent atoms. This exceptionally challenging objective has the potential to revolutionise key areas of 21st century science" (Moriarty 2008). The trope of digital matter as open question, as nothing otherwise than virtual, turns around to *potentialize* a scientific revolution: the present fiction of computer-controlled precision chemistry entrains a completely digital world, where matter can be broken down into its most discrete component parts and recoded differently. In the words of the nanoscientist Ralph Merkle: "What the computer revolution did for manipulating data, the nanotechnology revolution will do for manipulating matter, juggling atoms like bits" (Merkle 1992).

Such performative accounts of digital matter strikingly instantiate what N. Katherine Hayles has called the "Regime of Computation": the emergent technoscientific worldview in which "code is understood as the discourse system that mirrors what happens in nature and that generates nature itself" (Hayles 2005: 27). Under the Regime of Computation, the algorithms employed by human-created computer simulations become increasingly interpreted as commensurate with those that generate the universe itself – imagined to be a vastly powerful information machine running codescripts at the very limits of material existence (Lloyd 2002, Wolfram 2002) – and matter becomes everywhere subject to the interventions and controls of programming languages. As Hayles writes: "For scientists making the strong claim for computation as ontology, computation is the means by which reality is continually produced and reproduced on atomic, molecular, and macro levels" (Hayles 2005: 3).

Symptomatic of the Regime of Computation, nanotechnological visions of the coming Age of Digital Matter suggest that, at a certain level – the level of nanoscale phenomena – there is no absolute difference between materiality and digitality. Enframed by nanotech operations, matter at the nanoscale would seem to become discontinuous, modular, and combinatorial, governed by quantum source-codes that can now be "hacked" (McCarthy 2003). Nanotechnology envisions, or rather discovers that the world has always been digital, and therefore endlessly reprogrammable (Baldwin 2001, Thacker 2004: 115–140). As technicians of digital matter, we would then be able to modify our environments, our bodies and our societies with the seeming ease of modding a computer program. This fantasy of digital matter lures nanotech research and development from today's primitive techniques into the speculative future. For instance, in the case of Jim Von Ehr, the founder of the nanotech company Zyvex, his "background as a software entrepreneur led him to the realization that Atomically Precise Manufacturing – creating "digital matter" – could become a huge new opportunity to manufacture products better, faster, and cheaper than any previous technology" (Zyvex 2008). "It intrigues me," Von Ehr has said, "to do for the world of atoms what software has done to the world of pixels and bits. The attraction of molecular nanotechnology to a lot of software people is that we're used to creating virtual worlds starting with an idea and instantiating that in pixels and bits. It's fascinating to think that we might have the tools that help us instantiate that in the world of atoms. Because we're made of atoms" (Von Ehr in Lovy 2007). According to the discourse of digital matter, then, there is no longer any meaningful distinction between an atom and a bit, a chemical reaction and an algorithm, an organism and a program – or indeed, real life and video game.

With the coming Age of Digital Matter as a background assumption, an epistemic grid or circuit upon which much current research operates, it is no wonder then that many nanoscientists already interact with the nanoscale world as if playing in a video game world. In 1991, the computer scientist Warren Robinett, then at the University of North Carolina at Chapel Hill, together with the chemist R. Stanley Williams, then at UCLA, invented a "NanoManipulator" – a device that joins a scanning probe microscope to a virtual reality environment, decked out with a stereoscopic head-mounted display, a joystick controller, and a haptic interface in the form of a force-feedback arm (Robinett et al. 1992, Sincell 2000). This technology for exploring atomic surfaces and manipulating molecular objects was designed as a "real-time immersive virtual-world interface to [nanotech] instruments," transforming measured scientific data into a navigable computational environment (Taylor et al. 1993: 127). The project evolved over several years under direction of the computer scientist Russell M. Taylor (who initially implemented the system as his Ph.D. dissertation project [Taylor 1994]), with early contributions from the computer scientist Frederick P. Brooks, the physicists Richard Superfine and Sean Washburn, and several other colleagues at UNC-Chapel Hill. Today, the NanoManipulator system and its commercial descendents (such as those now manufactured by 3rd Tech and Zyvex) enable scientists everywhere to plunge into a simulacrum of the nanoscale world and experiment in real time, maneuvering atoms by maneuvering pixels.

Which is why experimenting with a NanoManipulator often seems like adventuring inside a computer-generated playground; as Washburn has noted, "It has a lot of the same things you see in fancy arcade games" (Washburn in Caudle 2000: 3). Certainly, visitors to NanoManipulator labs have regularly commented on such similarities. For instance: "The nanoManipulator multiplies the visualization and control [of molecular systems] nearly one million fold, so that researchers can interact with a system as if they were playing a video game" (Simon 2001: 36). Or likewise: "The nanoManipulator works much like a virtual-reality game" (House 1998: 1). Or yet again: "Say you've got a nifty nanoscale object that you want to look at, test, or just play with. . . . You need a special tool called a nanomanipulator. . . . Movements can be controlled . . . using joysticks, just like a videogame, and the nanomanipulator uses a PC interface" (Edwards 2006: 60–61). Other examples abound. Moreover, several former members of the UNC NanoManipulator research team, including

Jason Clark, Mark Finch, and Tom Lassanske, have since moved on to prominent careers in the commercial video game industry. The NanoManipulator tool therefore seems totally enmeshed in the aesthetics and social networks of gaming culture.

And no wonder: Robinett's original conception of the NanoManipulator as a "virtual-world interface" was indebted to his own long association with the video game industry and its overlap with Virtual Reality research. Between 1977 and 1979, Robinett worked for Atari where he created the game *Slot Racers* (1978, Atari), as well as the blockbuster *Adventure* (1979, Atari). In 1980, Robinett left Atari to co-found The Learning Company, a venture into educational software, where he designed a graphical adventure game about logic circuits, *Rocky's Boots* (1982, The Learning Company). He shortly thereafter joined fellow ex-Atari programmer Scott Fisher on the Virtual Environment Workstation Project at NASA Ames Research Center. Moving to Chapel Hill in 1989, Robinett translated elements of those virtual worlds he developed at Atari, The Learning Company, and NASA for the collaborative nanoscience projects ongoing at UNC, which eventually evolved into the NanoManipulator design (Rheingold 1991: 22–37, Lenoir 2000: 298–299). As Robinett explained in 1991, around the time he and Williams were first considering how to link up VR games with real nanotech instruments:

> [I]t has only been recently, after video games and educational software were established industries, that the scientific world has accepted the idea that computer graphics can help them understand their piles of numbers. This is now called "scientific visualization." It took scientists over a decade to see what was obvious to every kid the first time he touched a video game—the power of interactive computer graphics. (Robinett in Rheingold 1991: 24).

Today, the power of scientific visualization to make sense of data and turn "piles of numbers" into sensory experience has become indistinguishable from the peculiarly haptic quality of the video game, this bodily engagement with the video game that Robinett aptly describes as "touch." While in 1994 the controls for the NanoManipulator involved a QuickShot Python joystick (created for the Nintendo Entertainment System), the joystick's lack of native force-feedback required supplementation with a customized force-feedback arm in order to "feel the [molecular] surface" and produce a fully haptic experience (Taylor 1994: V.4). Yet by 2003, researchers from the Institut für Kristallographie und Angewandte Mineralogie at Ludwig-Maximilians-Universität (LMU) Munich were able to simply purchase a "commercial force-feedback joystick (FFJ), originally designed for computer games," and refit the device directly to an atomic force microscope (AFM) (Rubio-Sierra et al. 2003: 903). They thereby built their own nanomanipulator for immersive interaction with real molecules – in this case, human chromosomes – by virtue of off-the-shelf video game equipment. The chosen joystick was the Logitech "Wingman Force", which employs a series of motors to transmit forces to the player's hand. Working with Microsoft DirectX (a suite of application programming interfaces for developing computer games), the nanoscientists created a software system for producing a scalable force along the joystick whenever the scanning tip of the microscope runs into DNA. Operators use the analog joystick to navigate the digital terrain mapped out by the AFM and to play with any chromosomes encountered during the journey.

Although this improvised nanomanipulator generates media images by physical interaction with the real molecules of the sample, operators interact with the instrument in precisely the same way as they would interact with the video game system upon which it is based. And as users of various nanomanipulators have discovered, the "nanomanipulator experience" remains identical even when the probe microscope is disconnected and the system runs from data stored on disk (Taylor et al. 1993: 131). In fact, training with a nanomanipulator in its "off-line user interaction mode" teaches the user how to work with molecular material in the form of an endlessly rebootable "realistic nanoworld":

> [T]he use of physically based simulation techniques of 3D multi-body nano-systems would enhance the operator's skills by learning and feeling a realistic nanoworld in an off-line user interaction mode. Then, by practicing the adequate gesture through trial-and-error schemes, the operator would be able to reproduce the nanomanipulation tasks in a real environment (Sharma et al. 2005: 12).

Repetitive play (trial-and-error) inside the "realistic nanoworld" – that is, inside the simulation – shapes the operator's encounter with the belated "real environment" of the molecular sample. Nanomanipulation is comprehended in advance as "reproduc[tion]" of gestural "tasks" already mastered in offline mode, as programmable ludic behavior. The analog processes of the body – movements, affects, sensations – are thus entrained by digital processors, aligned and coordinated together with the software code that produces the graphical atomic landscape of the "realistic nanoworld." Which is now more real than the real. For the so-called "real" environment then becomes just a repetition of the computational playspace, a "reproduction" or simulacrum of the virtual: *the nanoworld reloaded*. The virtual-world interface as the site of nanotechnological investigation, the site of nanoscale access, is therefore the recreational matrix wherein reality is reprogrammed and matter itself is digitized, rendered nothing otherwise than digital.

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"If real is what you can feel, smell, taste and see, then 'real' is simply electrical signals interpreted by your brain."/*The Matrix*/1999/The Wachowski Brothers/
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Already, then, video games are deeply entangled with the ongoing evolution of nanoscale sciences and technologies. As we see, the software applications used for molecular visualization and 3D-rendering are the same as those originally invented for robust video game graphics. For instance, the NanoRule+ imaging program for scanning probe microscopes developed by Pacific Nanotechnology in Santa Clara, California, "incorporates a versatile set of visualization functions such as rendering, texture mapping, and special effects, which have [heretofore] been used to great effect in video games" (West and Li 2003: 24). Likewise, the simulated molecular systems studied by computational nanoscience – in many ways the leading edge of the field (Johnson 2006, Winsberg 2006) – rely on algorithms and physics engines characteristic of those driving interactive gameworlds. Such complex nanosimulations require processing capabilities available only with massive supercomputers or Beowulf clusters – or more conveniently, it turns out, consumer video game platforms. Consider the GAMESS (General Atomic and Molecular Electronic Structure System) application, a powerful code package for ab initio simulation of quantum chemistry and nanoscale intermolecular dynamics (Schmidt et al. 1993). At the University of Illinois at Urbana-Champaign, chemist Todd Martinez and his colleagues have been playing GAMESS on hacked Sony PlayStation 2 units, a research procedure they describe as "hijacking game consoles for molecular modeling" (Martínez and Patel 2003). As Martínez writes:

> [T]he fact [is] that gaming and computational chemistry applications have significant overlap. This last point means that one can conceive of obtaining higher performance from a COTTS [commodity-off-the-toy-shelf] strategy than would be possible using [Beowulf] clusters of x86 processors. Indeed, this is already the case today, with the Sony PlayStation 2 outperforming some of the fastest Pentium-III processors, at least for computational linear algebra (Martínez 2003).

At the levels of both hardware systems and software applications, the "overlap" between nanoscience and gaming would hence appear to be quite thorough, at least as far as their technical features are concerned: fellow travelers under the technoscientific Regime of Computation. Of course, all the while that these various fields of nanoscience have been absorbing and remodeling instruments and images from gaming culture, consumer video games such as *Obsidian* (1996, Rocket Science Games), *Total Annihilation* (1997, Cavedog Entertainment), *Xenogears* (1998, Squaresoft), the *Metal Gear Solid* series (1998–2008, Konami), *System Shock 2* (1999, Looking Glass Studios, Irrational Games), *Deus Ex* and *Deus Ex: Invisible War* (2000, 2003, Ion Storm), the *Red Faction* games (2001, 2002, Volition), the *Ratchet & Clank* series (2002–, Insomniac Games), the *X-Men Legends* games (2004, 2005, Raven Software), *James Bond 007: Everything or Nothing* (2004, Electronic Arts), *Nano Breaker* (2005, Konami), *Project: Snowblind* (2005, Eidos), *NanoQuest* (2006, Discover Science + Engineering), *Geckoman* (2007, Metaversal Studios), *Alien Syndrome* (Wii Version) (2007, Totally Games), the *Crysis* saga (2007–, Crytek), *NanoMission* (2007–2008, PlayGen), and many others have been proliferating plotlines and concepts inspired by nanotechnological predictions of programmable matter.

These various modes of cross-traffic between the worlds of nanoscience and the worlds of video games – exchanges of specific technologies, narratives, images, and patterns of conditioned response for human-computer interactions – mediate the way that both scientific and popular cultures understand and deliberate nanotechnology. Commercial gaming platforms, including personal computers as well as consoles like the Sony PlayStation and the Microsoft XBox, offer popular entertainments while at the same time lending themselves directly to the technical research agendas of those laboratories seeking to develop instrumental controls in an imagined digital realm of materiality, transcoding the molecular as the computational, reality as software. These same gaming systems provide audiences with narrative media objects and opportunities for interacting with programmable matter that reinforce certain epistemic features of nanoscience, conditioning in advance the social reception of our molecular future.

For if some scientists are currently incubating the Age of Digital Matter inside their laboratories by using video game technologies, learning how to interact with the nanoworld through computer simulations and joysticks, it seems evident that video games have strong potential for both modeling and molding our comprehension of nanoscale phenomena and nanotech systems. To be sure, consumer video games increasingly feature simulations of nanotechnology, and I argue that as consumers of these media objects play with them, learning how to manipulate virtual nanoworlds in a way that is phenomenally analogous if not even functionally indistinguishable from the way scientists are doing so with real nano instruments, contemporary culture is training to anticipate and use nanotechnology – programmable atoms, digital matter, and nano-computational environments – already in the present.

Video games enable consumers to play with advanced nanotechnologies and prepare for their cultural impact in ways that go far beyond the psychological effects of mere representation, for gamers experience fictive nano through an immersive virtual-world interface that turns digital matter into sensory experience. Here, data is made flesh – quite literally. At the intersection of user and digital media we find the body-in-code, as Mark Hansen has argued: the "body whose (still primary) constructive or creative power is expanded through new interactional possibilities offered by the programs of 'artificial reality'" (Hansen 2006: 38). Through interacting with the video game world, the user's body-scheme expands to both enter and enfold the artificial environment, generating its lived dimensions through motor action and tactile manipulation, giving it being through embodied engagement.

For video games are not representations, or images, or narratives, or codes, or sets of rules, per se; rather, as Alexander R. Galloway puts it, "*video games are actions*. . . . Video games come into being when the machine is powered up and the software is executed; they exist when enacted" (Galloway 2006: 2). The video game is an event that takes place across the biomechnical assemblage formed by the user's body, the hardware system and the software program. The embodied event of gameplay-as-action confers a phenomenal worldness onto the codes and computations that underwrite the virtual-world interface. Hence those nanotech objects encountered in video games, as with nanoscale objects encountered in the scanning explorations of a nanomanupulator or the software simulations of computational chemistry – as nothing otherwise than digital – are given form by the body as focalized components of an entire worlding-event. A physical materialization of the as-yet virtual. An enfleshment of vaporware. The Age of Digital Matter means that even as matter is rendered digital, so is the digital rendered matter in that space common to nano research and video game culture, the space of worlding between active body and computational system.

The power of video games for shaping nanotechnology can therefore hardly be underestimated, either conceptually or socially. The worldwide profits for the video game industry now rival the profits of Hollywood films and dwarf the proceeds of printed books. So when a video game features nanotechnology as either representation or ludic element, this nano-thing reaches a vast audience. Moreover, it is well known that video games are exceptionally good at training audiences for certain behaviors or patterns of conditioned response to given situations (Penny 2004). Airlines routinely train pilots on flight simulators, and military units routinely train soldiers with combat simulators created by professional gamemakers or even adapted directly from commercial video games (Lenoir 2003). For example, during the 1990s the US Marines trained on modded versions of the games *Doom* and *Doom II*, while more recently the Unreal Engine created for Epic Games' *Unreal* (1998) became the core of the frighteningly successful networked recruitment game *America's Army* (2002), distributed online as freeware by the US military (Riddell 1997, Lenoir 2003, Galloway 2006: 70–84). These interactive media achieve effective results with fewer risks and costs than analogous real experiences. So learning how to interface with nanotechnologies and nanoscale environments via computer games – like learning how to interface with aircraft or assault weapons – makes the issue of "fiction" or "nonfiction" practically irrelevant: equivalent emotional and proprioceptive responses to those technologies can be inculcated by purely simulated, fictive gameworlds. This is precisely why an interdisciplinary team of nanoresearchers in Grenoble have recently written that, "if the nanoworld is our chosen playground" for scientific development into the foreseeable future, then the necessary social task of training citizens to have an intuitive, embodied, everyday understanding of nano can be accomplished in two ways: "One way to develop this ... can be based on real nanosensors and nanoactuators. Another approach is to use virtual environments which can offer the nanoworld to us through real time multisensorial interfaces. This can dramatically enhance possibilities for easy exploration of remote realities foreign to our senses and can trigger a spontaneous motivation of the user similar to the one observed in video game player[s]" (Marlière et al. 2007: 2). In other words, virtual worlds that expose users to sensational encounters with nanotechnologies both train and motivate, providing a feel and a taste for nano, a consciousness and tacit awareness of nano and its manifestations, even in advance of its manifestations. In many ways, of course, this means that the distance between the digital matters of today's computer culture and the digital matters of the completely programmable future has already collapsed.

<<< LOADING >>>
"Games? You want games? I'll give you games."/*TRON*/1982/Steven Lisberger/
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So let's look at a few examples of video games that offer nanotechnologies for players to engage, examining the ludic and semiotic strategies through which they body forth digital matter. There are dozens of consumer games produced in the United States, Japan, Europe, and elsewhere that showcase ostensibly fictitious nanotechnologies while simultaneously plugging into the contemporary discourse of professional nanoscience and its visions of the future. For example, the recent *Nano Breaker* (2005), developed for the PlayStation 2 by the Japanese company Konami, projects a bleak virtual world that, albeit fantastic and wildly metaphorical, conjures connections to real developments in nanoscience funding and government policy – specifically, the formation of the U.S. National Nanotechnology Initiative in 2001 – thereby blending its science-fictional plotline with nonfictional topical references. The game opens with a startling animation sequence, overlaid with the following text/voice narration:

> In the year 2001 AD, the United States Government constructed an experimental island in response to the National Nanotechnology Initiative (NNI). They named it "Nanotechnology Island" and it was there they assembled the finest American analytic minds from every field—Business, Government, and Education—to form a united research project committed to unlocking the untapped potential of nanotechnology. With unlimited access to the world's most advanced scientific technology and a massive amount of government funds, advances in nanotechnology occurred at a startling rate over a short span of time. Twenty years passed. Concepts and machines that were considered fantasy in the 20th century were, one by one, becoming a reality. These new technologies were made available to the general public, causing drastic improvements in lifestyle on a global scale.
>
> Then, one day, the main computer regulating all the island's nanomachines suddenly went out of control. Every nanomachine on the island malfunctioned, from those in the research labs to the "ID Nanos" embedded in the bodies of the island's residents for identification purposes. Thus occurred the tragic birth of the "Orgamechs", living mechanical organisms whose bodies are comprised entirely of microscopic machines, from the molecular level on up (Nano Breaker, "01.Prologue").

In this game, the player faces nanotechnology as an out-of-control threat, but at the same time, the hero-avatar of the game – the "cyborg militant" Jake – relies on experimental military nanoscience for his offensive weaponry. Progressing through *Nano Breaker* involves discovering that nanotechnology might have devastating global consequences, but also that it is the most powerful and versatile tool for dealing with its own catastrophes. For instance, to combat the "Nanos" taking over Nanotechnology Island and producing the hideous Orgomechs, the player must learn (via complex button combos) to adapt Jake's native cyborg systems to the programmed applications of a "Plasma Blade", which, like a nanomanipulator, gives the player direct (and violent) access to molecular structures: "It's a new type of weapon we call a 'Plasma Blade.' Using this, you'll be able to destroy anything, down to the molecular level" (*Nano Breaker*, "O4.Jake"). Whenever Jake's Plasma Blade destroys nanomechanical components of the Orgamech bodies, the player sees nano "oil" splatter copiously across the screen, while distinctive auditory cues erupting from the speakers signal successfully executed strikes; moreover, during close combat with the Orgamechs, the vibration function of the PlayStation 2's DualShock controller whirs to life in the player's grasp, haptically transducing Jake's brutal contact with programmable matter.

Digital molecules disintegrate under the edge of our simulated nanotech instrument, and we see their dissection, we hear them, and we feel them in our own flesh. The tangible splatter and spray of nanomachines in this game might therefore be seen as giving a wicked new twist to Ian Hacking's famous condition for scientific realism about theoretical entities: "If you can spray them, then they are real" (Hacking 1983: 22). After all, through such video game acts of "nano breaking" we attain a recreational familiarity with the phenomenal dimensions of theoretical nanotech, even as nothing otherwise than digital. At the level of the biomechanical assemblage, within the transcodings of hardware-software-wetware, the digital comes to matter in every sense.

In science, as in fiction. The researchers at LMU Munich, when dissecting human chromosomes with their ersatz nanomanipulator, reported that the modified video game interface enabled them to observe and to feel the cuts being made by the instrument, down to the molecular level:

> Human metaphase chromosomes were ... mechanically dissected using a stiff cantilever and the manipulation interface [the nanomanipulator]. ... Two cuts in opposite directions were made using the positioning joystick for sample positioning, and the FFJ [force-feedback joystick] for adjustment of the loading force. The user obtained an interactive feedback of the applied force through the FFJ. ... The chromosome was totally microdissected and a chromosomal fragment was extracted (Rubio-Sierra et al. 2003: 905–906).

Here, it would seem, we find another kind of "nano breaker." Whether in the form of a Plasma Blade or a nanomanipulator, the virtual-world interface literally sensationalizes the *analysis* of nanoscale matter; we come to understand its properties, its responsiveness, its structure, its resilience, ultimately through its breakage – or rather, its digitization. Through mediated prehension, as if reaching "down to the molecular level" and stressing chemical bonds past their limits – thereby participating in a certain cultural logic of experimentation where "to dissect" is "to know", where "to break" is "to see" (Waldby 2000, Stafford 1991, Virilio 1989) – we encounter the nanoworld via discrete performances of "total microdissection", resonating here with the incessant microdissections that constitute hack-and-slash video games. In *Nano Breaker*'s staging of the Age of Digital Matter, over-the-top video game violence emerges as a metonym for the microdissections of digitization as such: the disintegration of the analog into measurable units, the slicing of continuous differentials into manipulable parts. For the fantasy of digital matter, after all, is ultimately about the transformation analog matter into "bits," where the computational sense of "bits" as binary digits overlaps entirely with the corporeal sense of "bits" as matter broken – or rather, in its predatory undertones, "bitten" – apart. Through the "nano breaking" of matter, the digital rendering that enables its translation into visual graphics and force-feedback controllers, we enact our prehension of the nanoworld, reaching down to the molecular level and feeling its vibrations and tensions, biting into it and getting a taste for it. The extreme violence of *Nano Breaker*'s gameplay, its repetitive cycle of excessive molecular dissection, becomes an allegory for the processes of nano-digitization whereby matter is made data and data is made flesh, brilliantly aligning with its narrative conceit that these technical processes of the Age of Digital Matter are also social, through and through.

For the social dimensions of nanotechnology are rendered equally palpable by the exaggerated splatter-horror of *Nano Breaker*. In a twist ending, it turns out that the Nanos did not go out-of-control on their own accord, but were caused to do so by a power-hungry American military general. The general monologues only moments before the climactic final "boss battle":

> Orgamechs are the next generation . . . And now I control them! And with this power, I will force all those before me to bend to my will! The whole planet, at my finger tips! . . . Do you really think a mere computer malfunction could lead to such perfect results? . . . It was within my authority to intentionally corrupt the main computer. . . . Everything has gone according to my plan (*Nano Breaker*, "19.Boundless Ambition").

The governmental funding initiative driving Nanotechnology Island in this game – namely, the NNI – here seems to be guided entirely by military investments and presided over by monomaniacal military officials; as one scientist in the game says:

> With the help of a huge government subsidy, [the nanoscientist who invented self-replicating nanomachines] was able to turn his dream into a reality on this island. I should have known the military was behind it (*Nano Breaker*, "14.Human Quality").

While the motive ascribed to military investment in nanoscience – global domination, or rather, *global digitization* ("The whole planet, *at my finger tips*") – resembles the hyperbolic plots of superhero comics more than realistic social critique, *Nano Breaker* nonetheless renders certain political conditions surrounding nanotechnology into playable format. After all, the US Department of Defense currently controls more than a quarter of the entire budget of the NNI, and military subsidies are indeed propelling advances in basic nanoscience around the world (Altmann 2006). So although this game features nanotech as an agent of apocalyptic horror, such (im)possible dangers are construed – or played – entirely as symptoms of ideology, situating the technology itself within a broader political context that must be understood and, in this case, withstood, for the sake of a peaceful future (that is, successful completion of the game).

Therefore, *Nano Breaker*'s shocking irrealism turns out to transcode an incisive social realism – it foregrounds and critiques the social ideology structuring its virtual world and implies metaphorical or affective congruence with its "exterior" social context (Galloway 2006: 70–84) – suggesting that what is actually "broken" when playing *Nano Breaker* – what is broken down, dissected, or analyzed – is less nanotechnology itself than the cultural conditions that even now make certain nanofutures available while foreclosing others.

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"You know what they say—you play the game too long, you start seeing shit and having seizures."/*Stay Alive*/2006/William Brent Bell/
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Nanotech video games typically depict their cutting-edge tools for rebuilding matter from the bottom up, for "reshaping the world atom by atom" (National Science and Technology Council 1999), as embedded in the political narratives of the virtual worlds in which they exist, but whose particular uses – ethical or otherwise – are not determined in advance. These cybertexts are ergodic in the sense that "non-trivial effort is required to allow the reader [or player] to traverse the text" and to comprehend the technocultural systems simulated within them (Aarseth 1997: 1). They require real labor, time, coordination and intellectual engagement (as well as indefatigable finger muscles!) to complete. As an effect of all this work and bodily fatigue, we become, for a time, inhabitants of the synthetic space; we learn to master its algorithmic rules, navigate its graphical terrains, acclimate to its politics, and adapt to its mythologies. In that space, we already live the Age of Digital Matter, and we come to intuit its possibilities – its promises and its threats – through action and experiment.

For example, the politically paranoid game *Deus Ex* (2000), developed for Windows and Macintosh by the Texas-based Ion Storm and later ported over to PlayStation 2 as *Deus Ex: The Conspiracy* (2002), requires nearly one hundred hours of playtime to complete, as well as a high level of literacy and a willingness to learn a good deal of information about various speculative sciences – especially molecular nanotechnology – in the process. In this game, corrupt governments use nanotech to design devastating plagues for purposes of war, while their own citizens must combat these forces by using protective nano. The player's avatar in this game, J.C. Denton – a former security agent turned against his conspiratorial government – has been cybernetically augmented with a variety of nanotech body-implants. These "nano-augs" provide J.C. with superhuman powers that enable him to unravel the conspiracy and deliver the future from corruption (hence, his overdetermined initials).

Although formally this game is a first-person shooter, *Deus Ex* actually relies on the player resisting the urge to fire weapons at all times and instead encourages stealth, covert surveillance, and the use of nano-tools. Certainly, the game offers players a huge arsenal of assault weapons, but we are more frequently asked to interact on an intellectual level with the gameworld to successfully restore order to global society. For instance, we must gather clues for scientific textbooks and databases to learn the rudiments of molecular nanotechnology and the mechanisms of the nano-plague.

In addition to learning from remediated didactic sources like textbooks and technical authorities, we also gain recreational knowledge of several possible forms of advanced nano through play. As we progress through the game, we upgrade our own nanotechnologies in various ways. A player learns to use different nanosystems embedded in the body or discovered in the gameworld strategically and sensibly – the game does not reward hack-and-slash tactics but rather demands that we use nano to observe, to escape, to heal, to communicate, to infiltrate databases and to interface with a wide variety of mechanical and computational systems. For example, the player might choose to learn how to build a nanomachinic "Spy Drone", which can scout ahead for dangers or electronically disable other digital systems:

> Advanced nanofactories can assemble a spy drone upon demand which can then be remotely controlled by the agent until released or destroyed, at which point a new drone will be assembled. Further upgrades equip the spy drones with better armor and one-shot EMP [electromagnetic pulse] attack (*Deus Ex*, "Augs: Spy Drone [Cranial]").

This drone becomes a nano-prosthetic extension of the player's eyes, ears and hands into the virtual world of *Deus Ex*; or rather, it is a prosthetic of a prosthetic, an avatar of an avatar, for it emerges physically out of J.C.'s head (assembled by his cranially-embedded nano-augs) and feeds data directly into J.C.'s HUD. It is a second-order extension of the virtual-world interface which seems to put the nanosystem directly into our hands. We maneuver the nanotech drone with our console, we teleoperate its controls and see through its visualization system. But the functionality of the drone is limited by both our own skills as operators of the gaming system as well as the software parameters available to J.C. at this point in the game (that is, the avatar's "tech level" for the drone, a mathematical variable of the program). In other words, our encounter with this nanosystem is designed to draw attention to the interface itself: the second-order avatar makes visible the limit or threshold of the worlding-event taking place between the computational activities of the console and the player's sensorium. We experience nanotechnology precisely as the foregrounded computational interface, the screen in all its senses. The game self-reflexively insists that nano materializes or presences only at the level of the terminal display whose transparency is the condition for teleoperation, telepresence, but whose inevitable intercession means that we encounter nanomaterial as nothing otherwise than digital, as always mediated or screened by the technological instruments and the technosocial systems that bring it forth and make it accessible to our eyes, our hands, and our imaginations.

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"Then you could throw yourself into a highspeed drift and skid, totally engaged but set apart from it all, and all around you the dance of biz, information interacting, data made flesh in the mazes of the black market."/William Gibson/*Neuromancer*/1984/
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The capacity of video games to program the nanofuture has not gone unnoticed by nanoscientists themselves. In the United Kingdom, software developer PlayGen has teamed up with the nanotech consultancy company Cientifica (www.cientifica.eu) as well as nanoscientists Mark Welland (Professor of Nanotechnology, Director of the IRC in Nanotechnology and Director of the Nanoscience at the University of Cambridge), Richard Jones (Professor of Physics at the University of Sheffield), and Wolfgang Luther (head of nanotechnologies at VDI – The Association of German Engineers), to produce the video game *NanoMission*, designed as an educational and recruitment tool for nanotechnology:

> Our aim is to inspire some of the brightest teenagers about the world of nanotechnology, potentially opening their eyes to choosing it as a career. Aimed at 12–18 year olds, NanoMission™ is an engaging learning experience which educates players about basic concepts in nanoscience through real world practical applications from microelectronics to drug delivery. . . . The key factor in the project is a firm grounding in real scientific facts and knowledge played out in an imaginative and exciting game world. As a result of close interactions with the scientific community, the game provides the most accurate three dimensional view of the nanoworld ever produced, which will help shift public opinion away from nano submarines and robots to a more realistic view of nanotechnologies (PlayGen 2007a).

NanoMission seeks to enlist young people to participate in shaping the nanofuture by separating "real scientific facts" and "real world practical applications [of nanoscience]" from fanciful notions of nanosubs and nanobots. As Kam Memarzia, PlayGen's managing director, puts it: "Working with the scientific community has enabled us to develop *NanoMission* based on real science rather than science fiction . . . We firmly believe computer games have a far greater role to play in today's society, especially in promoting learning & understanding the real world around us" (Memarzia in PlayGen 2007b). It would appear, then, that the simulated nanoworld of *NanoMission* and the fictive plotline animated within it – fighting the nefarious Dr. Nevil and his nanomachines – make "the real world" newly comprehensible.

In this game, players learn "real science" by passing through various adventure levels designed to educate about nanoscale imaging, nanomanipulation, nanomaterials, nano-electronics, molecular self-assembly, quantum theory and quantum computing, and several kinds of nanomachines. In the first demo level released in January 2007, the player must use nanomedicine to battle cancer (caused by Dr. Nevil) inside the human body. This first level of *NanoMission* is quite similar in design to other nanomedicine video games such as *Re-Mission* (2006, HopeLab), which align themselves with speculative visions of medical nanobots and nanosubs traveling through the human bloodstream (Nerlich 2005, Lösch 2006). But *NanoMission* rejects these speculations in favor of more "realistic" nanomedicine. The prefatory text to the nanomedicine module describes one of its "learning objectives" as "[d]ispelling the myth of small mechanical robots inside the body":

> Many of the early ideas about nanotechnology were based on the idea that simple mechanical structures could be built at the nanoscale using atoms as building blocks. These structures would, in theory, be able to operate very quickly and with high precision. However, many of the proposed devices would not actually work on this scale as chemical forces, viscosity and Brownian motion are the dominant forces in the nanoworld, rather than friction and gravity which we all are more accustomed to in our daily lives.
>
> As a result, designing any machine to operate in the body requires a rather different approach from simply shrinking a submarine to the size of a pinhead as happened in the film "Fantastic Voyage" (*NanoMission*, "Nanomedicine," 2007).

Even inside the game, the nanoscientist Professor Goodlove jokingly discusses the fantasy of a nanosubmarine in the veins, dismissing this idea as impossible: "This isn't a science fiction film, you know!"

Ironically, though, the central conceit of the game – the very conceit that makes this game playable – is itself a science fiction. For like *Re-Mission*, *NanoMission* gives the player a navigable nanoscale avatar to guide through the human body towards the site of the cancer. The Professor tells us:

> We must attack the cancer cells inside [the] body at the molecular level, by delivering cancer-killing molecules at the site of the cancer. . . . These molecules are highly toxic, they will do terrible damage to his healthy cells. Therefore we must deliver the molecules to the site of the cancer using nanoscopic carrier structures, called vesicles. These spherical structures possess compartments in which other molecules can be safely wrapped up and transported, and can even have tails attached to them, to propel them through the bloodstream. . . . We'll need you [the player] to select a vesicle and guide it through the bloodstream, using our simulation terminal (*NanoMission*, "Nanomedicine Demo": 2007).

To be sure, this nano-avatar is figured as a bio-engineered device instead of a "small mechanical robot inside the body", but in terms of gameplay, there is no difference: we teleoperate this (im)possible vesicle exactly as if we were teleoperating an (im)possible nanorobotic sub, piloting it with our "simulation terminal" (the game console) and monitoring its movements through our viewscreen. *NanoMission* promotes a speculative fantasy of direct-access, remote-controlled vesicles, endowed with endovascular visualization capabilities and light sources, and insists that all this is "real science" while nanosubs are fake and fictitious.

The game even cheekily offers players the option of attempting the mission using a nanosub instead of a vesicle, but this is designed to be a devastating experience if the player is so naive as to imagine that such a machine might be a good idea. While the vesicle is excellently mobile thanks to its adaptive flagellum and its "hairy coat of polyethylene glycol molecules . . . [that] help to shield it from absorbing antibody proteins", the nanosub on the other hand cannot move in the blood fluid because it has a propeller rather than a flagellum, and it is always quickly destroyed by the body's immune system. In asking players to select between the futile nanosub and the successful vesicle – "The choice is yours. Select one, and we'll see how it fares" – the game begs the question as to why we could not also give the nanosub an antibody-resistant coat of polyethylene glycol and similarly equip it with a flagellum rather than a propeller. But such a level playing field would spoil the political agenda of the game here, which appears to involve discrediting certain other forms of nanotechnology research, especially those invested in developing mechanosynthetic nanosystems and nanobots (e.g. Drexler 1992, Freitas 1999, Freitas and Merkle 2004). *NanoMission* thus launches yet another volley in the ongoing boundary disputes between various competing research programs seeking to control the disciplinary identity of nanoscience (Bensaude-Vincent 2004, Bueno 2004, Glimell 2004, Kurath and Maasen 2006, Kaiser 2006).

Authorized as a representation of "real science" (the game has been endorsed by the NNI coordination office, the US Institute of Physics, the UK National Physical Laboratory, the VDI, and the Royal Society of Chemistry), *NanoMission* typifies certain constitutive aspects of nanotechnology discourse at large, which has throughout its history continuously relied on the speculations of science fiction even while denouncing them (Milburn 2008). Indeed, nanotechnology's development in both science and culture has depended upon a complex suspension between novelty and banality, futuristic visions and technical immediacy, the hyped and the humdrum (Hayles 2004, López 2004, Hessenbruch 2005, Schummer 2005). The effect of this dynamic has been to continuously recreate the science as science fiction, and the science fiction as science: an endless "code switching" or transcoding, exemplified in an online blog by Richard Jones, one of the scientific advisors for *NanoMission*:

> If you were able to make a nanoscale submarine to fulfill the classic "Fantastic Voyage" scenario of swimming through the bloodstream, how would you power and steer it? . . . [O]ur intuitions are very unreliable guides to the environment in the wet nanoscale world, and the design principles that would be appropriate on the human scale simply won't work on the nanoscale. . . . In my group [at the University of Sheffield] we've been doing some experiments to demonstrate the realization of one scheme to make a nanoscale object swim . . . [and] suggest a strategy for steering our nanoscale submarines, as well as propelling them (Jones 2007).

In the ongoing adventure of nano, cinematic vehicles and scientific vesicles reverse-engineer each other, for while the former apparently "won't work", the latter “fulfill[s]” the fiction as its “realization”, and thereby becomes what it was not supposed to be: namely, a “submarine”. Even before these (im)possible sanguinary devices swim inside our bodies, scientists thus imagine being virtually inside *them*, remotely “steering our nanoscale submarines, as well as propelling them”. Likewise replicated in *NanoMission*, which insists on scientificity while demanding that players steer the vesicle from the “simulation terminal”, such transcoding renders the presumptive divide between real nanotechnology and video game fantasies invisible.

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"Science fiction . . . is no longer anywhere, and it is everywhere."/Jean Baudrillard/
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From video games to nanoscience and back again. By interacting with simulated nanotechnologies in the present, whether with a consumer game console, a laptop computer, or a research laboratory, gamers and scientists alike are learning how to play with real nanotechnologies, now and in the future. “Playing nanotechnology” does not only entail the manipulation of molecules, but also the anticipatory engagement with the ethical and societal implications of that technology. As nothing otherwise than digital, computational nano-things acquire physical and social dimensionality though ongoing acts of speculation – exploratory, economic, and imaginary – into the burgeoning multiverse of synthetic worlds and “realistic nanoworlds” (Castronova 2005). With the divide between programmable atoms and conventional atoms thereby diminishing both epistemologically and ontologically as the nanotech era looms increasingly closer, it would seem that any lingering difference between the two is, by now, really only a very small matter.

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Part III
Assessing "Nano": Repercussions on Research

The third part explores the interplay between NST and the assessment regime. In their contribution, *Arie Rip and Marloes van Amerom* draw attention to the intricate dynamics that have incrementally fostered what we currently see as the debate on the toxicity of nanoparticles. They compare the historic routes to this debate with the rise and fall of the scientific reputation of the visionary author K. E. Drexler, who published *Engines of Creation* in 1986. In his book, Drexler presented the scenario of self-replicating molecular assemblers, which, once real and released, could quickly turn the whole world into an undifferentiated mass of myriads of themselves (grey goo). Regarding risk, the nano-toxicity debate and the "gray-goo" scenario have remarkably different patterns. The Drexler saga is a story about active marginalization of the author (or, as Rip and van Amerom put it, of DREXLER, the spectre of the author) and a development strategy towards self-replicating structures. The nanotoxicity story however, could be operationalized scientifically and implemented because of its more focused (or reduced) perception of risk. The chapter integrates these findings into an innovative concept of evolving socio-technical "landscapes" that shape technological developments in society through what they both enable and constrain.

Armin Grunwald and Peter Hocke investigate the risk debate on nanoparticles as well. Their question is: Did the nanoparticle risk debate contribute to a "normalization" of the science/society relationship? They base their observations on a "social shaping of technology" approach, assuming that "ethical" discourses and reasoning actually can take part in the shaping of technology. But how does "ethics" contribute? A case study on the inclusion of technology assessment and social dimensions studies in the Forschungszentrum Karlsruhe (FZK) as well as a reflection about the risk debate on nanoparticles show that the contributions of ethics and similar reflections are not "strong" in the sense that they would affect the research agenda, i.e. the ways in which nanotechnology is formed and developed. But there are important "weak" contributions. The scientific and societal environment in which NST research takes place has been influenced and also modified to a remarkable extent. This changes the (social) reality of nanoscience: The nano-lab is no longer separated from society, but NST advances take place "under the eyes of" the public. In this sense, as the authors show, the risk debate on nanoparticles had remarkable impacts on the social and scientific environment of nanotechnology. Ethical inquiry has "normalized" nanotech.

Mario Kaiser in contrast investigates the ways different actors of the assessment regime make sense of what at first glance cannot be known: the unintended consequences of nanotechnology. To explore these unknowns, researchers, decision makers, and others might use technology assessment (TA) or applied ethics. They formulate their views in different text genres ranging from reports (TA), to pamphlets (published by think tanks for example), to scientific articles (applied ethics). These texts in turn enable and structure the articulation of different futures in order to pin down the unknown. Accordingly, the futures manufactured by the assessment regime range from governable, through democratizible, to futures, through which we reflect upon the ethical condition of the present. As the different futures also address different actors, such as decision makers in the case of TA or the public in the case of a think tank, Kaiser speculates on the societal function of this overall engagement with an unknown future as entertained by the assessment regime. By providing tailor-made futures, the regime enables, if not enforces different parts of our society to make decisions under conditions of radical uncertainty.

Emerging *De Facto* Agendas Surrounding Nanotechnology: Two Cases Full of Contingencies, Lock-outs, and Lock-ins

Arie Rip and Marloes Van Amerom

1 Introduction and Conceptualization

In a number of ways, the development of nanoscience and nanotechnologies is more reflexive than was the case for earlier new and emerging sciences and technologies. One indication is the common reference to the so-called impasse around (green) biotechnology, and how to avoid a similar impasse (For an example, see Colvin 2003; for an analysis in terms of folk theories, Rip 2006c). Related to this is the willingness to invite public engagement, if only as a precautionary measure. There is also reference to the importance of "responsible" development of nanoscience and nanotechnologies, e.g. in European Commission documents and in recent initiatives for voluntary codes. Clearly, there is now space for reflection and deliberation.

Does this imply that deliberations will play a constitutive role in the formation of nanotechnologies? The role and effect of deliberations will always be predicated on the emergence of openings for deliberation in the ongoing coevolution of nanotechnology and society, and the links with ongoing societal agenda-building. Thus, we need to understand the dynamics of co-evolution, the patterns that emerge, and in particular, which overall agendas become *de facto* dominant.

We present two case studies of these dynamics. The first case is about how Eric Drexler, once positioned as a founding father of nanotechnology, became excluded from mainstream nanoscience and nanotechnology. The fate of Drexler and his view is linked to the discussion of "molecular manufacturing" and, in relation to this, the possibility of a "grey goo" scenario.

The second case is about the emergence of potential hazards of nanotechnology, in particular of nanoparticles, as a legitimate concern. By 2006, there were concrete actions and reactions, ranging from regulatory agencies exploring what to do about nanoparticles, to some firms becoming reluctant to work with nanoparticles.

In both cases, there is discussion and debate, but not necessarily deliberation in the strong sense. On the other hand, some learning occurs in such controversies

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(Rip 1986), somewhat independently of the emergence of spaces for explicit deliberation. To take this into account, we use the metaphor of an evolving socio-technical landscape. "Landscape" indicates the backdrop against which actions and interactions are played out, which enables and constrains and thus shapes what happens. The landscape evolves, partly because of stabilization of certain agendas and arenas, actor constellations, and patterns in interactions. The key point is that "landscape" is not just a passive backdrop against which humans play out their affairs. It is itself constructed, and part of the "play" is to construct elements of the backdrop.

This conceptualization is like Giddens' notion of structuration, but now at the meso-level and with attention to actual dynamics. These dynamics include the buildup of socio-technical infrastructures and how they recede into the landscape.[1]

Just as gradients in a landscape (say, hills and valleys) shape the movements of people and other "mobiles" that traverse the landscape, a socio-technical landscape shapes action and perception. It can be seen as a tangible story, with routing devices to guide the "reader" without determining the reader's movements. Some of these routing devices have evolved naturally, and almost all of them are outcomes, at a collective level, of a variety of actor strategies, designs, and interventions, which to some extent (and after some time) are unintended by any of the actors. The landscape is a *dispositif*, just as much as the more explicitly socio-technical *dispositifs* studied by Foucault and others.[2]

A visualization of such a landscape is Sahal's (1985) diagram indicating trajectories of evolving innovations(Fig. 1).[3]

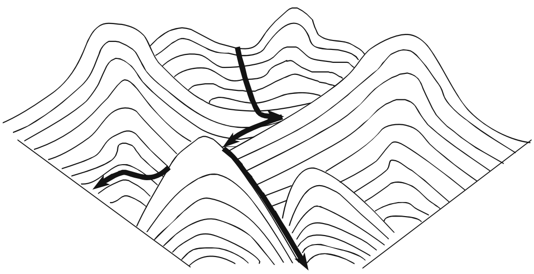

Fig. 1 Topography of socio-technical evolution (Sahal 1985: 79)

[1] "... mature technological systems – cars, roads, municipal water supplies, sewers, telephones, railroads, weather forecasting, buildings, even computers in the majority of their uses – reside in a naturalized background, as ordinary and unremarkable to us as trees, daylight, and dirt. Our civilizations fundamentally depend on them, yet we notice them mainly when they fail, which they rarely do. They are the connective tissues and the circulatory systems of modernity. In short, these systems have become infrastructures." (Edwards 2003: 185).

[2] Foucault (1977), Appadurai (1990) on "technoscapes," Barry (2001) on "technological zones of circulation." Barry (2001: 200) comments that "Foucault's analysis of *dispositifs* or apparatuses is too static to reveal the dynamic instability of socio-technical arrangements."

[3] Other visualizations are possible, such as the fitness landscape (Lansing and Kremer 1993, Jelsma 2003), the epigenetic landscape with its "chreodes" (Waddington 1975), and a potential field, as in electromagnetic theory.

While the diagram conveys a clear message about technology dynamics, for our purposes it can be misleading. The landscape is already full of paths and forks, and it is their (agonistic) interaction (for example, a battle about an industry standard) which shapes outcomes. For our broader use of the "landscape" metaphor, we must add further dynamics, in particular *de facto* agenda building. We are interested in the contour lines in Sahal's diagram, indicating gradients that enable and constrain, and how these came about, rather than in one or another particular path. We will map the evolving "contour lines" (broadly speaking) in the following case studies, which will allow us to understand the what is happening, as well as to consider possible future paths enabled and constrained by the evolving landscape.

Societal *de facto* agenda-building interests us, rather than the traditional focus in agenda-building analysis on one single arena and what happens inside. Societal agenda-building is a multi-arena process, and does not have a clear authority deciding on the agenda.[4] Kingdon (1984) is a good starting point for such analysis, because of his discussion of policy entrepreneurs and their skills, their networks, and how they can act on policy windows, openings, or opportunities to forge a new or change the existing agenda. An additional factor is how issues can become linked so that new alliances emerge (such as around radioactive waste burial around 1970, cf. de la Bruhèze 1992). Such (always partial) entanglements are a general phenomenon,[5] and they can become locked in and lead to path dependencies – which are themselves an example of *de facto* agenda setting and stabilization (cf. Rip et al. 2007).

Existing agendas, dominant discourses, and actor constellations are a backdrop to ongoing processes, e.g. emerging actor constellations around an issue, which promote stabilization of certain agendas – which thus changes the landscape. Still, "windows of opportunity" will occur, albeit fewer than before (cf. Stirling 2005). One circumstance reducing flexibility is how arenas stabilize by excluding actors that are no longer considered legitimate spokesmen. This is particularly evident in our first case, and it is reinforced by actors using (and relying on) stereotypical characterizations, in this case, of the Drexlerian view. Similarly, after 2006, risks of nanoparticles were generally expected to exist, while the uncertainties and lack of evidence underneath this characterization were black-boxed.

In our second case, the entanglement of actions, reactions, and emerging discourses and constellations is particularly evident. The health, environmental, and safety (HES) aspects of nanoparticles are now high on the agenda in the "nano world". They can thus be seen as a priority, and their implementation, a subject of inquiry. But these directions to go emerged from earlier entanglements, which included ongoing work on risks and debates on regulation. In other words, what can now be positioned as implementation of an agenda on risk started before such

[4]"Arenas and fora, and the various issues discussed and addressed there, thus involve . . . political activity but not necessarily legislative bodies and counts of law." (Strauss 1978: 124)

[5]The notion of entanglement is important, in order to avoid too-easy recourse to traditional interest and power explanations.

an agenda was in place. To understand such processes, where (so-called) implementation happens prior to goal-setting,[6] one has to reconstruct the processes' dynamics, rather than follow the linear histories that are produced by actors to support their current efforts to push for more and better risk research (e.g. Maynard et al. 2006).

This brief discussion of societal *de facto* agenda setting, together with our earlier (and technology-dynamics–inspired) consideration of evolving landscapes, allows us to visualize our approach as a multilevel characterization of interactions and entanglements leading to patterns and agendas that shape further action, but can also open up and shift. Figure 2 is of course a simplification, but it conveys a message about the importance of interactions, and especially interactions at the mid-level. All of these interactions add up to an evolving landscape with an overlapping patchwork of contours rather than one definite set.

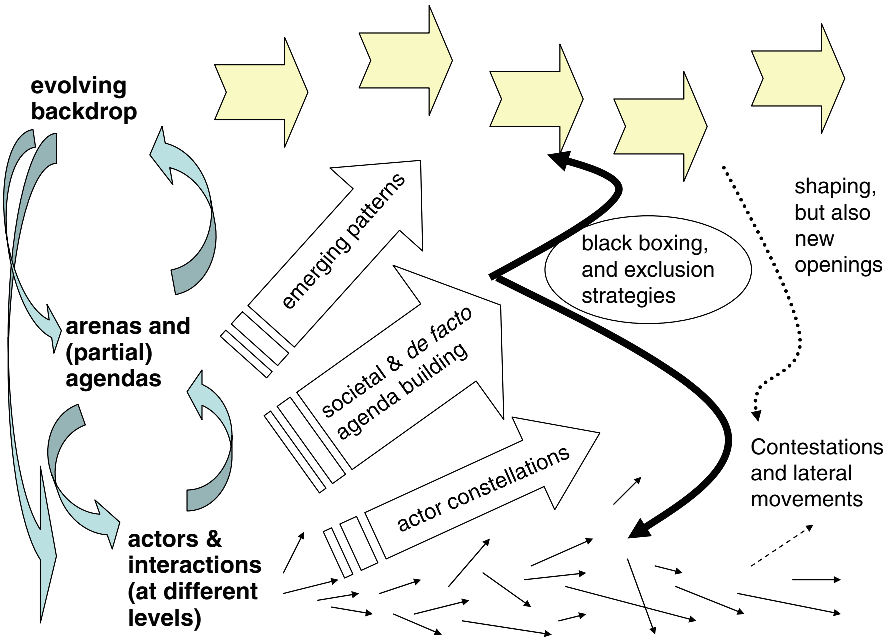

Fig. 2 Multilevel landscape dynamics

[6]Implementation studies have gone some way in this direction when emphasizing the importance of "bottom-up" processes (Hanf and Toonen 1985); cf. also Pressman and Wildavsky (1984) on mutual adaptation between policy making and what happens "on the ground," and who turned it into advice for modest policy making, or better, policy making that takes implementability into account. In other words, goals are modified by considering possible implementation.

In this visualization, the focus is on the meso-level and interactions with micro- and macro-levels. Larger "framework conditions" that are also part of the landscape are not indicated. Similarly, when we reconstruct our two cases and offer visualizations of their dynamics (in Figs. 3 and 4 below), we will not explicitly include such conditions as changing regulatory cultures (acceptance of precautionary measures, shift towards "soft law"), the role of disciplinary cultures (differences between chemistry and engineering, for example), and specifics of national cultures and structures.

To trace these multilevel landscape dynamics empirically will not be simple. One can isolate a specific question and apply standard social science operationalization and data gathering. The challenge, however, is to trace interactions and how these add up to up to a composite picture. In a sense, this is writing contemporary history. Thus, we have also relied on blogs and newsletters, which offer gossip; however, in the case of Howard Lovy and Tim Harper (TNT Weekly), it is authoritative gossip. We have also used our own experience in moving about in the nano-world. In addition, for the case of risks of nanoparticles, we created our own database of publications, documents, and commentaries.

Contemporary history writing is difficult. What one writes can be read as "taking sides," for example, for or against the Drexlerian vision, or for or against a moratorium on production and use of nanoparticles. We cannot escape these tensions, but we can recognize them and include them in our conceptualization. A way to do this is to thematize how visions and positions become stabilized and black-boxed. This is, in fact, a narrative approach. One example is to distinguish between Drexler, the person who acts (speaks and writes) in concrete situations, and DREXLER, the figure that is referred to and on which features are projected that may or may not correspond with the actual behavior and utterances of the person. One thread in our story of the Drexler saga is how the person Drexler is often eclipsed by the figure DREXLER and the changing (attributed) features of that figure.

2 The Drexler Saga

We were struck by the ease with which Richard Jones, nanoscientist and commentator, could say (and be accepted saying it): "Drexler, of course, is the name that can't be spoken in polite society."[7] "Polite society," of course, is the society of the mainstream nano-world, and there may be a tinge of irony in the way Richard Jones phrased his comment. But it does indicate how Drexler has become a figure: as Howard Lovy phrased it in correspondence with Eric Drexler, quoted on his blog: "Like it or not, the name of 'Drexler' is no longer your own" (Lovy 2003b). This

[7] Richard Jones made this remark in the Stanford-Paris conference on Social and Ethical Implications of Nano- Bio-Info Convergence, Avignon, 18-19 December 2006. He agreed to our quoting him this way.

is the outcome of a complex process in which "leaders in both industry and government are finding it easier to bring nanotechnology out of the fringe and into the mainstream, whetting the public's appetite with rudimentary commercial applications" if they "cast aside Drexler's vision, as well as his warnings" (Berube and Shipman 2004: 24). In popular texts, Drexler can still be positioned as one of the fathers of nanotechnology, but if nano-actors do so, they will be relegated to the camp of the "Drexlerians."[8]

There are, by now, quite a number of articles and book chapters that analyze the Drexlerian vision and its ambivalent fate (Kaiser 2006, Bennett and Sarewitz 2006, Berube and Shipman 2004, Bensaude-Vincent 2006, Milburn 2002, Milburn 2008, Selin 2007). As we reconstruct the history, there are two different but connected strands. One strand is the debate on the feasibility of molecular manufacturing, which became increasingly antagonistic from the late 1990s onwards. The other strand is the rise and fall of concern about the Grey Goo scenario, linked to the possibility self-replicating "nanobots." The debate peaked in 2003 and 2004, and then receded. These two strands may be linked to the exclusion of Eric Drexler from the main nanoscience and technology arena, from 2000 onward. After Drexler's claims about the principle possibility of molecular manufacturing (or assembly),[9] and the possibility of the Earth being turned into Grey Goo by the replicators needed for such assembly, had become topics of contention in the early 2000s, they now appear to be topics of non-contention. Thus, the stakes involved must have settled. In any case, now that funding for nanoscience and nanotechnology is assured, there is no longer a need for a Drexlerian prophet of nanotechnology. This is, at least, Drexler's own understanding of what happened (Drexler 2004).

In this section, we will first note how Drexler himself linked molecular assembly and a Grey Goo scenario in his *Engines of Creation* (1986). In the 1990s, the

[8]Interestingly, the Swiss research institute Swiss Federal Laboratories for Materials Testing and Research (EMPA) (see Merz in this volume), which has moved from materials science and technology into nanotechnology, in a 2007 booklet *Reise in die Welt des Nanometers* that explained nanotechnology to the general public, is prepared to say: "Formuliert wurden diese Visionen [of molecular manufacturing and molecular self-organization] erstmals 1981 von Eric Drexler. Er hat, 22 Jahre nach dem denkwürdigen Vortrag Richard Feynmans, dessen nanowissenschaftliche Vision aufgenommen und zu einer Vision Nanotechnologie weiterentwickelt. Heute gelten Eric Drexler, gemeinsam mit Heinrich Roher und Gerd Binnig, die im selben Jahr das Rastertunnelmikroskop erfanden, als die Väter der Nanotechnologie." Nanoscientists at EMPA told us this text was the responsibility of EMPA's communications department, not theirs.

[9]Note the difficulty of terminology: terms like "molecular machines" or "assembly" and "self-assembly" have been used (and thus claimed) by different parties, for different purposes, and thus with different meanings. "Molecular machines" is now a respectable research area with concrete findings, and the researchers eschew any reference to the Drexlerian use of molecular machines. "Self-assembly" is sometimes used to refer to Drexlerian replicators assembling copies of themselves, but chemists from Whitesides (1995) on have claimed the term for what a "society of molecules" can be induced to do, rather than the precise control of atoms/molecules envisaged by Drexler (cf. also Bensaude-Vincent 2006).

discussion of Drexler's speculative vision was constructive.[10] A first shift occurred around 2000, with contestation of the vision and positioning of the Grey Goo scenario as a concern. Both stabilized by 2004, together with the generally accepted exclusion of the Drexlerian vision from mainstream nanoscience and nanotechnology. To understand this stabilization, we will also trace the discussion in and around the U.S. National Nanotechnology Initiative (NNI).

In Drexler's *Engines of Creation* (1986), he describes "molecular assemblers" as devices capable of building products from the atom up, thus with absolute precision and without pollution. However, in order to do so (i.e. produce amounts that are visible and useful macroscopically), there must be lots of molecular assembling going on. So, these assemblers must also reproduce themselves. Assuming that the first assembler could make a copy of itself in 1,000 seconds,

> The two replicators then build two more in the next thousand seconds, the four build another four, and the eight build another eight. At the end of ten hours, there are not thirty-six new replicators, but over 68 billion. In less than a day, they would weigh a ton; in less than two days, they would outweigh the Earth (Drexler 1986: 172–73).

And so they would consume this Earth in the process. In other words, if the replicators are instructed to copy themselves, and there is no built-in stopping point, they will eat up everything and turn the Earth into Grey Goo (i.e. a jumble of replicators).

While the notion of Grey Goo was discussed, for example, in the sci. nanotechnology newsgroup, and referred to occasionally in the media, it only became part of an emerging societal debate on possible drawbacks and risks of nanotechnology after Sun Microsystems' founder Bill Joy made a plea in 2000 to constrain the development of converging technologies. Grey Goo became an image referred to in newspapers worldwide to imagine and discuss "nanotechnology" dangers (Anderson et al. 2005). Another input was the publication of Michael Crichton's 2002 science fiction novel *Prey*, which drew further attention to the notion of Grey Goo, although it was about out-of-control swarms of biological organisms created through nanotechnology (*Los Angeles Times* 2002; ETC Group 2004: 7). Nanoscientists all over the world were concerned about public and political reactions.[11]

Nanotechnology risk stakeholders who were demanding precautionary approaches to nanotechnology referred to, and imagined nanotechnology dangers in terms of, Grey Goo (Munich Re 2002, Arnall 2003, ETC Group 2003b). When it seemed that the UK's Prince Charles was concerned about nanotechnology because of Grey

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[10]We are indebted to Colin Milburn for offering insights (and references) into the nature of the early debate.

[11]*The Globe and Mail* of 26 November 2002, reporting on the debut of the novel, also quoted nanoscientist Wolfgang Heckl: "We have to take this seriously. If enough senators in the U.S. get phone calls from their constituents saying, "I just read *Prey* and I'm scared," it could have a real impact on our funding. Nanoscience is just in its infancy. We can't afford to be cut off." Interestingly, the Drexlerians were also concerned about loss of credibility, cf. how Chris Phoenix (Center for Responsible Nanotechnology) took the same (and misguided) approach of criticizing the science in *Prey* in his review in *Nanotechnology Now* (Phoenix 2003).

Goo fears (in April 2003), there was a new peak of media coverage on Grey Goo, inside and outside the UK (Feder 2003, Thurs and Hilgartner 2005).

Whether there was indeed public fear of a Grey Goo scenario or not (and there are indications that it was more a phobia from the nano-actors about the public's fears than actual public nano-phobia; Rip 2006c),[12] NST promoters were concerned that "popular fear of Grey Goo would be a harbinger of a general backlash against nanotechnology" (Hilgartner and Lewenstein 2005), and started to publicly deny the possibility of Grey Goo and attack and ridicule those who believed in it. Events in the UK are illustrative. Following the *Mail on Sunday*'s (27 April 2003) assertion that Prince Charles was concerned about nanotechnology in relation to fears over Grey Goo, Buckyball co-discoverer Sir Harry Kroto accused the prince of "a complete disconnection from reality." Lord Sainsbury, Minister for Science and Innovation, publicly denied the feasibility of the Grey Goo scenario. Chairman of the House of Commons Science and Technology Committee Ian Gibson reproached Prince Charles merely for mentioning Grey Goo: "we shouldn't be associated with scare stories – science fiction about grey goos… [because] When a prince speaks, people will listen" (Oliver 2003a, b).

This part of the story has been told before (though not always in this specific way). The big debate about the feasibility of molecular assembly, in particular debates between Nobel prize–winner Richard Smalley and Drexler, 2001–2003, appears to have been conducted independently of the Grey Goo scenario.[13] Smalley's arguments about "fat and sticky fingers" hinge on the fact that molecular assemblers are conceived as mechanical (cf. below). Drexler's counter-argument has been to refer to the assembling that goes on all the time inside living cells: it's natural, so it must be possible in principle. In this arena, there is only passing reference to the Grey Goo scenario. It is only later, when the Grey Goo scenario is picked up by critical organizations such as the ETC Group (the Canadian-based Action Group on Erosion, Technology and Concentration), and ascribed to visible actors like Prince Charles, that the link becomes active.

In the scientific realm, the discussion was about the feasibility of Drexler's ideas on molecular manufacturing. After relative inattention in the late 1980s and early

[12]Nanotech promoters appear to have overestimated the extent to which the notion of grey goo would capture the public's imagination and evoke resistance against nanotechnology (Thurs and Hilgartner 2005). In fact, a 2004 Internet search by ETC Group indicated that most entries referring to the "threat of Grey Goo as presented by Drexler and Crichton" were from nanotech promoters and scientists concerned over the alleged "public misunderstanding of nanotechnology" that was assumed to be the result of earlier publicity on the notion of Grey Goo (ETC 2004: 7).

[13]Here, we move away from Mario Kaiser's diagnosis that "there is hardly any doubt that concerns such as the possible future existence of grey goo have initiated a somewhat vehement reflection on the foundations that nanoscience and technology rest upon." (Kaiser 2006: 5). As we see it, Smalley (and also George Whitesides) took a chemist's view of the matter and criticized Drexler's engineering vision on that basis. The Grey Goo scenario is referred to only in passing. Bennett and Sarewitz (2006: 315) also emphasize such a link: the need to avoid Bill Joy's conclusion that certain lines of investigation should be relinquished (e.g. self-replication of nanobots, which might spread to current work in nanotechnology).

1990s, except in a circle of enthusiasts mostly at the Foresight Institute established in 1986, the discussion was taken up in a somewhat appreciative manner (Whitesides 1998, cf. also 2001). After open interactions at Foresight Institute conferences in 1995 and 1997, Smalley started to question Drexler's visions of molecular assemblers, and then actively attacked them in an article in *Scientific American* (2001). Smalley maintained that manipulator fingers on the "hypothetical" self-replicating nanobot would be "too fat" to pick up and place individual atoms with precision and "too sticky" to let them go after having picked them up (Smalley 2001: 68). Drexler's response was that his visions of molecular manufacturing never envisaged nanobots, making the "fat fingers" or "sticky fingers" problem irrelevant. The debate continued, and attracted wide attention when the protagonists had their say in *Chemical & Engineering News* on 1 December 2003 (Baum 2003). While to some extent inconclusive, the debate was seen by U.S. nanotechnology business and government actors, as well as many scientists keen to distance themselves from what they could now call science fiction, as a victory for Smalley (cf. Lovy 2003a). Drexler's ideas could be declared to be unfeasible, to the frustration of the Foresight Institute and other "Drexlerian" actors like the Center for Responsible Nanotechnology (CRN), who continued to appeal to the more speculatively minded.

Around the same time, in October and November 2003, a provision of the U.S. 21st Century Nanotechnology Research and Development Bill relating to molecular assembly was at stake in the struggle over how to position Drexler's vision.[14] The initial (House) version of the bill included a provision (written by California Rep. Brad Sherman, a Drexler supporter) calling for a study to evaluate the technical merits of "molecular manufacturing," and, if possible, prepare a timeline and a research agenda.[15] The Senate was less keen on such a provision, but the phrasing created a flurry of protests in the nanoscience community, and possibly pressure on members of Congress from representatives of the U.S. NanoBusiness Alliance and other NST promoters (Regis 2004).[16] In any case, the bill's final version now referred to "molecular self-assembly" and asked for "a one-time study to determine the technical feasibility of molecular self-assembly for the manufacture of materials and devices at the molecular scale." As commentators noted, self-assembly is a known process (and therefore "innocent"), but the key question is the interpretation of the subsequent clause on manufacturing at the molecular scale. Mark Modzelewski of

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[14]There were other bones of contention, like human enhancement (artificial intelligence which exceeds human capacity), but these are not linked to Drexler's visions (Fisher and Mahajan 2006: 11).

[15]A study "to develop, insofar as possible, a consensus on whether molecular manufacturing is technically feasible." And if feasible, the study would find "the estimated time frame in which molecular manufacturing may be possible on a commercial scale; and recommendations for a research agenda necessary to achieve this result" (quoted from Regis 2004).

[16]Peterson (2004: 12), vice president of the Foresight Institute, refers to successful lobbying of opponents to the molecular manufacturing vision. See also Tim Harper's comments (TNT Weekly 2003).

the NanoBusiness Alliance (when interviewed by *U.S. News & World Report*) said: "It is possible that some aspects of 'molecular manufacturing' might be investigated, but knowing the parties influencing the study, I doubt it. There was no interest in the legitimate scientific community – and ultimately Congress – for playing with Drexler's futuristic sci-fi notions" (quoted in Lovy 2003a, cf. also TNT Weekly 2003). Henceforth, Smalley's arguments became a key reference for the dismissal of Drexler's visions on molecular assembly, but somewhat independent from the debate about Grey Goo.

Thus, there were three arenas of debate and strategizing: developments around science and funding for nanotechnology, the nanotechnology risk debate in society, and the feasibility of molecular manufacturing. They are connected to one another, and references to Drexler as well as the activities of Drexlerians like the Foresight Institute and CRN are part of the connection. In other words, there are links, but they are not linear. Delegitimizing Grey Goo scenarios by arguing that molecular manufacturing is science fiction is one possible strategy, and it can be linked to attempts to exclude Drexler's visions, and thus Drexler, from "polite society." But other strategies and linkages are possible as well. Over time, though, a particular constellation of attributions and positioning can become dominant, and such a dominant constellation will then have a definite set of strategies and linkages to justify its actions.

By 2004, such a dominant constellation was emerging. While the 21st Century Nanotechnology Research and Development Act of December 2003 allowed for government-funded studies on the possibility of Grey Goo (Fisher and Mahajan 2006), there were no steps in this direction. Emerging government-funded research programs into the ethical and social implications of nanotechnology in the U.S. did not include the possible detrimental effects of molecular manufacturing as a research focus. Similarly in the UK, a report from the Royal Society commissioned by the UK government simply could state that the possibility of Grey Goo was not worth researching because Drexler's molecular manufacturing ideas had proved to be mere fiction (Royal Society 2004: 109).

The dismissal of a Grey Goo scenario also occurred at the side of nanotechnology risk-alerters: These identified possible risks, but these were not linked to Grey Goo scenarios. For example, the ETC Group still listed Grey Goo as a possible NST concern in 2003 (ETC 2003a) and, in the midst of the publicity surrounding Prince Charles' alleged Grey Goo concerns, criticized the dismissal of Grey Goo by NST promoters (ETC 2003c). However, in July 2004, in another communiqué, the activist group denied having ever spoken about Grey Goo, instead blaming NST promoters for having brought the concept of Grey Goo into circulation (ETC Group 2004). In the same month, Prince Charles publicly distanced himself from the Grey Goo scenario. More than a year after the public reference to his alleged Grey Goo fears in British newspapers, he denied, in an article in the *Sunday Independent*, having ever believed in the possibility of Grey Goo (HRH The Prince of Wales 2004). The statements may well reflect how ETC Group and Prince Charles used the notion of Grey Goo in the past as a means to draw attention to possible risks of nanotechnology. Clearly, there was no need to do so anymore in 2004, and such a reference might become counterproductive, isolating them from mainstream opinion. This is a tactical move, but it reinforces mainstream views, and will be seen and used as such.

The 2004 article written jointly by CRN director Chris Phoenix and Eric Drexler can be seen as an attempt to re-enter the nanotechnology arena as legitimate players by distancing themselves from Grey Goo, or to "Un-Goo" and align visibly with more legitimate concerns. There are substantial arguments in the article as well, but the article was received as a concession of defeat and a conversion to mainstream thinking. Phoenix and Drexler's argument is that, thanks to new technological developments, nano-manufacturing no longer needs autonomous self-replicating nanomachines. Military use (or abuse) of nano-manufacturing appears a more immediate threat (Phoenix and Drexler 2004: 869). Thus, there should be more attention to the security aspects of nanotechnology. Anti-Drexler nanotechnology promoters, however, portray the article as Drexler finally admitting that the prospect of Grey Goo had been a mere "fantasy" (for example, Institute of Physics 2004), which adds to his lack of credibility. Journalists accepted and copied this interpretation (see for example Rincon 2004, Sample 2004, Sherriff 2004, *The Scotsman* 2004). Thus, instead of overcoming Drexler's exclusion from the mainstream nanotechnology arenas, the article is used to continue his exclusion.

We visualize the dynamics in Fig. 3 below (note that the overall backdrop to these dynamics is not indicated).

Looking back, it is clear that there are two turning points in the developments: 1999–2000 and 2003–2004. In fact, these are turning points in the overall development of nanotechnology. For 1999–2000, Bennett and Sarewitz (2006: 312–313)

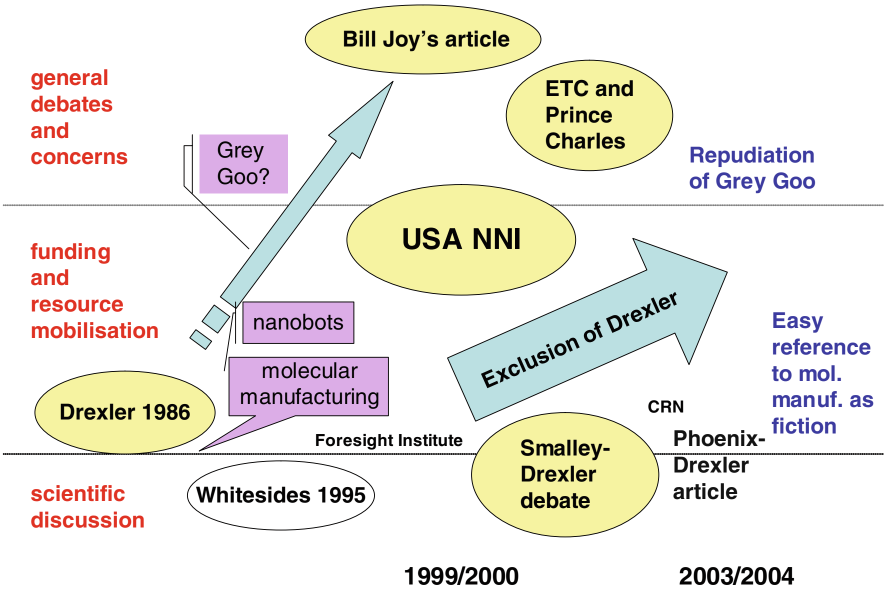

Fig. 3 The evolving landscape of the Drexler vision

show a steep rise in media interest. The 2000 NNI in the U.S. ensured and coordinated substantial government funding for nanotechnology research and, more generally, helped "the development of the burgeoning nanotechnology industry" (Guzman et al. 2006: 1401). The NNI indicated acceptance of nanotechnology, signaling its establishment as a field of research and setting a model for other countries to follow. Having obtained funding and political legitimacy, the construction of nanotechnology as an interdisciplinary but independent scientific field could begin in earnest. One further element of the situation was the competition for available funding by actors often holding very different views of nanotechnology. This led to implicit and explicit contestation over whose views were legitimate and feasible, and therefore deserving funding.

Boundaries were being drawn as to what comprised and did not comprise nanotechnology, as well as who were "legitimate" nanotechnology players and who were not (Kaiser 2006). All this is a common feature of emerging professions (Abbott 1988: 60). In the course of this process, Drexler's ideas on molecular manufacturing, which had been one of the guiding visions for nanotechnology (Robinson et al. 2007, Wood et al. 2007: 3), were dismissed as being too "far out" for the profession, and thus had to be redefined as fictional. As Milburn (2004: 118) phrases it: "nanotechnology managed to secure its professional future by combining fantastic speculation with concerted attacks on science fiction." (The latter is a rhetorical ploy to show that nanotechnology is a real science.[17]) "Regular nanoscientists" and nanotechnology business players phrased their promises in terms of what has been called "near-term nanotechnology" (Peterson 2004: 10): scanning tunneling microscopy and atomic force microscopy, nanotubes, supramolecular chemistry, and new ways of etching and constructing thin layers, as these techniques were perceived as being able to produce results relatively fast and enable the usage of nanotechnology for commercial purposes.

The connection of Drexler's visions to the Grey Goo debate became a further argument to exclude Drexler and the Drexlerians. For example, Modzelewski, spokesman of the Nanotechnology Business Alliance, accused Drexler of being "irresponsible" by thus endangering the development of nanotechnology and its enormous benefit for humankind. Smalley also used Drexler's concern about Grey Goo as a stick to hit him, accusing him of needlessly "scaring our children" with "scary stories" (Smalley 2003: 42). Drexler's association with Grey Goo was used as a moral justification for his "demonization" by the science and business community.[18]

[17] Milburn (ibid.: 122) then argues that "this rhetoric thoroughly deconstructs itself in a futile struggle for boundary articulation that has already been lost." For all practical purposes, however, from 2004 onward, the boundary was maintained without much effort through general acceptance of the claim that the Drexlerian vision was just speculation.

[18] Drexler himself articulated this dynamic. Brown (2001) reported that Drexler said that many scientists eagerly slapped the term "nanotechnology" on their research when it was viewed as "sexy," but became "a little upset to find that they had a label on their work that was associated

Boundaries are not made once and for all, however. Ongoing developments on what are now called molecular machines, including natural and artificial molecular motors, are hailed as “a significant step towards future nanomachines and devices” (Browne and Feringa 2006). Thus, speculation about molecular manufacturing continues and is actually taken seriously, as long as the linkage with Drexler’s vision is not emphasized. And even that is not problematic anymore: the UK Engineering and Physical Science Research Council has granted £ 2.5 million to “invent a nanomachine that can build materials molecule by molecule” (Van Noorden 2007). The approach is not Drexlerian (it relies on scanning probes which induce self-assembly), but one of the scientists involved is willing to say: “If it works, it will redefine nanotechnology as it should have been, ... referring to concepts promoted in the 1980s by U.S. engineer Eric Drexler, who suggested that nanotechnology would create tiny machines dubbed ‘assemblers’ that could drag atoms and molecules around to make copies of themselves, or other useful devices” (Van Noorden 2007). It is significant that Drexler’s ideas have to be explained: the present generation of nanoscientists is assumed not to be aware of them.

Allis (2007), a Drexlerian interested in concrete experiments, cashes in on these recent developments: “You’ve got single Si atom manipulation, Feringa’s optical motors, Tour’s got his nanocar. Those things aren’t dimer deposition to build diamondoid gears [a Drexlerian option], but they’re far more ‘mechanical’ than chemists were thinking 30 years ago, and they certainly hint at all the potential we have for fundamental control over matter. ”

It is doubtful whether these developments will lead to a rehabilitation of Drexler’s vision; the exclusion pattern has become institutionalized. This shows that our visualization in Fig. 3 should include ongoing nanoscience research and the expectations that are voiced about the research. From 2007 forward, we might see a revival of molecular manufacturing (under other labels), at least as laboratory curiosities.

3 Health, Environmental, and Safety Aspects of Nanoparticles

The emergence and recent broad acceptance of the acronyms ELSA (Ethical, Legal, Social Aspects) and HES (Health, Environmental, Safety)[19] in discourse on and governance of nanotechnology research indicates emerging stabilization of HES issues. The force of HES is itself the outcome of what could be labeled an emerging and stabilized path, at the meso-/macro-levels. It is instructive to reconstruct its emergence, including the contingent elements.

Around 2000, the broad promises of nanoscience were pushed – up to “shaping the world atom by atom” (National Science and Technology Council 1999) – and

with outrageous, science-fictiony sounding claims about the future and scary scenarios and other things. ... What nanoscale technologist would want the burden of such fears?” (Drexler 2004).

[19] Or sometimes EHS, cf. *The Economist*, A little risky business. November 22nd, 2007.

some concerns about the development of nanotechnology were starting, partly in response to the big promises voiced by and about the new U.S. NNI. The other generally visible issue was Bill Joy's 2000 warning about future technologies, including reference to the Grey Goo scenario (cf. preceding section). Two NSF-sponsored workshops on opportunities and societal implications collected a variety of essays, some of them referring to concerns about side effects of the development of nanotechnologies, including a "nano-divide" (between the global North and the South) and military usage and a new arms race (Roco and Bainbridge 2001, Roco and Tomellini 2003; see also Roco 2003).

On the environmental front, a Center for Biological and Environmental Nanotechnology (CBEN) was established at Rice University, and its scientists reported in March 2002 to the Environmental Protection Agency that engineered nanomaterials might accumulate in the human body, as well as potentially cause environmental degradation.[20] One indication of how little articulated that discussion was at the time is the January 2002 report by one of the big reinsurance companies, Munich Re: it raised concerns about risks in general terms, and there was very little response to its message – in contrast to the worldwide response a similar report, by Swiss Re, two years later produced.[21]

A first focus emerged when the ETC Group issued a communiqué, *No Small Matter*, in July 2002, in which its general concern about new technologies was applied to nanotechnology. The fact that action was proposed (specifically, to stop making nanomaterials until we know more about environmental impacts, and have this debated at the level of the UN) and the responses to that proposal (cf. *Small Times* 2002) was the beginning. The ETC Group followed this up with a report, *The Big Down*, in January 2003, which called for a moratorium on the commercial production of new nanomaterials (2003a). The immediate response was negation: denial that there could be risks, and denial that the ETC Group should be listened to. There was also fury about the ETC proposal for a moratorium on nanoparticles (*Small Times* 2003a). While in a news feature article in *Nature*, it was noted that "the debate is clearly gathering pace," while "some researchers ... feel that they don't need to join in the argument. 'They don't really see what the hoopla is about.'" (Brumfiel 2003: 247).

In the first half of 2003, the attention level for nano-risk issues increased together with the number of actors entering the arena. In April, the Woodrow Wilson International Center started its Project on Emerging Nanotechnologies, including a study on risk and regulation of nanoparticles. Also in April, U.S. congressional hearings on a new nanotechnology bill were the occasion for various actors to propound their message, including Vicky Colvin referring to lessons from the history of genetically modified organisms and the need, therefore, to anticipate and

[20]Interview (by Marloes van Amerom, 7 July 2006) with Vicky Colvin, Director CBEN.

[21]There are further indications, for example the lack of reference to nanoparticle risks in the Delphi study into benefits and potential drawbacks of using nanotechnology for health, commissioned by the German Bundesministerium für Bildung und Forschung, September 2002.

do research on potential risks (Colvin 2003). Later that same month, the news broke about Prince Charles' concerns (cf. preceding section), which contributed to the UK government, in June, commissioning and funding the Royal Society and Royal Academy of Engineering to have an in-depth look at these issues. The UK Institute of Nanotechnology, together with the Green Party members of the European Parliament and the ETC Group, organized a meeting in Brussels in June, to which staff of the European Commission felt it had to respond, informally.

Thus, there was an atmosphere of contestation. Illustrative is how nanotechnology promoters were prepared to dismiss, out of hand, the report commissioned by Greenpeace UK that came out in July that year (Arnall 2003). The report showed interest in the possibilities of nanotechnology, and did not call for a moratorium (it does note that a moratorium on engineered nanoparticles might prove to be necessary, should industry not invest more in nano-risk research). U.S. promoters of nanotechnology called the report "misleading propaganda" and said it was "too early to have these kinds of discussions" (Rob Atkinson, Progressive Policy Institute). Modzelewski of the NanoBusiness Alliance called it "industrial terrorism," while New York State Rep. Sherwood Boehlert (House Committee on Science and Technology) said: "[on] issues like this there will always be people on the extreme" (*Small Times* 2003b).

After the first-round denial of risks, and in spite of the ongoing occasional strong condemnation of concerns over these risks, 2003 can still be marked as the beginning of a next phase: At this point, possible risks of engineered nanomaterials were recognized, but these could be looked into while development continued (no real harm was expected). It was not legitimate to seriously discuss action implications of such risks, because that would mean a roadblock to further development. Inputs from toxicologists and epidemiologists (and scientists like Colvin) introduced some moderation.

The legitimacy of concerns about risk increased also because of first research results presented by Oberdörster to a 2004 meeting of the American Chemical Society which were widely reported as to their implications, as well as criticized as to methodology (see Oberdörster et al. 2005) produced response. Toxicologists defined research needs, and government actors (including in particular the European Commission) started to move to explore the issue. The ETC Group published an overview of relevant research in one of its occasional papers (ETC 2003b). The scientific arena was becoming active.

The balance shifted, irreversibly, with the appearance of reinsurer Swiss Re's report in May 2004, with its strong linking of risks of asbestos and risks of nanotubes, and nanoparticles in general (see also Menon 2004). Discussing (and researching) the risks of nanoparticles then became fully legitimate. One paradox, played upon by the ETC Group and Swiss Re alike, was that "size matters": if their small size is what gives nanoparticles their interesting properties, these same size-dependent properties can also create harm.

A specific "risk hierarchy" emerged, with most actors, at least officially, agreeing that the nanoparticle issue would be the most important and urgent risk to concentrate on, and the notion of Grey Goo being (re)framed as a "fictional" concern and a form of science fiction. While nanotechnology promoters now followed "prudent" scientists and nanotechnology risk alerters by recognizing the importance of, and engaging with, the nanoparticle risk issue, the other side had moved as well: nanotechnology risk alerters and reporters followed nanotechnology promoters in their rejection of Grey Goo as an issue (cf. preceding section).

By the time the Royal Society/Royal Academy of Engineering report appeared in July 2004, its message could not be dismissed: the introduction of nanoparticles into the environment requires caution because of the knowledge gaps about health and environmental impacts. Various nano-promoters did continue to critically evaluate ongoing research, and on that basis argue that there was still little cause for concern.

One further indication of the emerging closure was the establishment and composition of the International Council for Nanotechnology (ICON) in October 2004. Initiated by Rice University as a network to "assess, communicate, and reduce" HES risks of nanoparticles, it was able to include not only other research institutions, governmental agencies, and nongovernmental organizations (NGOs), but also representatives of the NanoBusiness Alliance. Corporate actors such as L'Oréal, DuPont, Procter and Gamble, and Unilever were founding sponsors. Clearly, there was sufficient common ground to have multi-stakeholder collaboration at this point.

The same growing agreement on the framing of risk issues (though not necessarily on what to do) enabled and was then reinforced by broadly inclusive meetings. One example was a major workshop organized by Swiss Re in December 2004. Also, working groups were set up, particularly by OECD. The UK government responded to the Royal Society/Royal Academy of Engineering Report and globally endorsed it. Initiatives to risk management became legitimate and consultants saw a business opportunity (e.g. Lux Research 2005; see also Nordan and Holman 2005). After earlier explorations, regulatory initiatives could now be considered. And nanotechnology promoters turned around, the most striking example being U.S. House Committee on Science's Chairman Boehlert (who had earlier condemned Greenpeace UK for putting risk on the agenda), who called for more funding into nano-risk research, noting that "this is the time to act, before we cause problems. This is the time to act, when there is a consensus among government, industry, and environmentalists" (PhysicsOrg.com 2005). Knowledgeable commentator Tim Harper (Cientifica) saw a "safety bandwagon" emerge (Harper 2006).

After stabilization of such a common ground – with a strong focus on risk, particularly of engineered nanoparticles – government agencies, NGOs, and companies started to engage with practicalities. For government agencies accepting a precautionary approach (Rip 2006a), there was the challenge of regulating without knowing what exactly to regulate. One approach then was to start with existing regulatory frameworks and apply them, perhaps while modifying them. The other approach was to address the uncertainty as such, for example by introducing a voluntary reporting scheme, as UK Department for Environment, Food and Rural Affairs (DEFRA) did in 2006. This would be an example of "soft law" (Trubek et al. 2006).

For companies, the advent of regulation resolves part of the uncertainties. In a world where HES risks may now be expected to occur, there is also the uncertainty about consumer reactions. If something untoward happens somewhere under the umbrella term "nanotechnology," that negative event will have repercussions for other products, even if these are (presumably) safe.[22] After the earlier marketing tactic of using the "nano" label for products, firms started to become more careful and delete "nano" from the labels of their products, or stop their line of nano-containing products altogether. Those who continued proceeded cautiously, and were willing to consider voluntary codes of conduct, so as to show good practice.

In Fig. 4, we visualize part of the dynamics (they are too complex to depict in one diagram), exemplified by nanotubes, and add some further features such as criticism of the present focus on risk.

One interesting phenomenon is how arenas overlap and how actor roles become hybrid. Government actors with regulatory responsibility (especially when they are pro-active) attend meetings and generally take part in a variety of arenas where informal societal agendas are built. Similarly, industrial actors mingle with other kinds of actors, especially if a somewhat neutral space is provided. An interesting example is the meeting organized by Swiss Re and the International Risk

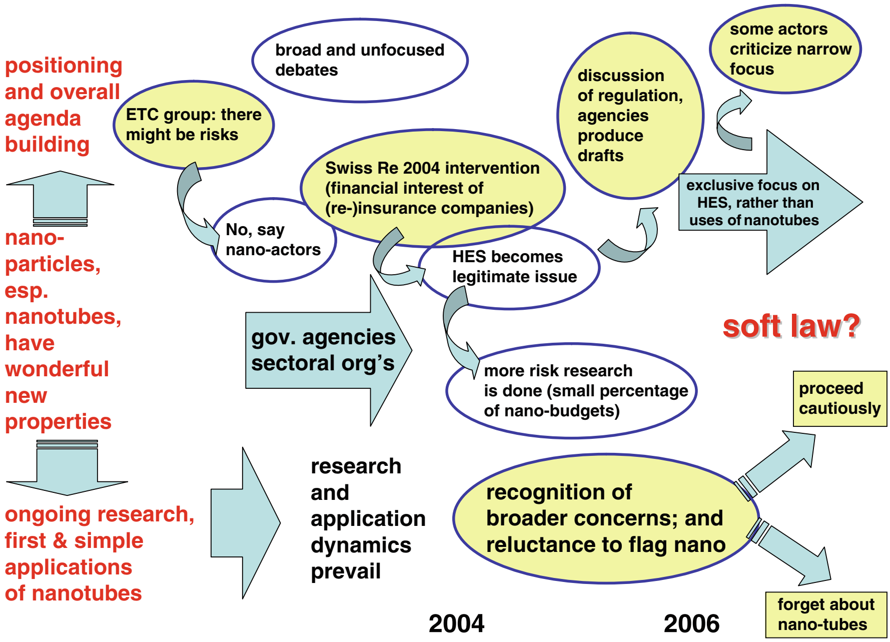

Fig. 4 Evolving paths in the "landscape" of nanotubes and their risk

[22]When a product featured as "nano" turns out to have health effects (as happened in April 2006 with the German bathroom cleaner Magic Nano), the first concern is about damage to the image of nano (and everybody was relieved that – this time – it was the aerosol in the can, not nanomaterials that were responsible for users' health problems; there may not even have been a nanomaterial in the product).

Governance Council in Zürich in July 2006.[23] The occasion was the publication of a (hopefully authoritative) report on risk governance of nanotechnology, authored by Ortwin Renn (a risk and public deliberation scholar) and Michael Roco (of the U.S. NNI) (see also Renn and Roco 2006a). Governmental and industry actors from across the world attended, as well as NGOs, scientists, and scholars studying nanotechnology in society. Dedicated workshops and mingling in the corridors allowed interaction and recognition of positions of other actors (and thus some learning).

The traditional distinction between formal agenda-building by authoritative (policy) actors, and informal societal *de facto* agenda-building becomes blurred. According to Shibuya (1996), for a risk issue to rise on the formal agenda, it needs to be taken up in both formal and informal agenda-building processes. However, the articulation and prioritization processes are not separate. This is why we needed the concept of an evolving landscape to map the processes. It also shows how earlier and ongoing actions and interactions about risk and governance can be repositioned, after stabilization of the agenda, as activities to implement newly articulated goals, which in this case are responsible innovation and risk governance.

In this evolving landscape, two paths are visible: one is the focus of concerns on risk, and in particular risks of nanoparticles; the other is the tendency to opt for soft law in the interaction between governments (and their agencies and advisers) and firms (and their associations, sectoral or otherwise, and alliances). While these two paths shape most of what is happening now, there are also other paths. One is the criticism of the narrow focus on risk and risk assessment, and not just by NGOs like Greenpeace. The other is the involvement of NGOs in the soft-law alliances, for example in the proposal by DuPont Company and the U.S. nonprofit Environmental Defense Fund for a voluntary risk-assessment framework that can be adopted by oversight agencies worldwide.[24]

There is now also increasing reference to "responsible innovation" in government documents (particularly of the European Commission) and some industry statements. While this may invite nano-promoters to consider broader issues, and allow other actors to raise questions about directions of development, responsible innovation is presently operationalized as transparency and some public engagement. And in the case of industry, also as a responsibility for safe handling of nano-production and nano-products.[25] The recent September 2007 initiative toward a "Responsible Nanotechnologies Code" is led by the UK Royal Society, an NGO

[23]The IRGC is a private not-for-profit foundation, based in Geneva, "to support governments, industry, NGOs and other organizations in their efforts to understand and deal with major and global risks facing society and to foster public confidence in risk governance." (quoted from Renn and Roco 2006b: 5) A conference report is available from Swiss Re Centre for Global Dialogue (2007).

[24]This framework is criticized by other NGOs; see the Open Letter by the Civil Society – Labor Coalition of 12 April 2007.

[25]Degussa's website on nanotechnology has an item to this extent on responsibility (www.degussa-nano.com/nano (accessed on January 27, 2008)), and BASF's Code of Conduct has a similar thrust.

(Insight Investment), the Nanotechnology Industries Association, and supported by a network organized by the UK Department of Trade and Industry,[26] envisages a broader approach, but it is not clear if and how it will be taken up. (For an overview of the present situation, see Kearnes and Rip 2009.)

4 In Conclusion

Our two cases show different patterns. The Drexler saga had an auspicious start, and Drexler's ideas inspired many people, including some of the later critics of the Drexlerian vision. But then the concept became weakened because its feasibility was a matter of in-principle argumentation, too "long term" or "speculative" or even "science fiction," depending on the position one wanted to take. The link with the Grey Goo scenario did not help either. Boundary work to exclude Drexler, or better, DREXLER, the stereotyped carrier of the Drexlerian vision, started in earnest after funding for nanoscience and nanotechnology was assured in 2000, and the exclusion was complete by late 2003. As Regis (2004) phrases it, "Drexler found himself marginalized in the very field he had inspired," while the specter of DREXLER overshadowed his attempts to remain a player. Clearly, by now, molecular manufacturing in the Drexlerian sense is a path not taken.

Where the Drexlerian agenda has collapsed for all practical purposes,[27] the concern-about-nanotechnology agenda has become stronger, and is operationalized and implemented in its more focused, or reduced, version of attention to risks, in particular risks of nanoparticles. The reversal occurred in 2004, from an open-ended situation of broad concerns and denial and contestation, to acceptance of risks of nanotechnology as a legitimate issue, and a situation in which government agencies as well as other actors should take concrete steps to prevent harm. By 2006, there was no way back, and as outlined in the preceding section, two paths had emerged in the overall landscape which shaped most of the activities.

Thus, in both cases, the entanglements led to *de facto* irreversibilities: no return for DREXLER; a continuation of the focus on risk and risk governance. The emergence of such irreversibilities is not a linear process, even if in retrospect one can tell a story of actions, interactions, and events leading up to the present situation. Also, there are contingencies, for example, the effect of Prince Charles' interest in nanotechnology in spring of 2003, which triggered concrete actions by other actors. However, the effect of what might be seen as a contingent action or event is predicated on, and to some extent shaped by, the contours of the landscape at the time. Another example is how Swiss Re's May 2004 report on risks of nanoparticles was

[26] See: www.responsiblenanocode.org (accessed on January 27, 2008).

[27] Even if the possibility of molecular manufacturing is kept alive in scenario-building exercises by the Center for Responsible Nanotechnology (CRN 2007), and in arguments about prudent anticipation (Lin and Althoff 2007).

a singular intervention and had effects as such. But if it had been written and published two years earlier, it would not have had these effects because the landscape was not yet amenable, as is clear from the very different reception of the München Re report of 2002.

Before inquiring into spaces for explicit deliberation in these developments, it is important to note that learning is occurring at the societal level, or at least at some collective level. One of us has called this "repertoire learning" (Rip 1986), in the sense that a better (more articulated) repertoire has developed that is available to actors to use (and misuse) and that will shape what are acceptable positions and actions. While struggles about definitions and directions linked to interest-driven strategies and overall agenda-building dynamics will not disappear, these struggles will be conducted in terms of the better articulated repertoire and thus be more productive. This productivity may well be predicated on following by-then stabilized patterns, as Swierstra and Rip (2007) have shown for moral arguments about newly emerging technologies such as genetics and nanotechnology. Therefore, openings and lateral action might be important to keep the repertoire evolving and adapting (cf. Rip 2006b).

There might be occasions where decontextualized deliberation, as in an (idealized) agora (cf. Nowotny et al. 2001), occurs, often orchestrated and supported by professionals, as in recent public engagement exercises about new technology. On these occasions, the possibilities and outcomes are determined more by the spaces that open up and allow for some deliberation, than by the deliberative processes and arguments as such. For example, prudent nano-promoters will be interested in longer-term issues (for example to avoid the impasse of green biotech), and thus prepared to entertain broader interactions and deliberations. This enables mutual learning. But learning is an effort, and actors will thus invest in learning only when they are forced to do so, to ensure their survival and/or to meet contestation. This applies to industrialists just as much as it applies to critical NGOs. In other words, while deliberative processes can assume that actors are able to learn and shift positions without much constraint, the real-world dynamics are full of emerging irreversibilities and stabilizing gradients. Shifts are always part of struggles.

The next step is then how to take repertoires and their dynamics, including the nature of the spaces, into account. We positioned and analyzed our two cases not just to understand what happens while outcomes are not determined linearly by intentions and actions of one or more actors. We showed how actions and interactions at the collective level (overlapping arenas, *de facto* agendas) are important in determining outcomes. This offers tools (at least by example) to reconstruct and diagnose what is happening, which can then be fed back to various actors. We have developed this approach one step further by creating scenarios of further developments, based on nonlinearity and complexity (see Rip and Te Kulve 2008 for a first overview). In workshops with heterogeneous participants, as we have organized, such scenarios are starting points to probe each other's worlds, rather than working towards a consensus, which is the traditional idea behind the call for deliberative processes. In that small way, processes of societal *de facto* agenda-building and articulation of actor strategies are mimicked. The effect is not consensus, but increased reflexivity.

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The Risk Debate on Nanoparticles: Contribution to a Normalisation of the Science/Society Relationship?

Armin Grunwald and Peter Hocke

1 Introduction and Overview

Since the very beginning of ethical reflection on science and technology, there has been ongoing discussion about adequately timing ethical inquiry in relation to scientific and technological progress. It has often been deplored that ethics fall helplessly behind technical progress and fall well short of fulfilling the great societal expectations of providing moral guidance. The rapid pace of innovation is seen as the main reason why ethical deliberations often come too late (Ropohl 1995). Being too late, however, implies that ethical reflections cannot have any impact because the respective technology and its social consequences are already in "the world": "It is a familiar cliché that ethics does not keep pace with technology" (Moor and Weckert 2003, see also Habermas 2001). Ethics in this perspective ("ethics last" model, cf. Moor and Weckert 2003) could, at best, act as a repair service for problems that have already arisen (Mittelstraß 1989). Concerns of this type also accompanied the early phase of ethical deliberation in nanotechnology (Mnyusiwalla et al. 2003).

These concerns have, however, motivated the emergence of new approaches. In this context, ethical reflection should start in very early phases of development (cf. introduction to this volume). Ethics can provide guidance and orientation knowledge even in the early phases of innovation because the basic technical information as well as information about the objectives and intentions related to the respective research and development (R&D) activities is available long before market entry. This information, with reservations regarding the well-known problems of the uncertainties involved, can be used to prospectively investigate the social impacts, consequences and implications of the technology under consideration, as is the business of prospective analysis and assessment in general (in the field of technology assessment, see e.g. Bechmann et al. 2007).

There are generally calls for ethical deliberation in cases of moral conflicts (Grunwald 2003). In R&D in innovative technology fields, ethics are required as

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soon as there are moral ambiguities, new questions, doubts or conflicts related to the technology under consideration and its social environment. The "ethics first" model (Moor and Weckert 2003) postulates comprehensive ethical reflection on possible impacts *in advance* of the technological developments in order to enable the further course of development to be influenced. In very early stages of development, however, only little, if any, knowledge is available about the fields of application, market acceptance, consumer reactions, and the consequences for individuals and society. Therefore, ethical reflection in this model has to contend with the fact that the knowledge available on the technology and its consequences is (often highly) uncertain and preliminary.

Ethical inquiry into nanotechnologies aims to influence the further course of development or, in short, *to make an impact* rather than being a mere ornament. The early stage of many developments in nanotechnology provides an advantageous opportunity: the chance and also the time for concomitant reflection, as well as the opportunity to integrate the results of reflection into the process of technology design and thereby contribute to the further development of nanotechnology (Moor and Weckert 2003, Fleischer 2002). Ethics and other types of prospective analysis and assessment, such as science and technology studies (STS), have largely recognised this opportunity: the hype of nanotechnology has been followed by a hype of reflection on the social implications and impacts of nanotechnology. It seems appropriate to question whether the latter hype is likely to have any impact. In a "strong" understanding of the social shaping of technology (SST) approach (cf. Section 2), we can expect impacts influencing the "shaping" of nanotechnology.

Within this broad field, we will focus on the debate regarding the risk of synthetic nanoparticles (Section 3) and investigate the relation between nanotech research and related STS research and ethical inquiry in this area (Section 4). In an institutional respect, we will consider in more detail the situation at the *Karlsruhe Research Centre* (Forschungszentrum Karlsruhe: FZK), where nanotech research and nanotech assessment have been performed in parallel within one organisation (Section 5). At the general level as well as at the specifically considered institutional level, we arrive at three conclusions (Section 6): (1) the absence of a strong influence of the ethical debates on the further course of nanotech research, as would have been expected following the SST approach, (2) a "normalisation" of the relation between ongoing nanotech research and ethical risk debate compared to earlier debates around technology and society, and (3) closer cooperation between different scientific disciplines within an integrative approach.

In this way, we aim to contribute to the debate on expectations concerning the relations between ethical deliberation and STS studies, on the one hand, and the scientific R&D agenda and actual technology development, on the other. By considering the nanoparticle case, we formulate a hypothesis that might be perceived as disappointing, or even devastating, by some parts of the STS and ethics community. With our results, we hope to stimulate further empirical case studies that indicate support, the need for modification or even a rejection of our hypothesis.

2 The SST Approach

In this paper, the SST approach is applied as a framework for considering the effect of ethical inquiry on technological development. Ethical reasoning is one of a number of activities that provide orientation and support societal opinion-forming and political decision-making. Within the various approaches that fall under the social constructivist paradigm, the impact of those activities is primarily seen in the field of technology itself: ethical reflection aims to contribute to the technology paths, products and systems to be developed (Yoshinaka et al. 2003). Theory-based approaches of *shaping technology* have been proposed, for example, by means of technology assessment (Rip et al. 1995) or variations of the social construction of technology (SCOT, cp. Bijker and Law 1994, Bijker et al. 1987). They have introduced strong claims for *influencing technology* by reflecting technology's social role and its consequences in the debate. The central message is that a "better" technology could be constructed by using SST or other social constructivist approaches: "to achieve better technology in a better society" (Schot and Rip 1997). The social construction of technology has even been extended to the social construction of the *consequences* of technology. In order to achieve a more environmentally and socially friendly technology, network-oriented approaches in the sociology of technology tried to control the problem of unintended side effects of technology by applying suitable strategies for shaping technology during its genesis.[1]

There are highly ambitious models of social construction and *constructability* of technology behind these approaches. With reference to the issue paper in this volume, one of the hypotheses to be examined in the following is that ethical reflection on nanotechnologies has contributed to the *formation* of these technologies and still does so rather than being a mere ornament to a self-dynamic and autonomous process.[2] The idea of *forming and shaping technology*, often by means of participative and deliberative procedures, stands in the foreground. The term "formation" seems to be clear in this context: it means that ethical deliberation is expected to contribute to the development of nanotechnologies in order to achieve "better" nanotechnologies. There are (at least) two variations on understanding the meaning of "formation of nanotechnologies" against the theoretical positions mentioned above:

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[1] As an example of a very ambitious and clear formulation: "If involving potential users allows considering a wide range of possible effects and exploring the opportunities and risks of alternatives in a broad social process of deliberation, the concept predicts that we can expect this to lead to a more user-friendly and low-risk socio-technical system with far less unintended adverse side effects" (Weyer 1997: 345 – author's translation from German).

[2] This position is in sharp contrast to approaches of early technology assessment which presupposed a technological determinism forcing society to adaptive measures. The objective of technology assessment was seen as predicting technology impacts and preparing society to be able to deal better with those impacts (following Grunwald and Langenbach 1999).

- Strong understanding: "contribution to the formation of nanotechnologies" means "influencing the development of nanotechnology" in the sense of *directly* influencing the R&D agenda of nanosciences and, therefore, the further course of research and technology itself. This would be the main understanding of the SST and SCOT approaches mentioned above.
- Weak understanding: "formation of nanotechnologies" means "formation of the perception of nanotechnologies", where the "perception" could be the public perception, the perception of the scientists, of stakeholders etc. – with possible impacts on how technology is embedded into society and with a more indirect influence on the research agenda.

In this paper, the main question is whether there is proof in support of strong claims for contributions of ethical deliberation to the formation of nanotech in practice. Ongoing processes of nanotech progress as well as of ethical deliberation on nanotech issues can be observed and interpreted like an experiment in a laboratory. The current situation of a parallel development of nanotech and ethics on nanotech permits an empirical analysis of the relation between theory and practice in this field, employing the case of the production and use of nanoparticles.

The main result is that there is only weak evidence for the "strong" understanding of ethical contributions to the formation of nanotechnology. In the literature and public discourse, traces of ethical deliberations influencing the pathways and roadmaps of nanotechnology and, thereby, affecting the nanoscientific agenda itself are rarely found. Ethical deliberations, however, clearly have had and still have concrete (other) impacts in other fields. While not directly affecting the nanoscientific agenda, they have complemented the view on what should urgently be done in other fields of research (like nanotoxicology) or have motivated public debate, thus contributing to nanotechnology as a public phenomenon. There is more evidence in support of the weaker interpretation of "contributions of ethical debate to the formation of nanotechnologies". The main findings of this paper suggest rejecting the stronger understanding of "shaping nanotechnology by ethical reflection" for its weaker counterpart. There is no evidence in the general public debate or in the discourse among important stakeholders from industry and science indicating any endeavours to incorporate ethical arguments in a broader sense and to allow such intervention to change the lines of technological development.

3 The Risk Debate on Nanoparticles

A vast potential market for nano-based products is seen in the field of synthetic nanoparticles (Paschen et al. 2004, Schmid et al. 2006).[3] New products are based on new properties of nanomaterials, which result from admixtures or specific

[3]Synthetic nanoparticles are artificially designed particles at the nanoscale (like fullerenes, nanotubes or the titanium dioxide particles used in sunscreens). In this paper, we will concentrate on

applications of nanoparticles, for instance, in surface treatment or in cosmetics. Furthermore, nanoparticles and nanostructured materials offer new ways of designing and controlling catalytic functions, including the provision of enhanced activity and selectivity for target reactions. Since the activity and selectivity of catalyst nanoparticles are strongly dependent on their size, shape and surface structure, as well as on their bulk and surface composition, being able to synthesise particles at the nanoscale with defined physical and chemical properties is an important step in achieving the goal of catalysis by design. This is just one of the many fields where nanotechnology will enable green chemistry and offer a route to a "green" nanotechnology (Fleischer and Grunwald 2008).

But all these potentials may come at a price. The production, use and disposal of products containing nanomaterials may lead to their appearance in air, water, soil, or even organisms and human bodies, possibly causing adverse effects (Colvin 2003). Their ways of spreading and interacting with other particles, their impacts on health and the natural environment, in particular their possible long-term effects are largely unknown at present. In this situation of large knowledge gaps and scientific uncertainty, the *precautionary principle* comes into the game (von Schomberg 2005, Grunwald 2008).

Nanotechnologies were perceived as seemingly no-risk technologies for a long time. Public perception in the 1990s was low. The prefix "nano", however, and this is a strong indication of a positive perception, was used in the media – not in mass media but, for instance, in science magazines – as a synonym for "good" science and "smart" technology. This situation changed radically in 2000. The positive utopias of nanotechnologies, based on a technical access to "the small", were inverted to horror scenarios, based on the same "small" technologies (Joy 2000). The ambivalence of technology-based visions became obvious (Grunwald 2006). The public risk debate on nanotechnology emerged around issues of visionary and more speculative developments. Topics like "grey goo", "nanobots" and "cyborgs" became well-known to many people within few months (Schmid et al. 2006: Chapter 5). Concerned groups began to think about analogies and parallels between nanotechnologies and technology lines with a tainted history in the public risk debate: nuclear technology and biotechnology (ETC Group 2003). Newspapers and reassurance companies put nanotechnology in the category of risky technologies. They quickly became aware of the risks of nanomaterials and related governance questions. Thus we were able to witness, in the mirror of public perception and mass media communication, the fall of nanotechnology from a synonym of "good" scientific and technological progress to a technology line that is expected to bear a lot of still unknown risks as well. Not surprisingly, this phenomenon quickly attracted growing interest in the fields of STS research, technology assessment and ethical analyses.

The emergence of the risk issue in combination with the fact of having practically no knowledge about side effects of nanotechnology led to severe irritation and to a

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synthetic nanoparticles of this type and not consider nanoparticles as unintended side effects of production or incineration processes.

kind of helplessness at the early stage of that debate. Statements from that time waver between an optimistic "wait-and-see" strategy (Gannon 2003), on the one hand, and strict precautionary and sometimes "alarmist" approaches, on the other:

> The new element with this kind of loss scenario is that, up to now, losses involving dangerous products were on a relatively manageable scale, whereas, taken to extremes, nanotechnology products can even cause ecological damage which is permanent and difficult to contain. What is therefore required for the transportation of nanotechnology products and processes is an organisational and technical loss prevention programme on a scale appropriate to the hazardous nature of the products (Munich Re 2002: 13).

The still most famous position on nanoparticle regulation is probably the ETC Group's proposal for a moratorium:

> At this stage, we know practically nothing about the possible cumulative impact of human-made nanoscale particles on human health and the environment. Given the concerns raised over nanoparticle contamination in living organisms, the ETC Group proposes that governments declare an immediate moratorium on commercial production of new nanomaterials and launch a transparent global process for evaluating the socio-economic, health and environmental implications of the technology (ETC Group 2003: 72).

The ETC work gave a significant push to nanotechnology regulatory debates in many countries but also increased the fears on the side of nanotechnology researchers of a broad public front of rejection and protest.

A completely different but also far-reaching recommendation aims at "containing" nanotechnology research: The Center for Responsible Nanotechnology (CRN)

> has identified several sources of risk from MNT (molecular nanotechnology), including arms races, gray goo, societal upheaval, independent development, and programmes of nanotech prohibition that would require violation of human rights. It appears that the safest option is the creation of one – and only one – molecular nanotechnology programme and the widespread but restricted use of the resulting manufacturing capability (Phoenix and Treder 2003: 4).

This containment strategy would imply a secret and strictly controlled nanotechnology development, which seems to be unrealistic and unsafe as well as undemocratic. Furthermore, this recommendation is irritating if we take the ideal of an open scientific community seriously.

All of these different proposals have enriched (and heated) the public and scientific debate. Seen from today's perspective, these proposals are documents of a very specific situation. Nanotechnology, while still in an embryo state, finds itself, more or less suddenly, the subject of a public risk debate. Nobody seemed to be prepared for this. The situation was characterised by severe challenges: while high expectations of benefits still dominated the debate, there was no reliable knowledge about the possible side effects of nanotechnology. Against this background, it is understandable that the first years of the nanotechnology risk debate were largely based on mere suspicion, irritations and uncertainties rather than on knowledgeable and rational deliberation.

In the meantime, however, things have changed considerably. An intensive debate on nanotech issues and risks has taken place in many countries. In 2003, the German Parliament debated about nanoparticles, informed by a technology assessment study (Paschen et al. 2004). The study of the Royal Society and the Royal Academy of Engineering (2004) resulted in many statements and recommendations aimed at closing the knowledge gaps and at minimising the possible risks resulting from production and use of nanoparticles by adopting a preventive approach. In the FZK technology assessment, researchers, toxicologists and nanotechnologists began thinking about common projects (cf. Section 5). Ambitious research programmes on possible side effects of nanoparticles, and ethical, legal and social aspects (ELSA) studies have been started (e.g. NanoCare 2006). Public unease concerning nanoparticles, however, has not disappeared. The call for a moratorium has been renewed in the case of nanomaterials in cosmetics (Friends of the Earth 2006). Empirical research on the public perception of nanotechnology shows considerable concern (but not rejection). Though the "MagicNano" case in Germany – a product with this name had to be recalled because of adverse health effects (in spite of its name, according to the company, no nanotechnology was used) – did not lead to a scandalisation of nanotechnology in the media, a high degree of sensitivity on the part of nanotechnology researchers has been the consequence (Grobe 2007). There is still no equilibrium or stability in the public's attitude to nanoparticles.

In order to avoid problems of wholesale public rejection of nanotechnology, or of running into situations of societal blockade like in the field of genetically modified organisms (GMO), it is necessary to establish trust-building measures, including an open, society-wide debate. At the heart of the challenge is the task of making precautionary thinking work at the level of concrete operations. The scope of possible side effects of nanoparticles, their magnitude and severity (in relation to the chosen level of protection) can currently, even in best cases, only be estimated in qualitative terms. Therefore, we are witnessing a typical situation of uncertainty where established risk management strategies cannot be applied (in the same vein, also Royal Society 2004: 4, Haum et al. 2004).

Ethical reasoning is required in such assessment work. As the debate on environmental standards for chemicals or radiation has shown (Gethmann et al. 1998), the results of empirical research do not determine how society ought to react. Safety and environmental standards – in our case for dealing with nanoparticles – are to be based on sound knowledge but cannot logically be derived from that knowledge. In addition, *normative standards*, for example concerning the intended level of protection, the level of public risk acceptance, and other societal and value-laden issues, enter the field. Because of this situation, it is not surprising that conflicts about the *acceptability* of risks frequently occur (Grunwald 2005b) – and this obviously constitutes a non-standard situation in a moral respect (Grunwald 2003, Grunwald 2005a). Therefore, the field of determining the acceptability and tolerability of risks of nanoparticles is an ethically relevant issue. In particular, there are a lot of sub-questions in the field of nanoparticles to be analysed and answered by ethical investigation and debate (Schmid et al. 2006: Section 6.2).

4 Observations and Interpretations

The ethical debate about risks of nanoparticles and their acceptability is an early debate in a twofold sense. First, the debate itself is young. Since it started no earlier than the beginning of this decade, we can still speak of an ethical debate in a rather early stage. Second, the subject of this debate is also in an early phase. A large part of the economic and technical potential of nanoparticles has not yet been realised but is expected to unfold in the future. In this sense, the case discussed above falls into the scheme outlined in the issue paper to this workshop: scientific work on nanotechnology meets early ethical reasoning about its potential impacts. This diagnosis allows interpreting the developments of the past few years in the field of nanoparticles in light of the question as to the contributions of the ethical debate to the formation of nanotechnologies.

4.1 Nanoparticles and the Strong Social Constructivist Position

The interface between society and technology has been conceptualised in different ways. In earlier social sciences, technology was seen as outside of society, partly influencing society in the form of determinism. In social constructivism (Bijker et al. 1987), a far-reaching assumption about the malleability of technology by society has been made. Other theories depict the link in this relation as a kind of co-evolution of technology and society (Rip et al. 1995). The choice of model in describing the relation between technology and society, or of the role of technology in society, to a large extent determines the patterns of observation and interpretation of what is assumed to go on. As pointed out in the introduction, we will take a simplified version of the social constructivist model as our point of departure. One of the basic ideas of the "social shaping of technology" by means of ethical deliberation, in our interpretation, consists of an ideal learning cycle involving scientists and stakeholders as well as the public:

1. Ideas emerging from science and engineering promise new technical capabilities and functions that give rise to visions for new applications, for problem-solving, for advancing welfare, health, sustainable development etc. A field of (often high) expectations, hopes and desires opens up.
2. The expectations and the technological paths toward fulfilling them are reflected and deliberated (by stakeholders, ethicists, innovation researchers, citizens, the media etc.) in view of the areas in society potentially affected (energy supply, health, sustainable development etc.), for example using the vision assessment approach (Grunwald 2006).
3. These deliberations and assessments result in clarifying relations between the offers and promises of science and technology, on the one hand, and demands and values prevailing in society, on the other, for example concerning the acceptance or acceptability of risks related to nanoparticles.

4. These results are fed back to the R&D system, where they are to be implemented into the goal systems for the further advancement of the technology under consideration. In this way, ethical reflection is expected to contribute to the R&D agenda and influence the further course of development.

This cybernetic loop is also supposed to allow avoidance of unintended technological impact (Weyer 1997: footnote 1). Learning at the interface of science and technology, on the one hand, and society, on the other, is systematically embedded in the processes of technology development. Such learning cycles could be applied at different stages in an R&D process and should lead, via cybernetic feedback loops, to adapting the emerging technical possibilities to societal needs and desires. This position is termed "strong" because reflective activities like ethics are expected to contribute to the shape of technologies rather than (merely) to their social embodiment. The question is whether the developments made in the past few years in the field of nanoparticles can be interpreted in this framework. Let us follow the steps mentioned above:

- Step 1 can be identified by looking at the promises and visions related to the benefits of nanoparticles. There is no doubt that this step has already taken place and can still be found in many documents in the field.
- Step 2 can also be found. The story told in Section 3 describes exactly what happened after the first phase: fears, irritation and concern motivated public debate and ethical reasoning.
- The status of step 3 in the field of nanoparticles is difficult to assess. There is an ongoing debate without any clear results. Classical risk management with accepted standards would be a typical result of that step, but things are not that well developed yet. There are results, but the analysis of their status leads to differentiated statements (see below).
- Step 4 has not yet been reached. The agenda of nanotech R&D as such has not been reviewed with respect to obtaining "better" technology.

The diagnosis at this stage of analysis is that a shaping of technology in the strong sense of "contribution to the formation of nanotechnologies" currently cannot be found. Most likely, the research agenda of nanotechnology has not been strongly influenced by ethical debate. Because of this observation, one should not speak of a "social shaping of nanotech" in a strict sense. Instead, there might be other types of "shaping", which will be analysed in the following section.

4.2 What about "Formation of Technology" in the nanoparticle Story?

Without a doubt, the risk debate on nanoparticles has had clearly identifiable impact. First of all, the diagnosis of great uncertainties in the knowledge on cause-effect chains motivated funding agencies and researchers to launch a vast amount of research into human and eco-toxicology as well as into environmental chemistry. There are a lot of ambitious projects, like the German NanoCare, where knowledge is created, assessed with respect to action strategies, and communicated. Second, many activities have been staged in the public sphere. For example, the first German consumer conference on nanotech issues recently took place. Third, there are ongoing analyses and processes at the regulatory level, for instance with respect to the precautionary principle (von Schomberg 2005, Grunwald 2008), or as involved in the REACH system of the European Commission, or the Toxic Substances Control Act of the United States (Wardak 2003). Fourth, the public perception of nanotechnology has become the subject of many empirical studies, primarily because of fears of public rejection due to the risk debate on nanoparticles (Scheufele and Lewenstein 2005, Hart 2008, Hart 2006, Cobb and Macoubrie 2004). Fifth, non-governmental organisations (NGOs) have entered the field, and some have called for a moratorium (ETC Group 2003, Friends of the Earth 2006).

The debate on the risks of nanoparticles has, without doubt, many direct impacts on public perception of nanotechnology, on the political and social awareness of potential risks, on the identity of toxicology (Kurath and Maasen 2006), on establishing new research fields and also on the emergence of new funding opportunities. In this way, ethical deliberation has had considerable impact that can be identified from today's perspective. In the following, we would like to interpret such impact against the background mentioned in the introduction and in the previous section. In what way did the ethical debate on nanoparticles contribute to the "formation" of nanotechnologies – beyond the verdict stated above that the "strong version" (cf. Section 2) of understanding the "contribution to the formation of nanotechnologies" as directly influencing the R&D agenda of nanosciences could not be verified?

In our observation, there are indirect and mediated impacts on nanotechnology caused by the risk debate on nanoparticles. It is the *scientific and societal environment* in which nanotech research takes place that has been influenced and modified to a remarkable extent. We would like to emphasise the following points:

- The research agenda has been influenced – not that of nanotechnology as such but of other sciences like toxicology and also of the social sciences, for example in the STS field. Funding agencies increasingly demand risk issues to be explicitly considered in funded projects or programmes (the Austrian nano-initiative is the most recent case). In particular, the quality of the planned risk assessment strategies increasingly serves as one of the success criteria in evaluations of applications for funding.
- Research identities of disciplines have been influenced, as Kurath and Maasen pointed out for the case of toxicology.
- Social awareness on nanoparticle risks has been increased without creating an atmosphere of rejection, fear or fundamentalism. The risk issue now self-evidently belongs to introductions to nanotechnology and to public lectures; it has become part of the nanotech "identity". Nanotech researchers are now aware of the fact that their research is "under observation" by ethical debates. The

nano-lab is no longer separated from society, but nanotech advance takes place under society's watchful gaze.

These observations are of course not surprising. Similar effects have been identified in ethical debates on other fields like stem cell research, too. Ethical inquiry does contribute to the course of development, but the contribution is more indirect.

4.3 The Normalisation Hypothesis

The thesis presented in this section is that the risk debate on nanoparticles has contributed to a "normalisation" of nanotechnology. Prior to this debate, the futuristic aspects of nanotechnology (like the nanobots or Drexler's molecular assembler) were in the foreground and subjects of public debate. The risk debate on nanoparticles, however, has brought nanotechnology "down to earth" in public debate. Nanotechnology has lost its futuristic character, for example in the mass media reports, and has come to be viewed in the same way as new chemicals and fine and ultrafine particles. The debate on nanoparticle risks made clear that nanotechnology is – at least in this field – to a large extent research on new materials. New materials, however, might be revolutionary in their technical details – but not in their social perception. There is much experience in society in dealing with new materials, and there has been a long-lasting debate on how to deal with their risks. Society is familiar with this issue: we embed hundreds or thousands of new chemicals into our technical surroundings every year, and we have had some uncomfortable experiences, as the asbestos story tells us (Gee and Greenberg 2002). We have regulations and procedures available to manage these problems. Even the ethical problems involved are not really new (Schmid et al. 2006: Section 6). The mechanisms of risk management and precautionary thinking are surely not directly transferable to the field of nanoparticles without specific adaptations (Schmid et al. 2006: Chapter 5), but the *type of problem* is not new to society – while the problem of nanobots really would have been a new one.

The risk debate on nanoparticles has also contributed to a normalisation of nanotechnologies in a second sense. Nanotechnology was perceived as a "clean" and "smart" technology for many years, as an ideal technology in strict contrast to traditional technologies symbolised by large chemical plants or the coal and steel industry. In this respect, the prefix "nano" was used as a purely positive symbol for a better future based on nanotechnologies. The risk debate has destroyed this entirely positive perception. Nanotechnology has become a "normal" field of technology with all the normal problems of potential hazards to human health or the environment.

In a third sense of "normalisation", the debate on nanoparticles might be an indicator rather than the source of normalisation. For some years now, nanoscientists, policymakers, and funding agencies have been concerned about the public perception of nanotechnology. Several years ago (ca. 2003–2005), the diagnosis became popular that nanotechnology might be the next communication disaster at the interface of technology and society after nuclear power energy and genetics. Calls for a moratorium on the use and release of nanoparticles, voiced by NGOs (see Section 3), fed expectations and fears in this direction to a considerable extent.

However, up to now, no such communication disaster has materialized. We still have a relaxed relationship between nanotechnology and the public. While the debate on possible risks of nanoparticles is still going on, it has not led to rejection or protest. Currently, it seems widely accepted (1) that "zero risk" is an inappropriate demand, and (2) that technological progress by necessity entails risk and uncertainty. It might be that the social perception of technology in general has changed or that society today has other concerns than technological risk. However, it seems more plausible that ethical deliberation of nanotechnology and related activities have contributed to this "relaxed" perception in the following way: In the field of nanotechnology, a lot of activities in recent years give evidence that dealing responsibly with risk has become a regular part of scientific progress and its political shaping, funding and regulation. ELSI activities, toxicological research and debates on regulation are major examples. Risk is not ignored or denied (especially not by nanoscientists and managers) but is actively dealt with. In this way, *trust* has been generated – and trust is a major issue in avoiding communication disasters.

The chapter below illustrates how, in the formation of nanotechnology research at the Forschungszentrum Karlsruhe, opportunities were missed for newly establishing cooperation both within the organisation and with research partners from the outside in the daily struggle for effective planning under conditions of limited resources.

5 The Institutional Case: Nanotechnology and Technology Assessment at FZK

The cooperation between Forschungszentrum Karlsruhe (FZK), as a big national laboratory with its own nanoresearch, and the Institute of Technology Assessment and Systems Analysis (ITAS), as one unit within this national research centre, is analysed to exemplify the general issue in the case of a concrete institution. The cooperation process can be divided into three phases: the set-up phase of the new research topic "nanotechnology" was followed by a second phase of exploring the potential of existing options for cooperation, which led to the third and ongoing phase of "peaceful coexistence with selective cooperation." Without overstressing the evolutionary character of this dynamic process, the introduction of the phase-specific differences allows the observation of the agenda-building of integrated disciplines and the process of coordinating the strategic orientations and preferred scientific orientations of nanosciences with technology assessment, which led to the existing but not very intensive forms of cooperation within the FZK.

The formation of the Institute for Nanotechnology (INT) at FZK in the summer of 1998 was embedded in a wave of science and technology policy-oriented activities which were influenced by both national and international developments (see Fleischer 2002: 111). As FZK reoriented its mission after downsizing its nuclear research activities, the highly dynamic sector of nanosciences became a research topic of extraordinary importance, in which the newly founded institute became a key player. The INT was led by a board of three directors including the French Nobel laureate Jean-Marie Lehn. The structure of the INT was formed by several working groups (and not by departments). From the very beginning, a close cooperation was established between FZK and the universities of Karlsruhe (Germany) and Strasbourg (France). Many heads of the working groups at the INT also worked at different top-level universities, which was helpful not only in generating successful research networks but also in ensuring highly professional basic research and scientific excellence. At the same time, the research agenda of the newly founded INT was established, which was less oriented to concrete technological (!) applications without eliminating them from the agenda. By reorganising its internal research structure, the FZK captured the opportunity to initiate a number of multidisciplinary work programmes, including new forms of cooperation and division of work with other FZK research institutes (like the Institutes of Materials Research).

Altogether, the INT established a special profile focused on "Electronic Transport through Nanoscale Systems" and "Nanostructured Materials", which started with ambitious aims and high expectations. A guiding principle in this context was to achieve high internal and external synergies. One instrument for achieving this goal was to invest in networking with nanosciences, which is facilitated by the interdisciplinary approach of this research per se and further strengthened by existing competences in related research areas (like microsystems technology). Following the programmatic discussion within FZK, this arena of synergy and cooperation also intended to integrate the systematic discussion of unintended consequences of new technologies, as established in technology assessment.

Parallel to the foundation of the INT, the network "NanoMat" was created. Similar to the networks of competence built up by the German Bundesministerium für Bildung und Forschung (BMBF; Federal Ministry of Education and Research) at that time, the aim of NanoMat was to enhance cooperation between researchers and partners from industry (see Hedderich 2005). The programme "Nano and Microsystems", which a few years later replaced the previous focus on "Microsystems" with the aim of linking research on microsystems with the new research topic "Nanotechnology", stimulated the establishment of an integrative approach within the FZK. This approach was also to allow to incorporate the study of risks and chances of these new emerging technologies together with the analysis of unintended impacts into the research agenda of the FZK, which was still under discussion. The principles of programme-oriented funding, introduced in the Helmholtz Association around the same time, included the explicit call to develop cooperative networks of researchers, integrating different disciplines and research institutes.[4] The development of concrete research activities within this

[4]The Helmholtz Association is an umbrella organisation comprising research centres like FZK that are mainly financed by federal funds. The individual centres of the association are controlled by a trans-institutional budget, which is distributed on application by different topics to specific institutes in the centres (cf. HGF 2003: 4).

type of steering instrument and the related coordination of research activities introduced the next phase that followed the establishment of the research topic "Nano" at the FZK.

In the course of breaking down the previously discussed options of intensified networking and cooperation into concrete research activities within the second phase (starting about 2002/2003), it became obvious that no common understanding could be reached on decision-making and on the modes of negotiating the research activities. Although nanotechnology was a highly dynamic and promising field of research, the limited resources available and the competitive situation within the FZK caused by the programme-oriented funding became a critical aspect in the process of reorganising the internal structures in Karlsruhe. On one hand, against the background of older technology conflicts (like those about nuclear power or genetic modification), there was an interest in avoiding comparable debates and conflicts about nanotechnology and in adequately reacting to the general risk debates of recent years and decades; this interest was predominantly articulated by natural scientists and engineers. On the other side, technology assessment was given little chance to explore ideas of systematic studies in cooperation with the institutes of the research centre, to discuss different possible paths of development, and to assess the impacts of a fairly new technology within its own "home organisation" in order to enhance its scientific standing. That there was a small window of opportunity is evidenced by a number of smaller events within the FZK (e.g. NanoVision 2003, 2004 and 2005) and a cooperation attempt between ITAS and natural-science oriented research units within the FZK; this project was discussed in the research planning of the FZK under the focus of a science-oriented roadmapping process (see Fiedeler et al. 2004). However, no substantial consensus on a promising concept was reached between the responsible directors and scientific boards of the FZK. The willingness to allocate resources (in terms of staff, time and budget) especially limited the possibilities for action and cooperation. Potential common interests (e.g. in the field of nanoparticles) were not strong enough to establish continued and fruitful discussions between the institutes involved and to constitute possible "boundary objects" between colleagues at an early stage of R&D.[5]

Besides the established procedures of decision-making and the official research programmes of the FZK, a number of first contacts were made between individual researchers (mostly not in senior positions), who were especially interested in the risks of existing "nanotechnologies" (e.g. nanoparticles, which are not a technology in the usual sense but which, as a research topic, belong to nanosciences) and thus identified a common problem: the "unintended impacts" of nanotechnologies and the risks and hazards for humans and social groups exposed to them. The toxicological risks, especially of nanoparticles, were a starting point that aroused the interest of individual FZK researchers outside of technology assessment to cooperate and use the possibilities of technology assessment without attracting the particular attention of the officials of the FZK.

[5] For a discussion of the concept of "boundary objects" see Star and Griesemer (1989).

Parallel to these first contacts between researchers from different FZK institutes, ITAS developed a thematic concept for the integration of the relevant research topics within its internal research group “Nano and Society”, which is designed to allow systematic “ideal-type” studies about unintended impacts in the concrete case of nanotechnology. A research design with empirical elements for problem-oriented technology assessment was outlined on the basis of this concept to both cover nanotechnological research at different levels of technology transfer and integrate relevant cross-cutting issues. These crosscutting issues include ethical aspects, risk discourses and public protests concerning aspects of nanosciences and nanotechnologies, as well as related strategies of new governance and mass media reporting on nanosciences.

As the activities of researchers and their cooperation, as mentioned above, are often determined by considerations of raising research funds, there was a need to write a number of proposals on different aspects mentioned in the ITAS “ideal-type” research design. These proposals were based on commitments that, to some degree, were not initiated in top-down processes by institute directors but by experienced senior scientists. With this strategy, a fluent change was introduced to forms of selective cooperation within the FZK. In this phase, the technology assessment activities of ITAS were oriented towards the concept of ideal-type technology assessment for potentially risky technologies at early stages, including ethical research. In the end, a number of research projects and work packages embedded in larger technology assessment projects were established to address issues and research topics of the nano debate; these projects represent the core activities of the ongoing third phase.

The characteristic element of this third phase is that the interactions and research cooperations on technology assessment topics extend beyond the Karlsruhe research centre. The network of research partners today is mainly located outside the FZK. Central activities in this field are the project “NanoHealth” and the ITAS work package “Knowledge Transfer” in the project “NanoCare”. In “NanoHealth”, the research fields of “synthetic nanoparticles” and “neural implants” are analysed as examples of “converging technologies”, while the work package “Knowledge Transfer” in “NanoCare” examines communication processes and intended dialogue between experts and the public on the potential impacts of manufactured nanoparticles on human health (see Bräutigam and Fleischer 2006, Krug and Fleischer 2007, Fleischer and Quendt 2007). In the summer of 2007, ITAS started a delphi survey (conducted in two waves) to analyse expert opinions on important visions in the relevant nano debate and nanosciences (NanoDelphi). In NanoCare, the ITAS team mainly cooperates with colleagues from the Institute of Toxicology and Genetics and, in NanoHealth, with the Institute for Applied Computer Science (both FZK), while important external partners are located at EMPA St. Gallen (NanoHealth, NanoDelphi), the Jülich Research Centre (NanoHealth) and in economic enterprises (NanoCare). The ITAS project “InnoMat” also selectively deals with research questions of nanotechnology. Its case studies include interviews with materials researchers from the Helmholtz Association as well as from the Fraunhofer Society and technical universities about their R&D experience in relation to nanosciences. Difficulties in the common assessment of chances and risks of developments in nanosciences encountered in the course of technology assessment research can also be found in this well-functioning cooperation with external partners, but they are handled in a constructive manner. The attention that technology assessment has received from neighbouring nanotechnological disciplines in the FZK is not very high; it is tolerated but not integrated into concrete projects of technological research.

In general, it is evident that technology assessment on nanotechnology has not become an important factor in influencing the structure of the nanoresearch agenda of the "home organisation" FZK. In the preparation of relevant decision-making processes, technology assessment results and the necessity of consultation and deliberation have been addressed. But on the level of institutionalisation and implementation of research agendas within the national laboratory in Karlsruhe, technology assessment plays a minor role; deliberation on specific research activities has been used only in a very formal sense. Rather, it is assumed that agenda setting has been more closely aligned with the structures of basic research. From the perspective of organisational sociology two conclusions can be drawn: (1) For the researchers and under this perspective also for the individual actors in the natural sciences and engineering of the FZK's "post-nuclear" period, the field of nanotechnology and nanoscience provides an explicit technological orientation and requires extensive coordination activities. Especially at the programmatic and pre-structural level, significant milestones have been set over the years. (2) In practice, however, security of action within an integrative approach, which can lead to goal-oriented research structures, cooperation and upstream deliberation of research paths, has been achieved only to a very limited extent. Restructuring processes in large institutions like the FZK (with about 3500 employees) always lead to multipolar competition for internal and external research funds; in this situation, competitors usually choose partners from established external institutions that specific affinity to their own agenda. This struggle for financial and human resources has hindered FZK-internal cooperation. As a consequence, research-oriented technology assessment has not been actively involved in shaping nanotechnological research.

The process of deliberation and discussion of the chances of integrating technology assessment into nanosciences at the FZK, especially in phase 2 and 3, was eclipsed by external, intervening variables like the "Initiative for Excellence" of the German Federal Government and the beginning reorientation of the FZK within the Helmholtz Association. The "Initiative for Excellence" is leading to a fusion of FZK with the University of Karlsruhe, while the reorientation of Helmholtz, as a second variable, has apparently led to a number of programmatic issues where "nanotechnology" is one among others (Autumn 2008). However, in the meantime, both technology assessment researchers and nanoscientists have been working intensively on their topics, oriented towards their own disciplinary contexts and established contacts. Such peaceful coexistence (neglecting the ongoing struggle for limited resources) is not simply a result of the rift between natural sciences and engineering, on one hand, and technology assessment, on the other, as shown in an essay by Alfred Nordmann, in which he impressively describes the work of one of the INT's founder directors, Herbert Gleiter: Different positions and concepts accompanied the formation of the research field "Nanotechnology" from the very beginning and were solved by specific activities aimed at integration in this early phase of stabilising nanosciences (Nordmann 2006). However, nanosciences at FZK did not lead to comparable integration activities, and consequently ITAS, as a promoter of problem-oriented systematic research on the unintended impacts of new technologies, was not linked closer to its own national laboratory. This means that ITAS was not successful in establishing interactive reflection on opportunities and chances of intensively coordinated research activities. Nevertheless, apart from this missed opportunity, professional research activities have been successfully pursued both in the discipline of technology assessment and in nanoscience.

6 Conclusions

Ethical reflection on nanotechnology, as has been shown, does not meet high expectations of contributing to the formation of nanotechnology in the sense of influencing its research agenda. The social constructivist position interpreted in the strong sense cannot be verified in the case considered. However, the risk debate on nanoparticles has remarkable impacts on the social and scientific environment of nanotechnology. This means that ethical reflection is not merely ornamental, although it is not able to contribute directly to "shaping technology". This is, in our eyes, a positive result: ethical analyses and STS studies have really contributed to a normalisation of nanotechnology, which means partially successfully embedding nanotechnology into society even in the case of the risk involved – and taking that risk seriously!

However, some of the STS and ethics community might perceive our conclusions on the absence of forms of directly shaping the course of nanotech development as disappointing, or even devastating. With regard to SST in the strong sense, our conclusions are indeed dramatic. Promoters of a strong SST approach could deal with this situation in different ways: they could look at other technology cases, in the hope for a different outcome there, they could try to falsify our diagnosis for the case of nanoparticles, or, if those strategies do not help, they might modify the strong SST approach and formulate a more realistic version. In any case, nanotechnology and especially the field of nanoparticles seem to be an ideal testing ground for STS and ethical approaches and the expectations they involve.

In the introduction, we mentioned the idea of SCOT to "achieve better technology in a better society" (Schot and Rip 1997). Although the present analysis has demonstrated that, with respect to toxicity, the nanotechnology of today is probably not a better nanotechnology than it was some years ago, we are in a different position now. The essential point is that the attribute "better" apparently cannot be defined in terms of nanotechnology alone. What is seen as better depends on the relation between technology and its societal environment. We have seen that nanotechnology today is much better embedded in society; it has been "normalised" by ethical inquiry. In this process, perception in general has changed, and this change also contributes to what "better" could mean. In fact, in further developing and improving the societal environment of nanotechnology by normalising and reshaping it in view of the field of new chemicals, it has become a "better technology" without having changed its technical parameters. In this way, we were able to observe ethical debate having a significant impact on the formation of nanotech without shaping nanotechnology at the technical level. From an analytical point of view, it seems to be promising to study the dynamics of differences in the perception of nanotechnology by stakeholders (like scientists or industrial experts) and the general public.

On the other hand, if the term "better" is broken down to the different societal subsystems (like politics, science, economics), the case of the Forschungszentrum Karlsruhe and the possible integration of technology assessment in deliberating research agendas gives an idea of what the next step could be. This next step has to do with communication, cooperation and decision-making within sciences and also at the interface of science and technology. The relation between technology, designed by public and private research laboratories, and its societal environment can be viewed as science doing its "normal" job in absence of any communication disaster, although there have been attempts at scandalising and making radical claims (like a general nanotechnology moratorium). Within the scientific subsystem, this can also mean that common reflection on technical, R&D and risk topics can lead to intensive cooperation between different disciplines including technology assessment and ELSI research and also to cooperative forms of agenda-setting and division of labour along the general topics of chances and risks. Further on, at the interface of science and the public, a constructive dialogue could be initiated about concerns that are mentioned with a certain continuity. In this context, it will be important for politics and also science policy to be willing to involve not only nano-oriented enterprises that aim to bring technology to society but also non-governmental and consumer organisations that articulate their concerns and interests with the intention of deliberating collective standards of safety and innovation.

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Futures Assessed: How Technology Assessment, Ethics and Think Tanks Make Sense of an Unknown Future

Mario Kaiser

1 The Assessment Regime: "Damned to Explore the Future"

"Zeitdiagnoses" such as *reflexive modernization* (Beck et al. 1994) call attention to the fact that our societies monitor their technological future in an ambivalent way: They keep one eye on benefits or innovations, and on risks or dangers the other. But it might be worthwhile taking a closer look at this ambivalence, for it also sets the ground for a division of labour. Despite of the fuzzy and intricate nature of the boundaries that separate those social domains in which the bright side of emerging technologies is up for speculation, from those in which the unintended consequences are subjected to deliberation, the two different social realms can be distinguished along the lines of the societal demands they address. According to an early verdict (Lane 1966), science and economy are expected to supply innovations for the reproduction of a "knowledgeable society". The exploration of the unintended consequences of these innovations, however, is assigned to a rather heterogeneous group of actors, institutions and professional discourses. *Assessment regime* lends itself as a term to classify these agents with regard to their *common* fate, which is to facilitate an exploration of the future in terms of unanticipated ethical, social or legal consequences, ensuing from society's advancement of novel technologies. Obviously, the study of unintended technological futures does not represent an end in itself. Rather, it is one of the regime's crucial steps in determining the acceptability of an emerging technology (cf. introduction to this volume).

Yet, what could such an exploration of the future look like? How does the assessment regime succeed in investigating something that does not yet exist – something, in fact, not even intended to exist? As the regime takes it upon itself to specify possible implications of *novel* technologies, experiences with former technologies turn out to be only of minor help. For instance: Attempts to compare a "future" nanotechnology with a past biotechnology occasion debates about the conception of such historic comparisons – their epistemic legitimacy, or their general

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purpose – instead of establishing a congruity between these technologies (cf. David and Thompson 2004).

In view of a lost continuity between past and future, it comes as no surprise to hear experts of technology assessment say that when specifying the unintended consequences of a particular technology,

> one is damned to explore the future, since only from it orientation and support can be expected (Bechmann 2007: 38).

2 The Discursivity of Futures

In 2003, *The Guardian* (Radford 2003) afforded us a glimpse into a somewhat messy future called into being by Prince Charles' publicly avowed fears of "green goo", a variant of its grey ancestor:

> The scenario is a familiar one: scientists open Pandora's box, awaken Frankenstein's monster, or maybe just play God. But this time the menace on the laboratory bench is undetectable with any conceivable optical microscope.
>
> It offers a nightmare vision straight out of science fiction – the destruction of the environment, perhaps even of the world, by robots smaller than viruses, able to share intelligence, replicate themselves and take command of the planet.

The passage unveils a future that is too contingent for an informed dealing with it. It is a future, in which nearly anything, as long as it is apocalyptic enough, can happen. More than that: It is a "monstrous" future, one that oscillates between object of ridicule and one of horror; between an ironic "nightmare vision" and a grave "undetectable menace"; between a man made peril and a self-replicating threat.

It seems no wonder that the UK Government, when faced with such an *undecidable* future, commissioned the Royal Society and the Royal Academy of Engineering to conduct a study that would "separate[e] the hype and hypothetical from the reality", as Ann Dowling, chair of the respective working group, put on record in *Materials Today* (N.N. 2003). The circumstances of this assignment can tell us a great deal about the hopes attached to the laborious exploration of nanotechnology's future. The government's mandate, the meticulous collation of evidence by the working group, the organization of numerous meetings with experts, stakeholders or selected publics, clearly indicate that the Royal activities targeted the production of *governable* or *decidable* futures. On a more abstract level we might think of this process as an enabling one: Not only the dignified institutions, but all parties belonging to the assessment regime are manoeuvred into taking a concern with the transformation of an undecidable future into more specified futures.

Regardless of the ontological and epistemological nature of these futures, the regime's manner of tackling them presents itself as a discursive phenomenon – by making sense of an uncertain and undecidable future. In their discourse theory, Laclau and Mouffe (1985) establish a distinction which permits to recast the difference between an undecidable future and more specified futures in terms of the discursive (or the field of discursivity) on the one hand, and discourse and its articulations on the other hand.

First, discourse is understood as a structured totality of articulations (ibid.: 105). These, in turn, are speech acts or meaningful practices that create relations between more or less independent elements and thus establish a discursive *order* or *structure* which rearranges, reconstitutes and stabilizes their meanings. In this sense, a discourse has much in common with a language game. Comparably to Wittgenstein's (2001: §2) famous one, which he conceives of as consisting of language ("bricks", "pillars", and "slabs") and of activities (bringing bricks, pillars and slabs), the notion of discourse involves both meanings and activities. The concrete practice of articulation combines elements into a structure which endows them with novel meanings and novel identities – hence a structure that is established through the stacking of bricks and slabs, and an institution that consists of "mere" articulations, function along the same lines.[1]

When it comes to political contexts, discourse theory foregrounds the circumstance that a discourse never acquires a stable structure. Rather, a specific discourse (or discursive formation) constitutes an attempt to fix meanings partially, which, since they are contested, always remain unstable. In its struggle for the stabilization of notions such as "democracy", "class", or "acceptability" the discourse contributes to an irreducible surplus of meaning which always transcends the meaning strived after by particular articulations. It is here that the discursive comes in, mirroring the contested field within which articulations compete for a partial fixation. With reference to Derrida, we may think of the discursive as a space that promises structure, while forestalling its achievement, since there is nothing that could provide the structure with a centre, a pre-discursive stability or a transcendental fundament beyond language and its rivaling articulations:

> The absence of the transcendental signified extends the domain and the play of signification infinitely (Derrida, cited in Laclau and Mouffe 1985: 112).

We may therefore view the undecidable, "messy" future of nanotechnology through the lens of the discursive: It is discursively constructed, yet marked by a surplus of meaning which invites descriptions such as "undetectable menace" or as "nightmare vision". This conception of the future as a radically contingent terrain can be of great help in gaining a deeper understanding of the discursive as a *field of undecidability*. To put oneself into a position in which it is possible to decide whether one should risk a sea battle[2] tomorrow or not, requires one to select or to construct a particular future from innumerable alternatives, a process which will hopefully produce enough information to base a decision on: "Given that the enemy's strategy will be this or that, and given that a victory will grant this or that advantage, the risk of tomorrow's battle can be taken." It is possible to make a decision, if, in advance,

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[1] The concept of a discourse consisting of articulations that do not only *utter* "bricks", but also *use* bricks to produce a *meaningful* structure shows many resemblances to concepts employed in Actor Network Theory, particularily to the notion of "association" (cf. Latour 2005).

[2] We refer to Aristotle's famous example in *De Interpretatione 9*.

the contingency characteristic of the undecidable future is reduced, and that future is transformed into a decidable one. Yet it may turn out that the decision, when it is eventually evaluated in terms of its effects, was wrong. In fact, *already the awareness of this circumstance must lead to the revocation of any decision the instant it is taken*. Thus the future confronts us with the paradox that we need to make decisions although we know that no informed decisions are possible. But not only does this paradox pertain to the future, it also affects sense-making processes in the political arena. For instance:

> [the undecidabilty] calls for decision in the order of ethical-political responsibility. It is even a necessary condition. [. . .] There can be no moral or political decision without this trial and this passage by way of the undecidable (Derrida 1988: 116).

Consequently, when considered as a field of discursivity, the (unintended) future of nanotechnology provides both at once: the condition of possibility and impossibility for its partial fixation. On the one hand, the discursive promises that we can reasonably structure the future of nanotechnology by decisions based on particular articulations of that future. On the other hand, it prevents its complete absorption by and into a particular discourse and its articulations. The unintended future of nanotechnology hence continues to constitute a field of undecidability, despite or rather because of making possible the articulation of a multiplicity of competing discourses.

3 The Assessment Regime: Making the Future Decidable

Back to the assessment regime, we are now in the position to describe its activities in terms of articulations the purpose of which is to fix meanings within an undecidable field of discursivity. Apocalyptic scenarios, such as Frankenstein's monster or the grey goo, can as easily emerge on the contested ground of unintended effects, as what are rather prosaic medical implications such as the potential toxicity of nanoparticles. It is on the same contested ground that the regime must fabricate articulations of the future to stabilize meanings and, as a result, to reduce contingency. In other words, the regime is confronted with the task *of articulating particular futures* vis-à-vis an *undecidable* one.

The regime does not operate in a societal or cultural vacuum, however. Because of its task to generalize and functionalize the contingent ways in which the future is articulated, the regime's daily business can be compared to that of a factory: It produces "solutions" for the future paradox. Since our societies need to make decisions concerning a future that resists safe decision making – despite of inviting it – the regime ultimately conceals instead of solving the problem: It offers ready made futures that enable, if not enforce *others* to make decisions.

An empirical analysis shows that the regime manufactures various futures which match the needs of a number of different actors. The Royal Society's report "Nanoscience and nanotechnologies: opportunities and uncertainties", which is considered as exemplary for technology assessment here, reveals how an undecidable future is segmented into a number of specified futures and how their specification as researchable and decidable futures goes hand in hand with their distribution and delegation to research and governmental institutions. By contrast, the discourse of applied ethics is not concerned with a *delegating institutionalization* of the future. Concrete future proposals are not processed, but only singled out as bases for reflecting on the present. Hence they assume the role of mirrors in which ethical deliberation can reflect the present, notwithstanding whether the individual subjects already possess the means to tackle the future. In this sense, ethics deals with issues of *preparing preparedness* for imminent futures. And last, in the case of DEMOS, the undecidable future is articulated in terms of a *radical democratization*. As the think tank seeks to involve the public by promoting all-inclusive participation, the future remains indeterminate and indifferently open to anyone who feels like joining in its co-creation.

When considering the relation between the different articulations of the future and the different "stakeholders" (institutions, individual subjects, the public) who receive the prepared futures, it is easy to see that the regime selectively *activates, prepares* and *enables* society and its various decision-makers to face the challenge of the unknown. Yet in doing so, it does not so much critically reflect or deliberate an unfamiliar technological future, as it non-coercively coerces society to deal with the constructed futures by decision. In other words, the regime generates future-inescapability: Damned to explore the future, it passes on the curse to society, and in turn damns it to make decisions.

4 Articulations and Representations of the Future

The diversity of the different articulations of the future prevents us from identifying factors that could harmonize the regime's activities epistemologically. Thus, neither nanotechnology as an object of shared scrutiny, nor a common rationality, with which we might handle future states of affairs, can consolidate all articulations. Generally, yet especially in the case of applied ethics, it seems that nanotechnology aligns the deliberations and the pondering of possible consequences only inconsiderably. Nanotechnology comes across as a "soft" technology, a quality which makes it easy to frame it in relation to the relevant assessment types (cf. Kurath, in this volume). The same applies to what we may call society's rationality. Although the different parties within the assessment domain do act on behalf of society – either in response to a self-defined demand or to an explicit governmental order – their articulations of the future are so diverse that no societal value agreement is of any help to explain the diversity.

It has become clear that nothing can really serve as common ground for all articulations of the future. But perhaps at least the cause of the diversity could be determined. For discourse theory, articulations not only serve the purpose of fixing meanings within a contested field of discursivity, but they also function as *means of representation* for those who study the unintended future of nanotechnology. Even though we are not dealing with political struggles here – struggles that would ask for representation in a strong sense (Laclau and Mouffe 1985: X) – the concept of representation still proves valuable to get to terms with the diversity of the articulations. By asking *who tries to represent themselves within an unstable and contested terrain, by which means and in relation to whom,* differences on the content level of the articulations can be linked to differences relating to representation. The fact that institutions charged with technology assessment employ reports as a means to articulate, i.e. to represent their views in the face of governmental decision-makers, or the fact that the ethical discourse represents itself by means of articles addressed to members of its community, has an immense influence on how the constructed futures turn out regarding their content.

More specifically, the means of representation, by taking on the role of crucial "background" structures, affect what an organisation like the Royal Society or what ethicists can ultimately say about an undecidable future. Evidently, the undecidable future is assimilated differently in a report than in a scientific article. An article is a format by means of which its author predominantly reproduces the views of his or her scientific community in order to represent his or her own standpoint vis-à-vis that community. A report, in contrast, obliges the institution that composes it to explain itself to an interested audience in order to furnish its recommendations with legitimacy. Due to the different modes of representation encoded within the concrete structure of different text genres, it becomes inevitable that different actors represent themselves by means of different articulations concerning "their" futures.

The means of representation, be they reports, articles or "pamphlets", establish a correlation between the representatives within a discursive terrain on the one hand and what they are let to articulate on the other hand. So the particular means become the most essential as well as the most probable tools for each specific investigation of the future. And it is exactly these specific means of representation that, in the end, come to be considered the only structures from which "orientation and support can be expected" (Bechmann 2007: 38).

5 From Future to Futures: The Case of the Royal Society

The Royal Society's report made short work of the "goo" that intoxicated the media. First, the discussion of "grey goo" was relocated from the actual report to the appendix. Second, it was labelled a "distraction from more pressing concerns", and third, the report made clear that it did not believe "that mechanical self-replicating nano-machines will be developed in the foreseeable future" (Royal Society and Royal Academy of Engineering 2004: 109). How could such a shift of focus have happened? More precisely, how did the Royal Society approach the discursive of nanotechnology's future in order to produce "more pressing" futures, i.e. stabilizing articulations?

5.1 Institutions and Reports: Mutual Dependencies

To figure this out we will need to take a better look at the particular report and at the structure of reports in general. Although this might seem odd at first, it will prove more productive to concentrate on the surface features of the report rather than on its content and meaning.

Usually, reports exhibit enormous variation as regards their form and content. Yet as soon as we begin to consider the relationship between the form of the report and the organization that makes use of it, the differences begin to appear less salient. Institutions that provide technology assessment – either because they have taken on a public mandate or because the government commissioned them – rely on reports for the achievement of their communication goals. The Royal Society's report offers itself as a prominent example here – although one might suspect that the Society does not represent a TA institution proper. A comparison with reports issued by other, mostly national, TA institutions,[3] however, confirms that the Royal Society did in fact acted as if it were a TA-institution.

Overall, reports are the primary instruments of communication that allow an institution to speak to the public or to decision makers. This holds for NGOs such as Greenpeace (cf. Arnall 2003) as much as it does for big reinsurance companies (cf. Swiss Re 2004, Munich Re 2002). Yet reports also seem to reflect the essential condition of existence of these organizations, since without regular publications many of them would virtually cease to exist in the public arena – "publish or perish" the mantra runs. Thus, a report represents the respective organization in a strong sense.

Correspondingly, most reports begin with a *foreword* or an *introduction* in order to *legitimize* or *authorize* the voice of the institution that issues them. The foreword explains why Greenpeace, for instance, feels it has the permission and feels "morally" obliged to speak out on nanotechnology. Opening questions such as "Why is Greenpeace interested in new technologies?" provide an opportunity for the organization to introduce itself, to state its goals, and to justify why exactly it *should* focus not only on nuclear power or on GMOs, but also on nanotechnology. By way of forewords or introductions, reports primarily enable an organization to enter a particular discourse and therefore to introduce itself to the public. In the authorization section of the report by the Royal Society – which is short, since the Society already enjoys back up of its voice by the government – it says:

> In June 2003, following its response to the BRTF, the UK Government commissioned the Royal Society and the Royal Academy of Engineering (the UK's national academies of science and of engineering, respectively) to conduct an independent study on nanotechnology. The terms of reference of our study, jointly agreed by the Office of Science and Technology and the two Academies, were as follows [. . .] (Royal Society and Royal Academy of Engineering 2004: 2).

The second significant component, seemingly almost as conventional as the authorizing introduction, consists of laying claim to the issue in question. These rhetorical efforts are commonly introduced by questions such as "What are nanoscience and nanotechnologies?" (ibid.: 5) and are answered with a *claim to constructing a*

[3]For Switzerland, cf. Baumgartner et al. 2003; for Germany, cf. Paschen et al. 2003; for Austria, cf. ITA 2006.

unity – something that reports usually accomplish by means of definitions, as we can see here:

> The first term of reference of this study was to define what is meant by nanoscience and nanotechnology. (ibid: 5)

Definitions seem to fulfil an ambivalent task. On the one hand, they meet the requirement of attributionality, which is the construction of some degree of unity and allows the mapping of possible consequences onto this – but no other – technology. On the other hand, definitions also come to govern the proper usage of the term "nanotechnology": Instead of describing nanotechnology, they *pre*scribe how different actors should use the term for communication purposes (cf. Decker 2006).

Yet the sheer numbers of examples meant to illustrate the definition in question conceals the ambivalence relating to what nanotechnology *is* or how the term "nanotechnology" should be used. As it is, a major part of the Royal Society's report introduces instances of current research, ponders developments in progress, and outlines expected applications.

5.2 A Report's Recommendations: The Delegation of Futures

Yet before we can highlight the crucial *recommendation* section, a brief shift of attention to the expansive *issue* section will prepare us for it. In the case of the Royal Society, the issues are detailed in four main chapters:

- Possible adverse health, environmental and safety impacts
- Social and ethical issues
- Stakeholder and public dialogue
- Regulatory issues

In terms of our purpose, the issues dealt with in these chapters only play a minor role compared to what happens to them in the *recommendations* – that part which, besides the introduction, really turns a report into a report. Recommendations are no more but the very articulations through which an organization can represent its "will" with regard to a particular topic.

The performative nature of the recommendations reflects this: They act as directive speech acts. As is well known, giving orders and making requests or recommendations does not function in the same way as assertive speech like statements, descriptions or assertions. These speech acts differ from each other with respect to their "direction of fit" (cf. Searle 1969; Searle 1979). Independent of any commitment to a truth theory, a statement, for instance, behaves as if the speech act did fit the world. Such a word-to-world relationship implies that if the statement is not true the statement is at fault and not the world. In the case of recommendations, however, the world is assumed to match the picture drawn of it in the recommendations: At some point in the future, the world should "behave" in the ways the recommendations have expected and prescribed it to.

If we accept that only the future is the target of directive speech acts, we must confront the question what the future looks like according to the Royal Society. What should the world look like according to its recommendations? Interestingly enough, the report seems to avoid concrete anticipations proactively, instead making sure that the future *proceeds,* albeit in a more specified manner. Such a forwarding of the future is achieved through involving other parties in further appropriations. To put it as pointedly as possible: *the unknown future of nanotechnology is delegated to other institutions*.

This delegation process is guided by specifications that concern the allocation of issues to institutions. By way of a kind of re-entry the issues specified in the main sections of the report reappear in the last chapter, though now in connection to the institutions to which the recommendations are addressed. Admittedly, not all recommendations target an institution, yet those that do, play a prominent role. First, with respect to "possible adverse health, environmental and safety impacts" the Royal Society recommends

> that [the] *Research Councils UK* [italics, M.K.] establish an interdisciplinary centre (probably comprising several existing research institutions) to research the toxicity, epidemiology, persistence and bioaccumulation of manufactured nanoparticles and nanotubes as well as their exposure pathways, and to develop methodologies and instrumentation for monitoring them in the built and natural environment (Royal Society and Royal Academy of Engineering 2004: 85).

Second, taking the "social and ethical issues" into account it recommends

> that the research councils and the Arts and Humanities Research Board (AHRB) fund an interdisciplinary research programme to investigate the social and ethical issues expected to arise from the development of some nanotechnologies. (ibid.: 87)

Finally, "stakeholder and public dialogue" can be understood as an instruction for the research councils to fund more sustained and extensive programmes of dialogue as well as of research on public attitudes to nanotechnologies:

> we recommend that the Government initiates adequately funded public dialogue around the development of nanotechnologies (ibid.: 87).

5.3 The Delegated Futures of Technology Assessment

How did the Royal Society discursively stabilized the scary future with which the Prince of Wales confronted us? Quite a number of steps are involved in the transformation of an undecidable future into more specific futures. Yet it is the striking compatibility of the "issues" with the institutions regarded as capable of coping with them that deserves our attention. By slightly overstating this relationship, we might almost begin to think that the Royal Society has divided and shaped the undecidable future into issues in order to match them with existing institutions. Despite this slight exaggeration, it is safe to say that the Society adjusts the unknown future of nanotechnology to fit the activities of current institutions.

What is important to note here, is that an initial undecidability or uncertainty has not been transformed into decisions or certainties, but rather into *specified uncertainties*. Accordingly, some institutions like the Research Councils UK or the Arts and Humanities Research Board obtained *researchables* from the Society, while others like the UK Government or the Health and Safety Executive received *decidables* – themes and topics, which will eventually require decisions, such as for the funding of a public dialogue.[4]

By delegating *specified futures* to different institutions, the Royal Society transforms a highly contingent future into decidable and researchable futures. Thereby it also puts the different actors into a position to decide – even falsely.

6 From Future to Futures: The Case of "Nano-Ethics"

Speaking of ethics, one feels compelled to address the weighty question of what ethics is really about. To simplify the task somewhat, we will focus on ethics as an academic discourse. Furthermore, we will take scientific articles for empirical data, leaving aside presentations or talks through which ethicists address each other or a wider public.

Such a paper-based ethics conforms to a scientific tradition. In other words, if an author seeks to direct professional ethical enquiry towards novel objects of investigation, he or she is obliged to justify such a change against the background of the relevant "Denkstil" (Fleck 1980 [1935]), of its theories and of its methods. If we make sure to evade the revolutionary implications, we may alternatively frame this challenge in terms of a "paradigm" (Kuhn 1970): Again, the author is supposed to explain how his or her novel topic fits the prevalent "disciplinary matrix"[5] of his or her community.

Against this backdrop, we may deduce the central question for an upcoming nano-ethics: How is the integration of nanotechnology into the ongoing academic discourse, the disciplinary matrix of ethics, established? More precisely, how does ethics appropriate nanotechnology's future as a morally (or ethically) significant topic?[6] It comes as no surprise that an answer to this question depends on how ethics transforms the discursive of nanotechnology's future into ethically significant articulations.

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[4]Interestingly, for uncertainties that underwent no specification, no institution was mentioned to deal with them. Thus, instead of assigning an institution the investigation of the possibility of a "grey goo", this scenario has been excluded as a mere "distraction from more pressing concerns".

[5]For the specification of a paradigm in terms of a "disciplinary matrix", see the postscript to the second edition of Kuhn 1970.

[6]Since we are not interested in *doing* ethics, but rather in *observing* it, the many reasons for or against the distinction between what belongs to the domain of morality and what belongs to the domain of ethics plays a minor role here.

We will retrace the steps by which ethics approaches nanotechnology with the illustrative help of two articles. They represent most distinctly what equally features in a wide range of other articles, although not in the same exemplary fashion. Hence, in the following, reference will be made to "Ethics in Nanotechnology: Starting From Scratch?"[7] by Ebbesen et al., and Berne's "Tiny Ethics for Big Challenges".[8]

6.1 The Academic Discourse of Ethics

In order to understand how the academia of ethics incorporates nanotechnology, we need to examine some of the primary formal characteristics of academic discourse.

The genre of the "scientific article" is the result of radical changes in the social organisation of science (cf. Daston 1992). Yet contemporary articles have preserved one feature of their generic predecessors: They address *potential authors* (Stichweh 1984: 427) rather than passive recipients.[9] While an author in the 18th century would have communicated with his scientific community via personal correspondence, explicitly addressing his letters to a scientific colleague, often enough a friend, an author nowadays calls on his audience more implicitly, for example by citing it, i.e. by citing other scientists. Such communicative self-references have become a necessary condition for the genesis and reproduction of scientific communities or specialised fields.[10] It does not come as a surprise that social integration within such a specialized community occurs through an article's proverbial inscription. This holds especially for authors who do not yet enjoy an established reputation, or for new objects of enquiry, in which cases such a listing may take up more than half of the article! This has the fatal effect that the greatest effort is not put into elaborations on the novel topic, such as nanotechnology, but into the reproduction of the scientific debates characteristic of the particular community.

The article by Ebbesen et al. is no exception in this respect. Half through it the question emerges of "How to Analyze Ethical Problems of Nanotechnology?" In what follows, the authors pursue a conservative argument in which they explain that existing approaches in the field of applied ethics, primarily Beauchamp and Childress' four principles,[11] are compatible with nanotechnology. In support of this proposal, the authors demonstrate which bioethical principles match the ethical issues possibly pertinent to nanotechnology. They devote most of their energy,

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[7]Ebbesen, Mette, Svend Andersen, and Flemming Besenbacher. 2006. "Ethics in Nanotechnology: Starting from Scratch?" Bulletin of Science, Technology & Society 26:451–462.

[8]Berne, R. W. 2004. "Tiny ethics for big challenges: calling for an ethics of nanoscale science and technology." Circuits and Devices Magazine, IEEE 20:10.

[9]Such symmetry of communication, specific to science, was already noted by Merton 1973 [1942].

[10]Besides this essential function, citations serve a wide range of other functions, as highlighted in the field of citation analysis. For the theoretical significance of such analyses in the context of STS, see Leydesdorff 1998.

[11]Ebbessen et al. refer to the 5th edition of Beauchamp, T. L., and J. F. Childress. 2001. *Principles of biomedical ethics*. Oxford, UK: Oxford University Press. The principles are: respect for autonomy, beneficence, nonmaleficence, and justice.

however, to the defence of Beauchamp and Childress's theory against its critics, and, above all, against the opposition to principlism in bioethics. Hence, while the former line of argument makes use of nanotechnology at least to illustrate the meaning of the principles, the latter nearly omits to mention it at all.

Nothing can better illustrate the affiliation with a particular *denkstil* than the constitutive debates of the respective communities. In the case of bioethics, the fundamental debate, which ensures its reproduction as an academic discourse, consists of a quarrel over the significance of principles as compared to contextualized values or virtues in which the latter are criticized for their relativism. Observing such productive disagreements from the outside, one could speculate whether the authors who do not take a firm stand in this dispute might not belong to the core *denkkollektiv* of bioethicists.[12] To show one's affiliation with this *denkkollektiv*, it is consequently more important to strengthen one's position either as relativist or as principlist, rather than to elaborate at length on the possible outcomes of nanotechnology.

Berne, too, commits to this constitutive controversy. Yet in contrast to Ebbesen et al., she takes the adverse position from theirs. For her, rule-based codes and guidelines are insufficient to address the deeper, more fundamental elements of actual human experience (cf. Berne 2004: 15). Assisted by the frequently quoted *Moral Imagination* (Johnson 1994), she formulates two goals that structure the article's argumentation. On the one hand, Berne strives to "outline the limitations of any rule-based morality" (Berne 2004: 13), on the other, she wants to show how moral imagination can be engaged. Regarding the restrictions of ethical codes, Berne bemoans that they fail to ensure some of the essential qualities of personal or institutional morality, that they represent a management tool instead of a moral landmark, and that they do not function along the lines of human cognition (ibid.). In short, "rule mongering is a sign of moral failure" (ibid.: 15, referring to Johnson). And it is moral imagination that is invoked against this ethical breakdown. It allows to reflect the narrative structures that frame nano-science and nanotechnology initiatives, or to engage imaginative forms of expression in order to envision the futures that could result from our technological pursuits (ibid.: 16–17).

6.2 Nano-Ethics: Preparing Preparedness for Futures in the Present

Now, how does this discussion concerning ethical principles and moral imagination relate to the future of nanotechnology? Both articles start with a description of nanotechnology, its visions, its developmental paths, as well as its possible applications.

[12]This dependency has remained undetected within the field. Even defenders of principalism have asked themselves what the difference is: "Fundamentals of bioethics or fundamentalism in ethics?" (Quante 2000). At the same time the dispute between "A critique of principlism" (Clouser and Gert 1990) and "Against Relativism" (Macklin 1999) is connected to the irritating question of whether applied ethics allows for a theory of morality or not.

It is here that differences in the framing of nanotechnology become apparent, and traceable to their origins in different academic lines of argumentation. Berne, for instance, lists applications with a radical potential, such as new medical prosthesis techniques or tiny intelligent machines whose impact on humankind cannot be calculated. On the basis of these "dramatic new capabilities" she concludes in agreement with her theoretical resentment against principles, that "conventional rule-based, prescriptive engineering codes and guidelines [. . .] are insufficient for the ethical development of nanotechnology" (Berne 2004: 10). By contrast, Ebbesen et al. think that a number of ethical aspects of genetics, biotechnology, and environmental science are analogous to ethical issues in nanotechnology (cf. Ebbesen et al. 2006: 453). Due to this comparability, they consider Beauchamp and Childress's principles as largely sufficient.

The link that exists between the framing of nanotechnology's future and the ethical position the authors defend within their community seems to be more than purely accidental. Accordingly, the "dramatic new capabilities" require more than rule mongering, while nanotechnology as a sequel to existing research can easily be covered by current ethical principles.

Although each of the two articles portrays nanotechnology's future differently, they nevertheless share an attitude towards technological futures. While technology assessment actively transforms an uncertain and undecidable future into more specified articulations of it, the ethical discourse, as illustrated here, holds back with regard to nanotechnology. It makes it appear as if matters relating to the development of nanotechnology were already settled and self-evident. It is plain that both articles embrace a form of technological determinism,[13] an attitude, which reveals itself in the use of conditionals – often counterfactual ones: "Let us assume for the moment that the claims of the wonderful new capabilities to be realized through nanoscale devices and procedures are realistic [. . .]" (Berne 2004: 11).

Interestingly, this determinism also shifts the focus to the present. Despite many differences, both articles are concerned with the degree to which we, who live in the present, are *prepared* for the future *ethically*. Both give emphasis to the question of whether or not our current principles, methods or ways of reasoning are capable of dealing with nanotechnology's future. Their answers are predictable: While Berne does not think so, Ebbesen et al. are "confident that the open-endedness of Beauchamp and Childress's theory makes it appropriate for conceptualizing emerging ethical issues of nanotechnology" (Ebbesen et al. 2006: 458).

In short, the attitude towards the future as entertained by the ethical discourse, is diametrically opposed to that of technology assessment. Instead of making an

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[13] Interestingly, Bern strongly refutes such determinism: "In fact, disagreements over which future technologies are myth and which are realistic [. . .] begin with the assumption that technology is a willful, evolving reality rather than a directed, socially constructed one. It assumes that technology evolves separately from human imagination, ambitions, and dreams when in fact technology is by its nature a social construction" (Berne 2004: 12). Although such a deterministic attitude is negated on a *theoretical* level, on a *practical* level, however, Bern has nothing to propose by way of a different way of thinking.

uncertain and undecidable future more concrete by specifying different researchable and decidable futures, the ethical discourse dispenses to a certain degree with an active processing of the future. The future, though, serves as a mirror through which ethical deliberation reflects the present condition and the degree of readiness our ethical conceptions have reached to face the future. Against the background of such mirrored futures, ethics does not strive to exert an influence on the future itself, but rather monitors or prepares preparedness for the future in the present.[14]

In this sense, ethics approaches the field of discursivity of an unknown technological future not so much through articulations concerning the future as through articulations concerning the present. In terms of representation, the articles reflect the two viewpoints available to the *denkkollektiv* of bio- (or nano-) ethicists: (a) the present as governed by ethical principles, which hold true for the future too, or, (b) the present as marked by values or virtues, which may differ in the future.

7 From Futures to Present: The Case of a Think Tank

> It was a typical Saturday morning in the Natural History Museum. Hordes of kids swarmed through the museum's doors, yelling and pointing as they caught their first glimpse of the diplodocus, whose 26-metre skeleton takes pride of place in the cavernous entrance hall.

Undoubtedly, a think tank, although hard to pin down with respect to its "essential" features, has much in common with an institution like the Royal Society. Both must bring themselves to public attention by means of publications in order to maintain their social existence. Despite this overlap, they appear to be focusing on different audiences. The passage cited above, with which DEMOS, "the think tank for everyday democracy", opens its deliberation on "Governing at the Nanoscale" (Kearnes et al. 2006), demonstrate this. It does not speak to decisions-makers, as the Royal Society report does. Nor does it address scientific peers, as the academic discourse of ethics does. Rather, it seems to concentrate on "members of the general public: parents, teachers, an osteopath, someone in IT" (ibid.: 11). Programmatically, it reflects the same audience that had a part in the "upstream" dialogue between scientists and citizens (the last stage of the dialogue took place at the museum mentioned above).

If we take the form of this publication into account, the assumption must be that it does not address political actors or scientists exclusively. It declares to be a "pamphlet"; in comparison to reports or articles, quite an interstitial, less confining and literally "unbound" publication type. Obviously, such an open format does not determine the content in the same manner as articles and reports do. In fact, "Governing at the Nanoscale" dissociates itself from articles and reports by allowing different ways of thinking to stand side by side: social scientific reflections

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[14] This finding however does not mean that ethicists do not seek to influence the ongoing debate about possible consequences of nanotechnology – on the contrary.

on science and technology, empirical evidence from focus group discussions and political reasoning.

More concretely, the publication critically reviews the GM debate, identifying its shortcomings, which are to be avoided in relation nanotechnology (Chapter 2). Its focus is on the "degree to which scientific research is informed by imaginaries of the social role of technology. Concerning GM, these tacit visions were never openly acknowledged or subject to public discussion" (ibid.: 24). The next chapter presents summaries of interviews conducted with nanoscientists, which reveal their imaginaries or visions. These can take the form of nanotechnology as an extension of the "miniaturisation imperative", of "control over the structure of matter", or of nanotechnology as a "socially robust science". The authors make clear that such visions challenge advocates of public engagement, as they "must now identify ways of opening up such imaginaries to scrutiny and accountability" (ibid.: 29).

Precisely because scientists, too, are experiencing difficulties in grasping the connections between these visions and concrete scientific practice, the paper concludes that more opportunities and incentives to reflect on the societal dimensions of their work need to be promoted. This diagnosis is followed by a proposal to do this "through direct engagement with wider publics, and it is to this challenge [that] we now turn" (ibid.: 40).

7.1 From Future to Expectations

How can we characterize this paper in terms of its mode of operation as well as its appearance? After taking into account its assumed audience, its publication type, and its line of argumentation, we are led to view it as a "democratizing" paper.

Firstly, it inscribes itself into the tradition of participatory technology assessment (pTA), which has been welcomed as a long-awaited replacement for the rather elitist and technocratic heritage of scientific TA.[15] As such it partakes of the discourse on deliberative (cf. Cohen 1989, Elster 1998), strong (Barber 1984), or discursive democracy (Dryzek 1990) as well. They all share the conviction that representative democracy has diminished the role of citizens instead of letting them participate via open deliberation or dialogue.

Although the pamphlet makes no explicit references to the relevant literature, it nevertheless subscribes to this democratizing motive by making clear that it deals with "governing" the nanoscale, while including "people, policies and emerging technologies" (Kearnes et al. 2006: front page). What ultimately emerges as appropriate means of governing is dialogue: "the technical and social complexity of nanotechnologies demands a genuine *dialogue* between scientists and the public" (ibid.).

[15] An overview as well as an evaluation of pTA projects in different European countries is provided by Joss and Bellucci 2002. For the US context, see Guston 1999. An anthology which discusses such a "democratization of expertise" critically was edited by Maasen and Weingart 2005.

Yet what exactly is subjected to such democratization – and how? Coincidentally, the answer to this question serves as an answer to another crucial question as well, namely in what manner the nanotechnological future is subjected to this assessment process. The "democratizing" procedure through which the future is approached and articulated is made explicit and promoted in the second chapter: "advocates of the public engagement movement [. . .] must now identify ways of making such imaginaries accessible to *scrutiny and accountability*" (ibid.: 29, emphasis MK). It is important to understand the framing of nanotechnology's future in terms of current imaginaries or expectations. This insight offers itself after a short excursion into the field of science and technology studies, which reveals some of the field's key attitudes. By citing and referring to Latour's *Science in Action*, the authors foster the viewpoint that "science is deeply social and cultural" (ibid.: 25). Seen from this angle, it seems only consistent to de- and reconstruct metaphysical entities as social (or psychological). As a result, the future re-emerges as nothing more than a host of implicit expectations, visions or imaginaries shared by subjects. At which point, finally, the expectations can be unmasked and exposed by research, i.e. in interviews.

Similar research that "opens the black box of science" does not serve the goal of merely *scrutinizing* the future. The identified expectations are ready to be fed back into the public dialogue as contestable values or disputable attitudes that need to answer to *accountability* requirements.

7.2 The Democratization of Futures

If we relate the deconstruction of nanotechnology's future to the expectations or imaginations of individuals concerning the ways in which technology assessment or ethics deal with a more or less unknown future, a striking difference emerges. By specifying researchables or decidables in the case of TA, and by using conditionals in the form of "what if" in the case of ethics, the future (or the many futures) can continue to exist – although in a more restrained, more specified, or better controllable manner: We are still in a position to rely on the "fact" that something might, could, or will happen. The metaphysical reality status of these futures is therefore not completely dismissed and refuted.

Yet in "Governing the Nanoscale", the future as such does not figure anymore. The future as a set of expectations and imaginaries is only real in the present, insofar as it governs human action. Still, there is a second factor that obliges such an articulation of the future to align itself with the present: The significant expectations are not simply regarded as operating within a fairly self-contained domain called "science" which warrants a strong binding force by providing guidelines for the social action of scientists. On the contrary, the normative goal is to disclose the "hidden" power the expectations or imaginaries exercise in shaping futures. By bringing them into the public sphere through dialogue, they become open to public evaluation, deliberation, and to accountability. Yet in the very moment in which they become subject to public auditing or accountability procedures, their power to shape a particular future is annihilated.

This makes clear that democratization involves two steps: First, as a necessary condition, "scrutiny", which involves the transformation of metaphysical objects into present psychological or social entities; and second, "accountability", which converts their exposal in the democratic sphere as value-laden expectations into further deliberation.

Through its pamphlet, DEMOS plays an interesting role in terms of representation. While it seeks to involve the public and therefore promotes participation on a large scale, it leaves the future accessible to anyone to co-create it. Clearly, DEMOS' articulations do not represent the institution in the same straightforward way as the recommendations in a report represent the relevant TA-organization, for instance. They do not articulate their own futures, *but futures of others for others*. That is why the think tank does not represent the expectations of particular groups or communities. Rather, it represents itself, in an abstract manner, as a form of democracy that manages to escape habitual politics. In order to perform this role, it must break an ominous future down into "democratizable" entities.

8 Conclusions

If the pivotal actors in a society decide to advance a novel technology, they simultaneously create novel futures. What appear to be the "most unknown" futures are the *unanticipated* consequences of a novel technology, for these cannot influence decision-making, precisely because they are not intended or anticipated. In other words, even if divine providence warrants a victory in tomorrow's sea battle, the decision to hazard a war remains a risk – due to unintended consequences. By implication, to obtain knowledge about them "one is damned to explore the future" (Bechmann 2007: 38).

This paper has tried to highlight how different actors of the assessment regime tackle a nearly impossible task – the exploration of the unknown. In doing so, they produce articulations of different futures with the purpose of fixing the meanings of an undecidable field of discursivity, i.e. of an undecidable future. The particular means of representation in this process of articulation are of immense importance, since they relate the actors, who try to represent themselves within a discursive terrain, to what these actors are "permitted" to articulate. As such, different text genres ranging from reports and articles to unbound pamphlets provide structures from which "orientation and support" in the investigation of the future can be expected.

Notably, the various genres do not determine the content of the articulations of the future in a strong sense, although they do restrict the possibilities of making sense of an undecidable future. It is rather unlikely that representatives of ethics could specify futures to institutions in the same manner as organisations of technology assessment do this in their reports. It seems even more unlikely that a think tank, which employs pamphlets for presenting its aims, would come up with articulations that reflect the current academic discussion about ethical principles or values.

In no lesser degree is the restricting effect of the different genres determined by those whom they address. The Royal Society and the Royal Academy advise *decision makers* like the UK government to forward researchable and decidable futures to already existing institutions. In contrast, DEMOS prepares democratizable futures for a *public* invited to participate in their deliberation. Finally, the scientific article, which facilitates communication in bioethics, addresses other scientists in the community. However, even if the article calls on other scientists, the articulations in it demand of us as subjects to reflect the present no matter whether we are prepared for the future or not.

By outlining in more detail the relations between the different attempts to fix the meaning of a highly contingent future by means of articulations and at the different "stakeholders" (institutions, individual subjects, the public) to whom the ready made futures are handed over, we have gained evidence in support of the hypothesis that the assessment regime as a whole selectively *activates, prepares* and *enables* society and its various decision-makers to face the unknown by means of decisions. As already noted, this is how the regime creates a form of inescapability: While it is itself damned to explore the future, it damns society to make decisions.

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Part IV
Assessing Dialogue: Governing "Nano" by ELSI

The fourth part takes a step back to critically review the ELSI landscape in a narrow sense, and the assessment regime in a broad sense. In contrast to the fifth chapter, however, it does so in a normative way.

Alain Kaufmann, Claude Joseph, Catherine El-Bez, and Marc Audétat ask "Why Enroll Citizens in the Governance of Nanotechnologies?" They argue in favor of public engagement for three different reasons: each type of actor has a limited rationality, citizens are the best judges of their own interests, and shared decision-making provides political legitimacy. But, as the authors demonstrate, there are important issues to consider and lessons to learn when planning public engagement exercises. Public participation needs a real multi-way exchange of information and may not always settle the discussions. The impact that a consultation should have needs to be clear from the beginning. Participatory TA processes frequently rely on a construct of the "ordinary citizen" as "innocent" (i.e. unbiased by specific interest), which is not without risks. Another difficulty is the unclear meaning of the label "nanotechnology" itself. Nanotechnology is not (yet) a set of specific projects but rather an "open space within which technology promises can be negotiated". Therefore it might be a false assumption that more participation and more "upstream" public engagement will avoid such controversies as those faced by genetically modified organisms.

Discussions about the societal implications of nanotechnologies are populated by visions, scenarios, and road maps of different kinds. *Risto Karinen and David H. Guston* look more closely at these attempts of introducing forms of anticipation into approaches of governance of technology. They explore "anticipatory governance", which embodies the concept of being as alert as possible without presuming to predict what is unpredictable. Their concept plays an important role in "incrementalism", as it was introduced into governance literature by Charles Lindblom in 1959, to make a point against the assumption that one could predict the real consequences of significant policy decisions. While roadmaps (for instance, Roco's well-known image of "four generations" of nanotechnologies) may be useful for convincing funders of the potential of a certain scientific development, they are less useful for anticipating future societal problems. Forecasts, on the other hand, run the risk of presuming that there is one clearly defined technological future that can be "extrapolated" from the past and present. The idea that Karinen and Guston develop and endorse is rather a *non-predictive* form of anticipation via scenario-building. Such attempts involve substantial work of Science and Technology Studies (STS) scholars and would increase dialogue about and understanding of not just one, but of a range of possible technological trajectories and respective governance frameworks.

Christoph Rehmann-Sutter and Jackie Leach Scully develop a tableau of different possible models of ethics for – or of – NST and ask "which ethics" is best suitable to discussing the issues of nanotechnology adequately. Their first set of ethics in the "acceptability frame" gets into difficulties because nanotechnology is at such an early stage of development. What could be "acceptable" or "inacceptable" is not at all clear. The second set of ethics asks about the desirability of certain developments. This has merits, because it does not just take desires for granted but questions the value of desires and wishes. While not entirely new, any ethics considering nanotechnology must place actual and possible developments in social and cultural contexts. The authors' third set of ethics takes a governance perspective and assumes that a more rational allocation of resources will help to develop technological solutions to the real problems of society and not just to products that can be sold on the market. The authors favor an integrated ethics (their fourth set) that recognizes issues of nanotechnology in a socio-technical systems perspective. How to pose the questions in ethics and which model of ethics we want to follow are influential questions when it comes to building assessment regimes in societies.

Why Enrol Citizens in the Governance of Nanotechnology?

Alain Kaufmann, Claude Joseph, Catherine El-Bez, and Marc Audétat

1 Introduction

According to the literature produced either by STS scholars or by many public agencies, nanotechnology[1] offers a unique opportunity for developing socially robust technological innovations within a sustainable future. In this context, learning from the GMOs controversy and moving toward an "upstream engagement" becomes one of the master narratives of public policies. This narrative is linked to the critique addressed to the approach of the Public Understanding of Science (PUS) taken by The Royal Society in the UK (The Royal Society 1985). PUS was an exemplary response from the scientific institutions to what was interpreted as a growing "gap" between science and society that started to be documented by surveys and reports as from the 80s. In this idea, a fuzzy entity called "the public" had to be educated and informed in order to support innovation and reduce social resistance to technology. The more detailed critiques were developed at the "Lancaster School" led by researchers like Bryan Wynne (Irwin and Wynne 1996). They summed up their vision of PUS in the famous "deficit model" in which laypeople were conceived as passive receptors of information to whom the institutions – be they universities, research centres, mass media, museums or schools – were supposed to provide education.

The deliberative or participatory turn (Blondiaux and Sintomer 2002) which appeared in the 90s is linked to the problem of governability in contemporary society, including the loss of ability of representative democracy to address scientific and technological issues. The role of experts and decision-makers in the environmental crisis, and in risk assessment and management, has raised many controversies. The irruption of concerned groups producing counter-expertise in the domains of environment and biomedical sciences also played a critical role in promoting a kind

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[1] In this chapter, we use the term nanotechnology although this singular form covers a wide spectrum of different technologies.

M. Kaiser et al. (eds.), *Governing Future Technologies*, Sociology of the Sciences Yearbook 27, DOI 10.1007/978-90-481-2834-1_11,

of "scientific citizenship"; this involved sometimes knowledge "co-production" in which scientists, experts, and laypeople collaborate closely to produce knowledge and solutions to common problems (Callon 1999, Kaufmann 2004, Kleinman 2000, Leach et al. 2007, Rose and Novas 2005).

The implementation of Technology Assessment (TA) can be viewed as one consequence of the problem of governabilty. It is a response from political institutions to the increasing mobilisation of concerned groups throughout society, and a means to cope with a legitimacy deficit. It is worth distinguishing two kinds of TA (Hennen et al. 2004). On the one hand, the "classical TA", born in the United States with the well known OTA (1972–1996), where the TA institutions are supposed to scientifically investigate the issue at stake and deliver unbiased and as comprehensive as possible knowledge about the technical, legal, ethical and policy aspects to policy-makers. This kind of work can be seen as a particular type of expertise in which the final output is a written report. On the other hand, the "public TA", or "participatory TA" (pTA), emerged later and gave rise to the well known consensus conferences developed by the Danish Board of Technology. Here, the process is turned to induce a communicative and participatory process in order to contribute to the formation of opinion, using a simulated public sphere corresponding to some kind of a Habermasian ideal (see Section 5 and 6). Worth to mention, a third kind of TA, constructive Technology Assesment (cTA), emerges from the Science and Technology Studies as an analytical perspective (Rip, Misa and Schot 1995). It aims at broadening design, development, and embedding in society by including more aspects and more actors. It brings in innovation processes more reflexivity among the actors. Constructive TA tries to overcome the limits of more institutional assessment approaches.

It is striking to compare the number of times participation is mentioned in official reports about nanotechnology with the lack of awareness of the issue of participation among academic, industrial and political actors, as well as in the public sphere. This is a real problem, since participatory initiatives are supposed to play an important role in defining the future of nanotechnology. In this chapter we first review the experience of participation in the domain of Technology Assessment. In a second part, we discuss the conditions for an effective contribution of citizen participation to the development of nanotechnology.

2 Why Public Participation?

Any attempt to discuss virtues and limits of public participation must begin by explaining why to supplement usual decision-making with more participatory public engagement. According to Fiorino's assessment of different institutional mechanisms of citizen participation in risk issues, three types of arguments are used to overcome the usual limitations of the technocratic approach to science and technology policy (Fiorino 1990). The first can be qualified as *instrumental*. It relates to the loss of legitimacy of political decision-making. Participation is seen as an improvement of the efficiency of public decision-making. But this context of distrust towards politics and the political class is, at the same time, one of decrease of concern and involvement of citizens in public affairs. The same point is made by Fung (2006) who insists on legitimacy, but also on a criterion of effectiveness in the governance of public affairs.

Fiorino brings in a second argument, a *normative* one. It says that in a democratic regime citizens are the best judges of their own interests and must therefore be allowed to raise their voice about technological or scientific decisions that can affect their lives or threaten their community. Fung (2006) uses similar arguments speaking of a criterion of justice close to the notion of empowerment.

A third argument is a *substantive*, or say an *epistemic* argument. It says that laypeople may produce knowledge and may identify solutions to problems complementing experts' knowledge. To put it in the language of the economists, participation is seen as a way to deal with the "limited rationality" of each type of involved actor. Here, the case of "popular epidemiology" seems to be emblematic of such a situation. Popular epidemiology "is a process by which laypersons gather scientific data and other information to direct and marshal the knowledge and resources of experts to understand the epidemiology of disease" (Brown and Mikkelsen 1990: 125–126). This argument corresponds to what Callon (1999) put under the umbrella of knowledge co-production.

Besides these arguments, as underlined by many authors (see for example Rayner 2003), citizen participation is ambivalent and limited. In practice, participatory procedures are too often an instrument of legitimisation in the hands of representative institutions. Legally, there is no mandatory articulation of participation with decision-making. Since it does not entail any kind of obligation on behalf of elected representatives, its leverage power is weak. Other limits, discussed below, have to do with the framing of the public good within participatory procedures. In spite of its limits, participation exists as a consequence of increased mobilisation of concerned groups, and remains, in our view, an opportunity for collective learning and democratisation.

3 Public Engagement, Participation, and Hybrid Forums

Smith (1983) defines public participation as an ensemble of procedures designed to consult, involve, and inform the public to allow those affected by a decision to have an input into that decision. In an attempt to establish a more precise definition of the concept of "participation", Rowe and Frewer (2005) have proposed a typology of the different public engagement mechanisms. Among more than one hundred different methods identified they distinguish three broad categories of public engagement mechanisms.

The first category is of *public communication:* information is conveyed from the organiser or "sponsor" – usually a governmental or regulatory agency – to the public. The information flow is one-way: the public listens and gives no feed-back on what is communicated. The common and problematic approach of the Public Understanding of Science falls into this category. Callon (1999) calls it the model of *public education* (*de l'instruction publique*). It draws together mechanisms such as TV broadcasts, public lectures, web pages, etc.

The second category is of *public consultation:* information is conveyed from members of the public back to the organiser of the initiative. In this situation, the sponsor is "listening" to the public and its opinion. This category comprises mechanisms such as public hearings, surveys, focus groups, etc.

According to the authors, only the third category can be characterised as fair *public participation:* information is exchanged between members of the public, stakeholders and the organisers. In those devices, a real dialogue can occur between the parties. It aims at going beyond information flows, and to allow negotiation and opinion shifts; the framing of the issues may also be put into question. This category comprises mechanisms such as citizens' juries, citizens' and consensus conferences, planning cells, decisional referenda, etc. It can be partly assimilated to what Callon (1999) has defined as *the public debate model*. Detailed presentations of the different methods and their use can be found in Gastil and Levine (2005) and Joss and Bellucci (2002).

However, a typology based on the theory of communication and procedural criteria is incomplete without cross-examination against "dialogical" criteria. Scientific knowledge and technological innovation usually imply a double delegation of power: the delegation to political representatives to decide in the name of the citizens, and, too often kept implicit, the delegation to scientists, experts, and technologists to find solutions (Callon et al. 2001).

These two delegations can be put into question within "hybrid forums" (Callon et al. 2001) which emerge either spontaneously as public controversies or as organised procedures by stakeholders or the authorities. Hybrid forums are open spaces where mobilised groups can debate socio-technical choices which affect them. The groups are heterogeneous; they may include experts, elected representatives, technicians, activists, NGOs, and concerned laypersons. The issues at stake and the problem raised imply heterogeneous knowledge and practices.

Socio-technical controversies may induce participatory procedures and, reciprocally, the latter may entail controversies. The literature reports examples where a participatory mechanism chosen in the third category (of fair participation) reduces the scope of deliberation opportunities and remains within the model of education of the public. In the case of GMOs, the agenda for discussion has been conceived many times in a very narrow manner, for example putting all the emphasis on the issue of food safety. Problems have arisen in participatory procedures, especially when the expertise was claimed to be undisputable and when concerned groups were kept apart (Rudolf 2003, Levidow 2007).

These difficulties are better understood with the following observation: the most important change in the public sphere, often referred to as the "deliberative or participatory turn", is probably not just the direct participation of non-experts and citizens. This change cannot be understood, nor can it happen, without the other complementary reforms, namely greater transparency in expertise, as opposed to the long time tradition of "confinement of expertise" (Callon et al. 2001), and greater pluralism of the interests represented in expert commissions and decision-making processes. In our view, participation and deliberation is directly linked to this reform of expertise and accountability.

4 The Issue of Impact

Since citizen participation does not bind decision-making, it is turned to promote deliberation. Most critics of public participation usually point to the absence of a real impact of participatory procedures in the public sphere or at the level of decision. This kind of criticism is often short-sighted, failing to adequately take the complex and multi-faceted nature of the issue into account. TA representatives sometimes try to underscore or refine this issue by replacing the rather linear term of "impact" by the one of "resonance". According to Hennen et al., "resonance in this sense describes any kind of observable reaction to a TA process in its societal environment" (Hennen et al. 2004: 58). And, "Impact of TA is defined as any change with regard to the state of knowledge, opinion held, and action taken by relevant actors in the process of societal debate on technological issues" (Hennen et al. 2004: 61).

Those broad definitions have been used within the European project "Technology Assessment – Method and Impacts" (TAMI) (Decker and Ladikas 2004), which identified three impact dimensions vs. three issue dimensions. Impact dimensions are (1) raising knowledge, (2) forming attitudes and opinions, and (3) initiating actions; while issue dimensions are (a) technological/scientific aspects, (b) societal aspects, and (c) policy aspects. This framework gives a 3×3 matrix of nine categories for which impact could be assessed: scientific assessment, agenda setting, reframing of debate, social mapping, mediation, new decision-making process, policy analysis, re-structuring policy debate, and decision taken.

Any attempt to evaluate an impact using a simple criterion, for instance, a direct consequence of any participatory procedure on decision-making, would fail to grasp the complexity of ways impact should be assessed in a specific context. However, it is fair to say that one often lacks data to evaluate this subtle issue. Far more attention should be paid to designing processes which allow a real measurement of impact using a sophisticated framework like the one proposed by TAMI. A linear appraisal of impact of TA neglects important dimensions: the effect of the process itself on the various actors involved and the fact that a given TA method will have very different effects, depending on the specific context, be it scientific, political or cultural.

An interesting perspective considers the dual dynamics between the microcosm formed within participatory processes and the macrocosm of the public sphere at large. Marris et al. (2008) have for example evaluated this process in the context of an interactive Technology Assessment in the case of the GM vine developed at INRA,[2] France.

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[2]French National Institute for Agricultural Research.

5 Participatory TA: Constructing the "Ordinary Citizen"

To date, more than sixty public engagement exercises on nanotechnology, often mixing participation of "ordinary citizens" with other approaches and actors, have been organised. A short synthesis of the outputs and methods used can be found in the report by the British Nanotechnology Engagement Group (Gavelin et al. 2007). The European project Citizen Participation in Science and Technology (CIPAST) provides an international review and database of participatory processes in the field of nanotechnology.[3]

Participatory methods like consensus conferences or citizens' panels are designed to produce advice representing the "common good". To achieve this aim they involve people who correspond to the abstract category of the "ordinary citizen", i.e. a kind of "disinterested citizen" able to produce judgement unbiased by specific interests of actors like private firms or NGOs.

Analysing the implementation of the *GM Nation*? public debate in the UK, Irwin shows that participation "prioritizes the "open minded" (or "innocent") citizen over those with existing views (the "activists"). [. . .] It suggests a model of democracy in which stakeholders can be marginalized and current polarizations avoided" (Irwin 2006: 315). We agree with him when he states, "the presumption of openness is not intended to block scientific progress, but instead to create a more open and reflective culture where new scientific possibilities can be fully realized. Put differently, the historical commitment to progress through science is maintained: the challenge is to find more inclusive methods to achieve such progress" (Irwin 2006: 308). In other words, the element of "openness" is supposed to allow a free discussion in an idealised public sphere. The idea in *GM Nation*? was to prevent the debate falling into the trap of the strategies developed by the usual stakeholders.

The construct of the ideal-type of "ordinary" or "innocent" citizen is also the outcome of various constraints. First, it follows from the quest for legitimacy of the participatory procedures themselves within the institutions of representative democracy, and towards the target audiences. Second, organisers of participatory procedures are looking for some kind of representativeness of the population, and various methods exist to obtain a sample of people using both randomness and selection. And third, participation should get as close as possible to the "average" citizen and mirror his or her concerns. This is a way of avoiding instrumentalisation on the part of certain stakeholders that would expose any participatory procedure to fierce criticism. The resulting constructs of "ordinary citizen" entail risks: the risk of excluding some important actors, and the risk of depleting the expected deliberation outcome.

Moreover, the figure of the "ordinary citizen" is a paradoxical one. As soon as he or she participates, she gains expertise and becomes an "active citizen". Andrew Barry makes an important point: the cost of the production of active citizens is underestimated. Many analysts seem to forget that to be actively engaged is not a

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[3] See www.cipast.org.

natural state and that “to become an active citizen – to take part in a debate, or a form of deliberative politics, engage in a form of direct action, to disagree – is a performance, and a performance which requires and has costs – not just in time and loss of earning, but in terms of exposure and personal relationship” (Barry 2000: 3).

6 The Role of Ethics in Participation

Another contextual element must be taken into account. It is the “ELSIfication” of research, which followed the implementation of the Human Genome Project (HGP) at the beginning of the 90s. As noticed by Bennett and Sarewitz, there were major limitations in the way the HGP’s ethical, legal, and social issues (ELSI) programme was implemented:

> From the outset it conducted research on the implications of science emerging from the HGP, but did not address deeper questions about what science actually ought to be done. Nor where the formal mechanisms by which ELSI research could feed back into the science policy-making process. Neither the genomics community supported by the HGP, nor the bioethics community who benefited from ELSI funding, sought to change this situation, which in fact protected the autonomy of both (Bennett and Sarewitz 2006: 319).

This criticism of the HGP displays important similarities to that directed at participatory procedures and their ability to impact science policy.

As far as participation is concerned, ethics can assume two different roles; first as an instrumental tool, and second, as a normative evaluation. The “role of the ethics of technology consists of an analysis of the normative structure of technology conflicts and the search for rational, argumentative, and discursive methods of resolving them” (Grunwald 2005: 188–189). In the context of pTA methodology, discourse ethics helps to frame debates with best practices. The credibility of the organising institution and of the output of the debate depends on the ethical standards applied to the deliberation process. Enhancing the management of pTA by high ethical standards potentially increases resonance (Klüver 2003).

However, implementing deliberation ethically does not guarantee that the debates involve deep ethical reflection. Ethics, values, and largest philosophical concerns must become part of the shaping of future technologies from their very conception (Frodeman 2006). Technological decisions have a normative background, which raises societal debate and conflicts over visions of the future and concepts of humanness (Grunwald 2005). A large pool of ethical views is indispensable to policy-makers and regulators to ensure that acceptable responses can be given to the dilemmas created by new technologies. Any limitation of the pool of available ethical arguments can lead to societal divisions (Fukuyama and Furger 2006).

As shown in an empirical study by Scully et al. (2004), laypersons and professionals talking about somatic gene therapy frame the issue differently. The assessments made by non-professional people focus on substantive rather than procedural issues. The question of “the ends”, as opposed to “the means”, are raised by laypersons. Other studies also demonstrated that lay views contribute to widening the pool of relevant ethical arguments (Fukuyama and Furger 2006). Therefore, participatory processes can be used as empirical methods to help map the moral landscape of the issues surrounding nanotechnology's developments. Norms and values at stake can be extended. The role that bioethics has played and the deficiencies of the ELSI program accompanying the HGP might be a starting point for reflecting on the role that the ethics of nanotechnology should play.

Hedgecoe (2004) warns bioethicists of the dangers they might face if they fail to take social science seriously; he calls for "critical bioethics". Based on these recommendations, the ethics of nanotechnology's developments calls for taking into consideration the role of ethics itself. Empirical research using social sciences' methodology should give rise to a more bottom-up approach to ethics. Making room for ethics in public engagement should lead to critical ethics that is well rooted in empirical research. "Following the actors", one essential motto of STS methodology, would challenge ethical theories and help go beyond the principalist and universalist approaches. Moral principles should be put to the test of empirical studies since humans and new artefacts constantly reframe their socio-technical environment and moral landscape.

7 Framing Nanotechnology as a Public Issue

Now that participation to Technology Assessment has been discussed, and in order to explore the role it may play with regard to the development of nanotechnology, the latter has to be framed as a public issue. In this respect, nanotechnology has to be considered together with the technoscientific imaginaries, the "economics of promises" it fosters, and in account of past debates and controversies about technological risks.

Technoscientific imaginaries have been defined by Marcus as socially and culturally embedded assumptions that unwittingly shape future worlds and possibilities through technoscientific practice and innovation (Marcus 1995: 4). Kearnes and Macnaghten et al. (2006, Kearnes et al. 2006b) have identified five main types of imaginaries which frame the developments of nanotechnology:

- nanos as the pursuit of the imperative of miniaturisation through the Moore's law in micro-electronics;
- nanos as the control over the structure of matter by manipulating individual atoms;
- nanos as a revolutionary technology inducing deep social reforms in all domains of society;
- nanos as a new science transgressing disciplinary boundaries;
- nanos as a promise for a socially robust technology.

The discourse framing nanotechnology's futures varies along those five dimensions according to specific cultural settings, and noticeably between the US and the European context. Anyway, the fact that many stakeholders take a positive view of the issue of public engagement and the necessity to engage upstream with technology's trajectories can be considered as quite a distinctive feature of nanotechnology's developments. As noticed by many STS analysts, as well as by public and private actors, this situation has a lot to do with the controversy concerning agricultural biotechnology: learning from the lessons of the GMOs controversy and moving towards an "upstream engagement" seems to become a dominant view. Kearnes et al. (2006a) provide a good example of this attempt to engage in a learning process in the UK context.

But constant reference to the "worst case" of GMOs can also be considered as one of the dominant "folk theories" of nanotechnologists, as they have been defined by Arie Rip. According to him, folk theories "are forms of expectations [. . .] being generally accepted, and thus part of a repertoire current in a group or in our culture more generally" (Rip 2006: 349). The GMOs case supports what Rip calls a "nanophobia-phobia" – the phobia that there is a public phobia –, since "there is not only an exaggerated interpretation of public concerns seen as an indication of fear, even phobia, of the new technology. Such concerns and fears are also projected onto the public, even when there are no grounds" (Rip 2006: 358).

It is obvious that the GMOs controversy has been an essential contribution to the democratisation of the debate concerning emerging technologies. It helped many actors to question the social control of technology. At any rate though, the nanophobia-phobia cannot be considered as a sufficient frame of reference to reflect upon public engagement in nanotechnology.

The excess of emphasis put onto risk issues by different actors in debates about technology has been noticed by many STS scholars and sometimes criticised. Many different reasons place risk issues at the centre of focus in public debates. Throughout society, risk is often used by social actors to raise their voice and put their concerns forward. At the same time, for innovators, the risk management of a new technology, both at production and consumption level is of high priority. To ensure success in marketing, they have to state that "everything is under control". Technology promoters have a tendency to close down the debate concerning the trajectory of a new technology by reducing citizens to selfish consumers or irrational individuals asking for "zero risk". This way, focusing on risks often reduces the numerous issues at stake deserving deliberation, and as a matter of consequence, impoverishes public debate.

We are observing with nanos that risk assessment, management and communication is again considered a critical issue. Indeed, size matters very much at the level of risk: the current knowledge about fine and ultra-fine particles is going to develop into a whole new branch of toxicology. Many policy documents acknowledge the sensitiveness of risk issues at the early stage of development and the necessary coordination of risk assessment at an international level. The problem of debating risks of nanos is maybe to be careful not to put too much emphasis on physical risks – leaving other critical issues unquestioned – while at the same time ensuring that a certain amount of R&D funding is directed at risk assessment. Although, for the moment, risk research is far back behind, and is insufficient in comparison with the rush for R&D (Maynard 2006).

8 Breaking Down the Nanotechnology's Nebula

The number of the scientific domains involved in nanotechnology, and their supposed impacts on society, challenges the possibility of implementing an informed and productive public engagement. This difficulty is mirrored in the scientific community and the private sector where no consensus holds on the reality of this supposed revolution or the more incremental nature of those transformations. The early stage of technological trajectory, usually presented as favourable for upstream public engagement, could here be seen as another challenge. We see this situation as a major difficulty for the running of participatory procedures in order to really grasp specific issues and to produce visions of nanotechnology's futures. One must ask, does the "GMOs lesson", usually invoked to promote early public engagement, really match the goal of debating nanotechnology?

What is particularly striking about nanotechnology is the fuzziness of the borders of the field. Those "enabling technologies" seem to encompass all sectors of innovation. The number of "promises" which are propounded is proportional to the number of domains which will supposedly be revolutionised by nanos. On the website of the Swiss Nano-Tera.CH project for example, one reads:

> The broad objectives are both to improve quality of life and security of the Swiss population across different levels of education, wealth and age and to create innovative products thus resulting in job and revenue creation. The improvement of human/environment conditions will enable a rationalization of resources and therefore a more efficient spending of government funds toward supporting the weakest section of the population (children, elderly, sick) and toward maintaining a safe environment as well as preventing disasters (fires, floods, pandemics). Systems to support high quality of life will find fertile ground in Switzerland, from both the consumer and supplier perspective. (www.nano-tera.ch, programme objectives section, consulted February 2007).

While this very marketing-like discourse may favour fund-raising for nanotechnology, it impairs effective public engagement. Observing the magnitude of the stakes alleged by nanotechnology's promoters, Williams states that we should perhaps "see nanotechnology, in the first instance, as a somewhat unruly construct of technology proponents. Nanotechnology becomes a space within which technology promises can be negotiated, and a broad space of strategic research, where what is at stake is the promise of fields of technology rather than specific projects" (Williams 2006: 330). Schummer in this volume provides a very sharp analysis of the so-called "NBIC convergence" (Roco and Bainbridge 2002) and its efficacy in orientating the visions of nanotechnology in the US context.

Williams's argument emphasises the difficulties of debating within participatory procedures about a "domain" like that of nanotechnology. Participation analysts have constantly pleaded for the opening up of participatory processes in order to allow an inventory of a greater number of issues and alternatives (Stirling 2007, Levidow 2007). This point is illustrated for example by Arnall and Parr (2005), who show that output of participatory exercises, whatever the technology, often results in a common pattern of broad questioning:

- Who is in control?
- Where can I get information that I trust?
- On what terms is the technology being introduced?
- What risks apply, with what certainty, and to whom?
- Where do the benefits fall?
- Do the risks and benefits fall to the same people?
- Who takes responsibility for resulting problems?

The recurrence or the "obviousness" of the concerns expressed by participants should not be an argument for dismissing the usefulness of engaging in participatory processes. They provide a qualitative frame of the concerns of citizens at a given period of time.

But the openness could well turn into fuzziness and confusion in the case of nanos. The situation is made even more complicated by some "attractors" like nanoparticles and risks, which tend to monopolise the attention of participants, leaving in the shade other important developments like nanoelectronics, RFID, human enhancement, environmental applications, energy issues, or nano weaponry. In order to productively debate the numerous aspects of nanotechnology, it is necessary to better differentiate the type of innovations and products that exist or are expected. At least three domains should be distinguished: nanobiotechnology, nanomaterials and nanoelectronics.

Taken as an undifferentiated ensemble, nanotechnology is the place of both excessive promises and exaggerated negative societal impact. Following Grunwald, a debate which oscillates between expectations of salvation and fears of catastrophes, cannot contribute to orientate the actors in a situation of increased contingency, rather exacerbates uncertainty (Grunwald 2008). There is a need to focus on more precise applications of nanotechnology, for example by building scenarios to allow citizens to contribute to specific domains. As far as participatory procedures are concerned, it is also possible to hybridise the methodology of the citizen conference with that of the scenario workshop, in order to let different options and perspectives for the future to be documented and debated. An interesting foresight exercise has been done in the Nanologue project, drawing scenarios which can afterwards be used for discussions with citizens (Nanologue 2006).

9 Conclusion

The issue at stake is "whether or not the participatory turn is an important and distinctive feature of the emerging 'nanosphere'?" The role attributed to the GMOs story in designing upstream participatory exercises is probably overestimated and might well constitute a kind of "folk theory" of nanotechnologists, too often agreed with by STS researchers. Technology Assessment and participatory TA have often been criticized for happening only downstream innovation trajectories. Starting the dialogue "upstream" is of course a prerequisite, but it can neither guarantee success nor does it imply that the output of participatory procedures will impact decision-making processes. The credibility of participation rests upon an engagement of the institutions towards the output of the process. Furthermore, the potential impact of participatory procedures on the trajectories of innovations remains as uncertain as is the articulation of participation with institutional decision-making. But, we do not follow Rayner when he considers participation as "just another layer of technocracy [. . .] and essentially a managerial discourse" aiming at promoting acceptance (Rayner 2003: 169).

In order to influence the technology's trajectory, it is essential to choose the appropriate moment and the right context for participation. As we have shown elsewhere, a preliminary analysis of the socio-technical networks embedding nanotechnology is needed in order to document the irreversible factors, and the path-dependencies, affecting the technology's development; Actor Network Theory (ANT) provides appropriate tools to reach this goal (Joly and Kaufmann 2008). This approach could possibly allow a re-politicisation of the innovation process, so that concerned groups and citizens could intervene, and participate with policy-makers in order to redefine the power relations.

Participatory Technology Assessment relates to the governance of new technology and risk, but not to the innovation process itself and its outcome of final marketed products. That is why, in our opinion, public engagement should be concerned with the issue of *how, where and when* citizens should participate in the innovation process to enter the socio-technical networks supporting the emergent technology. Gathering knowledge about the sociotechnical networks and the economics of nano-innovation is a critical task, partly bearing on the shoulders of STS researchers.

We agree with an important point made by Andy Stirling, who criticises the usual dichotomy made between expertise and participation. He proposes to evaluate the contribution of both by way of common criteria based upon their ability to "close down" or to "open up" the issues. Their beneficial contributions can be assessed on common ground: "instead of focusing on unitary prescriptive recommendations, appraisal poses alternative questions, focuses on neglected issues, tests sensitivities to different methods, considers ignored uncertainties, examines different possibilities and highlights new options" (Stirling 2007: 229).

Recognising that nanotechnology is partly "constituted" by participation does not mean that participation or any other form of public engagement alone can impact research policies and the innovation process. Again, to be effective, they must be intertwined with, and not dissociated from, the proper expertise processes. They must be articulated with the social mobilisations and be flexible enough to include emerging concerned groups. It would be mistaking to simply consider that more participation and more "upstream" will avoid such controversies like those about GMOs. This vision would miss the point about innovation, and it would misplace the role of participation, making it a fabric of illusions.

It is very difficult to imagine that a participatory process could for example influence the roadmap of the micro-nanoelectronics in the Grenoble nanodistrict, which is related to a worldwide context of research and competition (Joly et al. 2005).

However, we can imagine that participation could influence other fields, such as the design and life-cycle of goods containing nanoparticles, the implementation of nanodevices in energy storage or in environmental remediation, the RFID and its social control implications, or the envisioned body implants and other human enhancement devices.

Any public engagement initiative about nanotechnology always has to be considered as a unique adventure. The fact that it is organised at a local level, let's say the French Grenoble nanodistrict (Joly et al. 2005), or at a national level, like in Switzerland or the UK, may lead to totally different framing and impact. The whole process of interaction between the actors involved is often more important than the written output which is communicated. For us participation is not only the place where some citizens can raise their voice about science an technology, it is a place for collective learning offered to experts, policy-makers and stakeholders.

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Toward Anticipatory Governance: The Experience with Nanotechnology

Risto Karinen and David H. Guston

1 Introduction

This volume argues that the emergence and institutionalization of nanotechnologies can only be fully grasped with respect to the ways contemporary reflections and deliberations contextualize them as future technologies. Because nanotechnologies are currently inchoate, even those stakeholders who recognize an interest in them often operate with only loosely formed and sometimes ill-conceived expectations of them. Even so, such projections are essential resources in legitimating and authorizing decision-making. In debates on nanotechnology, the future is "an active arena, one both pregnant and populated with agendas, interests and contestations" (Selin 2007: 214).

Nanotechnology is often portrayed as a disruptive or even revolutionary technology that will have significant implications at an undefined point in the not-too-distant future. Visions, scenarios, and road maps populate discussions of nanotechnology – partly to mobilise necessary resources for building infrastructure, skills, and knowledge (van Lente and Rip 1998, Brown et al. 2000, Selin 2007). But reflections into the future serve other functions as well. The joint construction of future projections brings together a host of otherwise diverse stakeholders and begins to institutionalize these emerging networks in preparation for future activities (Spinardi and Williams 2005: 61–62).

While there has been a recent upsurge in discussion of, and resources dedicated to, environmental health and safety issues in nanotechnology, discussion about the longer-term societal implications and governance – or risks other than health or environment – are often absent or submerged. When present, they are portrayed as barriers to progress or, marginally better, as instruments to encourage the "acceptance politics" (Barben 2006) of developing nanotechnologies by stilling the waters of conflict and controversy.Nevertheless, the way in which societal concerns have been taken into consideration in the development of nanotechnology development

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is arguably unprecedented. As exemplified by the 21st Century Nanotechnology Research and Development Act in the United States (Fisher and Mahajan 2006), but found in other nations and regional governments as well (Barben et al. 2008), policy demands for the integration of nano-scale science and engineering (NSE) and societal research have pushed research on societal implications from mere risk-based formulations toward broader considerations of desirability (Bennett and Sarewitz 2006). In comparison with other recent scientific and technological endeavours such as genetically modified organisms or genomics, there are many warrants for the claim that we are better prepared than we have ever been to face the challenges of governing an emerging technology.

This chapter has two major, intertwined purposes: The first is to assess this claim of preparation and to suggest that, despite the seemingly better position of the social and ethical studies of nanotechnologies compared to those of genomics, this position is still not very advantageous. The other major purpose of this chapter is to explore the concept of "anticipatory governance", one of the ways that scholars are developing not only to study nanotechnologies but to begin to integrate their work with NSE research, engage the public about its priorities and values, and anticipate and assess nanotechnological futures.

Our first task is providing a highly stylized history of NSE research, with which we will compare a similarly stylized history of anticipatory governance to show how the latter's development has lagged substantially. We then demonstrate further lag by examining the funding activities of the US National Science Foundation (NSF) for societal implications research. We introduce "anticipatory governance" in this context, and so we then provide a modest intellectual genealogy of the term, which has not yet been done in the literature to the extent that we can discern. Onto this more specific description of anticipatory governance we reflect two sets of practices – the work of the International Risk Governance Council for nanotechnology, and the work of the Centre for Nanotechnology in Society at Arizona State University (with which we are both affiliated). We conclude that while anticipatory governance is a plausible and worthwhile agenda, its success is dependent on a context even less conducive than initially conceived.

2 Reconstructed History of NSE

The work of historians (Kim 2008, McCray 2005) shows how there may be many different histories of nanotechnology, but McCray (2005) documents one increasingly canonical "creation story" which credits Richard Feynman with articulating the guiding vision in his 1959 speech, "There's plenty of room at the bottom." While Feynman laid out the prospects of manipulating matter at the molecular and atomic scale, the term "nanotechnology" did not arise until a decade-and-a-half later, when Norio Taniguchi (1974) introduced it to describe the engineering of materials at the nanometre level. The tools necessary for even beginning to enable these visions, however, were not fully developed until the 1980s, when the scanning tunnelling microscope and the atomic force microscope (Mody 2006) allowed scientists to visualize and even manipulate individual atoms. In 1990, IBM-sponsored scientists famously wrote the company logo in xenon atoms (Eigler and Schweizer 1990). Improvements in microscopy and analytical techniques enabled the high-profile discoveries of "buckyballs" and carbon nanotubes, molecules with nano-scale shapes and structures that give them special properties (Maynard 2006).

Nanotechnology also started to emerge from laboratories in the 1980s, largely at the crossroads of science, fiction, and futurology. Eric K. Drexler's (1986) *Engines of Creation* stretched Feynman's original visions of molecular manufacturing and self-assembly – to some, like buckeyball discoverer Richard Smalley, beyond reason. Still, nanotechnology remained outside the attention of wider public until the turn of the millennium, partly spurred by Bill Joy's widely cited "Why the Future Doesn't Need Us" (2000) and partly by the increased political interest and consequent federal funding of NSE research in the US (Bennett and Sarewitz 2006).

While US federal investment in NSE R&D started with a modest program in 1991 (McCray 2005), by 1997 policy entrepreneurs like Mihail Roco began convincing others that without a more substantial investment the US would lag behind its global economic competitors and miss out on leading the next industrial revolution. Following a pattern established by other large research programs, Roco helped push for interdepartmental coordination to institutionalize nanotechnology policy at the federal level. The Interagency Working Group on Nanotechnology was established in 1998 and became central for developing the vision and mobilising support for the "National Nanotechnology Initiative" (NNI), which President Clinton announced in 2000 in a speech at California Institute of Technology that invoked Feynman.

The NNI encompasses funding from nearly all US agencies that sponsor any R&D; it has since supported NSE research by funding individual investigators and teams, creating multidisciplinary centres of excellence, and developing networks and other research infrastructure. The total investment of the NNI, including US$1.5 billion allocated in 2008 and another US$1.5 billion requested for 2009, comes to nearly US$9.5 billion. In addition, industry in the US currently spends about $2 billion per year in R&D. State and local governments have also become active, as have small businesses and investors.[1] Increasing numbers of consumer products utilizing nanotechnologies have emerged; as of June 2009, more than 800 nanotechnology-based products or product lines were available in the consumer market.[2]

3 Reconstructed History of Anticipatory Governance

Governance commonly refers to the move away from a strictly governmental approach to one in which a variety of regulatory activity by numerous and differently placed actors becomes possible without detailed and compartmentalised

[1] http://www.nano.gov/html/about/funding.html (accessed on August 13, 2008).

[2] According to the Wilson Center Project on Emerging Nanotechnologies. http://www.nanotechproject.org/44 (accessed on June 19, 2009).

control from the top (Lyall and Tait 2005: 3). We use the term "anticipatory governance" to refer to efforts to prepare for the necessary activities and build the capacities essential for such broadly-based activities. The debates begun in the 1950s on the relative merits of incrementalism laid down some of the foundations for contemporary thinking on governance.

In a small but important synchronicity for our purposes, Charles E. Lindblom introduced incrementalism to the literature in "The Science of Muddling Through" in 1959, the precise time as Feynman's vision. While Feynman was imagining the benefits of mastery of the tiniest parts of our material world, Lindblom was acknowledging the complexity of social life and the inherent impossibility of predicting the consequences of significant decisions or policies. Lindblom (1959: 88) advocated policy-making through incremental adjustments on previous decisions, because such a method "will be superior to any other decision-making method available for complex problems in many circumstances, certainly superior to a futile attempt at superhuman comprehensiveness". He explained the lack of drastic policy changes in Western democracies with an existing, fundamental agreement between decision-makers and wider public that potentially disruptive issues should be avoided altogether – an agreement that limited policy debates to the marginal details. Non-incremental policy proposals were irrelevant because politically impossible and, moreover, they would be unpredictable to implement because meaningful comparisons could only be made between present and like-present policies. Most importantly for our purposes, however, Lindblom (1959: 86) also argued that because our knowledge about the social world is limited, a wise policy-maker would proceed "through a succession of incremental changes" to avoid making serious mistakes.

Lindblom's argument influenced policy thinking widely.[3] But incrementalist thinking did not penetrate the early technology assessment movement, and when the US Congress created its Office of Technology Assessment (OTA) at roughly the same time as Taniguchi coined "nanotechnology", it was framed as a more ambitious and rational-comprehensive approach toward forecasting the effects of new technologies (see NAS 1969, also Bimber 1996). Moreover, congressional insistence on controlling OTA's agenda for inquiry – while allowing the office to flourish some time for being responsive – also served to defeat any capacity it might have developed for foresight.

The importance of Lindblom's argument to current thinking about the governance of emerging technologies lies in two insights: first, his questioning the capacity of a small number of decision-makers at the top of organizational hierarchies to collect and analyze comprehensive information, discern options and prognosticate outcomes, and finally choose policies in a rational manner; and second in his emphasizing the unavoidable, unintended consequences of major decisions.

[3] Among the most influenced works were empirical studies of budgeting (e.g. Wildavsky 1984) and the relationship between agendas and policy change (e.g. Kingdon 1995), as well as normative studies of policy change (e.g. Gilmour 1995).

Recent literature on governance in fields of political science, public policy, institutional economics, and organizational studies takes these insights further to argue that a decentralized network of stakeholders located at multiple levels (local, regional, national, and supra-national) of a system with permeable and flexible boundaries will be able to communicate and act in a self-regulative manner that the attainment of certain jointly agreed goals becomes possible (Lyall and Tait 2005: 3–4).

While we do not necessarily believe that self-regulation as such should be the only desired form of governance, it is critical to recognize that governance is a capacity that is lodged throughout society and not simply relegated to public sector – government – hierarchies. Indeed, Lindblom's critique of rational-comprehensive decision making applies as well to private sector hierarchies. One may argue that the mutual adjustment required by the market provides a greater incentive for quick learning and adaptation than do, say, elections, but one might also argue that the career-length time horizons of bureaucrats or a mission like security provides greater opportunity for rational-comprehensiveness than the quarterly reporting of profit and loss. Thus, the key insight is not public versus private modes of analysis or regulation, but the capacity of a narrow set of actors atop hierarchies anywhere versus the capacity of a more distributed set of actors or network throughout society.

OTA gradually evolved away from its underlying rationale of foresight and toward a more incrementalist form of policy analysis – although this and any further transformation was cut short by the closing of OTA at the behest of congressional Republicans in 1995 (see Bimber 1996, Bimber and Guston 1997). In Europe, numerous versions of technology assessment developed, often modeled in ways after OTA but fashioned to fit local parliamentary institutions and political cultures (Vig and Paschen 2000, and also Smits et al. 1995, Grin et al. 1997, Schot and Rip 1997). But it was not until the futurist strain of technology assessment crossed with the constructivist school of science and technology studies (STS) – itself only emerged from more traditional history, philosophy, and sociology of science in the late 1970s and early 1980s – that "constructive technology assessment" (CTA) developed in the Netherlands and aimed at reducing the costs of trial and error inherent in incrementalist policy and enabling more robust decision-making in the absence of the predictability of outcomes (Schot and Rip 1997).

Thus, as these two highly stylized histories show, the conceptual tools likely to be helpful in engaging with a potentially revolutionary technology emerged at roughly the same time that public funding to develop that technology began to gear up, but well after the important tools and several of the pioneering discoveries had occurred and in an institutional context recently devoid of the one large capacity to assess research directions and technological outcomes. It was not just the comparatively sluggish development of conceptual tools: As Bennett and Sarewitz (2006: 316) have argued, STS scholars demonstrated no recognition of nanotechnology as an issue (other than, tellingly, as a new theme in science fiction) until after Roco and his fellow advocates created the NNI with a flourish of revolutionary rhetoric: "[On] the eve of the NNI, the community of scholars devoted to understanding the social embeddedness and implications of science and technology were playing no part in the gradually unfolding societal discourse about nanotechnology".

There is a second irony – more profound than the synchronicity of Feynman and Lindblom – that, although policy makers and the public have generally agreed to proceed in incremental steps, the governmental support of R&D intentionally aims at societal transformation – the kind of unpredictable change that incrementalism attempts to avoid. This sought-after transformation is precisely the point of the title simile in Vannevar Bush's (1945) influential *Science: The Endless Frontier* – that the encouragement of scientific research and development would provide the same, but endless, social transformation that the western frontier provided to the US. And although science policy *cognoscenti* had been contemplating the collaboration of social scientists with natural scientists for the purpose of moderating some of the potentially worst aspects of that transformation since even before Bush's report,[4] it was not until the 1960s that social science truly surfaced on the public funding agenda in the US and not until the late 1980s in conjunction with the Human Genome Project that a large research initiative incorporated a research agenda for the ethical, legal, and social implications (ELSI) arose with some very modest expectations of transforming the broader R&D agenda.

The genome ELSI program, however, failed to meet expectations that it would create an independent, research-based voice for social scientists and humanists to connect with and influence genome research policy (Cook-Deegan 1994), and this failure was evident to at least some observers as the NNI was beginning. Responding to the first calls for proposals from US NSF regarding the societal aspects of nanotechnology, which were formulated and evaluated with minimal input from the STS community, Guston and Sarewitz (2002) proposed a program of real-time technology assessment (RTTA). With intellectual roots in European technology assessment as well as US incrementalist thinking, STS, and innovation studies, RTTA offered to create something like CTA for the US context and, at the same time, redress some of the difficulties that genome ELSI had experienced. Part of this approach developed into language concerning "anticipatory governance".

4 Societal Research on Nanotechnology

One instrument of governance, and one often presupposed to precede all other instruments, is the creation of knowledge as the foundation for action. It is thus a third irony that a large-scale program of NSE R&D was initiated by people who understood the idea of knowledge-creation as an instrument of governance and who built into that program social research on nanotechnologies, but who had not paused to imagine much beyond the positive economic consequences of the new industrial revolution they intend to spark. Had they paused, however, they would have found little assistance, because it was the draw of federal funding that created

[4]The Steelman (1947) report, the more liberal and social scientific counterpart to the establishment Bush report, quoted a National Academy of Sciences report from the pre-war period advocating collaborations between natural and social scientists.

societal research on nanotechnology, rather than any particular vision, foresight, or collaboration on the part of the STS community – thus cushioning the already substantial head start for NSE research beyond serious consideration of its societal aspects.

This cushion became more evident as the funds started to flow. Although research on societal impacts was financed from 2001 onward at an individual and team scale, the NNI created more than one dozen Nano-scale Science and Engineering Centres (NSECs) before creating the two Centres for Nanotechnology in Society (at Arizona State University and at the University of California, Santa Barbara) as the central nodes in a nanotechnology-in-society network in 2005.[5] These two centres were awarded US$6.2 million and US$5 million, respectively, but tracking the remainder of societal research spending in the NNI is difficult. The 2004 NNI Strategic Plan parses the structure of the programme into seven program component areas (PCAs), of which one is called "Social Dimensions". This PCA includes research on environmental, health, and safety (EHS) aspects of nanotechnology, as well as education-related activities and public outreach and research directed at identifying and quantifying the broader societal aspects of nanotechnology including economic, workforce, educational, ethical, legal, and other social implications.[6] On one hand, this broader framing of societal research is consonant with the emphasis on governance advocated here. On the other hand, much of the workforce and educational spending is programmatically oriented to promote nanotechnology and does not represent neutrally oriented scholarship or decision support.

Since 2004, funding within the "social dimensions" PCA distinguishes between EHS research and other funding for research on ethical, legal, or societal issues and education-related activities. The actual 2005 budget for the entire PCA was about US$68 million, roughly 5.7% of the NNI total for that year. The estimated share of expenditures for 2006 was about 5.5%, and the requested share for the 2007 budget was 6.4%. In each year, EHS research received just above half of the PCA funding. The budget request for 2008 included an increased total of US$97.5 million, or 6.9% of the US$1.4 billion request. But the major increase occurred in the environmental component, which was US$58.6 million, meaning that the "societal" (which includes education, workforce, etc.) as opposed to the "environmental" component of the PCA remained stagnant, despite the creation of centres and the overall increases in NNI expenditures. The proposed 2009 budget lays out more than US$76 million for EHS, a large increase from 2008, while the education and societal dimensions component barely budged from US$39 million to US$40.7 million.

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[5] And none of the early awards, including Rosalyn Berne's ethics work (Berne 2006), the nano-STS work at University of South Carolina or the technology transfer work at UCLA, was aimed at intervention rather than description.

[6] See The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2007 Budget. http://www.nano.gov/NNI_07Budget.pdf (accessed on January 27, 2008).

NSF is the main sponsor of research within the PCA, distributing about two-thirds of all PCA funds and more than 90% of the research on other societal issues.[7] Several agencies, including Department of Defense (DOD) – which now funds more than one-quarter of NNI R&D – fund no societal research within the PCA. Although it is difficult to assess whether, first, the funding in total addresses future challenges sufficiently and, second, whether funding predominantly through the NSF sufficiently integrates societal concerns into nanotechnology R&D, it seems clear that the scale and distribution of funding for societal aspects (as opposed to EHS) does not speak to the ambitions of the 2003 Act.

5 Anticipatory Governance

It is into this context – already behind the game in the development of conceptual tools, the establishment of a major program, and the funding of projects – that anticipatory governance emerges. How it emerged is still somewhat mysterious, as even in this age of web searches, a proper intellectual genealogy of anticipatory governance is difficult. Guston and Sarewitz's (2002) use of it seems unselfconscious, and they do not appear to have used it prior to the 2002 paper. Searching in Google Scholar for the precise phrase "anticipatory governance" yields sixteen hits, all of them from 2001 or more recently save one, a master's thesis by Feltmate (1993) entitled *Barriers to Sustainable Development in North America: Historical Naivete, Media Limitations, and non-Anticipatory Governance*. Of the next most recent references, one is a doctoral thesis by Gupta (2001) entitled *Searching for Shared Norms: Global Anticipatory Governance of Biotechnology*, and the other is a chapter by Baechler (2001) in the *Berghof Handbook for Conflict Transformation*. These two references exemplify what appears to be two familial strands for the term: one in environmental studies represented by Gupta, her further work (2004; 2006), and a reference to it (Biermann and Dingwerth 2004); and one in public administration and management, including writings by Caldwell (2002), Mendoza and Gonzalez (2002), Hartzog (2004), and Anbari and Kwak (2004).

A third strand is related to nanotechnology, with its earliest reference in Guston and Sarewitz (2002) and an article and introduction in a special issue of *Area* by Anderson (2007) and Anderson et al. (2007), respectively.[8] Neither of these pieces cite Guston and Sarewitz, although elsewhere and not using the term, Kearnes and MacNaughten (2006), MacNaughten et al. (2005) and Doubleday (2007) each cite Guston and Sarewitz (2002). There is, however, a relationship between Gupta's post-dissertation work and Guston and Sarewitz: All were present together in the founding years of CSPO – then the Center for Science, Policy and Outcomes at

[7]See National Nanotechnology Initiative: FY 2009 Budget and Highlights, http://www.nano.gov/NNI_FY09_budget_summary.pdf (accessed on August 13, 2008).

[8]Roco (2006) and Kuzma (2007) use the term but are not found on Google Scholar search; their usage seems directly derived from Guston and Sarewitz (2002).

Columbia University, now the Consortium for Science, Policy and Outcomes at Arizona State. That period incubated both sets of work, and Guston and Sarewitz's use of the term may imply some unconscious sharing from Gupta, while Gupta's (2003) citation of Guston and Sarewitz (2002) may imply that she was aware of their usage, while not making specific reference to it.[9]

To the extent that can be discerned, each of these scholars seems to mean roughly the same thing by anticipatory governance – a distributed form of emerging political order with an emphasis on long-term thinking – but with one critical caveat: The public administration scholars seem to reject anticipation because they reject prediction; whereas, the environmental studies and nano scholars seem to embrace anticipation for exactly the same reason. Mendoza and Gonzalez (2002: 12), for example, write:

> *Anticipatory governance*, which is akin to Henri Fayol's *prevoyance*, means foretelling the future and preparing for it. It highlights the need for public organizations to have a long-range view of the future since the consequences of public policies and management decisions extend to future generations (italics in the original).

Guston and Sarewitz (2002:96) equivocate somewhat in their first use of the phrase, which nevertheless seems to imply the public administration meaning:

> The fear of untoward political interference in the research and development (R&D) process no doubt played a role in the failure to apply fully the tools of social science to the problem of enhancing the societal benefits of science and technology. But the reasons for this approach were — and remain — rooted in a central truth about the development and proliferation of technology in society: that this process is largely unpredictable, and thus not subject to anticipatory governance.

On the other hand, for Gupta, anticipatory governance relates to a "category of governance problems facing us, which have the twin characteristics of scientific and normative uncertainties", which she describes as akin to another term of uncertain heritage but clearer connotation, precautionary governance.[10]

6 Two Visions of Governance

Perhaps a more useful way to think about this series of ironies and the belated and ambiguous but potentially significant development of anticipatory governance of nanotechnologies is to see them as results of an on-going discourse about the costs and benefits of NSE research and its outcomes. One should then ask what

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[9]There are still deeper roots for the concept of anticipation in connection with governance, and while we agree with an anonymous reviewer's comment that there are "non-trivial chunks of sociology of science, expertise, "triple helix" and commercialization, public understanding of science", etc., that contribute to anticipatory governance (indeed, see Guston and Sarewitz 2002), there are still more direct lineages from Toffler (1970), his description of "anticipatory democracy", and follow-on literatures.

[10]Personal communication with the authors: January 2, 2008.

kind of governance could develop if the techno-scientific and societal aspects of nanotechnology were in fact deliberated in a more integrated and systematic manner.

One plausible example of such an effort is the International Risk Governance Council (IRGC) for nanotechnology. In a White Paper, IRGC (2006: 12) aims to integrate "a scientific risk-benefit assessment" – both EHS and ELSI – "with an assessment of risk perception and the societal context of risk" – what the paper calls "concern assessment". The paper is based on conceptualizing and combining two separate frames of risk appraisal (both consisting of risk assessment and concern assessment) with a roadmap for the future development of nanotechnology.

Roadmaps plausibly satisfy the anticipatory aspect of "anticipatory governance". Their practice arose in the 1960s, and they developed, in particular, within the semiconductor industry in order to forge a consensus vision of the relationship among research strategies, technology development, and business opportunities. "Roadmaps can be seen as an attempt to make explicit the guiding assumptions within an industry ... Their benefits derive from alignment within and between organizations, and the communication this requires" (Spinardi and Williams 2005: 61). Roadmaps can also be understood as scripts staging the scene and setting the tempo of production (Selin 2007).

The roadmap used by IRGC is Roco's (2004) formulation of four generations of nanotechnologies: passive nanostructures, active nanostructures, integrated nanosystems, and molecular nanosystems. After an analysis of the risk governance system for nanotechnology at the different stages of the four-generational roadmap, the paper makes recommendations on appropriate risk management strategies.

In the White Paper, however, the roadmap exists logically prior to the consideration of risk management, and it remains unclear what feedback loop if any exists from the risk governance considerations to the development of the technology itself. The paper notes that in the longer term the focus will be on social desirability of anticipated innovations, thus acknowledging the uncertainties in technology development. The paper also recommends scenario-building exercises as one way to create an effective risk management system, but the scenarios it suggests are about alternative societal developments that should be considered in order to build robust risk management strategies. The scenarios are not about alternative ways technology and society could co-evolve, or even about alternative ways technology itself could evolve. Technology development is the immutable constant, and societal developments, which are supposed to be processed through effective risk management strategies, are the variables.

The paper therefore begins to answer some basic questions about anticipatory governance, e.g. the kinds of governance practices that are needed when third generation and fourth generation technologies take shape in the laboratories, emerge into the agendas of regulatory agencies, and finally meet the markets. But IRGC leaves aside the more challenging questions about the NSE research agenda itself, e.g.: How should governance challenges about the latter generation nanotechnologies influence the ways earlier generations are developed?

While technological forecasts such as roadmaps can establish the parameters for discussing governance, they also easily manifest as static objects that fix expectations and encourage the presumption that there is one clearly defined technological future. One can see here then why the public administration perspective would reject anticipatory governance. If one rejects the premise that the roadmap is predictive of any particular future, as the incrementalist perspective encourages, then one would reject the governance discussion that follows, as well as the vision that motivates it.

But anticipatory governance is not wedded to the idea of prediction, and there are methods other than the roadmaps and the particular kinds of scenarios that IRGC dealt with, that can help advance the goal without embracing the illusion of prediction. Working from a similar perspective as Gupta, described above, Sarewitz and Guston (2005) attempt to reclaim anticipatory governance as a capacity, necessary to develop, that is built through early connection with a research agenda and hobbled by the reification of R&D decisions into marketable products. Still more recently, after several years of conceptual and practical work on anticipatory governance with CNS-ASU, the term has seemingly come to mean, *pace* Mendoza and Gonzalez, "[not] foretelling the future [but still] preparing for it." As Guston (2007: 380) has argued, for example, anticipatory governance is about "the ability of a variety of stakeholders and the lay-public to prepare for the issues that NSE may present before those issues are manifest or reified in particular technologies".

Barben et al. (2008) further argue that anticipatory governance can be pursued through a large-scale research "ensemble" of foresight, public engagement, and integration of social science inquiry with natural science and engineering practice. Building on Guston and Sarewitz's (2002) call for the use of scenario development and other non-predictive tools, Barben et al. (2008: 991-992) conclude:

> Anticipatory governance implies that effective action is based on more than sound analytical capacities and relevant empirical knowledge: It also emerges out of a distributed collection of social epistemological capacities, including collective self-criticism, imagination, and the disposition to learn from trial and error.... [A]s the concept of "anticipation" is meant to indicate, the co-evolution of science and society is distinct from the notion of predictive certainty. In addition, the anticipatory approach is distinct from the more reactionary and retrospective activities that follow the production of knowledge-based innovations – rather than emerge with them.

CNS-ASU embraces an attempt to do exactly this – develop anticipatory governance through capacities for anticipating socio-technical change, engaging with publics, and integrating social research into NSE research. CNS-ASU thus combines the agenda of anticipatory governance with some of these more reflexive elements, omitted by IRGC, that serve to question the NSE research agenda itself. CNS-ASU pursues this goal, in particular, through scenario development along two trajectories, open-source scenario development and more traditional scenario development workshops.

In the open-source scenarios (Selin forthcoming), CNS-ASU researchers have created plausible, nanotechnological "scenes" – precursors to scenarios – that have roots in the published scientific, popular science, and science fiction literatures.

Having drafted the scenes, reminiscent of technical product specifications, CNS-ASU researchers have then vetted these scenes for plausibility with focus groups of relevant NSE researchers. The focus groups include discussions about pathways and timelines for technical development that are akin to roadmaps, and the generation of keywords that are then checked against current NSE databases to identify current and emerging work in these areas. As of this writing, scenes are being placed into specifically designed web applications to allow their interactive development among a variety of different publics. CNS-ASU researchers will then analyze the varieties and details of responses and provide feedback to the NSE research communities working in these areas.

In the more traditional scenario development workshops (Selin 2008a), CNS-ASU researchers have coordinated a two-day interaction among NSE researchers, social scientists, ethicists, and relevant clinical, legal, and financial groups to discuss plausible future developments of, in this case, personalized medical diagnostics ("doc-in-the-box" technologies). Using a traditional method that focuses on identifying key uncertainties in techno-scientific and social development, the workshop developed socio-technical scenarios imagining doc-in-the-box technologies across dimensions of high to low value and collective to individual use context. Among the preliminary findings of the workshop include the recognition on the part of the lead NSE researcher of technological lock-in (e.g. the QUERTY keyboard) as a potentially critical concept for doc-in-the-box, and the change by one graduate student of the types of bio-markers on which her research will focus toward those that, upon the reflection occasioned by the workshop, she believes will be more socially valuable.

This experience with scenario development suggests – albeit in a preliminary fashion – that anticipation can be marshalled in a non-predictive way to begin to influence the trajectory of techno-scientific development. While it may be, as Schummer argues elsewhere in this volume, that the best way to predict the future is to create it, these creative powers are too often presumed to be scientific and technical rather than socio-political and cultural. Moreover, this sentiment preserves the future as the sole domain of the powerful. Anticipatory governance carves out a way for social scientists and humanists to help create the future, and it explicitly recognizes that certain capacities need to be built and augmented in order for society to construct more productive and fairer futures. Thus, the aim of such exercises would not be to agree on any one desired technological trajectory and suitable governance framework, but to increase dialogue about and current understanding of the range of possible technological trajectories and respective alternative governance frameworks, and to elaborate how these two future projections should develop interactively. Such activities then enhance the capacity to make decisions that bear fruit under different, even unforeseen, conditions, rather than reify the mirage of making good long-term decisions based on fixed techno-scientific extrapolation. Such scenario-building exercises should not be one-time efforts, but form a continuous process enabling discussions throughout the multiple choices in developing nanotechnologies and their governance structures.

7 Conclusion

This volume argues that the institutionalization and emergence of nanotechnologies can only be fully grasped with respect to the ways various contemporary reflections and deliberations contextualize future technologies. In this chapter, we explore how the practice of anticipatory governance could contextualise nanotechnology development. First, it might open up technological trajectories to considerations of social desirability by making explicit feedback from societal considerations to technology development. Second, it could challenge existing thinking on governance by illustrating the different ways technology could evolve. Third, it could change the dynamics of mobilizing resources for techno-scientific change by making it more difficult to make definitive knowledge claims about the future of nanotechnology or its governance in general. Instead of merely promising gains or sufficient safeguards, stakeholders would need to elaborate on the causal path from the present to the future and thus reveal the implicit presumptions of their claims. Fourth, it could enable stakeholders to reflect upon how their visions are performative of the future, leading to innovative constellations among them. Fifth, by openly acknowledging the problem of prediction, it could lead to more robust capacities in the face of even unforeseen events.

Anticipatory governance, however, faces significant challenges. First and foremost, with respect to nanotechnologies, it is still running behind a very large and dynamic techno-scientific enterprise. Moreover, as Guston and Sarewitz (2002) articulated, there are challenges of scale and support (in comparison to the techno-scientific area), there are challenges of participation – how to engage an unwitting public and how to identify latent stakeholders – and organization – how to create the necessary research groups that can interact productively with NSE researchers on one hand and publics on the other. Barben et al. (2008) provide something of a blueprint for many of these challenges in their description of the research ensemble at CNS-ASU and its attempt to implement anticipatory governance through foresight, engagement, and integrative activities. But even they identify a number of challenges and further ironies of this agenda, most generally the challenge of STS researchers taking on a greater in actively constructing, rather than observing the construction, of the future. While such questions require ongoing, reflexive assessment of the agenda and its practical details,[11] it does require that "STS researchers become more visible and significant participants in their own right, and – perhaps for the first time – instruments of governance themselves" (Barben et al. 2008: 994). But this would be a happy instrumentalization in our view, as not only should knowledge creation be seen as part of the governance process, but governance should also be seen as a part of the knowledge creation process (Guston and Sarewitz 2002).

[11] As one such reflexive activity, in October 2008 CNS-ASU conducted a "visioning workshop" to assess plausible future trajectories across twenty years of anticipatory governance as a social technology (Selin 2008b).

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Which Ethics for (of) the Nanotechnologies?

Christoph Rehmann-Sutter and Jackie Leach Scully

It has become commonplace to assume that a new technology needs an ethical accompaniment of some kind. But what should this accompaniment aim to achieve? If we ask this question seriously we need to look carefully at all those things that constitute the ethical concerns within the field, including the identity of the ethics itself and its relationship with technology. Should it be an accompaniment at all? The relationship of a companionship between ethics and technoscience, if it is not inappropriate, is at least unclear. So in our title, should it be the best ethics *for* the nanotechnologies, *for* the social issues implied by or connected to them, or *of* the nanotechnologies, in the sense of an independent level of normative or evaluative judgment?

The statement about the need for an ethical accompaniment opens questions about why there is such a need and about the kind of objectives of such an endeavour. *Why ethics? What is the role of ethics in the overall endeavour of reflection about technoscience and innovation in our societies?* These are the questions that will be tackled in this chapter. There are some tacit understandings of ethics in society that are historically situated. In their present forms, images of ethics have developed as "bioethics" or "applied ethics" in clinical medicine or in other innovative fields like genetic and reproductive technologies in the last third of the twentieth century.

In part, the ambiguity of the role of ethics has derived from the plurality of approaches in basic moral philosophy. In the different approaches to ethics – from Kantian deontology, the different versions of utilitarianism, Aristotelian ethics of a good life, Levinasian alterity to ethics of care and others – we see different ambitions and objectives (for an overview see Lafollette 2000).[1] Given the plurality of identities and approaches in contemporary moral philosophy, which has its own

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[1] Lafollette's ethics anthology has Caspar David Friedrich's painting Evening (of 1821) on its book cover, showing a forest at sunset, with about a hundred dark trees, the last light gleaming in between the stems. The direction from which the heavenly light is coming seems to be clear, but there are many different places where roots can grow into the earth.

M. Kaiser et al. (eds.), *Governing Future Technologies*, Sociology of the Sciences Yearbook 27, DOI 10.1007/978-90-481-2834-1_13,

history and rationale that are beyond the scope of this chapter, the ambiguity of ethical approaches to nanosciences and technologies (NST) is perhaps less surprising than it would be if ethics were a well-established "normal" science in the Kuhnian sense (like mathematics or quantum mechanics), with a set of uncontroversial methods ready to be applied to a new field of practice. The same controversy about the definition of reasonable aims of ethics also existed (and still does) in the field of bioethics, for instance about the ethics of genetic engineering, which has been a much more clearly identifiable science/technology from its beginning in the early 1970s. The identity of ethics remains a philosophical question, and the problem of the right aims and the best ambition *of ethics* is arguably one of the fundamental questions of moral philosophy itself. Therefore, the discussion, to which we would like to contribute may not be a sign of the immaturity of practical ethics but an interesting ethical issue in itself.[2]

Another part of the reason for the ambiguity of the role of ethics in the field of NST is the non-uniqueness of ethics as a reflective discourse about the societal implications of science and technology. Ethics, if it can claim to have a reasonable role, must clarify it within the context of other approaches (including anthropological, sociological, discursive, historical, even participatory approaches) that are clustered together as science and technology studies (STS). There are other forms of knowledge (scenario research into the future, empirical risk research etc.) that are crucial. And beyond that there are also certain other forms of cultural reflection like art or literature that may be preoccupied with some of the same topics. Therefore, a clarification of the aims and roles of ethical research in the field of NST is necessary because of interdisciplinarity. Ethics needs to be identifiable within an interdisciplinary collaboration concerning the societal implications of NST.

This line of discussion can have direct practical consequences. The role ethical experts (not the discipline but its players) can have in the public sphere depends on the assessment of the role of ethics. Questions may be very straightforward. What are the pitfalls of ethics within heavily financed and sometimes controversial international research initiatives? Can ethics be mandated, for instance, to fulfil defensive political functions? Or is all ethics *in* or *for* NST necessarily "mandated" as a functional element within an effort to prevent public criticism (or "to prevent the escalation" of public criticism "early", as the program for a Swiss series of dialogues on societal issues of NST suggested[3])? Or, seen from another angle, what can be gained or lost by incorporating "ethics" into the ELSA[4] parts of NST research programmes?

Over the last two decades we ourselves have been active in the ethics of biomedicine, particularly genetics and genomics, and we will draw on our expe-

[2]In this essay, we use the terms 'ethics' and 'moral philosophy' as synonyms, and we contrast them to 'morals', 'moral attitudes' etc., implying that the former is a critical reflection on the basis, principles and implications of the latter.

[3]Meili 2003.

[4]Ethical, legal and social aspects. There are other acronyms as well: ELSI (ethical, legal and social implications) in the US, or GE3LS (Genomics, Ethics, Economics, Environment, Law and Society) in Canada.

rience here. Those questions, however, even if they have been discussed previously, cannot be seen as solved. NST is not the same *social phenomenon* as biotech and biomed. Its development follows a different logic. In the case of NST we are, for instance, more "upstream" in the flow from basic research to technological innovation. But if one thing can be learned from the earlier ethics of gene technology, it is that it *remains* important to discuss these meta-ethical questions seriously, again and again. The alternative would be insensitivity towards the implications of ethics' *own* communications. As contributing ethicists, we are intervening in the process of social realization of technological futures, whether we realize it as such or not. We are not standing outside the field as non-participating observers, adding judging comments here and there. This is another claim that we shall explain and defend in this chapter: ethics intervenes as communication in the communications about NT.

Explicit references to bioethics and to gene technologies are frequent in the nanoethical literature, often in the form of an appeal to learn something from earlier debates and avoid repeating the same mistakes. One example is V. Weils' paper in the US National Science Foundation report "Societal Implications of Nanoscience and Nanotechnology" from a conference held in 2000:

> Our history with earlier technologies suggests the need to devise processes and settings for information exchange with and wider participation by members of the public in order to promote transparency ... Failing to nourish genuine information exchange, they may invite the very opposition they wish to ward off ... avoid seeing it as a problem of one way communication downward (Weil 2001: 194).

Doing better, for Weil, means including participatory elements in the debate. Others have emphasized this need too, most recently the authors of reports by the Swiss Academies of Arts and Sciences (2008) and the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) of UNESCO (2007). But since participatory approaches also involve strands of thought and discourse that are called "ethical", they cannot avoid the question of the role of ethics.

We will start by mapping the landscape of current ethical approaches to NST and by grouping them into types. We shall discuss one example in each category according to its strengths and weaknesses. Our discussion will be analytical as far as possible, but it cannot be purely descriptive, for the obvious reason that the aim of the chapter is to learn from examples and to develop methodological and procedural suggestions for ethical research in the field.

1 Acceptability and Beyond

The heritage of the ethics of NST from other technological fields extends into the key concepts and reading frames used in ethics to identify, describe and analyse ethical issues. One of these is the assumption that ethics deals with the public or individual acceptability of new technologies. We call it here the "acceptability frame".

One example is the discussion about the "enhancement" of human body functions with microchips and implants supported by a human-machine interface.

Summarizing the debate, Bachmann (2006) reports a series of "ethical questions" that are raised by such potentially possible human enhancements:

> How risky are the interventions in the individual that are necessary for the enhancement?
> Which possibilities of enhancing sensory, cognitive and emotional capabilities should be made accessible for all?
> How can we judge neuro-implants that allow a kind of remote control of individuals and make it possible to restrict autonomy and free will?
> Is there a risk of stigmatisation of minorities like disabled people?
> At what point do we trespass beyond human nature, i.e. at what point do members of our own species become human-machine hybrids? Would such an act be consistent with our self-understanding, our idea of embodiment and human identity? (Bachmann 2006: 110f; our translation)

According to the acceptability frame, a technological solution needs to be assessed for whether it will be acceptable to those who might use it or be affected directly or indirectly by it. Are the risks and side effects too severe for the proposal to be acceptable? This approach implies a basic social situation in which scientists produce something and offer it to others, who, after being informed about its nature, benefit and risks or other implications, can accept or refuse it. In the free market situation, a technological device goes over the counter, i.e. it changes owner on the basis of a contract of sale. Or, particularly in the medical or therapeutic situation, somebody is treated with it, or it is given to somebody to use. In medical research with human subjects, an ethics committee must check whether a research proposal is acceptable for patients or healthy volunteers, i.e. whether it is compatible with their rights, their dignity and their health. Afterwards, the patients or healthy volunteers are required to give their free and informed consent (or refusal) before being included in the study.

Sometimes, the technology may escape from the laboratory inadvertently. The *Frankenstein* mythology is based on the idea of an unplanned escape of biotechnology into the social world outside the laboratory, where it leads an autonomous life, putting other people into danger (Rehmann-Sutter 1999). Perhaps the most well known adaptation of the story of uncontrollable technology in the context of NST is Michael Crichton's novel *Prey* (2002), where the unacceptability of the nanobots is the obvious assumption. I do not quote from the novel directly, but from a brief "digested read" article in *The Guardian* (Anon., Dec 14, 2002), which is remarkable in that it highlights exactly this aspect of the story:

> The chopper swooped low over the Nevada laboratory. "Good to see you," said Ricky. "We've got a big problem. We were building this swarm of undetectable nano-particles capable of spying anywhere, and, er... they've taken on a life of their own. They're reproducing and evolving scarily quickly. They've already killed some animals and now they're attacking us."... The digested read... digested: You know there's all these scientists doing scary stuff out there, man, and we don't know anything about it. I tell you, man, we're all going to die. Help.

In fear of such situations the key ethical question appears to be one of acceptability, meaning more than the *fact* that concrete people accept a technological offering at a particular historical time. Acceptability means rather that a technological offering (or a side effect of a technology, or an escape) *can* be accepted or *should* be rejected *for good reasons*. It has two conceptual elements:

1. Potentiality: a technological offering has the potential to be accepted (because it is good for people, because its risks and side effects are under control etc.).
2. Reasonability: a technological offering can be a reasonable solution for certain problems in anticipated, but reasonably possible situations. The reasons used for establishing these claims can be explained and defended.

Both these conceptual elements combine to make acceptability a key notion, providing a structured framework for discussing more diffuse "concerns" ethically in a clear and straightforward way. But acceptability also carries a *social presumption* that makes this concept problematic. It is assumed that a particular type of *situation* hosts the key ethical issues. This presumption can be shown to contain at least the following two elements:

3. Conceivability: in order to assess the acceptability of a technological offering, it is necessary to be able to establish in what the offer consists, what it is conceived for etc. To discuss the acceptability "of NST", for instance, it would have to be established in what NST will consist. (This condition is obviously not fulfilled at this time.)
4. Provider-user interface: there is a divide between providers who develop, shape, assess and offer the technology, and users who buy and use it, or who are affected by its unintended side effects. The ethical question arises at the point when the technological offering leaves the hands of the providers and gets into the hands of users, or where the effects of technology use have an effect on others. (This shifts the focus away from participation in "upstream" decision making processes, i.e. in the many selective decisions that have been made beforehand.)

Beyond the conceptual implications and social presumptions, which are perhaps inadvertently taken on board when using the acceptability frame, there is also a *normative assumption* behind this concept of acceptability that it seems important to bring into the open.

5. There is a suggestion about the kind of questions that are most relevant in the ethics of technology. They are questions about the limits of the "ethical" use of technology. "Is it acceptable?" means something similar to "Is it moral?" Such questions demand Yes or No answers, at least at the end of the day. Acceptability is a binary notion that has two values. It is, or it is not acceptable. The "ethics" constructed within the acceptability frame deals with moral *limits* that have to be respected. Morality, on the other hand, is constructed as a discussion about limits.

This normative assumption of the acceptability frame is controversial because of the other questions that also deserve to be discussed in ethics, but disappear into the background because they cannot be captured within the frame of moral limits. These questions include, for example, the objectives of technological development, the relative significance of problems in contemporary societies, what makes a development an improvement of the human situation, what are the criteria for a good and fulfilled life, what makes an excellent and responsive researcher (in the ethical sense of the virtues) within the context of a society that has deep-rooted and urgent problems and conflicts (like global warming, the loss of biodiversity, poverty, exploitative economic relations etc.). Such questions are connected with technological development and need to be understood when looking at decisions regarding technological development from an ethical point of view. But as a result of their inherent presumptions, they cannot be tackled using only the acceptability frame. It is, however, uncontested that the acceptability questions are still important issues. But an ethics of technology that aims to bring the ethical implications of a new technology into debate needs to understand them within a far broader context.

Mario Kaiser, in a paper on the interdependence of the identity and ethics of nanotechnology, refers to the discussions within NST about whether there can be a distinction between serious (rational) ethical concerns and non-serious (irrational) ethical concerns regarding NT. The obvious example is the molecular assembler and "grey goo" scenario. Is it a rational concern that something of this sort could happen? The background is that concerns of this sort, for some authors, did serve as reasons for asking for a moratorium on NST as a whole, which sounds, of course, grossly exaggerated to others. But how could this question of "rationality" be answered, for instance in the pivotal debate between Smalley and Drexler? Kaiser convincingly concludes – against both parties in the debate – that such far-fetched extrapolations into the future are underdetermined by rationality. Therefore, such unlikely concerns are to be considered not as rational *or* irrational (which would presuppose a decision about their rationality) but as "arational" (Kaiser 2006: 668). Instead of being reliable contributions to ethical discourse, which is their intended face value, they have rather played a role in the societal negotiations that led to the identification of NST as a distinct field with an identifiable internal rationality.

On the basis of this, Kaiser has demonstrated that the ethics of NST will enter a dilemma if it poses the questions in the acceptability frame. Which technology, if any, should be acceptable? According to which rationale should the acceptability of an NST research field be established? Possibilities are evidently still emerging.

2 Desirability Instead?

In two recent papers, Bert Gordijn (2005 and 2006) introduces a powerful argument against discussing acceptability at such a global level as "nanotechnology". This notion encompasses fields of research and development that are too heterogeneous to be treated ethically as a whole. According to Gordijn, the question of an identity of "NT in its integrity" is potentially even irrelevant for the careful ethical assessment of these particular fields. There are great differences between, for example, the ethical implications of nanotechnologically produced neuro-implants to boost the memory, and those of nanotechnologically produced filters for recycling water, or nanosize devices for surveillance (Gordijn 2006: 319). The fact that (any) scientific or technological connection or overlap between these different applications exists that links them together into one general category of "nanotechnology" is irrelevant when we look at their social and ethical implications. They represent such different fields of practice (in terms of aims, means, side effects etc.), and are based on such different sorts of decisions (about practical and in part political questions) that they need separate and independent treatment.

Gordijn goes beyond this, and proposes a structure that could re-frame the ethical debate about NST. He suggests an assessment of the *desirability* of different NST fields. In a three-step procedure they should be checked for whether (1) they are oriented to desirable objectives, (2) a continuation of research in the field actually contributes to the realization of these objectives, and (3) the ethical concerns that accompany such a continuation are surmountable or tolerable.

The key notion here is desirability. Paralel to the distinction between mere acceptance and acceptability, desirability implies a distancing from the actual existence of certain desires in society. Desirability is an evaluative term that questions the factual existence (or non-existence) of desires and asks which desires are based on good motives. "Good" reasons, in this context, are reasons that are not only "sound" or "logically defensible", but morally or ethically good. Good reasons represent "good" values. Desirability, therefore, opens a discussion in the context of a "good life".[5] The implications of desirability are quite different from those of acceptability. While acceptability seeks the limits of reasonable acceptance of a technological offering (or its collateral effects), desirability raises the question of whether it is *really* worth striving for it. If the discussion moves to this level, it is ethically important because it does not take wishes for granted that are partly epiphenomena of a certain socially constructed and historically shaped form of life. The need for "fast food", for instance, is an empirical fact for many city dwellers today, because their lunch breaks are short. The desire, however, is a product of conditions of life that could also be changed. Fast food is not really worth desiring, because it is unhealthy, it reduces social contact to a minimum etc. "Desirability" looks beyond the *fact* of desire and calls for a re-directing of wishes towards what is good for human beings.

The criterion of desirability certainly has merits, because it allows ethics to draw attention to the level at which decisions are being made about which line of development or which strategy of research should be favoured, and whether they are being taken seriously as strategic, goal-directed (and often publicly financed) behaviour, rather than the blind following of factual wishes, or the willingness to pay on the market in an existing society, and ask whether they are the product of desirable desires.

But there are also problems. One is connected to the problem of underdetermination. Are the intended objectives that are *currently* used to justify or

[5]Martha Nussbaum (1990) discusses the roots of the idea of a "good life" in Aristotelian thought and its implications for ethical politics.

identify a certain field of research and development in NST also reliable indicators of the *future use* of its end products? This may not be the case. Technological development is not a pre-organized, goal-directed process where fixed objectives are followed over many years. It is rather an opportunistic and contingent evolution proceeding from step to step, often in unforeseen ways. Development is always open to new uses of techniques, not intended by those who previously developed them. A good example of such changes to the use of technological solutions is the steam engine. First developed as a utilizable construction by Thomas Savary in around 1699 to pump water in mines, after the contributions of James Watt and others, the steam engine changed its use to allow the development of, among other things, locomotives in the emerging railway system, which had a tremendous impact on society (Derry and Williams 1960: Chapter 11). Another example is the magnetron, a high-power microwave generator, developed for military purposes (radar for bombers and early warning in World War II, see Swords 1986), which now has civil uses in microwave ovens and navigation, uses that cannot easily be disqualified as undesirable. The history of technology is full of examples of technological opportunities being recombined in new circumstances. Who might have foreseen that radio technology, which was developed to broadcast programmes and attained an individualized use by a few radio hams with huge installations of self-made transmitters and antennae in their attics, would one day be used to develop a worldwide network of cell phones carried by nearly everybody in industrialized countries, which has deeply influenced the social and communicative behaviour of people around the world? The cell phone network today embodies different objectives from those that would (or could) have been assessed by the ethicists of technology in around 1950. Who would have foreseen, for instance, that cell phones could then be combined with little digital cameras in order to produce and exchange pictures? Developers and users interact. It is not possible to discriminate reliably between the desirable and the undesirable, before the level of concrete applications has been reached.

And there is a further point that calls for the picture to be substantially enlarged. Sometimes the objectives that are present in the social realization of technology depend on the context of developments within a competitive free market economy. In Europe, a few years ago, a new kind of start-up aviation company entered the market, offering flights at incredibly low prices, lower even than train tickets, and less than the cost of driving by car. Flying from Basel to Berlin with *easyjet* today, to take one example, costs less than a hundred Swiss Francs, all taxes included. Flying has become the cheapest way to get to other cities in Europe. Peoples' behaviour has changed accordingly. An academic may be supposed to attend to a business meeting in Berlin in the morning and to participate at a reception in the evening in Basel. New social expectations of this kind have emerged. If somebody fails to meet them, the burden of excuse is on her/his shoulders. The fact that jet flying contributes heavily to global warming, much more heavily than all other transport systems, has become a cause of a mildly bad conscience for many, but not (yet) a factor that influences a responsive development of the system. Flying *per se* was and still is, perhaps, a desirable objective, but the reality of the "objectives of technological developments" is much more complicated than that. If an ethics of technology is not prepared to react to these developments at the level of the real society, it loses its subject. By analogy, this may apply to nanotechnological developments as well.

Steps 2 and 3 in Gordijn's programme are meant to halt certain fields of research if they (2) do not look like being capable of reaching the set objectives, or (3) the ethical issues that accompany them seem to be too difficult to solve. Despite the start in step (1) with a broader question than that of acceptability, the procedure ends up as an acceptability check. A sub-field of NST would be unacceptable for further finance and support if it does not meet criteria (2) and (3). The suggested framework assumes the perspective of an ethics committee with the power of control, like the IRB[6] in clinical research, which can make decisions about the approval a clinical study.

Instead of being too tied to the intended future of NT, the ethics of NST should look more carefully at the social practices that constitute the *reality* of technology. Current practices develop, sometimes in unforeseeable ways. Ethics should keep up. Therefore, the ethics of science and technology needs to engage in interdisciplinary collaborations with empirical social sciences. Much empirical knowledge is needed for an up-to-date technological ethics. To find ethical and social issues reliably, it is necessary to adopt a bottom-up strategy,[7] while not relying too heavily on pre-formulated strategic research objectives. This is a plea for involving and focusing on not only the future, but also the present.

Also important is the question of desirability for or to *whom*? Bruce Lewenstein (2005) points to the fact that the realization of technology takes place within social relationships, and often involves the exercise of power. This may be in the interest of certain groups and not in the interest of others (it may even be against their interests); it may include some and exclude others. Objectives may be desirable for one group but not for another. The results depend on who has the means to realize the technology accordingly. The idea that artefacts have politics "built into" them was put forward by Langdon Winner (1980). His examples were taken from simple technology like low highway bridges that favour rich people with modern cars that fit underneath. When technology is built into society it should always be asked whose desires count and whose desires are marginalized.[8]

[6]Institutional Review Board. The paralel structures in Europe are called Research Ethics Committees (Rippe 2007, Woods 2007).

[7]This also recommends Lewenstein (2005), however with a different argument that focuses on the implications of the exercise of power in social relationships.

[8]We have made a similar argument in extenso on genetic enhancement (Scully and Rehmann-Sutter 2001).

3 The 'Novel Ethics' Frame

A striking phenomenon in the nanoethics debate is the frequent occurrence of the question about the need for a "new" ethics. Paul Litton (2007), in a paper in the *Hastings Center Report* explains how such a nanoethics would be considered novel: as "genethics" or "neuroethics" were novel. It should represent "a radical change in the way we address ethical issues", and "a novel ethical approach to the future". He refers to papers by George Khushf (2004) and Jean-Pierre Dupuy/Alexei Grinbaum (2004) who, in his view, have claimed this. Perhaps unsurprisingly within his rhetoric, Litton comes to a negative answer.

He goes through a list of "serious ethical issues" that will be raised in current and upcoming decades. The unique properties of many nanoparticles raise health and environmental concerns; advances in nanomedicine will raise concerns about human enhancement; there will be rising health care costs and rationing, and increasing diagnostic powers; new tracking devices may threaten individual privacy; there will be justice-related concerns about the distribution of wealth due to the economic effects of a technological revolution that is financed nearly exclusively by already rich countries (Litton 2007: 20). But Litton observes that: "these ethical issues are already raised by other technologies" (Litton 2007: 20). We agree. But what follows from this?

Litton's suggestions are:

1. "[W]e should not spend resources developing the ethics for a Drexlerian world" (Litton 2007: 24). The predictions that underlie these scenarios are simply too speculative and improbable to justify being seriously investigated by a nanoethics that costs money and time.
2. Wait and see the upcoming details of NST developments. A "nuanced ethical reflection cannot begin . . . until we see the details" (Litton 2007: 24). Treating NST as a whole is futile because the internal differences are too great to justify a one-for-all approach. Instead, an issue-by-issue ethical approach is needed. And for this, the ethical debate must be properly informed by science.
3. Most crucial right now are "extensive safety and environmental studies", which are not within the remit of ethics. "Our primary ethical challenge will be gauging the adequacy of the toxicology studies and the developed standards for introducing nanomaterials into common usage" (Litton 2007: 25).

This position leads to disillusionment for the ethics of NT. Either the issues are not worth studying, or they cannot yet be captured, or the only respectable task that remains is rather one for toxicological safety review boards than for ethics.

We also think that many (if not all) of the issues raised with regard to NST have precedents in other fields of technology and are not "new" in this emphatic sense. However, the novelty of the issues may be a poor indicator of their relevance and urgency for ethical reflection. Sometimes, old questions may be good questions (Jömann and Ach 2006: 54). And even those old ethical questions (like the questions of justice, desirability, disability and capability, risk etc.) may need careful reconsideration when raised in the context of a novel field of science, and this may justify the funding of ethical studies. The justification of nanoethics does not come from the novelty of its issues, but from their social relevance. Nanoethics is not different from other fields of ethics because it uses “novel approaches” to ethics, or because NST is radically new, but because it is concerned with a complex new field of science, the applications of which have important impacts on society, social relationships and the human-nature relationship. The title “nanoethics” could also be abandoned. Like bioethics, which is not a distinct ethical theory but a field of issues bound to the “biosciences” (“life sciences” to be read in the most general sense, see Rehmann-Sutter 2006), nanoethics is a field of practically oriented ethics that could also be identified as just one concrete field of ethics or practical philosophy.

In a discussion it is sometimes helpful if somebody stands up and asks the others, who may be too much involved in the difficulties of their argument, not to reinvent the wheel. And this allows a reconnection with the results of previous work. However, the approach via the novelty of issues neglects two important points, which, when considered, may change the picture.

1. The role of ethics and of ethicists is taken for granted: ethics should analyse concerns that arise when technology develops. When we look from the perspective of ethics in general, this is not self-evident. Why should an ethics of technology adopt a non-participatory observer position, waiting until specific concerns about technological developments become visible. This would be a wait-and-see approach to technology, starting from the assumption that there are no fundamental problems with how technological development and its implications for our societies are *currently* organized, which could perhaps be discussed in the unique window of opportunities that such a novel, emerging field like NST opens.
2. Technological development is isolated from its social and cultural context. On a global level, we have some huge and relatively new problems that relate to the consequences of technology use. On the other side, societies are increasingly dependent on further technological developments in order to solve older problems. In this situation the question of how the decisions and selections of technological development, implementation and use *in current social structures* are made is very important. And we cannot rely on old answers in other contexts. The science-society relationship should be studied at a deeper level than simply where problems of acceptability or desirability arise. Reflection needs to include this relationship itself, how it is organized into societies. Above all, the science-society relationship has multiple ends. It is not only about the providers’ dilemmas. Therefore, we need to look at the social and cultural contexts of technological development, selection, implementation and use, not only theoretically but also empirically. As we have seen in the field of genetics, this can lead to a much more nuanced and enlarged picture of what can be considered “ethical issues”. From a social networks perspective, technology developers and providers (scientists, companies, physicians) are not the only relevant actors, so

are the users (lay people, consumers, patients) who make decisions and integrate technologies into their life world, and interpret and reinterpret them in the context of meaningful and identity-constituting narratives. By investigating these multiple perspectives, the inventory of ethical issues will automatically enlarge and other concerns and issues might be prioritised.[9] This considered, the "novelty" of the questions to be discussed within NST appears perhaps less relevant.

4 The Governance Approach

In 2006, UNESCO published a report on "The Ethics and Politics of Nanotechnology", which is worth considering because of its sensitivity to issues that appear only from a global perspective. It may be another example of the need to include more perspectives in order to perceive more ethically relevant aspects. Before tackling "concerns" like the potential toxicity of nanoparticles, the report describes the relationship between NST research and the UN's Millennium Development Goals.[10] Many of the possible applications of nanotechnology could address those goals to the benefit of developing countries. The report states (with reference to Salamanca-Buentello et al. 2005) that "there are a number of areas that could benefit the poorest nations far more than any commercial development would – areas such as energy storage and conversion, water treatment, and health and disease diagnosis and treatment" (UNESCO 2006: 13). And it asks: "By what mechanisms should such research be promoted?" (UNESCO 2006: 13). This touches many ethically relevant topics that range from conflicts of interest between market economy and academic science to issues of resource allocation among research areas in NST and the participation of the poorest nations in the innovation process.

And it represents a different approach to the ethics of NST (or any technology) in general. In contrast to a "wait-and-see approach" or to the "acceptability and desirability frame", such an ethics of governance is more ambitious from the outset. It starts from the assumption that at least some of the research can be oriented in order to serve important social developmental goals. It does not *direct* research to these goals, but it would support those initiatives that might contribute to solutions. The ambition consists in introducing a rational selection mechanism that is, at least in part, independent of market economy. The alternative would be to let the existing selection mechanisms of free market competition work on their own.

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[9] In a series of qualitative empirical studies of the ethics of gene therapy, genetic testing and embryo donation (Scully et al. 2003, 2004, 2007, and Haimes et al. 2008 we demonstrate that the moral perspective of different actors may differ considerably. Therefore, for a deeper understanding of the providers' ethical dilemmas, an account of the ethical issues from the perspective of the (potential) user or patient is necessary.

[10] See www.un.org/millenniumgoals, (17-03-08).

In this approach, ethics has an obvious role and responsibility at different levels. One is the identification and interpretation of the goals of development. This is the topmost level of research governance. Problems and needs are more or less urgent, they affect a variable number and different groups of people. There may be no uncontroversial lists of problems and needs available, because any selection also involves social and political recognition of problems and of affected groups. Prioritised problem lists represent the anticipated distribution of technological means. There are values involved, some of them obvious, others less so. And these values need to be identified, put into context and discussed transparently. A further level is the prioritisation of initiatives relating to the development goals. Here too, it is not just efficiency nor the potential to be implemented economically that matters but also the social implications of desired technological developments when set alongside others.

This does not imply a change in the system from freedom of science towards a research master plan. We think that research needs its freedom to develop. But there are selections, and the mobilisation of associated values, in every selection that is already done when technology is developed for a view to a potential application for marketable products. Nanotechnology is already a far from economically disinterested field of basic research. If transparency allows us to identify the market forces driving nanotechnological development, we should also be able to make use of analogous transparency to identify and evaluate other involved factors and agents. Why should only the market determine what will be financed and realized, and not other factors as well?

In such a governance approach the basic structures of science-society relationships would be re-assessed from an ethical perspective. By contrast, this could not be expected from a "wait-and-see approach" or from a pattern of acceptability. Such an assessment needs social engagement on the part of ethicists, in order to understand the decision mechanisms that are in place, and to conceive strategies to bring ethical considerations into the selection procedures of science policy. The results of this ethical work could then be incorporated into appropriate research funding mechanisms.

5 Ethics Upside Down – or on its Feet Again?

Inspired by the emerging phase of NST and prompted by the difficulties with the acceptability frame, Kaiser (2006) calls for a change in perspective: "turning ethics upside-down". Instead of discussing the acceptability of technological offerings, ethics should observe how ethics itself is established and implemented. "By turning ethics upside-down, I have chosen to observe how normative concerns *are* managed by different social actors, rather than discuss how ethicists *should* cope with controversial concerns and visions" (Kaiser 2006: 672). An ethics of NST, according to Kaiser, should adopt a sociological, observant perspective towards itself and towards moral discourses that are present in the shape of disputes about the demarcation and rationalization of NST.

Empirical ethics, however, needs to be reflective and to investigate the role and the impacts of ethics. There are methodological concerns about empirical ethics that have been discussed extensively and have led to different practical methodological solutions (Borry et al. 2004). The most frequently mentioned issue is the danger of a "naturalistic fallacy", i.e. the false deduction of prescriptive conclusions from descriptive premises. To explain a longer argument brief: normative conclusions cannot be derived from empirical observations, but the decision about which questions should be treated is closely related to what we know of the situations and dilemmas that may arise. Or it may not be theoretically possible to discern, without empirical investigation, who could become vulnerable to what, and under which circumstances. The role of sociology is not just "to scoop up the facts" for ethicists (who already know what to ask), but also to scrutinise how ethicists and others construct the problems (Haimes 2002, referring to Nelson 2000).

This perspective will reveal, as Kaiser mentions, that ethical deliberations and reflections "are not innocent" (Kaiser 2006: 673). They are also part of the game, so to speak, but they adopt a reflective attitude and are attentive to their own role within the game. The example Kaiser provides is the exclusion of the post-human, the molecular assembler and "grey goo" scenarios from the list of rational concerns. The UNESCO report confirms this exclusion with its own arguments. They appear in the report in a chapter entitled "Distractions – Ethical Issues that Aren't" (UNESCO 2006: 19), because they distract attention away from the real practices of science and technology. With the inclusion or exclusion of concerns from a list of "ethical concerns to be rationally tackled", ethics itself contributes to shaping the identity of the field on which it critically reflects. Analysed logically, such ethical arguments present a circular structure. However, a problematic logical circle can be avoided, if the decisions about inclusion and exclusion of concerns are discussed openly and without prejudice. It needs to be clear which standards of rationality are applied in such manoeuvres.

But then, we claim, ethics is actually not upside-down, but on its feet again. A sociologically informed view of value judgments and moral discourses, including the forms of ethics, contributes most reliably to normative ethics. Such a normative ethics can take hold of those social processes it needs to evaluate.

The argument can be turned around. If normative ethics of NST avoids the questions that will be raised after a critical observation of ethical and moral evaluation processes, it will be a naïve player in a game that is ruled by others, mainly by those who most powerfully shape the development of technology. Such a reduced ethics would risk becoming something like a "conscience for sale". It would not only risk its intellectual independency but also contradict its ambition to reflect on the deepest questions and the actual possibilities – which would be rather superficial.

Feminist bioethics is particularly sensitive to such power games. Margaret Urban Walker (1998: 77ff) suggests the ethical strategy of tracking responsibilities – assumed, denied, justified – in society. What would this entail in the context of NST? The concrete relationships between scientists, engineers and those using the devices and tools they are developing, and also the concrete relationships between users and others need to be analysed critically. Would there be conflict between the responsibilities that institutions and authorities would accept, and those that the public would want them to accept? What could be said about the responsibilities of the public?

Carefully tracking responsibilities and investigating the moral understandings of participants in a society, however, is not only an empirical task. Ethics "on its feet again" is not reduced to sociology. But it would start with empirical sociological and anthropological research, adopting a descriptive and hermeneutical approach that aims at understanding the networks of actors, the roles and functions in sociotechnical systems, and the moral understandings of participants in deliberative discourses around NST. And it would bring the crucial issues about values to the forefront of the discussion. Tsjalling Swierstra and Arie Rip (2007) have proposed elements of such a method for an ethics of new and emerging science and technology. The contribution of ethics would be to help participants to discuss these ethically relevant issues in a transparent way, without losing the implications for the obligations and duties we have towards each other and towards the biosphere, the implications for justice and for our understanding of the common good, well-being and "good life".

Ethics, in this conception, is essentially a *reflective loop within* the social processes of innovation and development, not a moral science outside of society. It is not bound to eternal moral principles that serve as a kind of a historically independent Archimedean point, but it needs to proceed pragmatically, taking into consideration the moral understandings of the other participants at a given time and a given place within history, and constantly opening questions about which strategies of action are better contributions to society than others. It is a reflective loop that challenges the automatism of the inner- or inter-system mechanics in technological societies, and defends a perspective of morality, values and the conception of what is ultimately good. In such a perspective, ethics will recognise urgent problems within society and assess the potential of a new technology to solve parts of them. It will identify and discuss the ambivalences, and it will defend an awareness of the risks of a new technology, the risks of deepening certain problems or of not recognizing others, or even of creating new ones.

6 The Sociotechnical Systems Perspective

If ethics starts by taking seriously its own position within a structured and dynamic society, one of the first tasks for ethics is to clarify its own role. This, however, needs an assessment of the processes and dynamics of the society in which new and emerging science and technology develop. In a recent paper, Deborah Johnson (2007) distinguishes two different frameworks for seeing technological development, each with a particular role for ethics. One framework assumes technological determinism, i.e. believes that science and technology follow a logical path of development, and social order follows necessarily from technological order. Within this framework, ethical analysis could have "only a narrow and reactive role":

> In a technologically deterministic framework, the role of ethics is to identify problems resulting if the endpoint of a line of research is achieved; they can identify potential negative consequences and potentials for abuse (Johnson 2007: 25).

Real development of technology within societies however, does not justify the assumptions adopted by technological determinism. The process is rather contingent: “Technological development is a complex of contingent elements with multiple actors pushing and pulling in various directions” (Johnson 2007: 25). This reflects a growing consensus in the recent literature of Science and Technology Studies. Technology is not merely the material objects or artefacts (the machines), but the social and technical systems that together make artefacts work within a context, or in one word “sociotechnical systems” (Winner 1986: 35). “Sociotechnical systems consist of artifacts together with social practices, social arrangements, social relationships, and systems of knowledge” (Johnson 2007: 26). This perspective brings ethics and technology much closer together. “Since technology is social practices, social relationships, and social institutions as well as artifacts, technology *is* stuff for ethics” (Johnson 2007: 26). These social practices can be examined through the lens of ethics, i.e. by confronting them with questions of values, and analysing them using the repertoire of ethical theories. The position of nanoethics, therefore, is *in the middle* of dynamic sociotechnical systems.

> The role of nanoethics is to engage in conversation with others about what kind of world *should* be constituted (Johnson 2007: 28).

The stringency of ethical questioning will not be lost by this move. But in this perspective there is a role for ethical discourse *early* in scientific and technological development. Ethics’ role is not only to evaluate the products before they are delivered for societal use, but to engage in a reflection about the direction of scientific and technological development itself. Ethics, as Johnson emphasizes, “is positioned and expected to influence the development of the technology” (Johnson 2007: 23). This is the very intention of ethics, not a surprising side effect of ethical discussions.

Another line of thought, which combines well with the sociotechnical systems perspective, concerns the divide between theory and practice. It criticizes the assumption that epistemological questions are only important in theory building, whereas ethical questions have their rightful place where knowledge is applied. There are practical, even normative implications in theory itself. The example of a “genetic programme” as an interpretative pattern for genomics shows that “basic” scientific ideas can carry normative implications. (On metaphors in genomics see Nerlich and Hellsten 2004, on ethical implications see Rehmann-Sutter 2002). The same could happen in NST. Is the cell, for example, a “bag full of nanomachines”? Is the human mind a brain? And what then is the brain? An information processing machine, a “computer” that can be made compatible through nanotechnological brain-machine interfaces with other computers outside? What are the normative implications of such descriptions, which are used mainly (but not only) in popular science? What are the normative implications of technological projects that introduce machines into bodies? Has something changed in our understanding of embodiment? And how is our understanding of embodiment ethically relevant?

It seems necessary to undertake empirical research in order to challenge assumptions, and uncover new responsibilities, dependencies, and areas of concern. As mentioned above, this might mean revealing new ethical issues, but it differs in that it is bottom-up or data-driven, rather than attempting to devise and impose "new" ethical theory or deal with "new" technology. Once a new facet is identified, it often becomes apparent that it was present in earlier technologies, but that the new technology presents it in more salient ways. For example, there are emerging issues concerning embodiment. Our understanding of corporeality is ethically relevant because (1) changes in embodiment alter how we consider ourselves and others to be vulnerable, and in what ways; (2) we experience our selves as embodied selves in the world. Therefore, altering the nature of that experience (for example through the introduction of nanomachines into the body) might have implications for our understanding of selves as human. But the issues of extending the capabilities of the body by introducing or adding technical devices are in no way new.

7 Conclusions

What ethics should do in relation to NST – how and in which role it should approach NST – is still unclear. It is not enough simply to call for an "ethics" of NST (nanoethics), because ethics can mean and do multiple, very different things. In our paper we have examined a series of different frames that are currently used to discuss and assess nanoscience and nanotechnologies from an ethical perspective. Note that we did not invent any of these different frames, but identified them by analysing the existing literature on the ethics of NST in a systematic way.

The ethics of nanoethics, which we have attempted here, is not simply qualitative empirical work on literature samples, using the methods of discourse and content analysis. It includes a comparative *ethical* evaluation of ethics frames, which need to be put into practical contexts, and to be treated themselves as practices. Ethics can be considered not just as a doctrine or theoretical discussion, but as a communicative practice: as a kind of practical intervention in itself. Ethics does things with words. And because each deed leaves another deed undone, it involves the selective allocation of intellectual energies and of public attention. Therefore, in order to make best use of these limited immaterial and material resources, we cannot but conclude that the ethics of nanoethics is a field that needs adequate funding. Not to do so would be like practising medicine without investigating the evidence of the efficacy or side effects of the approaches used. The choice of the intervention proposed by nanoethics, like those proposed by medicine, should be evidence-based.

We have seen that the *acceptability frame* puts ethics (sometimes even ethics professionals) into the uncomfortable role of a moral judge, saying either Yes (ethically acceptable) or No (immoral) to a new set of technology development trajectories, long before it is clear what their development will involve. This is, as we have seen, highly problematic. *Desirability* has been proposed as a criterion that is better applicable in a situation so far upstream from the development. But the underdetermination of technological development by plans and visions, and the relativity of the question to social power distributions, makes it just as problematic. The *novel ethics frame* is unreliable because the social relevance of a problem does not depend on its novelty. We then examined the potential of two more promising approaches. The *governance approach* focuses on the selection and prioritization of the most urgent problems in our globalized society that may be solved through new nanotechnologies, and introduces steering mechanisms and incentives for research funding. Finally, the *sociotechnical systems approach* fundamentally criticizes technological determinism and adopts a practical perspective on technology itself. The ethical questions arise in the context of a discussion about which kind of world should be constituted through technological practises.

We are rarely at a loss for questions. Some of them are bound to certain perceptual frameworks, that we have tried to differentiate in this paper. However, the recommendation cannot be to exclude questions because they are connected to a frame we reject for one reason or another. Rather, we must learn to discern the relevance of certain types of questions as opposed to others. The governance and sociotechnical systems perspectives seem better suited to this because of their more realistic and comprehensive background assumptions.

Instead of plunging into the moral discussion with ready-made sets of questions that we happen to have at hand, the task of an ethics of emerging NST is to think carefully about which questions to ask, about which have priority, and about which need to be posed but are *not* contained within the existing question sets.

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Part V
Deconstructing the Assessment Regime

The fifth part brings together papers that critically review the assessment regime by investigating it conceptually or theoretically – in each case, however, with an empirical eye toward the assessment phenomenon.

Alfred Nordmann and Astrid Schwarz pose a simple yet critical question: Why is it that nanotechnology could count on the unanimous engagement of nearly all actors with stakes, even dissenting ones, in its research and development? In their contribution, Nordmann and Schwarz propose a theoretical framework that complements existing approaches of power in current regimes of knowledge production, insofar as it adds the notion of *seduction*. Seduction begins to operate as soon as there is an unbounded space of options. Instead of reducing options, seduction makes them invisible by maintaining concepts that, in the absence of seduction, could be contested, such as sustainability. In the presence of seduction, however, such notions invite everybody to contribute to a "sustainable", "European", or "responsible" development of nanotechnology. As Nordmann and Schwarz argue, this power helps to explain why, from a game with limitless possibilities, ineluctable necessities may finally emerge: Seduction invests empty concepts with the power to hold our conflicts and differences at bay.

In his chapter, *Matthew Kearnes* observes a significant shift in the scientific governance, particularly concerning nanotechnology. By way of a "deliberative turn" as well as a "governance turn" the drive toward transparency and objectivity has not only accelerated, but also gained a literally new quality, namely a focus on *qualitative* methods. In contrast to Power's observation on a predominance of *quantitative* audit and accountability techniques, a range of new *qualitative* procedures such as public dialogue, engagement, deliberation and innovations in soft-regulatory approaches stands as new mechanisms for "giving account" in complexly governed liberal democracies. Kearnes concludes that this new logic stands for a qualitative turn in contemporary governance – a reversal of previous commitments to calculation, quantification, and enumeration.

In the final contribution, *Sabine Maasen* turns to the reflexivity deployed in ELSI and similar discourses. She takes the immense expansion and intensification of public reflexivity as indicative of a decisive shift in current knowledge base. With regard to its substance, she observes a move from big concepts (liberty, capitalism, revolution) to practicable, marketable, usable ideas. As to the rationale, novel forms of intellectuality do lesser focus on scientific expertise, but rather on creative and innovative networks of ideas that allow the participation of various actors. With regard to the stylization of this intellectuality, she describes a shift towards exchanging ideas and creating something new among different groups. Maasen correlates the changing conditions of this public reflexivity with a society that has (allegedly) lost trust in its science and therefore takes measures to increase transparency and control. In this sense, the intellectuality as embodied within an assessment regime responds to the demands of what Michael Power has called an "audit society".

Lure of the "Yes": The Seductive Power of Technoscience

Alfred Nordmann and Astrid Schwarz

What are the forces that determine the development, diffusion and appropriation of emerging technologies? This question becomes particularly pressing and particularly difficult to answer with respect to the current status of nanotechnology. This technoscientific enterprise is marked on the one hand by nearly unanimous endorsement and on the other hand by an apparent absence of power. The following reflections serve to address this challenge by suggesting a suitable theoretical framework that is needed at least to complement extant accounts of power implicit in current regimes of knowledge production. The proposed framework posits a seductively structured space of options. This space is unbounded, and demands no determinations, decisions, claims, or contestations. It is maintained by the pleasure of saying "yes" in the course of empty talk. Even as we are drawing on a number of characteristic examples, we are not using empirical methods to corroborate our assessment of the current status of nanotechnology. Our theoretical considerations require no more than the recognition that the question of power needs to be related to the pleasures of engagement with nanotechnology.

1 The Phenomenon: Seduced by Nanotechnology

In November 2006, the Canadian *Commission de l'éthique de la science et de la technologie (CEST)* issued one of countless position statements on *Ethics and Nanotechnologies*. In most respects it is like all such reports: It provides an overview of nanotechnologies and draws attention to various areas of concern. If there is something unusual about this document, it is by way of a subtle difference of tone, namely in the way in which "the Commission" represents itself.Normally, the collective author of such position papers or reports is an anonymous voice that stands invisibly behind its careful assessments and considered opinions. Explicitly or implicitly, the argument often proceeds from a "whereas" to "recommendations" that are supposed to be implied by a conjunction of background values and

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the established facts. In contrast, the CEST-Commission appears as a personalized subject as it recapitulates its struggles for the reader. It tells the story of a group of people (the members of the Commission) who have been told all kinds of things and who must now make sense of it in order to make recommendations to the ministries of Quebec. A typical paragraph reads as follows:

> *Occupational safety*. Two observations caught the attention of the Commission. The first of these is that it is worrisome how little research has been undertaken until now on the possible consequences of nanomaterials on human health and safety. One of the obstacles noted by the IRSST and which may in part explain the lack of knowledge in industrial hygiene is that "tools normally used in industrial hygiene to evaluate the exposure of workers are ill-suited to the applications of nanoparticles in an occupational setting," whereas "the little data available suggests that exposure during the manipulation of powders may be considerable." The second observation is that specialists do not agree on the relevance of existing regulations. While waiting for further research and more complete regulations that are better adapted to the specific characteristics of nanotechnologies, the Commission considers that the principle of precaution should guide actions to be undertaken in order to protect occupational health and safety (Commission 2006: v).

Again, there is nothing unusual about these observations and the recommendation of a precautionary approach,[1] but the Commission's telling of the story expresses that these observations and recommendations arose simultaneously from a sense of frustration and a sense of possibility: In the face of stark warnings, the Commission is bewildered by a lack of research and disagreement among the specialists; yet it calmly awaits the required information that is surely to come, recommending to proceed with caution in the meantime. And thus the Commission on ethics adopts a rather weak notion of ethics. There is no laying down the law, no specification of limits or thresholds, there are no obligations or prohibitions. Instead, caught between frustration and possibility, the Commission issues a vague injunction to search the right way out of the predicament and to pursue what is generally known as the responsible development of nanotechnology.

If the previous passage expressed the Commission's predicament in terms of the difficulty to make sense of conflicting bits of information, there is also a more open expression of bewilderment and conflictedness:

> A first observation to be made about nanotechnologies is that there is a flagrant lack of information about what they are. If there is no common understanding of what nanotechnologies are how can informed decisions be taken by legislators, researchers, business people, workers or citizens? [. . .] It is with great curiosity and interest that the Commission initiated its deliberation on the ethical issues raised by the development of nanotechnologies. On the one hand, because the subject is still little known; on the other, because the possibilities opened up by the development and use of matter on the nanometric scale currently seem virtually unlimited. It is moreover easy to marvel at, and be carried away by, the euphoria and enthusiasm shared by many people involved in nanotechnology. (Commission 2006: v, xii)

[1] Note that this appeal to precaution is strangely toothless. This precautionary attitude consists in waiting-with-vigilance for a state of knowledge that may never be forthcoming. Precaution could also be invoked to justify the prohibition of certain actions at least until the time when the desired state of knowledge is reached.

Admittedly, then, the Commission finds it hard to resist the seductive voices of euphoria and enthusiasm even without quite knowing what nanotechnologies are. Of course, it tempers this euphoria by demonstrating proper restraint – by paving the way for the responsible development of something that is yet to take on definite shape and meaning. As it outlines how to do the development of nanotechnologies right, the Commission assumes that there is a right way.

And indeed, this is how euphoria and enthusiasm rather than doom and gloom prove irresistible: It is all about getting things right and thus there is nowhere in the document a clear sense of what could go wrong or how the development of nanotechnology might fail.[2] Not quite knowing what nanotechnologies are (which is the source of frustration) actually reinforces rather than contradicts the Committee's impression that these might open up "virtually unlimited" possibilities. The story of the so-called GMO-disaster behind us, a world of unlimited possibility before us, who could reject the invitation to participate in the pursuit of responsible development – especially since the very invitation and its acceptance affirm that we are on a responsible path, indeed?

Like most other reports and recommendations on ethical and societal aspects of nanotechnologies, the Commission's position paper raises a broad range of concerns, recommends mostly procedural actions, raises issues of sustainability and global equity alongside protection of consumer health, calls for public engagement and dialogue. It finally urges (like all such reports) further study of the ethical and societal aspects of nanotechnologies. Closely in line with other reports and recommendations, the Commission's position paper avoids even the possibility of the normative "no" of ethics and the law but joins the concert of "yes"-sayers – yes to responsibility, yes to the invitation to determine what nanotechnology can be, yes to shaping transitions from imagined possibility to real societal benefits, yes to the participation with other stakeholders, academics, artists in the global project of doing nanotechnology right, and thus: yes to the nanotechnologies of which one does not know what they are, whether available regulations can be applied to them, what they can and can't do. By saying yes, the members of the Commission and other committees accept an offer that is nearly impossible to refuse, for, who could be against the responsible development of nanotechnology? And that such a responsible development is possible is paradoxically confirmed by the very fact of our ignorance about it – "nanotechnology" is undetermined as of yet and thus still capable of taking on all kinds of positive determinations.

To be sure, throughout the history of the modern world, advisory boards have been saying "yes" to technological development. They did so by joining the master narrative of progress, economic innovation, human betterment, intellectual enlightenment. There is nothing paradoxical about this and one can also find

[2]Compare the three scenarios of nanotechnological development that were suggested and developed by the Wuppertal Institute: They show two ways in which the development could go wrong and one way to do it right. Here, the responsible way of developing of nanotechnology coincides with and is measured by the eventual success of nanotechnology. And the responsible way consists in everyone taking responsibility – not in terms of being accountable but by caring for the success of nanotechnology (Türk et al. 2006).

throughout this history other social actors who refused and resisted this narrative. The current coalition of "yes"-sayers is constituted differently, in line with the peculiar constitution of "nanotechnology" itself. It is not at all a coalition of technophiles but includes those who are disaffected by economic imperatives, global and social inequities, the exploitation of human and natural resources. These skeptics share with promoters of nanotechnology the conviction that the nano-world is upon us already – not only in material reality or concrete blue-prints, but in the form of vague promises and expectations and by way of the large-scale project that many societies are embarking upon. As such, the nano-world cannot be questioned or refused anymore. It is on this supposition that philosophers and social scientists but also various publics and policy makers are invited to talk and think about it.

The generality of this claim might be questioned especially since it appears to be founded on a few sample reports. Surely, there are some who can, might, or will refuse to join in. However, by virtue of the way in which the nanotechnology-discourse is structured, no inductive argument and cumulative listing of "yes"-sayers is required here but it suffices to argue from the almost total absence of "no"-sayers. Indeed, it is for two reasons far more difficult to say "no" rather than "yes" to the responsible development of nanotechnology. First, in order to say "yes", it is enough to see some promise in some version of nanotechnology, and in order to say "no" one has to reject the very possibility that there can be a responsible development of nanotechnology. Second, to reject the very possibility of responsible development would be easier if one were dealing with a reasonably well-defined technological development such as nuclear power and inherent problems regarding safety or dual use for military as well as civilian purposes. Thus, in order to say "no" to nanotechnology one has to first construe it in a very specific way in order to then deny that any pursuit of such a technological project is in some sense irresponsible. It bears close scrutiny, therefore, to see how the few who have tried to distance themselves from the entire project need to balance their construal against the danger of making themselves irrelevant by construing "nanotechnology" in such a way that it is not recognizable by the "yes"-sayers (compare Dupuy 2007, Joy 2000, or the ETC-Group 2003).

Thus, before ethical and political deliberation of nanotechnology can even begin, it has for the most part stopped already. But once we enter the nano-world willingly and with good cheer, we are most welcome to help decorate and improve it (compare Nordmann 2007a). If only by way of curiosity, euphoria, and enthusiasm, even Ethics Commissions find themselves entangled in this world. The Commission from Quebec, for example, surrenders to the lure of the "yes" and is at the same time upset about the flagrant lack of information.[3] This raises suspicion, of course.

[3]This is also how these reports are read. The most radical (also by no means unusual) recommendation of the CEST-Commission is taken by authors and readers alike to be quite innocuous and common-place: "health and environmental monitoring agencies [are to] establish the mechanisms needed to assess the toxicity of processes and products derived from nanotechnologies prior to authorizing their commercialization" (Commission 2006: vi). In light of what is known about medium-term or in-principle obstacles to the establishment of such mechanisms (Maynard

When just about everyone says yes to something, when skeptics and promoters join forces in a common social project of constructive engagement, one would suspect that what draws them together is a kind of *zwangloser Zwang* or non-coercive coercion. No one is exerting force or telling them what to do, and yet this unification of heterogeneous actors seems to require a depersonalized force that holds them together and silences dissent. This raises, in other words, the question of power: If the Commission surrenders to the lure of the "yes", what kind of surrender is this, and what is the seductive power that draws it?

The following pages are dedicated to the identification of this power. They seek to highlight the need for a theory of technoscientific power, developing for now only its political dimension: How are options regarding the acceptance and rejection, modification and critique of nanotechnology structured, and how is conformity to this structure maintained? This sketch will have to be articulated more fully and expanded to include the economyof limits and excess on the one hand, the underlying hopes and fears and the methaphysical conception of humans, technology, and nature on the other.[4] Taken together, these various pieces of the puzzle may one day yield a comprehensive account of the eros of technoscience.

2 Definitions of Nanotechnology: Plenty of Room for Social Shaping

Any attempt to study the power of contemporary technoscience and of nanotechnology, in particular, runs up against the problem that they suggest a field so wide, so open to social shaping and future determination that it appears impossible to find a place for power. Since Hegel, Marx, Freud, or Foucault it is well known, of course, that power need not emanate from a specific person, ruling class, apparatus, location or source, that it can be everywhere diffused throughout a social world. Power in this sense is much broader than just a matter of the political sphere. Its differentiation allows for outlining the political itself and thus includes it. So conceived, social power links up with the forces of nature that are everywhere present but become apparent only in specific constellations. According to Thomas Reid, "power is not an object of our external senses, nor even an object of consciousness ... Indeed every operation of the mind is the exertion of some power of the mind; but we are conscious of the operation only, the power lies behind the scene" (Reid 1788: 6 f., compare Röttgers 1990: 491). But in the case of the technosciences, what is that power behind the scene and above all, how should the scene be described?

Numerous stories are being told about the social dynamics that are said to account for nanotechnology's rise to prominence. Many of these draw on folk conceptions

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et al. 2006), this recommendation is tantamount to a moratorium on the commercialization of nanotechnology – but it is taken by all parties merely as a call to "proceed with caution".

[4]So far, Astrid Schwarz has begun articulating the "economic" dimensions (Schwarz 2009, Schwarz and Nordmann forthcoming).

of corporate interests, technological determinism, global competition, or a general idea of progress and its attendant faith in the technological fix (Rip 2006). All such accounts go some way, but none is adequate to capture the power of the so-called "enabling," "emerging," "general purpose" or "key" technologies, of "application-oriented fundamental science" or "basic gizmology" (Jones 2005).

What the "enabling and emerging technologies" have in common is the broadness and vaguenss of their promise. According to a EU-report on regimes of innovation in the current knowledge society, the regime of economics of techno-scientific promises "draws on an uncertain future, and derives its force from the uncertainties. Upstream solutions are thus promised for downstream problems, without having to take the details and socio-political dynamics of the downstream problems into account" (Felt et al. 2007: 22).[5] Accordingly, nanotechnology has the promise to differentiate into specific nanotechnologies where each might stimulate the economy or provide a technical solution to a societal problem. Simultaneously, it is also understood that nanotechnology might just do no such thing or do it in an entirely unpredictable, unintended way such that it may just end up yielding more harm than good. Indeed, whether nanotechnology will prove to be economically, societally, environmentally beneficial is precisely what needs to be secured and determined by developing it responsibly. The very definition of "nanotechnology" leaves its future development so radically undetermined that it supports linkages to innovation imperatives, globalization, growth curves, miniaturization trends, the rhetoric of sustainability or metaphysical programs. As we will show in more detail below, the power of nanotechnology therefore does not reside in what it can or will do, but in this very indeterminacy and emptiness.

How, then, is "nanotechnology" defined, and how does this definition suggest a field so wide, so open to social shaping and future determination that it appears impossible to find a place even for a power that is everywhere diffused? Sometimes, nanotechnology is defined in distinction to nanoscience and sometimes it is defined as a hybrid of science and technology (nanotechnoscience). Either way, most definitions refer to interesting, scale-dependently discontinuous properties of matter at the nanoscale and go on to suggest that nanotechnology is *whatever* one might usefully do with these properties as they become functionalized in a technical system

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[5]The report goes on to identify a problem associated with this regime of the economics of techno-scientific promise (ETP): "The ambivalent role of policy makers, promoting the specific interests around the technoscientific promises and taking the public interest into account, is unavoidable under the regime of ETP. This can become problematic when concerns are raised about the new developments: space for public deliberation quickly becomes reduced to polarised interactions for or against the technoscientific promise" (Felt et al. 2007: 23). In contrast, we are showing that technoscientific promise has allowed for the construction of a space for public deliberation that excludes polarised interactions "for or against" but – beyond "interests" – unites those who have no choice but to be "for" the technoscientific promise. This is not to say, of course, that these polarisations have not occurred in respect to biotechnologies and might not come about even in regard to nanotechnology.

or device (e.g. Royal Society 2004).[6] On three levels at once this unbounded "whatever" invokes an immersive image of open space that is opposed to a power-structure that separates an inside and outside. These definitions thereby delocate, even deny any presence of power.

2.1 Unbounded Nanocosm

What is open and unbounded is firstly the "nanocosm" itself. This space is waiting to be colonized and in US-American parlance it represents a (once again: last) frontier that is, by definition, pushed outwards further and further: "small wonders, endless frontiers" (US National Research Council 2002).[7] Taking up Feynman's invitation to "enter a new field" with "plenty of room" (Schwarz 2004), nanotechnology moved beyond crystallographic images of dense lattice structures to images of surface landscapes that extend indefinitely and await to be settled (Nordmann 2004).[8] Verbal reports about an uncontrollable quantum-physical world to the contrary, its visual appearance is that of an inviting space that offers little resistance to nanotechnological conquest (Schwarz 2009).

2.2 An Open Future

To this image of physical space corresponds an image of our nanotechnological future. This future is not pictured, narrated, or conceived as a period in (historical) time or in terms of what and who we will become. The future of nanotechnology has no purpose or determinacy and demands nothing from us. Instead, it appears as a space of unlimited possibility for new forms of engineering and different ways of being.[9] The visions of Eric Drexler and Ray Kurzweil, the transhumanist dreams of enhanced humans, the foresight scenarios and science fiction elements in research proposals all conjure a different, perhaps utopian world that is quite disconnected from the present. Indeed, the appeal to another scientific and industrial revolution or

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[6]It may be possible to provide a delimiting definition of nanotechnology, one that refers only to the capabilities that have been disclosed by available instrumental procedures (compare Nordmann2008). It is significant for the context at hand that there appears to be no scientific or policy interest in developing such a delimiting definition of a finite set of practices or intended applications.

[7]The story of the American frontier might be told as follows: It was "closed" only when the continent had been settled and the westward expansion concluded, e.g. when the colonists ran out of the openness suggested by the very existence of the frontier. Since the Western frontier-experience has served as a resource for the formation of a shared identity, Americans have been seeking out new frontiers ever since. After Vannevar's Bush "endless frontier" oriented American science to ever-new-challenges such as space-exploration, nanotechnology is challenged only by limits of imagination (Jeanne Cortiel: in conversation).

[8]To be sure, Feynman was "read into nanotechnology" and his role of founding father is a retroactive construction (Toumey 2008).

[9]The most trenchant critique of the future imagined as a mere space of possibility has been provided by Jean-Pierre Dupuy (2002).

to a "singularity" underscores that this future does not somehow "grow out" of the present but that it is a strange and exotic space (a technological paradise?) that beckons us to enter it and inhabit it in ways that are unconstrained by the present.[10] The first to take up this invitation were Don Eigler and Erhard Schweizer who were soon followed by many others with symbolic demonstrations that, indeed, we can enter this world and do as we please: They wrote the name of their laboratory or of their employer in molecular fashion and thus constructed a proof of concept for "shaping the world atom by atom." Any actual further development of nanotechnology is referred to the space of possibility that was opened up by arbitrarily inscribing our names and thus ourselves into the all-pervasive realm of molecules that constitutes just about everything (Nordmann 2006).

2.3 The Agora

To these two images of physical space and of the future conceived as space of unbounded possibility corresponds finally the third – that of nanotechnology's openness to social shaping. It is a "key technology", after all, and as such pretends to say nothing about the doors and their locks that need to be opened or closed with the help of the keys. Show us a lock, show us a problem that needs to be solved, nanotechnology promises, and we can make the key or create a solution. In order to identify relevant problems and matching solutions researchers, policy makers, industrial stakeholders, citizen representatives, social and human scientists can come together on common so-called technology platforms.[11] In the conception of "mode 2" research, such platforms are conceived as a space quite literally, namely as the Agora and thus the market-place of ideas that lies just outside the gates of parliament in ancient Greek democracy (Gibbons et al. 1994). This space is characterized by the absence of determinate power. It is the unbounded space of discursive

[10]According to Martin Rudwick, pre-Darwinian representations of other geological epochs did not place them in historical continuity with present-day flora and fauna. Instead, they looked like pictures of another world, not unlike the pictures brought back by sea-faring naturalists. The "past" thus looked like some place in the South Sea (Rudwick 1985). The "future" of nanotechnology refers to a similarly disjointed simultaneous reality – the idea of exotic otherness steps in when our imagination of a historical future fails us. Against this failure, Jean-Pierre Dupuy (and Hans Jonas) propose a heuristics of fear that would help us conceive our historical future (Dupuy 2002, Jonas 1984). Such a heuristics of fear may have been effective in stopping the nuclear arms race between the US and USSR. It is currently doing work in regard to global warming. There is no analogue for nanotechnologies (and good reasons, perhaps, why there couldn't be a heuristic of fear with respect to "enabling and emerging technologies"): Indeed, stories of "grey goo" and other scenarios of nanotechnology-gone-wrong serve to flatter nanotechnology in that they reinforce notions of its unlimited potential. They do not serve as a vantage point from which to critique nanotechnological developments as such.

[11]Technology platforms are an instrument of EU science policy. They are akin to various similar initiatives that bring stakeholders together for areas such as nanomedicine, nanoelectronics, etc.

possibility that complements those of technical and historical possibility.[12] For the time being, the exercise of a freely constituted political will appears constrained, if at all, only by the laws of physics: Technically, historically, socially, everything is thought to be possible except that which is physically impossible. The arbitrariness of the name that is inscribed at the nanoscale anticipates the vision of perfect atom-by-atom shaping of a new and improved world. Similarly, the global abundance of technical possibilities foreshadows the global abundance of processes and products that will be forthcoming from nanotechnology. And similarly yet again, the plasticity and infinite malleability of nanotechnological programs and visions is proof of concept for social shaping and for our ability to responsibly steer the development of nanotechnological development. Wherever one looks in nanospace, there appears to be just openness and an absence of a structure that might exclude certain options, that separates winners from losers, insiders from outsiders, that could foreclose a possible future, that constrains our will to shape the world according to our designs.

"Nanotechnology" is a kind of pure technoscience precisely because it presents a vacuous and merely formal coincidence of the three images of emptiness and unbounded space. It has been criticized especially for its affirmation of a simple faith in the social shaping of technological development. These critiques tend to highlight that the indeterminate conception of a merely enabling key technology contains within itself another void in that it obscures power. Aant Elzinga made this point in regard not only to nanotechnology but the discursive regime claimed not only for it but the technosciences more generally:

> [T]he rhetoric of much of the "new production [of knowledge]"-talk may thus be interpreted as part of the self-effacing culture of globalization that hides inequities and aggressive deeds by nice-sounding words like freedom, deregulation or reconfiguration. [. . .] Neo-liberal ideologues with their free market and deregulation talk suggest we are witnessing a withdrawal of the state, whereas in practice with the WTO and EU-policies we are actually experiencing stronger socioeconomic intertwining that go beyond the state/market divide. In the EU the state is actually an active player in S&T policies. What is needed therefore are efforts to demystify the current neo-liberal and deregulation talk rather than turning research policy doctrines into its tacit echo. (Elzinga 2004: 16–17)

Elzinga calls here especially for a critique of globalization as the backdrop for nanotechnological development. The ground for such a critique has been laid by the description we offered above of the nanotechnological colonization of a seemingly unbounded physical space that stands ready for conquest. But so far, this analytical description did not involve a political theory or critique of colonialism and globalization, and did not provide even a first attempt at articulating a conception of power.

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[12]This is not the place to explore the connections between these various spaces of possibility. One such connection is the discursive identification of physical possibility (all that is not contradicted by known laws of nature) and technical possibility (all that can be humanly engineered). Another connection was suggested to us by Ann Johnson, namely a new science and practice of management that construes management as a generic problem-solving exercise. Different kinds of general purpose technologies (management being one of them) may be reinforcing each other in the production of unbounded discursive, technical, and historical space.

3 Political (Non-)Structure: The Power of Seduction

According to Jean Baudrillard, "[s]eduction is stronger than power." It is this strength, of course, that makes seduction particularly powerful:

> [Seduction] is reversible and mortal, while power, like value, seeks to be irreversible, cumulative and immortal. Power partakes of all the illusions of production, and of the real; it wants to be real, and so tends to become its own imaginary, its own superstition (with the help of theories that analyze it, be they to contest it). Seduction, on the other hand, is not of the order of the real – and is never of the order of force [. . .](Baudrillard 1990: 46).

A space of options that is structured seductively would lack an intelligible structure. One would be drawn into this space by way of immersion. No one would need to make an irreversible commitment, because the only way leads into and there is no way out of this space. Seductive entry requires no force, only every one's good will. Such a space would hold everyone in their own freely assumed place, and everyone could recognize themselves without distortion. Seduction would thus appear as a power more powerful than the kind of power that requires force to establish its own realities of hierarchies, of inclusion or exclusion, of submission to a regime. A physical analogue to such a seductive space would be a hall of mirrors. We enter it at our pleasure and move about it in structured, indeed collective ways. The structure remains unobstrusive and unintelligible, however; we are fully immersed in it and encounter no outside that would provide a vantage point of criticism. Tellingly, the mirrors themselves are perfectly vacuous and offer everyone an opportunity to recognize everywhere only themselves.

For an adequate account of the power of technoscience, we suggest that we have to move with Baudrillard beyond his juxtaposition of seduction and power,[13] and that we require an account of how a seductive space of options becomes instituted. Baudrillard himself clearly acknowledges that seduction goes beyond traditional conceptions of power in just these ways and that it can thus assume the place of power. We need to see just how this applies to the power of technoscience:

> Seduction [. . .] is never of the order of force nor relations of force. But precisely for this reason, it enmeshes all power's real actions, as well as the entire reality of production, in this unremitting reversibility and dis-accumulation – without which there would be neither power nor accumulation. It is the emptiness behind, or at the very heart of power and production; it is this emptiness that today gives them their last glimmer of reality. Without that which reverses, annuls, and seduces them, they would never have had the authority of reality. [. . .] [Seduction] is a power of attraction and distraction, of absorption and fascination, a power that cause[s] the collapse of not just sex, but the real in general – a power of defiance. [. . .] It implies a radical indetermination that distinguishes it from a drive – drives being indeterminate in relation to their object, but determined as force and origin, while the passion of seduction has neither substance nor origin. It is not from some libidinal investment, some energy of desire that this passion acquires its intensity, but from gaming as pure form and from purely formal bluffing (Baudrillard 1990: 46, 81 f.).

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[13] On Röttgers's interpretation of Baudrillard (and Bataille) power is identified with rationality and disenchantment, reifying the circle of production. In contrast, seduction, challenge, and cunning are three kinds of processes that work against the principle of power (Röttgers 1990: 529).

By pursuing Baudrillard's suggestion that the power of technoscience owes to purely formal bluffing, we do not reject but seek to complement extant STS-accounts of power. If we cannot adopt any of them straightforwardly, this owes to the apparently uncoerced, near-unanimous endorsement of nanotechnology. In the absence of powerful global actors like Monsanto, this endorsement cannot be explained simply in reference to commercial or political interests, to the effects of privatization and changing notions of intellectual property. Indeed, questions of ownership of knowledge can play only a subsidiary role when it is still very much unclear whether nanotechnology is under pressure to produce a certain kind of knowledge and in what sense, moreover, it produces knowledge at all.[14] This pertains also to Foucauldian accounts of knowledge/power and regimes of knowledge-production: As opposed to information technology, genetic engineering, and synthetic biology, nanotechnological research does not articulate a coherent program or body of propositions that structures actions, shapes identities, excludes difference. Finally, Callon, Latour, et al.'s notion that power-effects are associated with obligatory passage points in the development of a research trajectory does not apply to the case of a "general purpose" technology that includes a flexible variety of trajectories.[15] Instead, the threefold openness of nanospace emphatically makes room for a number of alternative trajectories, it always invites further considerations and identifications to attach themselves. Metaphorically speaking, even where diverse actors move at tangents and touch each other only incidentally, they are still nudging the nanotechnological project forward. This holds true for the diverse research communities that are gathering under the "nano"-label, it holds true for governmental and non-governmental organizations that explore potential benefits and risks from various interested positions, it holds true for radical critics of nanotechnology who flatter it by granting it the power to effect great things. Instead of being jointly committed to action at some threshold, passage point, or moment of decision, incidental encounters in the apparent openness of nanospace are sufficient for the emergence of certain necessities to act with regard to nanotechnology, and thus sufficient for the foreclosure of this apparently open space to shape the development of nanotechnology.

Our main thesis is that the seemingly open and undefined nanospace is not filled by determinations, decisions, *faites accomplis*, statements, claims, contestations that seek to appropriate it for some project rather than another and that exclude other claims. Instead this space is filled for the most part by empty but pleasurable talk. Reports from arenas such as ethics, technology assessment and political deliberation, of precaution and science policy pop up like soap-bubbles and fill this space – and taken together, everyone re-enforces everyone else.

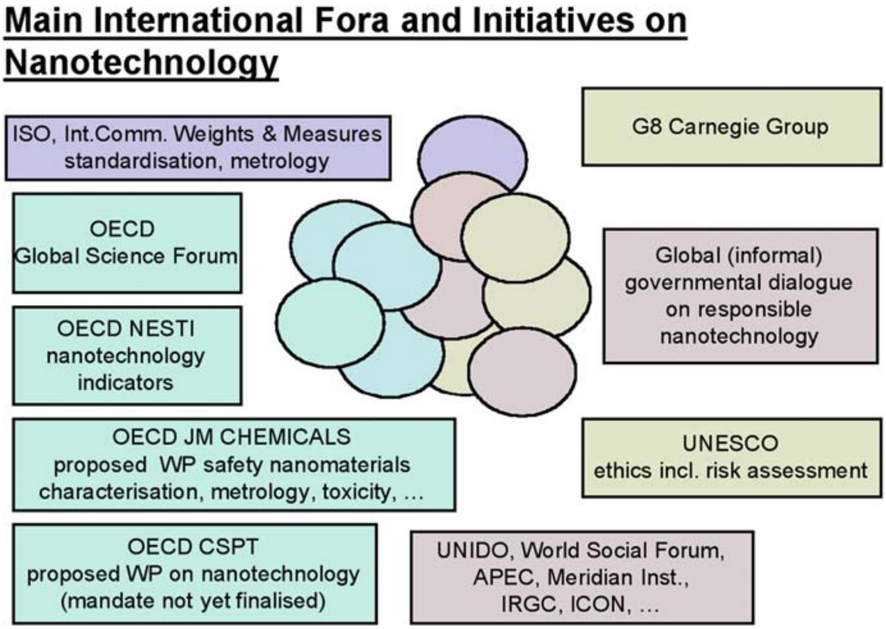
Clearly, our thesis about the bluffing power of technoscience and its empty space filled by meaningless talk carries a significant burden of explication. In particular, it

[14] At its current state of development, nanotechnological research is arguably oriented to the acquisition and demonstration of basic capabilities of visualization, manipulation, intervention (Nordmann 2008).

[15] See especially the volume *Power, Action and Belief,* edited by John Law, where Michel Callon, but also other authors are dealing with the term "obligatory passage point".

needs to be shown how an empty space can become filled with emptiness such that it admits nothing but the perpetual reproduction of a seductive space of options that no one has chosen but that everyone is maintaining pleasurably. Without being closed off, the indeterminate wide openness of nanotechnology is so full of discourse and activity that its fullness powerfully excludes fundamental critiques and achieves the absence of alternatives.

The following chart offers a point of entry. It comes from Renzo Tomellini, one of the chief architects and promoters of the European Nanotechnology Initiative.[16] It celebrates the diversity of international discourses that consider environmental and societal dimensions of nanotechnology. Each of them is a forum and, as such, characterized by openness to a great variety of interests and opinions. Each of them produces reports and opinions that do not go much further than that of the Canadian Commission: They tend to ask for research on risks, for better characterization of substances, for more public engagement and increased vigilance by organizations like themselves – in other words, they don't say much. In doing so, they aggregate and reinforce each other, filling the slide with their demonstrations of responsibility. Others are welcome to join in (indeed, the slide is a work-in-progress that is updated regularly) – and thus the slide signals openness and at the same time communicates



[16]See, for example: www.nanotec.it/GovernareNano/slides/RTomellini.pdf (01-01-08) or, www.feast.org/conference2006/documents/6.5_Tomelllini.ppt (01-01-08). (We would like to thank Arie Rip for drawing our attention to this.)

that the deliberative space is becoming ever more densely settled by those who have joined in the responsible development of nanotechnology and are here to stay.
This graph empowers nanotechnology and authorizes it as a central concern of the European Commission. While these bubbles nicely display the openness of space for meaningless talk, they raise the question how meaninglessness and openness can exert power at all.

Another example may take us a step further. It reflects the confluence of research programs, visions, and hype in nanotechnological development.[17] In his case study of one of the more successful European nano-enterprises, the iNANO-Center in Aarhus, Arne Hessenbruch points out how the language of its director Flemming Besenbacher is nurtured by the pleasure of constructing or making possible futures: "Barthes' jouissance may well resemble the feeling of exhilaration prompted by nanohype" (Hessenbruch 2005: 47). It is precisely in the construction of incredible, unfathomable, and yet in a vague sense possible futures that the openness of nanotechnology and the meaninglessness of discourse become a source of power.

Power depends, after all, on visions or fictions of potential action that underwrite the possibilities of action. These fictions of power are not only necessary, they are also effective in that imagined power becomes real power: "There is probably nothing more important in the ability to dispose of future actions than the ability to dispose of the visions about the ability to dispose of such future actions" (Röttgers 1990: 494). Where these visions or fictions of power come cheaply as in a discourse of unlimited technical potential, power does not need to be exerted but fades away or withdraws into the performance of representions: This power is effective by symbolically anticipating a generality, by performing in the medium of signs what nanotechnology may one day be able to effect in the world. It is immune to the critical gesture of unmasking its fictionality of power if only because this gesture is no less empty than its target.[18]

The case of mutually reinforcing empty talk (our study of the societal impacts of nanotechnology shows that we will need more study of societal impacts) and the case of hype (as rehearsal of the ways in which nanotechnology will powerfully transform the world) point in the same direction[19]: Powerful necessities emerge from the fact that concepts like "nanotechnology", "convergence", "responsibility", "sustainability", mean what everyone intends. This statement can be read in at least two different ways: On a first interpretation such concepts have contested

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[17] Numerous authors have shown how hype and funded research are not only equally important, reinforcing each other, but indivisibly entangled in nanodiscourse.

[18] An intermediary example was developed in Nordmann 2006: Spelling "IBM" with individual atoms and other forms of "molecular writing" is a rehearsal of nanotechnology's promise to realize completely arbitrary human designs. The manipulation of atoms on a two-dimensional plane for the creation of symbols, symbolizes in an anticipatory fashion the real unlimited effectiveness of an envisioned nanotechnology.

[19] The recruitment of ethics in the establishment of nanotechnology could provide a third case to the extent that anticipatory ethics treats a merely hypothetical future as something that may as well be real. Only by assigning to ethics the power of adjudicating what an all-powerful nanotechnology might do, "nanotechnology" becomes empowered as that which will effect the good and bad in our future.

meanings as they are appropriated into completely heterogeneous contexts.[20] This corresponds to a process of identification by which identities are constituted and maintained by selectively identifying with specific contents (Kearnes and Wynne 2007: 140). These identifications or appropriations foster the illusions of the various actors that they can accumulate them towards a position of power.[21] On first sight, one might say just this about the concept of sustainability since it is employed by conservation agencies and the chemical or pharmaceutical industry as well as by policy makers and consumer organizations. On the second interpretation, however, the promiscuity of meanings comes from the common use of the word where the commonality of use posits a homogeneous field which then becomes reified: The concepts promise that they can accommodate the intentions that are attached to them by various actors – their lack of specificity is compensated by a fullness of sociability. In the words of Baudrillard, this lack of specificity is "the emptiness behind, or at the very heart of power" (Baudrillard 1990: 46). It supports a process of identification that allows us to identify with nothing in particular but with mere possibilities of realization.[22] This latter interpretation fits the case of "sustainability" as well as that of "nanotechnology". Despite a critical awareness of the plethora of meanings and definitions that are covered by "sustainability" the word has not lost its accommodating magic: the really seductive charm of the term is that it promises from the start that it reconciles without contradiction ecological and economic notions of sustainability. Similarly, the reification of an open and indeterminate concept renders "nanotechnology" resistant against differentiation. Emptiness is thus at the very heart of a power that creates this homogenous field not by willful production but by seduction.[23]

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[20] This reading corresponds roughly to the notion of "plastic words" as characterized by Uwe Pörksen. Those plastic words commute between scientific and everyday language and thereby become "constructive elements of models that are followed by reality. They are like templates that magically generate models of reality; and the step from a word towards reality seems to become very small" (Pörksen 1988: 67, translated by the authors).

[21] This is where Baudrillard speaks of power as being "cumulative and immortal" and partaking of "all the illusions of production" (see above).

[22] Some of the present remarks are inspired by Yannis Stavrakakis (2005). His analysis is based on Lacan but fails to see the difference between an identification with something (which can serve to produce ethnic or national or otherwise parochial identities) and an identification with emptiness (which can serve to produce an unbounded solidarity among those who are no longer separated by subscribing to different frameworks of interpretation).

[23] As mentioned above, Hegel, Marx, critical theorists, or Foucault do not suppose that power needs to localized in particular offices, social classes, persons or institutions. In a sense, each offers an account of how power can arise in a vacuum and like a fine ether it can be everywhere diffused. Here, the notion of emptiness as a source of power has a different and rather more specific meaning: Power is a desire for fullness (and the production of a corresponding reality) that starts from the emptiness of merely symbolic interaction. In regard to reality, this desire is everywhere frustrated ("this is not it"!) and is thus a constant hunger. What better way to feed this hunger but by the promise of an unlimited potential – a promise that creates a fullness of participation and solidarity among all those who jointly engage in the empty play of symbols. (For this Lacanian account see Stavrakakis 2005: 73.)

When Mario Perniola speaks of a "logic of seduction" he refers primarily to this contrast between willful contestation or the affirmation of subjective interests on the one hand, and on the other hand a sense of necessity or irresistibility that arises from the occasion. We have stressed the "spatial logic" of seduction, that is, the way in which actors are drawn into a space in which there is only the single option of saying "yes" to the responsible development of nanotechnology. Perniola focuses on the appearance of necessity and its logical force. By doing what they have to do under the circumstances, the seducer and seduced follow merely the dictates of reason. By the same token, this obedience to the situation produces powerful constraints on action.[24] Again, the discourse of sustainability serves as a good example: Since the term promises to accommodate without contradiction ecological and economic conceptions, it commits environmentalists and economists to move beyond their antagonism and to seek out "win-win situations". Without an explicit decision or deliberative process, they preserve the alliance they have entered by appealing to the same concept, and thus preserve the concept's promise that resides in its emptiness. With this emergence of necessity comes a non-coercive coercion to maintain the project they have joined and that has joined them. This holds equally for the various parties who find themselves together engaged in the "responsible development of nanotechnology" – the notion of "responsibility" is non-divisible and undermines antagonisms: If someone manages to mean something by that term, this becomes unimpeachable, and it is therefore not an option to say "what you mean by 'responsible' is not what I mean by 'responsible'".[25]

As noted above, the emptiness at the heart of this joint production of necessity corresponds to a lack of subjectivity and identity on the side of those who enter into the game of seduction. The fullness of identification arises only from the fact that everyone is joining the game. As Perniola points out, the key to persuasion is not held by the one who talks and tries to persuade but by the ones who listen and coordinate what one can say to what is being said.[26] And thus one finds that in the space of unbounded possibility there is surprisingly little room to maneuver (*Spielraum*) and that sustainable development or the responsible development of nanotechnology simply *must be* and therefore *must be possible* as the result of everyone joining together in a game of mutual seduction.

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[24]"La séduction est ainsi union entre raison (gnome) et force (rome), de façon à prendre des décisions avec celle-là et à obtenir un résultat pratique avec celle-ci'" (Perniola 1980: 4).

[25]When it is argued, for example, that it might be irresponsible to forego the potential benefits of nanotechnology and that it is therefore responsible to develop nanotechnology even in the face of uncertainties and risks, proponents of a precautionary approach do not dismiss this argument and do not expose it as a sleight of hand. The situation demands that one must do justice, without contradiction, to both meanings of "responsibility". The joint commitment of all parties to "responsible development" produces that commitment.

[26]"Donc, il existe une *logique de la séduction*, qui s'impose autant à l'être séduit que à la séducteur, qui a une dimension totalement indépendente et opposée à leur volonté subjective, qui est en rapport avec le *kairos*, avec l'occasion. En conséquence, l'activité du séducteur n'est nullement l'affirmation de sa volonté subjective [. . .]" (Perniola 1980: 4).

4 Examples: Pleasures of the Game

According to our hypothesis, the surrender to the lure of the "yes" occurs in a seductively structured space of options: It is a space that draws in and does not exclude, a space that is seen only from a fully immersed vantage point that provides neither critical distance nor an outside perspective (compare Nordmann 2007b), a space that has to be entered even by potential opponents and that has no exit. Meaningless talk and the seeming openness of nanotechnology exert power through the emergence of necessity as various actors in a world of impurity and contingency become entangled in a web of concepts that mean what everyone means – that is, that no longer mean what they might mean to any one actor in isolation, but that have a promiscuous non-meaning which all actors respect in the game of seduction.[27] So far, we have described this game and the way in which it structures and coordinates action. We also need to suggest the mechanisms and stratagams by which actors become recruited to play and sustain that game. "Seduction" refers to a logic that unfolds as soon as one enters a certain space, discourse, or hall of mirrors. If games of seduction are not normally considered morally neutral, if they can become ciphers of libertinage on the one hand, decadence and loss of autonomy on the other hand, this is because these games have a certain valence in moral economies that should lead us to enter or to resist them. Further stories are needed in order to uncover the strategies by which the power of technoscience is maintained.

Many such stories can be and some have been told. One of them shows how the systematically ambiguous conception of "efficiency", forges a powerful alliance of actors regarding nanomedicine (Nordmann 2007c). Another concerns the notion of "possibility" in regard simultaneously to "technical feasibility", "compatibility with the laws of nature", and "social acceptability". Similarly, there is a telling reluctance of scientists and philosophers to disambiguate the multiple meanings of "self-assembly" or "self-organization". Yet another story revolves around "nanotechnology" in the singular and the pleasure of constructing and maintaining this illusory and powerful construct (Kaiser, in this volume). Quite another story can be told about the production of roadmaps that seduce stakeholders to freely speculate on the basis of their specific expertise.[28] Then again, one might tell a story of "risk" as a term that serves as a sponge to absorb all societal concerns and that simultaneously serves as a cipher for the manageability and for the precise technical and conceptual control of technology-in-society (Wynne 2008). Two further examples require a slightly more detailed sketch.

[27] To be sure, "non-meaning" is a horrible "non-word" but perhaps as necessary for the analysis at hand as the term "unpolitics" in Felt et al. (2007).

[28] This was suggested to us by Ann Johnson.

4.1 The Pull of the "etc."

The simplest way to introduce nanotechnology is to move quickly beyond abstract definitions and present a list of all that nanotechnology can do. For example, talking about the environmental benefits of nanotechnology a typical powerpoint presentation might offer the following list:

- sensors for monitoring ecosystem health
- waste-free manufacturing processes
- pollution-eating artificial microbes
- filters to separate oil from water
- etc.

The point of the list is expressed by the "etc." in the last line. Even where that "etc." does not appear explicitly, the list is not a shopping list, not a list of action items, and not a list of options that await to be ranked, adopted or eliminated. Instead, t is an essentially open-ended list: Nanotechnology is all this and more! What has been done so far, what is being done, what we currently think can be done, all this is only a sign of what else might be coming. And this "what else what might be coming" designates the infinite potential of nanotechnology. The implied "etc." moves beyond the finitude that characterizes and delimits any simple enumeration. It is the finitude of our imagination and the finitude of all particular research endeavors even as they are summed up collectively. If this is a first transgression of boundaries that is effected by the "etc.", it brings about another pleasurable *Entgrenzung*: The heterogeneous actors who are collected together by this list lose their distinctiveness and become fused in the name of "nanotechnology" and the horizon of all that is possible. "With nanotechnology, the environmental problems will take care of themselves."[29] – this statement is naive or absurd only at first sight. It articulates the meaning of the lists that culminate in "etc." Once all the powers of nanotechnology are fully developed, the list completes itself and all problems give way to nanotechnological capabilities.

4.2 Pleasurable Fusions in "Green Nanotechnology"

Green nanotechnology might be the most irresistible of all currently available games of seduction: As we noted above, both "responsible development of nanotechnology" and "sustainable development" *must be* and therefore *must be possible* as the result of everyone joining together (Schwarz 2009, Schwarz and Nordmann

[29] "Mit der Nanotechnologie werden sich die Umweltprobleme von selber lösen." – The statement was made during a popular presentation of nanotechnology by a speaker of the Wuppertal Institute during an event at the Deutsches Museum in Munich, October 2006.

forthcoming). Its activities and programmes could well be seen as a sort of climax of the indeterminacy of meaning and conceptual emptiness of nanotechnology. Wordings like "Responsible Nanotechnology: Green Nanotechnology", "Green Nanotechnology: it's easier than you think," or "Nanotechnology provides 'green' path to environmentally sustainable economy" are ubiquitous.[30] Just as in the sustainability discourse, the "green" in green nanotechnology refers to necessities situated at the intersection of economic and environmental benefits, simultaneously retaining the technoscientific openness of the space of possibilities. Actors with radically different values and interests become entangled in a game that is already paying off: When you mean ecological sustainability you become committed to economic sustainability, and vice versa.[31]

Indeed, nanotechnology does not even need the tautologous qualifier "green" because the whole enterprise promises to eradicate poverty and overcome the limitation of resources by providing material goods – pollution free – to all the world's people. Along similar lines, it is said to reverse global warming while solving the energy crisis. Even without taking account of particulars or restricting itself to "environmental problems", nanotechnology perfectly fits with the sustainability discourse in that it addresses the limitations of natural resources. Because it should require less material and produce less waste, a nanotechnological bottom-up world is said to be more sustainable than a traditionally constructed top-down world could ever be. This was already a central message of the first policy presentations of nanotechnology[32] that established the heuristic and rhetorical framework for the pursuit and perception of nanoscale research and that identified nanotechnology with the objectives of global sustainability or environmental claims in general: From the beginning nano was touted as an inherently benign technology, if only because nature itself is thought to be an engineer who uses principles of bottom-up construction.

Thus, in nanotechnology two strands appear to converge that are usually considered contradictory: on the one hand "green" represents strategies of preservation, by referring to the lawful limits to growth, in short by saying "no". On the other hand there is the boundless space of "nano" that is full of discursive and technical possibility, held together only by the pleasure of saying "yes". Looking at this situation of a "no-but-yes" we can better understand the seductive power of a term (green nanotechnology) that was meant to be a mere tautology. The promise of "green"

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[30] http://crnano.typepad.com/crnblog/2004/02/green_nanotechn.html (03-01-08) http://www.nanotechproject.org/publications/archive/green_nanotechnology_its_easier_than (03-01-08) http://www.physorg.com/news96781160.html, (03-01-08).

[31] A report "Nanotechnologies for Sustainable Energy: Reducing Carbon Emissions through Clean Technologies and Renewable Energy Sources" (published in June 2007) highlights that current applications of nanotechnologies will result in a global annual saving of 8,000 tons of carbon dioxide in 2007, increasing to over a million tons by 2014. It also states that over the next seven years, the highest growth opportunities will come from the application of nanomaterials to making better use of existing resources, rather than generating new forms of renewable energy.

[32] "Shaping the World Atom by Atom", published in 1999 by the U.S. National Science and Technology Council (NSTC), chaired by Mikael C. Roco and commissioned by President Clinton.

consists in part in its reference to the historical success of the environmentalist discourse that seems to offer the possibility of saying no, and therefore of bringing a limiting factor into play. However, just as soon as it is brought into play, the notion of (unlimited) possibility draws us beyond these limits into a realm of technological opportunity. This pull towards the "yes" has been given voice also within environmentalist debates. In their provocative book *Break Through: From the Death of Environmentalism to the Politics of Possibility* (2006) Nordhaus and Shellenberger[33] call on fellow-environmentalists "to replace their doomsday discourse by an imaginative, aspirational, and future-oriented one. [. . .] We should see in hubris not solely what is negative and destructive but also what is positive and creative: the aspiration to imagine new realities, create new values, and reach new heights of human possibility". They ask explicitly "how [we] can get from No-sayers to Yes-sayers? From pessimistic stories to optimistic stories?" At least some of their readers chime in: "Nordhaus and Shellenberger are right. The Industrial Age gave us an environmentalism of limits and a politics of 'no'. The Creative Age requires a politics and culture of 'yes'."[34]

5 Hedonistic Strategies: The Politics of Technoscientific Power

What do these stories tell us about the moral economy that gives positive valence to the technoscientific game of seduction and entices us to enter and say yes to the nanoworld? The moral economy in question is that of hedonism, a regime of pleasure and the denial of limits.[35] Pleasure has obviously played a major role in our account so far: it can be found in the unlikely alliances, in the wonderful fusion of people and interests, in the displacement of any conceivable problem by a technical solution, in the seemingly endless and playful diversity of images and objects, the magical tools for manipulating and ordering things in a still unsettled space, in the jouissance, exhilaration, or enthusiasm of forging possible futures, of identifying the actions of nature with that human engineers and then identifying technoscientific with artists or designers who creatively shape and reshape the world. All this opens up irresistible possibilities of gaming and tinkering in a world that seems to be ready

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[33] Shellenberger and Nordhaus prompted fierce debate with their self-published essay *The Death of Environmentalism* that provides the basis for *Break Through*. One of its most disputed claims is that environmentalism cannot deal with global warming because the issue is more complex than pollution problems. Also, American values are to have changed since the environmental movement's successes in the 1960s. Thus, it would be better if environmentalism faded away so that a new politics can be born in Amercia.

[34] Comment by Richard Florida (author of *Rise of the Creative Class)*; for more such statements of praise see www.thebreakthrough.org/#quotes, (04-01-08).

[35] This is not the place to elucidate the alternative moral economies that might support the game of seduction. If hedonism and the pursuit of pleasure appear rather obvious, this is only a sign of the very same times that sustain a remarkable optimism about nanotechnology's ability to cure the world's ills. Ourselves pleasurably implicated in the game of seduction, the authors of this paper would like to believe that the pleasures at issue might involve specifically democratic virtues.

at hand and that appears free from any traces of history or limiting representations: It is a world that simultaneously offers facts and fictions and that invites us to enter and move around in it, probing it excessively and in a passionate way. The meaningless bubbles that settle and reify the discursive space with empty talk appear seductive precisely because of their radical indetermination in relation to their objects and in the missing substance, they are “pure form” that occupies the space of possibility.

When “concepts mean what everyone means”, this translates to a strategy of seduction whereby we please each other by denying that this meaning therefore needs to be contested. When social conservatives, business leaders, and environmentalists mean something different by the term “sustainability”, this does not mean that the proper meaning of “sustainable development of nanotechnology” awaits determination. The different interpretations do not lead to conflict because they are not to be settled, and they are not to be settled because we can only mean what everyone means and not something else. That is, we must claim consistency e.g. between economic and ecological sustainability. This claim of consistency provides pleasure as an unlikely alliance proceeds in unexpected harmony, and at the same time it constrains the meaning of “ecological (or economic or social) sustainability”, thus reducing the space of possibility. We might call this the pleasure of *Entgrenzung*, that is, of an *ecstatic transcendence of limits or breakdown of the barriers that separate us*. More generally, this *Entgrenzung* is at work in the conflation of concepts and meanings that relieves us of the pressure to distinguish various notions of technology, certain tasks, or notions of efficiency.

A second seduction-strategy was alluded to above. When given a second chance to do things right this time, a bond of hopeful pleasure is forged by embracing this chance. After the so-called “GMO-disaster” which is generally attributed to lacking sensitivity and the arrogance of science and governance, nanotechnology invites everyone to join in its responsible development. And so one joins together to do good, inevitably feeling good about oneself. As mentioned above, this eliminates the insignificantly small word “no” from the apparently open discursive space. Accordingly, this is the pleasure of an *exhilarating celebration of civic virtue*.

A third occasion for mutual seduction is the unboundedness of technical potential, the endless lists of benefits, the “all is possible”[36] with its “global abundance”, and the whole of humanity as its beneficiary. Thus, everyone becomes invited to foster social imagination for the potential benefits of nanotechnology. Rather than take the imagined benefit as a claim that seeks priority over others, all proposals join the pool of possibility. And rather than critique each claim for its lack of technical feasibility or societal urgency, the community of actors welcomes all of them. All this encourages a kind of collective narcissism with everyone Parayzed in the delighted gaze at the pool of possibilities. The pleasure derived from this can be described as *hedonism of possibility*.

[36] Here “all is possible” goes further than “everything is possible”, it goes beyond a list of denumerable items.

In a rather more specific context, an occasion for mutual seduction is *Europe* and the pleasure of discovering one's *Europeanness* (Nordmann 2009). To the extent that stakeholders join on the European level to engage together in a responsible development of nanotechnology that is informed by European values, they are afforded the opportunity to let their Europeanness inform this joint commitment and, inversely, let the joint commitment stand in for their unsuspected commonality as Europeans (Felt et al. 2007, Nicolaidis and Howse 2002, Stavrakakis 2005).

All these strategies (more could be mentioned) initiate a game of seduction among actors and from that uncoerced game emerge coercive commitments that take over the space of possibility: We are at this point in time committed to a sustainable, European, efficient development of nanotechnology that is full of unspecified promise, such that these various values cannot be questioned or contested but must mean what we can all mean by them. From a game with possibilities thus emerge ineluctable necessities as our mutual seduction invests empty concepts with the power to hold our conflicts and differences at bay. By being open to interpretation and at the same time remaining impervious to interpretation, these terms can draw the consensus of those who use the term and imitate each other in a use that does not presuppose a sharing of meanings.[37] The persistence of this vacuous (empty at the core) consensus proves powerful in that it forecloses a radical "no", in that it forces research and development into the straight-jacket of "efficiency", in that it discourages the articulation of non-stereotypical visions and even the assertion of special interests (those of patients, or workers, of the disabled etc.).

Seduction entangles us with one another as we follow a discursive strand into a maze or knot, finding ourselves in a voluntary association with others who are playing the same game – and the very fact of this association around a practice and a game, around the occasion provided by a word devoid of determinate meaning creates the pleasurable illusion that we have common ground from which everyone can pursue their goals without compromising those of the others. Thus, interestedness drops out and power creeps in, namely the enchanting power of pleasure[38] – a euphoric agreement on symbols, words, rituals of faith in the future. We end up mutually enchanted, committing ourselves to something that we cannot survey, and agree to more than we can possibly mean.

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[37] The theory of power as emerging from the pleasure of mutual seduction should thus be complemented by Pierre Klossowski's account of *simulacra*. Compare Baudrillard as quoted above on seduction "without substance and origin," "gaming as pure form" and "formal bluffing."

[38] In light of standard conceptions that tie power to interest, this sounds paradoxical. Power is to be a rationalizing expression, a rathionalization of pure interest, and its effect the disenchantment of the world (Röttgers 1990). – And yet, this "magical" form of disinterested power is familiar from various "invisible hand" accounts (Adam Smith to the *Matrix*).

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The Time of Science: Deliberation and the "New Governance" of Nanotechnology

Matthew Kearnes

1 Introduction

How do we understand the time of science? More precisely how might we imagine the relationship between the production of scientific knowledge and the emergence of the quixotic period we know as "the contemporary"? For Foucault, understanding the contemporary – or the modern – is central to his genealogical approach. Understanding the present is, for Foucault, a matter of discerning the interdependencies between knowledge and power – that the epistemic constitution of the contemporary. For example, commenting on Immanuel Kant's brief essay: "An answer to the question 'What is enlightenment?'"[1] Foucault draws a line of affinity between the critical tradition and his own historico-discursive techniques on the question of the present:

> If one cares to think of philosophy as a form of discursive practices with its own history, it seems to me that with this text on Aufklärung one sees philosophy ... problematising its own discursive present-ness: a present-ness which it interrogates as an event, an event whose meaning, value and philosophical singularity it is required to state, and in which it is to elicit at once its own *raison d'être* and foundation of what it has to say (Foucault 1993: 11, emphasis in original).

One might therefore characterise Foucault's analyses of knowledge and power as an attempt to understand the emergence of modernity epistemologically. The contemporary is conceived not simply as an unfolding historical period – between the past and the future – but as rather as a "sedimentary bed ... made from things and words, from seeing and speaking [and] from the visible" (Deleuze 1986: 47). Foucault imagines the present as strata or "historical formations" which are distinguished by the precise arrangement of contemporary power/knowledge (Foucault 1980). As such Foucault's analyses of the figure of the anthropos in the development of the human sciences (Foucault 1970) and his well known characterisation

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[1] See Kant (1926).

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of the play between transparency and visibility in contemporary disciplining institutions (Foucault 1973, 1975) might therefore be read as component elements of a broader discursive approach to the problem of the present. The accomplishment that Foucault achieves is to therefore enable an analysis of ways in which contemporary power/knowledge are embodied in mundane techniques, routines and technologies.

In this paper I seek to understand "the time" of contemporary technoscience – that is the interdependencies between science, technology and contemporary political power – by examining the techniques involved in the governance of science, particularly in the field of nanotechnology. For Foucault knowledge is both constitutive of and a product of its time – of the discursive and epistemic formations that that frame its very fabrication. One might extend this analysis to suggest that both science and technology are products of historically and geographically specific social and political relations, whilst simultaneously reproducing such relations. Jasanoff (2004) use the "idiom of co-production" to characterise the interdependence between "the scientific" and "the social". She suggests that given that "science and technology permeate the culture and politics of modernity" that:

> The texture of any historical period, and perhaps modernity most of all, as well as of particular cultural and political formations, can be properly appreciated only if we take this co-production into account. . . . Knowledge and its material embodiments are at once products of social work and constitutive of social life; society cannot function without knowledge anymore than knowledge can exist without appropriate social supports. Scientific knowledge . . . embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments and institutions – in short, in all the building block of what we term the social (Jasanoff 2004: 2–3).

In this paper I characterise the "texture" of the present through an analysis of contemporary UK science policy and its interdependence with what Rose (1996) characterises as the governance of "advanced liberal" societies. In what follows I argue that though scientific practice operates as a model in the imagination of contemporary (neo)liberalism this interdependence is also embodied in the more practical governance of science – through which science becomes an object of civil administration. Whilst much co-productionist inspired research has tended to focus on the way in which science embodies and reproduces social norms I focus here on the mirror of this relation. Rather than simply suggest that science is a "product of its time" I explore the significance of contemporary technoscience for understanding the present. By adopting a Foucauldian notion of the epistemic nature of historical formations, I explore the ways in which the civil administration of science, particularly in contemporary UK science policy, is central to the imagination of modern, liberal forms of political power.

In this paper I discuss two recent developments in UK Science Policy, and consider their implications for the construction of contemporary forms of political power. The first of these developments, is what a number of authors have identified as the emergence since the mid-1990s of more distributed, "innovation" focused definitions of science policy. In this context, the old justifications for State patronage of research – of the socially progressive nature of scientific advance (Bernal 1939) or its military and strategic significance (Bush 1945, Eisenhower 1959) – have given way to a more procedural concern for providing the conditions for innovation. It is *innovation* rather than *science* that matters now. Streamlining the curious relationship between advances in knowledge and the development of new technologies is increasingly central to the way that governance is imagined internationally (European Commission 2003, High Level Group 2004). In this context a range of "systems" metaphors have emerged that represent what is now commonly referred to as a "governance turn" in science policy (Hackmann 2001). In concert with the broader influence of governance thinking across a range of policy domains (Rhodes 1996) the relationship between state power and scientific practices is increasingly cast as distributed and multilevel in nature (Expert Group on Science and Governance 2007, Féron and Crowley 2003). A range of "systems-based" metaphors – particularly the notions that national science policy might be thought of as an "innovation ecosystem" (Lord Sainsbury of Turville 2007) or "National Innovation System" (Sharif 2006) – have facilitated this governance turn in science policy. Set in the context of the wider influence of systems metaphors in governmental and administrative theory (Hughes and Hughes 2000, Schneider 2004) such metaphors alter contemporary conceptions of political power and the nature of modern statecraft.

The second development in science policy that I discuss in this paper is the increasingly "deliberative" mode through which such policy initiatives are imagined. As I, together with colleagues, have described elsewhere (Kearnes and Wynne 2007, Kearnes 2003, Kearnes, et al. 2006b, Macnaghten, et al. 2005) in the governance and regulation of contemporary science we are witnessing the increasing use of a new set of such governmental technologies – principally public deliberation, ethics and foresight – built into the technological development at upstream stages. Though there is considerable debate about the precise role that these techniques might play in the governance of science[2] recent science policy in emerging technoscientific fields, such as nanotechnology, is marked by a broadly international consensus on the need to incorporate ethical analysis, public engagement and regulatory innovation into nanotechnology development programmes (European Commission 2004, HM Government 2005, 2007, Roco and Bainbridge 2001). Representing an development of earlier ESLI research programmes, associated with the mapping of the Human Genome Project, Macnaghten et al. (2005) and Nordmann and Schwarz (in this volume) suggest that these deliberative and anticipatory techniques are increasingly cast as central to the successful development of nanotechnology.

In defining the nature of contemporary governance, Rose and Miller's (1992) distinction between the "problematics of government" – that is the rationalities that

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[2] See Hagendijk and Irwin (2006) and Irwin (2006). On the recent "upstream turn" see Fisher et al. (2006) and Joly and Rip (2007).

constitute the logic of government – and the technologies of government – defined as the "the complex of mundane programmes, calculations, techniques, apparatuses, documents and procedures through which authorities seek to embody and give effect to governmental ambitions" (p. 175). Importantly, Rose (1996) suggests that advanced liberalism is embodied in what he describes as the "techniques of governance". Given this distinction between the problematics and techniques of government Rose and Miller (1992) also insist that liberal governance is embodied in the numerous of "calculative technologies" that have recently proliferated in contemporary social life. For example, Power (1997) demonstrates how both the "idea" and "practice" of audit have, since the 1980s, begun to be used in a variety of new contexts, producing what he terms an "audit society". Drawing on methods from financial accounting, the installation of forms of audit culture in multiple spheres of public life is based on the presumed independence and objectivity of the auditing practices and the notion that "giving account" through such techniques produces the kind of transparency upon which liberal democracy is based. Porter (1995) provides a backdrop to this analysis, tracing interlocking developments in the mathematical and statistical sciences and the association of calculation, quantification and positivism with notions of objectivity, freedom and truth. Techniques of calculation are central to the "mundane operation" of liberal governmentality, given that it is presumed that enumeration makes things explicit and produces transparency. The increasing ubiquity of such techniques across social life is based on their presumed objectivity, producing a kind of expert-led knowledge in the construction of forms of "government without politics".

What I am seeking to understand here is the broader relationship between national science policy and contemporary conceptions of power – and how this is embodied in the techniques for the deliberative governance of nanotechnology. Though clearly not unique to nanotechnology, the emergence of nanotechnology research programmes has been an important site for institutional innovation in what a number of authors refer to as the "new governance of science" (Gottweis 2008, Irwin 2006, Lengwiler and Simon 2005, Nowotny et al. 1994). Gottweis (2008) characterises the emergence of new forms of scientific governance as a shift from "modernist" to "post-modernist" forms of state-craft. In this account – of the distribution of governance across both State and non-State actors and the creation of new, spaces of participatory and deliberative governance – we also see that both the rationales and techniques of "state" governance have changes. These approaches are an increasingly explicit feature of science policy itself. Accordingly I argue that nanotechnology policy has been significant in the development of new modes for the governance of science. In particular, I suggest that in the governance of nanotechnology we are witnessing a modulation of contemporary neoliberal forms of power, accompanied by the emergence of qualitative forms of governance that augment the now ubiquitous reliance on calculative techniques. The circulation of discourses of openness, transparency and participation in contemporary science policy – and the incorporation of deliberative techniques into nanotechnology research programmes suggests that the techniques for publically accounting for nanotechnology are increasingly qualitative in nature.

2 Science and the Rationalities and Techniques of Governing

To question the “time of science” is therefore to examine the relationship and interdependence between scientific practice and the emergence of contemporary formations of power/knowledge. There a three principle axes through which this interdependence is manifest. Firstly, science provides an *epistemic* framework through which to imagine notions of liberty and freedom that are central to the imagination of contemporary politics. Jasanoff’s (2005) notion of “civic epistemology” highlights the increasingly central role that knowledge plays in the discursive production and maintenance of public life and politics. Referring to the “institutionalised practices by which members of a given society test and deploy knowledge claims used as a basis for making collective choices” (ibid.: 255) she suggests that: “in technology-intensive societies, the construction of governmental credibility necessarily encompasses the public production of scientific knowledge” (ibid.: 258). Science here operates a form of public epistemology that frames the constitution of public life and the conditions of possibility for collective and institutionalised decision making. Similarly Knorr-Cetina (2007) suggests the centrality of this form of public epistemology in what she terms the “culture of knowledge societies”. Extending her notion of epistemic cultures inherent in the institutionalised practices of science to an analysis of the constitution of the public sphere she suggests that:

> Epistemic cultures are the cultures of knowledge settings. If the argument about the expanding presence of knowledge settings is right, what we call society will to a significant degree be constituted by such cultures. It is for that reason that epistemic cultures can be seen as a structural feature of knowledge societies (ibid.: 362).

For Knorr-Cetina public life – indeed contemporary society itself – is constituted epistemically. The time of science is therefore the time of modernity in that scientific advance is cast as central to the very imagination of “the modern”. The *a priori* reliance on method and detachment for example provide resources through which to construct liberalist conceptions of autonomy and liberty.

Secondly, aside from the epistemic interdependence between science and the constitution of contemporary forms of public and political life the organisation of scientific research has traditionally been cast as a *social model* of liberalist and republican ideals of freedom. Science, itself classically understood as the domain of freedom *par excellence* based on the primacy of knowledge as the key to freedom (Merton 1973, Polanyi 1962, Ziman 1983). In addition to providing an epistemology of freedom the organisation of the science – indeed the very republican ideals of science – operated as a model in the constitution of contemporary forms of public administration. Accordingly a number of authors have written about emergence of a “post-war consensus” (Edgerton 2007, Hart 1998, Hughes and Hughes 2000, Krige 2006, Krige and Pestre 1997) in which science emerged as a new, and central, concern for modernising liberal democracies in the years immediately after the Second World War. The development of the state apparatus for the governance of science in the years immediately after the Second World War – particularly the formation of scientific institutions and research support mechanisms together with the embedding of science as a policy concern across a range of government institutions (Hart 1998) and the wider role of scientific expertise in public culture and public administration (Balough 1991, Barnes 2006, Deutsch 1963, Taylor 2005) – is crucial to the cotemporaneous emergence of what might be described as trans-Atlantic liberalism.

Lastly, Rose and Miller (1992) introduce a third conception of the relationship between science, technology and contemporary power. As introduced above they distinguish between what they term "political rationalities" – the combination of the epistemological nature of contemporary political cultures and the interdependence between the (neo)liberal forms of governing and science as an object of such governance as the political rationalities – and what they term "governmental technologies". As such science and technology fulfil a more mundane role in the *techniques* of governance. In particular, recent analysis has demonstrated the centrality of techniques for quantitative calculation in the imagination of modern power. For Rose, the use of such techniques imbues modern statecraft with the rationality of science. Elden (2006), for example, sees the development of modern forms of power from the emergence of notions of the territorial boundary of political constitutions, and the broader development of Cartesian method and geometry. He suggests that "modern technology requires a view of space as map-able, controllable and capable of domination; modern politics is able to fully exploit this" (ibid.: 3). Notions of calculation, quantification and computation – and their embodiment in a multitude of statistical and auditing techniques that are now ubiquitous across social life – offer a kind of numerical objectivity and transparency that is beyond the State.

In this way we can distinguish three distinct forms of interdependence between contemporary political culture and the practices and epistemologies of technoscience. Science provides a form of epistemic rationality in the co-constitution of civic virtue and political norms whilst the governance of science itself is an increasingly central policy domain through which (neo)liberal rationalities of government are developed and deployed. More practically technoscience provides a raft of techniques and technologies of calculation, quantification and auditing which have become central feature of forms of distributed governance. Therefore in contemporary scientific governance we might distinguish between the "problematic of governance" and the nature and techniques of statecraft. Below I explore the shifting relations between the rationales and techniques of governance, exploring the ways in which in contemporary UK science policy we witness the emergence of an increasingly qualitative logic.

3 Governance *Turn*

As outlined above contemporary UK science policy is characterised in two decisive shifts, that mark new ways in which political power, and the State's capacity to coordinate science is re-imagined. Significantly, the combined effect of both of these shifts is a modulation in the inter-relationship between the epistemologies, rationalities and techniques of governance.

The first of these shifts is what has become commonly referred to as the "governance turn" in science policy. A number of authors have identified a "governance turn", in which government capacity became redefined as shaping and steering policy objectives, rather than direct control (Borrás 2003, Borrás and Jacobsson 2004, Bulkeley et al. 2007, Hood 1983, Rhodes 1996, Schneider 2004). In Rhodes' (1996) analysis of the shift from government to governance, "governance signifies a change in the meaning of government, referring to a *new* process of governing; or a *changed* condition of ordered rule; or a *new* method by which society is governed" (ibid.: 652). The governance turn in policy and regulatory thinking therefore designates a shift in the discursive definition of political and governmental power. Rather than rely on the ability of central governments to "command and control" through traditional regulatory and legislative mechanisms the governance turn suggests that governments are increasingly operating in a "steering mode" – setting incentives and goals, defining targets, and shaping public policy objectives.

There is not the space here to develop a full characterisation of the governance turn – and its particular expressions in UK science policy. However it is worth rehearsing the now familiar diagnosis that national governments no longer simply "govern" science directly. Recent studies in science policy studies suggest that models of scientific governance based on hierarchal, top down government have given way to more distributed forms of governance (Féron and Crowley 2003, Hackmann 2001). Significantly this governance thesis is increasingly articulated as the "problematics" innovation governance – particularly in definitions of contemporary the role of central government as both "steering" scientific developments and "setting the conditions" for innovation. Though this account of the "governance turn" speaks of a distribution of governmental capacity beyond the state, it is also clear that this distribution is a feature of contemporary statecraft. That is the distribution of governance across a range of state and non-state institutions is now cast as a model of how to govern for innovation. The role of the state is transformed to that of "steering" or setting the conditions for innovation. For example, UK science policy is increasingly dominated by a range of metaphors which represent scientific research and development as an "innovation system". For example, UK policy articulates a notion of an "innovation ecosystem" that includes a range of institutions and mechanisms, such as R&D tax credits, research councils, patent and IP legislation, private and commercial funding of R&D, and the newly formed technology strategy board recent (Lord Sainsbury of Turville 2007). For example,

> An economy's rate of innovation depends on a *range* of activities and the *links* between them. To provide the best conditions for companies in the UK it is necessary to consider an innovation ecosystem and not a number of disconnected policies. . . . Improving our innovation performance requires an assessment of all elements within the innovation ecosystem. If we want to raise the level of innovation in our industries to the highest level, each element of our innovation system must be functioning effectively (Lord Sainsbury of Turville 2007: 24–37).

In this context, the overwhelming discursive priority is the stream-lining of relations and links between the range of organisations in this ecosystem (Department for Innovation Universities and Skills 2007, HM Treasury 2003, 2007). In place of "command and control" notions of science policy and regulation, the role of state power in relation to scientific practice is increasingly defined as "steering", "streamlining" and "setting the conditions" for innovation. Significantly, in addition to research funding and knowledge transfer programmes, public engagement and deliberation, foresight and new approaches to regulation are cast as part of the innovation ecosystem (Department of Trade and Industry/Department for Education and Skills/HM Treasury 2004).

4 Deliberative *Turn*

The second innovation in governance evident in recent science policy – especially policy UK policy on nanotechnology – is the proposal to incorporate ethics, social science and direct public participation into nanotechnology research programmes. Although not unique to nanotechnology the constitution of nanoscale research through contemporary science policy has represented an important site for institutional innovation in what a number of authors have begun to speak of as a "deliberative turn" in contemporary governance (Benhabib 1996, Chambers 2003, Cohen 1989, Dryzek 1990, 1996, 2000) and scientific governance more specifically (Brown and Michael 2002, Chilvers 2008, Hagendijk and Irwin 2006, Irwin 2001, 2006, Kearnes and Wynne 2007). Indeed Irwin (2006) terms this deliberative approach "new scientific governance" suggesting that:

> Taking the British example, from the late 1990s there has been a partial, but nevertheless significant, rhetorical shift towards a style of scientific governance based on public dialogue, transparency and democratic engagement. Assertions of the importance of public trust and the need to take social concerns seriously now represent a standard part of the policy repertoire (ibid.: 300).

Thus while there is debate as to practical implications of new forms of deliberative or participatory governance in science policy – and the extent to which this deliberative rhetoric represents an authentic *renewal* of democracy – the rationale of governing has itself become more deliberative. As such the norms of deliberative theory have been increasingly become an explicit feature of both policy discourse and the conceptual repertoire of contemporary statecraft (European Commission 2001, United Nations Economic Commission for Europe 1998). For example, Dryzek (2000) dates the emergence of a deliberative turn in contemporary governmental thinking to the "final years of the second millennium" which:

> Saw the theory of democracy take a strong deliberative turn. Increasingly, democratic legitimacy came to be seen in terms of the ability or opportunity to participate in effective deliberation on the part of those subject to collective decisions. . . . The essence of democracy itself is now widely taken to be deliberation, as opposed to voting, interest aggregation, constitutional rights, or event self-government. The deliberative turn represents a renewed concern with the authenticity of democracy: the degree to which democratic control is substantive rather than symbolic, and engaged by component citizens (ibid.: 1).

Deliberative theory therefore represents a shift in both the rationales and techniques of governance. Principally, deliberative theory speaks of a concern for renewing the authenticity and legitimacy of democracy. Naturally this call for the renewal democracy legitimacy is accompanied by a range of new deliberative governmental techniques – that broadly seek to enable direct stakeholder and citizen participation in decision making. European proposals for new forms of deliberative forms of democracy emanate from a diagnosis that posits high levels of public distrust in state institutions, and a broad disconnection between political decision making and the population.

This diagnosis operates, in Gottweis' (2008) terms, as a "trigger" for governmental innovation in deliberation. Similar triggers operate in the specific case of science and technology policy. For example, Irwin (2006), Brown and Michael (2002) and Litfin (2000) identify that a crisis of public trust – or a "legitimacy crisis" – has triggered institutional self-reflection and innovation in scientific and environmental governance. In the particular case of UK science policy this legitimacy crisis emanates from a series of recent technoscientific controversies – concerning for example, civil nuclear power, Bovine spongiform encephalopathy (BSE) and genetically modified crops and foods (Better Regulation Task Force 2003, House of Lords Select Committee on Science and Technology 2000, Royal Commission on Environmental Pollution 1998). This series of public controversies were characterised by a number of common features – initial official assurances of safety followed by reluctant admissions to the contrary (Kearnes et al. 2006a). Indeed, the institutional responses to the emergence technoscientific controversies have been a principle mechanism for the promotion of participatory and deliberative discourses in UK science policy. For example, the Royal Commission on Environmental Pollution (1998) report *Setting Environmental Standards* which responded to public concerns about environmental toxicity suggested that environmental decision making should be "informed by [public] values" (ibid.: 113). Similarly the Philips Report (Lord Phillips 2000) into the controversy concerning emergence and identification of BSE and variant CJD in the United Kingdom found that one contributing factor to failure in existing risk communication strategies was that "Government had a problem with credibility" and that "to establish credibility it is necessary to generate trust . . . generated by openness" (ibid.: 265).

Importantly, both reports, together with a range of public engagement and deliberation initiatives were key mechanisms for the official (re)consideration of policy failures and proposals for the renewal of democratic credibility through deliberative mechanisms. Accordingly recent science policy is marked by the emergence of a new deliberative consensus and the use of forms of public consultation and participation together with broader programmes of science communication and public education (European Commission 2002, 2006, HM Treasury/Department of Trade and Industry/Department of Education and Skills 2004, Joss and Belucci 2002).

A second trigger for intuitional innovation in the governance of science is what Gottweis (2008) refers to as the "ethicisation of governance". He suggests that:

> A common feature of the politics of life areas . . . concerns the salience of a language of ethics and morality. Issues turned out to be strongly framed in normative terms such as "moral obligation" or "responsibility", the qualification of certain courses of action as being

> "ethically permissible" or not, "moral" or "immoral" or imperatives to "relieve suffering", to respect "human dignity", "protect human dignity" or promote "animal welfare". It seems that today in governance the language of logos is increasingly complemented by a language of "ethos" and "pathos". . . . We can therefore speak of an ethicisation and emotionalisation of governance that has taken place in the politics of life areas (ibid.: 281).

For Gottweis the turn toward the use of deliberative techniques in scientific governance is also in-part explained by the emergence of ethics as a emergent framing of technoscientific innovations – particularly in the life sciences. Whereas institutional reflection of recent technological controversies is often framed by *risk* as a central discourse, Gottweis points to the significance of discursive repertoires drawn from ethics and morality in public debates about innovation in reproductive, genetic and stem-cell technologies. Confirming this analysis, Macnaghten et al. (2005) trace the emergence in nanotechnology policy of a consensus regarding the potentially constructive role that both social science and public engagement might play in the development of both nanoscience and nanotechnology. Building on the model established by the ESLI programme of the Human Genome Programme, in which a proportion of genetics research funding was reserved for identifying the ethical, legal and social implications of human genetics research, early nanotechnology policy documents spoke of nanotechnology as a "rare opportunity to integrate the societal studies and dialogues from the very beginning and to include societal studies as a core part of the [nanotechnology] investment strategy" (Roco and Bainbridge 2001: 2). The primary assumption made in the ESLI programme is that the discourses of ethics and morality are appropriate in the consideration of the broader societal implications of emerging technologies. Secondly the institutional response is in the ELSI programme, and furthered in recent approaches to nanotechnology, is to embed ELSI research into technoscientific research programmes.

In UK science policy authors have pointed to a Parallel shift in emphasis from earlier models of the "public understanding of science (PUS)" and science communication to more dialogue based approaches to "public engagement" (Gavelin et al. 2007, Wilsdon and Willis 2004). Institutionally this shift in emphasis from a PUS model to a more deliberative model of public engagement was confirmed by the replacement, in 2004, of Committee on the Public Understanding of Science (COPUS) grant scheme by the "Sciencewise" programme, an explicitly dialogue centred mechanisms for funding public engagement on science and technological development. In light of this shift in emphasis Kearnes and Wynne (2007) note the striking absence of risk in this shift of governmental rationality. They suggest the earlier impulse toward openness based on a reflection of the centrality of risk and uncertainty in decision making has been replaced by rhetoric of the "moral case" for public deliberation. Accordingly, transparency, openness and direct public participation are represented as characteristics of virtuous "good government". The increasing use of participatory and deliberative techniques might therefore be regarded as a form of public demonstration of the "authenticity" of governance (Brown and Michael 2002).

5 The "New Governance" of Nanotechnology

Whilst not unique to nanotechnology, the recent establishment of nanoscience and technological research paradigms have constituted an important site in the development of new models in the governance of science. Over the last five years an international policy debate has emerged concerning the appropriate mechanisms for the governance and regulation of advances in nanotechnology. In this emerging policy debate initial concern has been raised about the possible eco-toxicity of nanomaterials, together with the broader socio-economic and ethical dimensions of a broad range of possible nanotechnologies. Kearnes and Rip (2009, in press) suggest, in debates about nanotechnology we are witnessing the coupling of regulation and broader research governance and coordination. This constitutes what they term an "emerging governance landscape". For example specific debates regarding the regulation of novel nanomaterials are increasingly conceived as one element of the broader governance of nanotechnology. Roco (2006) identifies this shift in what he terms "policy modernisation" in which regulation is cast as part of the broader governance of emerging technologies. In reviewing the shift from modes of *government* to modes of *governance* he states:

> In the most common current usage of the term, "governance" implies a move away fromthe previous *government* approach (a top-down legislative approach that attempts to regulate the behaviour of people and institutions in quite detailed and compartmentalized ways) to *governance* (which attempts to set the parameters of the system within which people and institutions behave so that self-regulation or the ecosystem achieves the desired outcomes), or put more simply, the replacement of traditional "powers over" with contextual "powers to". . . . These assumptions underline the switch from government alone to governance in debates about the modernization of policy systems, implying a transition from constraining to enabling types of policy or regulation (Roco 2006: 3).

In this sense governance is increasingly conceived as incorporating both research policy and risk-based regulation. As innovation has become a central motif of national science and technology policy, concern has shifted to a consideration of the appropriate governance structures and arrangements to enable the successful development of science and technology (Jamison 1989). Accordingly, Roco indicates that the re-conceptualisation of government as governance in the also entails a positioning of research policy and regulation as "enabling" rather than "constraining". In casting regulation as simply one of a number of "tools of government" set in the context of the overall governance of nanotechnology development and commercialisation, arguments are made in favour of regulatory frameworks that enable the development and commercialisation of nanotechnologies.

Kearnes and Rip (2009, in press) characterise this approach as embodied in a range of initiatives – both State and non-State led – that seek to modulate the direction of nanoscale research trajectories. Such initiatives includes the increasing use of forms of voluntary soft-law (Bowman and Hodge 2006, Dorbeck-Jung and van Amerom forthcoming) the incorporation of ELSA research and public deliberation in order to modulate nanoscale research, and the recent proliferation of voluntary codes – particularly those concerning the “responsible development of nanotechnology” (see for example: European Commission 2008). The combined effect of these three features of the emerging governance landscape of nanotechnology demonstrates institutional innovation in the use of voluntary forms of regulation as part of an overall governance approach.

In UK nanotechnology policy this voluntary approach to regulation is set alongside the increasing delegation of research governance to non-State and quasi-State bodies. In addition to the traditional role played by research councils in funding curiosity driven academic research the newly formed Technology Strategy Board (TSB) has become an important node in the governance of nanoscale innovation. The Technology Strategy Board began life as an advisory body within the former UK Department for Trade and Industry (DTI) and became an independent body in July 2007 after the reorganisation of the UK Department for Innovation, Universities and Skills (DIUS) and the Department for Business, Enterprise and Regulatory Reform (BERR). The TSB originated from an *Innovation Review* published by the DTI (2003) which identified a weakness in UK technology strategy. Whilst recognising the strength of UK support for curiosity-driven science, the report recommended the formation of a new technology strategy to “identify technology priorities”, “stimulate an industry based technology programme” and “influence a much wider set of Government policies as well as the behaviour of business and other participants in the innovation system” (ibid.: 59). Originally conceived as a departmental‘advisory body for the reorganisation of‘existing knowledge transfer‘programmes within government, the TSB has recently become a “non-departmental public body” which operates at “arm’s length” from central Government. The current mission of the TSB is therefore to:

> Identify promising new technologies emerging from the country’s research community and ensure that businesses are able to identify potential commercial applications (Technology Strategy Board 2005: 6).

The formation of the TSB – and its increasing significance in nanotechnology policy is consistent with the governance turn in UK science policy which represents the role of central government as setting the fiscal, legal and regulatory conditions for innovation. Importantly the TSB represents a explicit delegation of government to a non-State body in coordinating future innovation and technology policies. Led by representatives of the “business community” the TSB coordinates a Collaborative Research and Development (CR&D) scheme together with a number of Knowledge Transfer Networks (KTN) and Knowledge Transfer Partnerships (KTP) in identifying “key emerging technologies” and setting “innovation platforms”. Significantly in the area of nanotechnology, is identified by the TSB as a “key technology area” built on existing strengths in materials research. Through the establishment of a “Materials Innovation and Growth Team” and a number of knowledge transfer networks in materials science this approach marks a move toward a strategy based on “innovation governance” over traditional science policy. Indeed the establishment of the TSB and its leadership in coordinating knowledge transfer and industrial pull-through in nanotechnology research has been significant mechanisms through which notions of innovation governance have been more widely taken up by other institutions. After repeated calls for the greater streamlining of the innovation ecosystems UK research councils have responded with a more strategic "grand challenge" approach, which I discuss below.

An additional element of this shift toward "innovation governance" is a distinct deliberative turn in contemporary policy rhetoric. For example, UK policy on nanotechnology increasingly indicates an official commitment "to enable [public] debate to take place "upstream" in the scientific and technological development process, and not "downstream" where technologies are waiting to be exploited but may be held back by public scepticism brought about through poor engagement and dialogue on issues of concern" (HM Treasury/Department of Trade and Industry/Department of Education and Skills 2004: 105). This move toward direct public participation in science policy is positioned as a response to a series of technological controversies. Nanotechnology is therefore cast as an opportunity for the "lessons learned [to] be incorporated into the design of research programmes and regulatory measures" (Involve 2005: 5).

Public engagement is therefore represented as a mechanism through which to restore public trust by increasing the transparency and accountability of scientific governance and policy development. In place of Power's notion of the audit culture processes – indeed technologies – of public dialogue, engagement and deliberation stand as new mechanisms for "giving account" in complexly governed liberal democracies. Accordingly Irwin and Michael (2003) describe the discursive setting to current participatory approaches to science and technology as an "aspiration to transparency" manifested in acts and techniques of "enunciation". The strategic use of forms of public engagement and deliberative techniques is thus set in the context of a drive toward both transparency and accountability – a form of making things public whilst thereby making them less "political" – now ubiquitous in liberal governance.

The culmination of this approach is an explicit shift in contemporary UK policy and regulatory discourse – away from notions of "risk governance" to those of "innovation governance" that incorporates public deliberation as one element alongside more traditional forms of innovation and technology strategy. For example, a recent report by the Royal Commission on Environmental Pollution (2008) outlined the nature of this policy shift in approaching nanotechnology:

> Ultimately however, many of the questions raised by developments like those in the field of novel materials are trans-scientific in nature. They extend beyond the (important) issues of risk and risk management to questions about the direction, application and control of innovation. . . . The more substantive challenge, therefore, is to find the means through which civil society can engage with the social, political and ethical dimensions of science-based technologies, and democratise their "licence to operate". It has been characterised as a challenge of moving beyond the governance of risk to the governance of innovation (ibid.: 72).

The twin goals here are to both stimulate innovation in nanotechnology, whilst ensuring that adaptive and anticipatory structures are in place to deal with potential risk management issues and more substantial social and ethical questions.

Significantly, in this shift in emphasis from the "governance of risk" to the "governance of innovation" direct public participation and deliberation is to play a formative role:

> The intensity of the public engagement effort is in part a reflection of the speed and scale of innovation. But it is driven also by concerns about possible societal responses to particular technologies. ... Such motivation, whilst not always explicit, has also been an important factor behind public engagement initiatives in the UK, although the Government has stated its aims more broadly, in terms of building a society "confident about the governance, regulation and use of science and technology". We urge that the emphasis be placed on these broader objectives. The full value of engagement and deliberation will not be realised if these activities are seen primarily as an exercise in securing acquiescence to new technologies. Rather, they should constitute an important component in a system of innovation governance (ibid.: 73).

The Royal Commission on Environmental Pollution report makes explicit reference here to another report recently published by the UK Department for Innovation, University and Skills (DIUS)[3] – *A Vision for Science and Society* (2008). This consultation document, which aimed to develop a new strategy for the UK "science and society" initiatives and articulated three goals of public engagement and wider science communication initiatives – building: "a society excited by and valuing science"; "a society that is confident in the use of science"; and "a society with a representative and well-qualified scientific workforce". Here a particular kind of society – characterised by an enthusiasm for science and technology – are cast the "societal conditions" for enabling innovation. In this vein Kearnes and Wynne (2007) characterise contemporary nanotechnology policy – and particularly contemporary discourse of "enabling" citizen participation and dialogue – as producing a kind of "politics of enthusiasm". Clearly now society – that is "the public at large" – are envisioned as part of the system of scientific governance, as component elements of what UK science policy refers to as an innovation ecosystem.[4]

This model of innovation governance is embodied in the recently completed public and stakeholder consultation in the development ofa "Grand Challenge Call" on "Nanotechnology for Healthcare".[5] This process explicitly incorporated qualitative research on public aspirations concerning healthcare and potential

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[3]Two new UK government departments – the Department for Innovation, Universities and Skills and the Department for Business, Enterprise and Regulatory Reform – were created in June 2007 from a reorganisation of the pre-existing departments for Trade and Industry and for Education and Skills.

[4]This vision of science and society initiatives producing confidence and enthusiasm attracted much critical commentary – not least from the social scientific community (Doubleday et al. 2008; Kearnes and Doubleday 2008) – which largely suggested that the vision represented a regressive policy move, away from integrated public engagement to earlier models of one-way science communication based on the assumption that confidence and enthusiasm are the *only* appropriate public response to science and technology. However, despite these criticisms it is instructive that the goals of the vision are couched in the language of *engagement* and *deliberation*. As such it demonstrates the contemporary interdependence of notions of deliberative and innovation governance.

[5]This consultation was conducted by the UK Enginnering and Physical Sciences Reserach Council (EPSRC) as part of a broader cross-research council programme *Nanoscience Through*

concerns about nanotechnology innovation in developing the precise framing of the research call. As such it demonstrates the qualitative incorporation of "the social" in a systems of innovation governance.[6] Conceived as a part of a broader cross-Research Council programme *Nanoscience Through Engineering to Application*, Engineering and Physical Sciences Research Council (EPSRC) coordinated the development of call for research funding which demonstrates the growing significance of forms of direct public participation and deliberation in contemporary innovation governance. Significantly the funding call was conceived as part of a "grand challenge" approach – which itself is a new approach adopted by UK research councils in response to emerging notions of innovation governance and the establishment of the Technology Strategy Board. For example the *Science & Innovation Investment Framework 2004-2014* articulated the need to develop a model of research that responded to contemporary "grand challenges":

> We need to enhance a culture of multidisciplinary research in the UK and provide the underpinning infrastructure and funding mechanisms to support it. This is a critical challenge. Over the next decade many of the grand challenges in research will occupy the interfaces between the separate research disciplines developed in the 19th and 20th centuries. The nations that succeed in producing high-tech economies will be the ones that are best able to adopt a flexible approach to research for the greatest added value. The US, Japan and Germany are already investing in multidisciplinary capability (HM Treasury/Department of Trade and Industry/Department of Education and Skills 2004, 22).

Here we see the crystallisation of a model of innovation governance in the positing of a particular model of "multidisciplinary research" oriented to respond to "grand challenges" in order to secure competitive advantage in a global economy. Given the repeated calls for research councils – who have, in UK science policy, operating at "arms length" from central government – to take a more active role in promoting knowledge transfer and commercial innovation the grand challenges, approach represents one mechanism through which the councils have responded to this emerging policy agenda. Internal EPSRC documents are explicit on this point. For example, the *2007/2008 EPSRC Delivery Plan* states that:

> Following the 2006 Nanotechnology Theme Day, EPSRC's Council approved a strategy for nanotechnology aimed at building on previous investments. In 2007/08, we will engage a nano "champion" to help co-ordinate a focused programme which seeks to pull through nanoscience into engineering and applications. Partnership with the Technology Strategy Board and the Science & Technology Facilities Council will be a key component of this.

Engineering to Application. The "Grand Challenge: Nanotechnology for Health Care" is the second in a series of three managed reserach programmes, focused on "addressing societal and/or economic issues where nanotechnology can make a unique and significant contribution" (RCUK 2008). Though this managed approach represents a shift in emphasis from the previous reliance on "responsive mode" funding (Hayter 2003) the overall budget of the *Nanoscience Through Engineering to Application* represents only a fraction of current UK funding in nanotechnology related research.

[6] A similar process was also carried out on stem cell research, incorporating qualitative public engagement research into research planning on Stem Cell Research (Bhattachary 2008).

> The champion will help to identify the specific areas of focus for the programme, with the research using a "grand challenge" approach (ibid.: 21).

The need identified here is for a more coordinated approach to supporting research in nanotechnology, including a "champion" to help industrial pull-through of academic research, more explicit partnering with the Technology Strategy Board and the identification grand challenges for the constitution of future programmatic research fields. Significantly the "Nanotechnology for Healthcare" grand challenge was developed through a three-stage consultation which included: web based consultation, a "town meeting" with members of the research community and a two stage public dialogue conducted by the market research firm BMRM (Bhattachary et al. 2008). As such the approach taken demonstrates the an attempt to coordinate "application focused" research through the incorporation of public opinion and sentiment into research planning. Structured over a two-stage process the public consultation asked to discuss, compare and debate six possible research priorities within healthcare oriented nanotechnology research:

1. Nanotechnology for Diagnostics
2. Environmental control of pathogens
3. Nanotools for drug discovery
4. Nanotechnology for regenerative medicine
5. Nanotechnology for drug delivery
6. Nanotechnology for combined diagnostics and delivery of therapies or "theranostics"

Conducted over four sites in the UK, and using a mixture of stimulus material, and expert input from both scientists and social scientists, the public participants were asked to rank each of these possible areas of research in terms of their priority. Although the results of this ranking not directly translate into specific framing of the funding call, Jones[7] (2008) reports that:

> The dialogues provided a clear steer about the relative priorities of the six potential application areas of nanotechnology for healthcare. Positive features were found for all six areas, but a clear rank order emerged once all the benefits and concerns had been taken into account. The highest priority was for applications of nanotechnology for the prevention and early diagnosis of disease, with better-targeted drug delivery for serious diseases coming second. The biggest misgivings were reserved for "theranostics" – the idea of combining diagnosis and therapy in a single, automatic device. This was perceived as being potentially disempowering (ibid.: 578).

[7] Prof. Richard Jones was at the time the Senior Strategic Advisor to the EPSRC for Nanotechnology who had presided over the development of the grand challenge call and the interpretation of the results of the public dialogue, and their eventual incorporation into the framing call for research projects.

For Jones the import of this public consultation lay in clear distinction between technologies areas perceived as “empowering” and those perceived as “disempowering”. He goes on to suggest that:

> Fears about disempowerment and a loss of control prompted by the idea of theranostics emerged as an important example of an area where some researchers and the public do not see eye to eye. These issues of control and agency are likely to be important in a number of other potential applications of technology (such as, for example, the promise of autonomous cars) and deserve more general consideration (ibid.: 579).

In this we see not simply the “incorporation” of public opinion into a nanotechnology research programme. Rather we see the couching of the very problem of nanotechnology governance in terms of empowerment and disempowerment. Though the notion of empowerment translates rather diffusely into the final funding mechanism initiated under the Nanotechnology for Healthcare Grand Challenge it does demonstrate the evident transformation in innovation governance. In addition to a policy reflex to demonstrate openness and accountability nanotechnology governance is construed in this case in qualitative terms, through notions of agency, empowerment and disempowerment. In the increasing invocation of “the social” in contemporary innovation governance we also see that governmental technologies have themselves become qualitative.

6 Conclusion: Towards a Notion of Qualitative Governance

How then can we make sense of this interweaving of forms of innovation and deliberative governance in contemporary UK approaches to nanotechnology? How can we understand the *time* of contemporary science policy? That is, what does the nature of contemporary science policy signify about the constitution of the present as a particular modulation of power/knowledge? I have argued here that though the “time of science” is the “time of modernity”, in contemporary scientific governance we are witnessing the emergence of a new settlement at the interface between the rationales and techniques of governing. Though science has provided both the epistemic framework and techniques for advanced liberal governance we see that in the governance of emerging research programmes, such as nanotechnology, governance is re-imagined as “innovation governance”. Based on a range of systems metaphors innovation governance entails the increasingly delegation of governing capacity to non-state bodies, whilst simultaneously entailing a shift in the nature of state-craft itself. Significantly the terms and problematics of governing are imagined in qualitative terms – public enthusiasm, emotions and empowerment.

As stated above, in conceptualising “governing the present” (Rose and Miller 1992) distinguish the rationales of governing from governmental “know-how”.[8] For example, Rose and Miller (1992) insist that notions of quantification and calculation are central to liberal governance and are embodied in a range of “calculative

[8]See also Miller and Rose (2008).

technologies" that have proliferated in modern social life. For Rose and Miller contemporary governing is effectuated by a combination of political rationale and political technologies. The particular modulation of power/knowledge that characterise the present therefore emerge at the interface between the rationales and techniques of governing.

What is significant then about recent developments in scientific governance, particularly concerning nanotechnology, is these notions of "giving account" and the drive toward transparency and objectivity are increasingly addressed through qualitative methods: principally programmes of public engagement and deliberation and recent innovations in soft-regulatory approaches. Augmenting Power's notion of the techniques of audit and accountability, a range of new techniques of public dialogue, engagement and deliberation stand as new mechanisms for "giving account" in complexly governed liberal democracies. Irwin and Michael (2003) notion that an "aspiration to transparency" in manifested in acts and techniques of "enunciation". In this transformation of notions of transparency – from those of audit and accounting to forms of public enunciation – we see a fundamental shift in the public discourse on "accountability" and "responsibility". Similarly, Brown and Michael (2002) the discursive and epistemological character of recent debates concerning biotechnology has become much more explicitly qualitative. They suggest that:

> Modernity counterposed the emotions against rational thought, intuition against explicit evidence, subjectivity against objectivity. What we are seeing in contemporary debates about biotechnology is evidence of a shift in the modern epistemological picture. The language of rationalistic authority is being supplemented (at the very least), it seems, with a language drawn from the naturalistic repertoire of emotions (ibid.: 270).

This conscious calling upon the emotions – and the explicit articulation of the "problem of government" as the "problem of public enthusiasm" and collective sentiment – is again consistent with what Kearnes and Wynne (2007) term a "politics of enthusiasm" and Gottweis (2008) characterises as the shift from modernist to postmodernist forms of state-craft. At the interface between contemporary forms of scientific and deliberative governance we see the emergence of a notion of innovation governance that represents a modulation of contemporary neo-liberal forms of both power and state-craft. This is evident in the summoning of social enthusiasm and broader public sentiment – and the techniques designed to elicit them – that augment the more traditional calculative rationalities of contemporary state-craft.

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Converging Technologies – Diverging Reflexivities? Intellectual Work in Knowledge-Risk-Media-Audit Societies

Sabine Maasen

1 Scaling Down Science, Scaling Up Debate

The technological changes of the present are both complex and most likely far-reaching in their consequences. They thus force us to rethink various issues – among others, the relation of techno-science and society (Gibbons et al. 1994) and, particularly, the role of reflexive activities and institutions accompanying the current shift in this relation. True, scholars dispute whether this shift has involved a radical transition (e.g. Godin 1998, Rip 1997) or just an extension of earlier trends (Weingart 1997). Most of them, however, hold that science has become both more visible and more accountable than ever before.

Perhaps the most significant indicator of the emergence of this new relationship has been the introduction of a formal "ELSI" or "ethical, legal, and social implications" component for scientific funding of key technologies. It has been introduced with the Human Genome Project (HGP), headed by the Department of Energy and the National Institutes of Health in the USA. From the 1990s onwards, the pertinent programs had spent more than US$ 100 million by the end of 2001 (McCain 2002). Ever since "the ELSI acronym has come to stand for the increased participation of "society" in science and also that social science and humanities understandings can be brought to bear on issues of science in society" (Davenport and Leitch 2005: 138). The widely-held understanding is:

> If the knowledge within scientific/industrial communities is not appropriately shared with regulatory agencies, civil society and the public, risk perception/management may not be based on the best available knowledge, innovative opportunities may be lost, and public confidence in transparency and accountability may erode (Policy Brief 2007: 11).

Accordingly, reflexive discourses regularly accompany the emergence of all major key technologies. In fact, they arise ever-earlier and occur in ever-more diversified forms. In the course of this happening, such deliberative discourses assume far more than just a commenting role: they rather shape or co-produce (Callon 1999)

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the technologies in question. While this had been the prime goal when establishing ELSI, it has not yet been studied as a phenomenon *sui generis*. Indeed, as ELSI and related evaluative and reflexive activities acquire a co-productive role in the technologies they reflect upon, they are about to lose their distance and become active players instead. They do so, thus the argument of this volume on the assessment regime of key technologies, by providing and debating ideas that frame the ways in which the key technology in question can be thought of, which, in turn, frame the ways in which this technology can become an object of science (e.g. agenda setting), of politics (e.g. funding priorities), of law (e.g. modalities of regulation), of economics (e.g. product innovation), and so on.

And there is more: Intervention by way of reflection proceeds, to be sure, very indirectly, very polyphonically, yet rarely discursively. These characteristics notwithstanding, the sheer extension and intensification of public reflexivity is indicative of a decisive shift in current intellectuality. While this claim may be surprising for some, there are good reasons to suggest that next to Snow's two cultures of intellectuals (scientific and literary) and Brockman's third culture (public intellectual), there are further cultures of intellectuality emerging. While a fourth culture (if one is at all inclined to label it that way) is connected to so-called ideas-work in contemporary knowledge society, comprising intellectual professions as well as professions of the intellect (see p. xx), I see a fifth culture arising, agoral intellectuality, convening a heterogeneous ensemble of participatory arrangements of deliberating key technologies in the science policy domain. More often than not, the latter are staged enterprises, capturing only some of the attributes of the ancient agora (Vallentin 2002: 1): First, a modern agora provides a forum or space for debate that is open to all citizens. Second, all citizens have the opportunity to actively participate in the debate. Lastly, citizens have the opportunity not only to speak but also to exchange views and challenge each other as they debate issues. Both novel groups of contemporary intellectuals, ideas-workers and agoral intellectuals, to be sure, are heterogeneous groups with different knowledge bases, interests and values. However, they all perform what Thomas Osborne calls intellectual work.

Thus, co-evolving with modern, techno-scientifically based knowledge and risk society, we are witnessing the expansion of intellectual figures (e.g. scientific, literary, public, and agoral intellectual), forms (e.g. from expert statements to participatory arrangements) and forums (e.g. expert panels or blogs). Elaborating an idea by Pierre Bourdieu (1989a), intellectuality today thus presents itself as a "think tank", that is, as highly intensified, diversified, only loosely interconnected, yet ongoing discursive work at framing what an emerging technology is or should be about, and where it is or should be going. NST (Nanoscience and nanotechnology) are a pertinent case for this variegated landscape of intellectual work as it lends itself not only to all sorts of deliberative and regulative practices, even more so as it converges with other (bio-neuro-info-...)technologies, but also to a noticeable amount of speculative activity due to the elusiveness of the overall endeavour.

To begin with, its utter elusiveness (e.g. Schummer 2004: 15) already shows in the fact that the scientific community could not agree but on bare parameters regarding what NST involve: (i) research and technology development at the atomic, molecular or macromolecular levels, in approximately the 1–100 nm range; (ii) creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size; (iii) the ability to control or manipulate on the atomic scale.[1] The crucial issue for all is the novelty and unpredictability of what occurs at this scale as the properties of materials can change in fundamental ways.

Having agreed upon these bare essentials, things rapidly become far less defined. For instance, NST already extend across a huge range of fields, from chemistry, physics, and biology, to medicine, engineering, and computer science. Moreover, working at the nano-scale also requires a high degree of interdisciplinarity. Hence, what is true for key technologies, in general, is especially true for NST: all disciplines are engaged in processes through which not only terminologies, but also identities and agendas, as well as politics, marketing strategies, etc. are being defined, contested, and adapted.

This process is further complicated by the fact that, from their inception, NST have enjoyed lively public debates, more often than not in a bipolar fashion (MacNaghten et al. 2005). For their advocates, NST are seen to have huge economic and social potential, provoking a "new industrial revolution" that will lead to breakthroughs in computer efficiency, pharmaceuticals, nerve and tissue repair, surface coatings, catalysts, sensors, materials, telecommunications, and pollution control (European Commission 2004, House of Commons Science and Technology Committee 2004, Roco and Bainbridge 2001). Research funding for NST is increasing rapidly (Lux Research 2004). At the same time, ethical, social, and environmental concerns that originated with dystopian fears of "grey goo" (Drexler 1986, Joy 2000) have gained attention because of the potential toxicity of nanoparticles and the need for effective regulation (Nature 2003, Royal Society/Royal Academy of Engineering 2004). Nongovernmental organizations (NGOs) as well as Prince Charles have demanded a more precautionary approach (ETC Group 2003, HRH The Prince of Wales 2004).

Given this unruly landscape of nanotechnology – the diversity of research issues, disciplines, actors and institutions involved – it is perhaps a small wonder that the task of reflecting and rethinking the meaning of this key technology for ourselves and society as well as for the science-society relation is highly diversified as well: futurologists, writers, consulting firms, technology assessment, philosophers, think tanks, NGO's, nanoscientists, STS, transhumanists, citizens' juries are all busy in understanding what might happen. They do so by deliberations, prophecies, and regulations. They write reports or pamphlets, they publish brochures or blogs (e.g. Nanopublic 2007), they design video games and nano-images, they build roadmaps and scenarios, they organize panels or public hearings, and they appear in scientific and public media.

While NST are special in the extent and variety by which they have become subject of ongoing deliberation and regulation, it is not at all special with respect to

[1] The definition is that of the National Nanotechnology Initiative: www.nano.gov, (19-05-08).

the general trend of co-governing key innovations by way of intensified intellectual activity. In the latter perspective, NST are but yet another, albeit most telling example. Therefore, instead of discussing NST, the remainder of this article will follow a more general argument; NST as well as the plethora of other key innovation indicate nothing less than a fundamental change in the relation of science and knowledge society. Basically, it is a move toward strengthening their link. This move came about in what I would like to reconstruct as three steps. The following paragraphs will, step-by-step, demonstrate the successive broadening of intellectuality and elaborate on Thomas Osborne's helpful heuristic to analyze contemporary intellectual landscapes in our medialized knowledge and risk societies. The afterword will then link the explosion of intellectual work to another characteristic of modern societies: their being audit societies. In audit societies, working on or with ideas is a means of governing complex and unpredictable technologies, thereby making the latter work.

2 Democratization of Science, Expertise, and Intellectual Activity

As is well known in science-policy circles, the relation of science and society has undergone a few noticeable shifts throughout the past decades. All of these shifts are connected to a notion of democratization. David Guston points out that when it comes to democratization in the realm of science this

> does not mean settling questions about Nature by plebiscite, any more than democratizing politics means setting the prime rate by referendum. What democratization does mean, in science as elsewhere, is creating institutions and practices that fully incorporate principles of accessibility, transparency, and accountability. It means considering the societal outcomes of research at least as attentively as the scientific and technological outputs. It means insisting that in addition to being rigorous, science be popular, relevant, and participatory (Guston 2004).

In idealtypical reconstruction, this general move has come about in three steps, the last one of which we are just entering. Judged from retrospect, these steps can safely be regarded as ever-more refined versions of what democratization in the realm of science is supposed to mean.

At the first stage, we witness what has become known as *democratization of science*. The general democratization, the de-mystification of scientific knowledge and of scientists themselves, and the shift toward new public management have resulted in increasing demands addressing the scientific community. The latter is increasingly held accountable for the public expenditure allocated to it for research. In essence, it means that the promise of the eventual acceptability and utility of knowledge production is no longer taken at face value but has come under much closer scrutiny (Guston and Kenniston 1994). In academic discussion, this has been accompanied by a discussion on the "robustness" of knowledge and on the dispersal of sites of knowledge production outside of the established universities and research institutions (Gibbons et al. 1994, Nowotny et al. 2001).

In a second phase, scientific expertise has come under the influence of a related demand. A general shift is seen to be taking place from a legitimation through knowledge to a legitimation through participation. Participatory mechanisms are meant to foster the acknowledgement of extra-scientific knowledge and values. Hence, in the second stage, we witness a *democratization of expertise* (Maasen and Weingart 2005). As Sheila Jasanoff specifies, science and democratic politics are today joined in three ways that foster the role of citizens:

> First, in processes of social identity-making, including the identity of the citizen as a generator and consumer of knowledge (. . .); second, in the coming together of consumption and citizenship, so that the power of the consumer's purse, knowingly exercised, is produced to promote normative ends; and third, in the work of politically relevant knowledge production, in which citizens play an indispensable role, supplementing the contributions of professional experts (Jasanoff 2004: 91).

What I would like to suggest now, is that we are just entering stage three in altering the relation of science and society: In addition to new modes of knowledge production (*democratization of science*) and extended accountability (*democratization of expertise)* we are currently witnessing the *democratization of intellectual activity*. Like new modes of knowledge production and extended accountability, the diversity of intellectual activity is put into the service of legitimizing science and technology. It is, however, less concerned with the production of technical or scientific knowledge, but rather with the production of reflexive knowledge evaluating and commenting upon the technology in question. In other words: it is about knowledge for orientation. Given that technology projects such as HGP and NST are huge, costly and controversial enterprises, and that neither their factual outcomes nor their long-term effects on society can be predicted, the intensification and extension of deliberative and regulative activities come as no surprise. NST, in particular, seem to evidence that along with the complexity and unpredictability of a technological enterprise reflexive activities intensify and diversify as well.

Indeed, NST have emerged as a key science and technology policy topic, and are expected to pose a number of significant governance challenges and opportunities for a wide range of stakeholders – including government, industry, and the public – in the near future. Establishing appropriate management strategies for governing nanotechnology entails debating diverse issues, such as prioritization of research and development, internationally coordinated risk research strategies, effective oversight mechanisms, commercialization of consumer products, and measures to involve the public and increase trust in government. This is a project that is accomplished at a diversity of sites, using various media, thereby engaging different actors for diverse audiences. NST thus usher in an intensified and diversified intellectual activity, the agenda of which is to democratize complexity and uncertainty, and the hidden agenda of which is to govern complexity and uncertainty, not least by way of actively involving stakeholders as responsible citizen-consumers.

Deliberative-regulatory activities thus are double-faced: They contribute to increasing transparency and participation (democratic aspect), yet they operate as tools for effective governance of complex technologies as well (managerial aspect). Hence, they co-produce NST by marking out spaces of what to do (in research, in politics, ...) and by establishing procedures of how to do it (by marketing strategies, by internationally coordinated regulation, but also by participatory processes, ethics councils, etc.). Knowledge for orientation thus emerges as necessary attendant phenomenon as well as a constitutive element governing techno-scientifically based societies.

3 Intellectual Activity Today

Recently, Petra Schaper-Rinkel (2006) claimed that policy-making can be described as making an attempt to establish a situation of predictability within a field of uncertainty and unpredictability. By analogy, this holds for ELSI activities as well as they are meant to make sense of complex phenomena, especially by marking out spaces of acceptability, the most important contemporary vehicle being public reflection, often assisted or staged by experts and/or science political organizations. This, in my view, is intellectual activity, if intellectuality is understood in the broadest sense as an elaboration of ideas. In the era of extended expertise, intellectuality is likely to be a public or agoral (or professional, see p. xx) enterprise. Moreover, ideas are likely to be largely based upon techno-scientific knowledge in order to defend or contest their fruitfulness. The prime objective of agoral intellectuality, however, is to provide what any type of intellectuality is essentially about: providing orienting frameworks of what is or should be happening on whatever knowledge base is deemed appropriate (scientific, philosophical, literary, common sense, etc.).

At this point, it is important to note that intellectual activity working on or with ideas in order to provide orientation is not ornamental to but rather a necessary attendant phenomenon of contemporary knowledge society. Knowledge society today, thus the general consensus, is both widely based upon and utterly threatened by science and technology (Weingart 2001, Stehr 2005): On the one hand, the degree of innovation and specialization allows for a hitherto unknown extension of options for action in ever-more domains of society. On the other hand, however, after decades of huge investment in science, as the expected producer of endless technical fixes to societal problems and risks, science and technology have come to be seen as risky themselves. The label risk society highlights the adverse consequences of technology (Beck 1992) and has swept across knowledge societies since the 1990s. Efforts at democratizing science and expertise have taken the shape of two prominent reactions to those opposite trends. Reaction one: keep engaged in science, yet engage society in science. Reaction two: keep engaged in knowledge production, yet engage not only in techno-scientific knowledge, but in knowledge for orientation as well.

The latter appeal is again not ornamental to but rather a necessary attendant phenomenon of contemporary knowledge society. Precisely the highly specialized, controversial character and unpredictability of techno-scientific knowledge has led to the proliferation and urgency of knowledge for orientation. While knowledge for orientation comes in various forms and fashions, from various speakers and for various audiences, it mostly comes *as knowledge*. Ethics, transhumanism, futurologists, STS, regulators, market analysts – they all attempt at sorting out what is happening and what "we," "they", or certain groups can or should do on the basis of knowledge, thereby producing knowledge themselves. Even when it comes to debating values and interests, it occurs by way of presenting and defending them as assertions, hence, as knowledge.

In a functionally differentiated society this diversity allows to include many different modes and styles of sense-making (pertaining to law, politics, media, ...) with different levels of engagement and accessibility for the general public. That is to say, the very nature of techno-scientific innovation (specialization, legitimation) leads to the urgent quest for orientation. In a highly differentiated society this quest is manifold: from market analysis to foresight studies, from NGO protest to transhumanist visions, from expert panels in policy circles to science fiction, from think tanks to upstream engagement – they all join in, as especially the case of NST amply demonstrates (see the articles in this volume).

4 Intellectuality, Cultures One to Three

Should this really be called "intellectual activity"? Without deeper reflection, intellectuality makes us think of "the intellectual," hence, seems to be reserved for the writer, the scholar, the philosopher, the charismatic person, the visionary, the "bearer of universal values" who, in a grand gesture, provides us with interpretations, meaning, and direction. Indeed, what is commonly meant by "intellectuals" are historically formed, specialized professional ranks identified on the basis of their position within hierarchical social relations. However, as I would like to maintain, we are currently witnessing a dramatic shift in the practice of intellectual activity – a shift that again is an attendant phenomenon of contemporary knowledge societies.

Intellectuals have long since been the object of closer inspection, more often than not guided by the question whether or not they form a homogeneous group. Early approaches were preoccupied with the question of whether or not intellectuals form a class or culture: one such approach, pioneered by Antonio Gramsci, saw intellectuals as bound to their class of origin; a second one, associated with Karl Mannheim, treated intellectuals as classless; a third, put forward by Julien Benda, suggested that intellectuals form a class in themselves (for an overview see Kurzman and Owens 2002). In 1959, C.P. Snow portrayed twentieth-century British and American intelligentsia as stratified into two "cultures", literary and scientific (Snow 1936/1993).

The description of the intellectual as a person who identifies with a subject "endowed with a universal value," was effectively buried in an essay by Jean-François Lyotard (Lyotard 1983). Herein, Lyotard argues that the grand narratives of emancipation and enlightenment, which had previously legitimated the idea of the intellectual, have undergone a process of fragmentation and decline in the "post-modern" world of the late twentieth century. As a result, there is no "universal subject-victim" anymore with which the intellectual can identify (e.g. the proletariat). The notion of the intellectual can consequently no longer be sustained. And, indeed, changes are seen to have occurred in society in the second half of the century which have rendered the idea of the intellectual as the bearer of universal values, the representative of truth and justice for all, increasingly difficult to maintain.

This conforms perfectly to Foucault's notion of the specific intellectual who "takes power" within "specific sectors, at the precise points where their own conditions of life and work situate them (housing, the hospital, the asylum, laboratory, the university, family and sexual relations)" (Foucault 1981: 126). "In this sense theory does not express, translate, or serve to apply practice: it is practice. But it is local and regional.... and not totalizing. ... It is not to 'awaken consciousness'" (Foucault 1981: 208). Intellectual work is instead now "an activity conducted alongside those who struggle for power, rather than consisting simply of their illumination from a safe distance" (Foucault 1981: 208); it operates at a local level, in immediate and concrete situations, and in particular institutions.

In the 1990s, John Brockman painted a similar picture – elaborating on Snow's two cultures by adding a third one: It

> consists only of those scientists and others who reside in the empirical world, who through their work and expository writing are taking the place of the traditional intellectuals and media in rendering visible the deeper meanings of our lives, redefining who and what we are in terms of our own species, the planet, and the cosmos (Brockman 1995: 16).

He noticed "a great hunger for new and important ideas," an "increasing willingness of citizens to educate themselves" (Brockman 1995: 18) as well as a growing media attention for scientific topics, all of which have led to the emergence of a new group of intellectuals, complementing literary and scientific intellectuals. Brockman calls them "new public intellectuals".

Moreover, as Douglas Kellner points out, the political battles of the future will not only involve a wider range of actors (public intellectuals) but will also occur in new public spheres and be increasingly impacted by media, computer and information technologies. Hence,

> to be an intellectual today involves use of the most advanced forces of production to develop and circulate ideas, to do research and involve oneself in political debate and discussion, and to intervene in the new public spheres produced by broadcasting and computing technologies. New public intellectuals should attempt to develop strategies that will use these technologies to attack domination and to promote education, democracy, and political struggle – or whatever goals are normatively posited as desirable to attain. There is thus an intrinsic connection in this argument between the fate of intellectuals and the forces of production which, as always, can be used for conservative or progressive ends (Kellner, no date).

Summarizing, especially since we have come to label contemporary Western society as both knowledge and risk society, we also observe a drift towards an enforced consumption of ideas, that is, of knowledge for orientation. In the course of this happening, intellectual work engages more actors, public intellectuals trying to provide knowledge for orientation in public media of all sorts. Interestingly enough, however, the very pursuit of knowledge for orientation, meant to counter the unpredictability and controversial character of complex socio-technical achievements (or promises thereof), are also increasingly regarded with distrust, notably when the scientists themselves provide the service.

> There is a wide-spread suspicion of scientific authority, and people who extend the boundaries of scientific knowledge are frequently accused of "playing God". Such accusations are not only leveled at individuals involved in genetic research or genetic therapies, but also at those attempting to develop our understanding of nanotechnology and of human health in general (Furedi 2004: 173).

Public intellectuals, hence, are confronted with ambivalent responses as well – all accounts (be they moderate or enthused) are regarded as guided by (vested) interests (see e.g. Jay Kurzweil) and open to serious debate, at least. Indeed, third culture scientists market their ideas directly to citizen-consumers engendering support to help secure patronage on many different levels: public interest groups, foundations, university and college administrators, government, agencies, and policy makers. Science has its lobbyists and third culture scientists contribute in their own way toward popularization of their projects.

The paradox is striking: an increasing demand for scientific evidence, the flourishing of popular science books, massive investment in education, universities, and private research co-exists with a decrease of trust in specialized knowledge. And, indeed, while there have always been individuals and institutions guiding individuals or collectives, there seems to be an ever-growing need for advice, expertise, and intellectual sense-making. Offers abound: to counsel and to be counselled seems to be the order of the day, for individuals and institutions alike (Maasen 2004, Maasen and Sutter 2007). Some authors even suggest talking about today's societies as "advisory societies" (*Beratungsgesellschaften*; see Fuchs 1994a, 1994b). The paradox vanishes, though, once looked at from a different angle. Advice, expertise, and intellectual work directly respond to a key feature of knowledge society: the increase of reflexivity. The rise of sense-making co-evolves vis-à-vis highly specialized, complex and unpredictable knowledge-based societal developments (e.g., Weingart 2001). The expansion of sense-making activities is marked by a move toward democratization as well: by involving ever-more players, sites and media. It is within this development that the role of intellectual work has to be re-thought as well.

5 Intellectuality, Fourth and Fifth Culture

Bourdieu's alternative approach was to abandon the intellectual as a figure and rather describe the properties of the "intellectual field" as a whole (Bourdieu 1989a, 1989b, 1990). From this angle, other properties of intellectual activity come to the fore that seemed troubling before. Most importantly, the intellectual field is hardly unanimous and consensual, as it comprises numerous subfields, strict hierarchies, and virulent conflict – indeed, Bourdieu acknowledged "the tendency inscribed in the very logic of the intellectual field towards division and particularism" (Bourdieu 1989b: 109). At the same time, however, Bourdieu's concept of a field also stressed the possibility that (some) actors in the field may share (some) interests, however grave their disagreements. In place of a definition, Bourdieu gave the analogy of a game:

> Players agree, by the mere fact of playing, and not by way of a "contract," that the game is worth playing, that it is "worth the candle," and this *collusion* is the very basis of their competition (Bourdieu and Wacquant 1992: 98).

In this view, what is true for science is true for intellectual activity of public intellectuals, too. It is also marked by competition and controversy – this time, in the pursuit of producing reflexive knowledge.

While opening up intellectual activity for conflict and discourse, the notion of an intellectual field is still confined to the higher intelligentsia. Despite all talk about Mode 2 concerning actual forms of knowledge production, which is precisely about "a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localised context" (Gibbons et al. 1994: 3), when it comes to intellectual work, the sociology of knowledge still sticks to the notion of the traditional intellectual, if in terms of a field rather than a figure. However, given modern medialized knowledge society and given the ubiquitous call for "social robustness" of science and technology (Nowotny et al. 2001), this notion is severely challenged. On the one hand, ideas work has come to permeate knowledge society, on the other, participatory arrangements provoke agoral forms of intellectual work.

Ideas-work: In knowledge society, there is the evolving group of so-called knowledge workers, pertaining to the growing workforce of those

> who are members of "intellectual professions" (doctors, lawyers, engineers) or the "professions of the intellect" (the more pedestrian ranks of scientists, academics, not to mention the myriad research and knowledge workers in industry and business (Osborne 2004: 436).

For this group, knowledge is an "immediately productive force" (Stehr 1994: 185), they include (new) media workers, as well as activities concerned with marketing, consultancy and modern business. By sketching this workforce working on and with ideas, Osborne, too, arrives at the conclusion that perhaps "this has to do with something like the "democratization" of ideas-work; ideas no longer being the property of the few, such that it becomes almost everyone's responsibility to create ideas" (Osborne 2004: 436).

Agoral intellectuality: In this domain, participatory arrangements emerge, ranging from citizen juries (e.g. NanoJury) to participatory expert panels, on national or European level, operating face-to-face or in virtuality, yet all ultimately resting on the Greek concept of agora. In Greek, agora means to gather, to congregate, to assemble and is also related to the verb *agoreuo*, which means to deliver a speech in a public gathering, assembly or court. The "Greek agora, or market place, was where citizens met to discuss and debate topics of importance ... It was the site of the daily business of everyday life, but it was also the place where philosophers debated ethics" (Tidwell 1999: 6). From the descriptions of the ancient agora, agoral intellectuality is characterized by a forum or space for debate that is open to all citizens, by the opportunity for citizens to actively participate in the debate as well as to exchange and challenge alternative, or even opposing ideas about a technology in question (Davenport and Leitch 2005). Participatory arrangements thus described also contribute to extending the meaning and forms of intellectuality today. Again it is about democratizing this activity, this time to citizen-consumers in order to articulate and debate ideas concerning the *what*, the *how* and the *to what end* of a technology.

These two developments, the emergence of ideas-work as well as of agoral intellectuality, to be sure, do not leave the nature of ideas, as a basic element of intellectuality, unaffected: under these conditions, ideas become "local, strategic, sagittal and fleeting ... mobile and 'vehicular' rather than oracular" (Osborne 2004: 436). From a constructivist perspective on ideas, this is not at all surprising. Ultimately, ideas are meant to *account for* the problem at hand, whether it concerns a market analysis of a future nanoproduct, a risk analysis of a certain nanotechnology or an ethical deliberation on fairness in access to achievements in NST. That is to say, a constructivist perspective "views the nature of ideas as radically open-ended. Ideas are constituted in and through the process of their articulation and representation" (Woolgar 2004: 452). Working on and with ideas, in our medialized knowledge and risk society, is no longer confined to literary, scientific or public intellectual but opens up to novel "cultures," either professional or agoral.

While it may be too early to assign ideas-work and agoral intellectuality the status of specific cultures of intellectuality, the mere idea (sic!) is meant to incite a second thought about the status of intellectuality today. Given this ongoing trend toward intellectuality as a highly specialized, partly competitive activity, albeit commonly guided by an attempt at producing knowledge for orientation, this move reveals its double edge: While it certainly is a move toward democratizing the science-society relation, it is also a move toward an audit-culture, this time presenting itself as governance by ideas. On a more general plane, the argument is that the function of intellectuality today can only be sufficiently described when it acknowledges all types of intellectual cultures: scientists, writers, ideas-workers, public and agoral intellectuals. What is more, fixating the landscape of intellectual activity concerning a given technology at a given point in time requires sorting out such landscapes of intellectual work along an enriched set of criteria. Thomas Osborne recently provided such a heuristic.

6 The Intellectual Landscape Today: A Heuristic

Osborne suggested differentiating the "epistemic forms that are drawn by different actors or even by the same individuals at different times and in different contexts to legitimate or even just make sense of particular kinds of intellectual conduct" (Osborne 2004: 437). More specifically, each form can be described along four dimensions: issues of substance, issues of rationale, issues of stylization and issues of strategy.

1. The "substance": a sense of the *what* of intellectual work: that is a conception of intellectual work as the production of scientific truths or of interpretations of the world or of big ideas or whatever.
2. The "rationale": a sense of the *why* of the intellectual work as a particular kind of obligation, for instance, the pursuit of scientific truth as the only kind of truth, the pursuit of ideas to innovate, and so on.
3. The ethos of "stylization": a sense of the *how* of intellectual work, that is, the particular kind of ethos that the form will embody, the intellectual as a "man of truth", as a revolutionary activist, and so on.
4. "Strategy": a sense of the desired *impacts* of the intellectual work; the way in which the intellectual work is supposed to impact upon the outside world, on the present and on the future; science as the domination of nature, critical intellectual work as the pursuit of enlightenment (Osborne 2004: 437)

Based upon this scheme, Osborne differentiates four main types of intellectuals: the legislator and the interpreter, known from work by Zygmunt Bauman (1987), as well as the expert and the mediator (Osborne 2004: 438ff.).

	legislator	interpreter	expert	mediator
substance	Politico-cultural programs	Culture as text	Factual knowledge	Ideas
rationale	Cultural order	Translation between different cultural frames/groups	Truth: autonomous & powerful	Culture of innovation
stylization	Master reality by abstractions	Civilised conversation	Virtuoso of detail, (advisor)	Trading ideas among heterogeneous groups
strategy	Socio-political order	Mutual recognition/ Understanding	Information for policy	Creative culture of ideas (non-ideological)

This, in my view, is not so much to be equated with persons as with types of intellectual activities. In this view, it is less interesting to know who acts in which way, e.g. the philosopher and ethicist as "legislators" or the visible scientist (Goodell 1977) as "expert" – rather, to repeat, this heuristic is meant to depict *different types of intellectual conduct.* These may be pursued by people or by organizations, and they may be engrained in corresponding procedures as well.

At the same time, however, it is important to highlight the fourth type in Osborne's scheme, the mediator. I agree with Osborne who considers this type to be becoming the most prominent one, even if it bears elements of each of the other types:

> If the legislator has ideas, they are universal not discrete; if the expert has ideas these are rigorously tied to the state of things (the specialist's ideas mirror the world as it is), if the interpreter has ideas, then these are ideas of others; but the mediators very ontology is to

> facilitate an idea . . .the mediator needs others and produces (ideas) in relation to others – hence mediation is integrally public, collective and interactive (Osborne 2004: 443).

The type is not only indicative of but also highly functional for embedding knowledge and technology in our society, which is not only a knowledge and risk society but also a highly medialized society. Small wonder, then, that the mediator type, above all represented by professional and agoral intellectual work, assumes the role of an overarching model of producing, disseminating and debating ideas, to which all other types of intellectuality (sometimes more, sometimes less) increasingly refer. Intellectuality is about to become diagnostic instead of prophetic, its boon and bane being the enormous variegation of diagnostic activities, meandering between mutual ignorance and controversy, and inevitably valid in the short-term and for specific problems only.

Making use of Osborne's heuristic, the argument can be specified as follows. The discursive formation of democratized intellectual work is not about dogmas or ideologies. We rather see a shift from "big concepts" such as liberty, capitalism, revolution, etc. (Bourdieu 2000: 1) to practicable, marketable, usable ideas. This is the *substance* of the contemporary formation of intellectuality. It does, to be sure, not at all rule out charismatic intellectuals from appearing, but they co-exist and partly compete with other modes and positions – the expert, the stakeholder, the futurologist, the designer of nanopictures. As to the *rationale* of the contemporary formation of intellectuality, we see a shift from a monopoly of science-based expertise toward innovation and intellectual creativity among experts and many additional actors operating on widely different schemes and using various means of communication. Regarding the *stylization* of the contemporary formation of intellectuality, we see a shift towards exchanging ideas and creating something new among different groups in very different settings for entirely different purposes: economic (market analyses), political (governance), entertainment (video games), edutainment (NanoConvention, NanoMessenger). Finally, concerning the *strategy* of the contemporary formation of intellectuality, we see "a shift from the predictive and normative frameworks . . . to the more provisional and diagnostic concepts" (Osborne 2004: 443). This multiplicity of diagnostic work conforms not only to the diversity of research going on, but also to possible interactions as envisioned in the concept of converging technologies.

Stretching Pierre Bourdieu's ideas a bit further, we may conceive of this discursive formation of democratized intellectual activity as a *think tank* of people, institutions and settings all engaged in making sense of the unpredictable. While their activity is not all coordinated, yet highly visible not least due to modern media society, on a discursive level this collective practice shows two distinct achievements. On the one hand, intellectual activity has become specific and thus meets specified needs for orientation; on the other hand, taken together, the sheer amount and massiveness of these activities mark out spaces of perception, thought and action. Put differently, they mark out spaces of attention and acceptability within which deliberation and regulation may seem desirable and/or do-able. It is in this very fundamental way that this new style of intellectuality intervenes: with many voices, without a claim to coherence or sustainability. It creates a, albeit somewhat wobbly, sphere of things to talk about – online with techno-scientific developments or even preceding them.

This new style of intellectuality corresponds to a society which articulates an increased demand for meaningful communication about science and technology; it also corresponds to a society in which this demand has become highly differentiated; and it corresponds to a medialized society: intellectual activity has largely become public, collective, and interactive. To be sure, it also responds to academia becoming more and more integrated into the market and the instrumental reason of corporate pragmatism and professionalization in which efficiency and technocratic specialization become the privileged standards of value. It also responds to citizen-consumers calling for increased accountability of science and technology, while, at the same time, rejecting grand prophecies, be they dystopian or utopian. This is not to bid farewell to big ideas altogether, yet the question is: *for whom, in which way, what for, how long, in contrast to or in line with which other ideas . . .?*

7 Afterword: Ideas in Knowledge, Risk, Media, Audit Society

In all domains the complexity of knowledge and the plurality of norms not only give rise to risk and uncertainty but also evoke responses that are meant to steer and stabilize the different domains in a highly decentralized fashion. Hence, as the sites of producing and processing knowledge multiply in societies based upon knowledge and marked by risk, the sites (i.e., institutions), media (real or virtual) and procedures (formal or informal, individual or collective) of producing knowledge for orientation diversify as well. In these, extensively medialized, societies we observe a shift toward "vehicular ideas" (McLennan 2004) – all of which are embedded in trends toward democratizing intellectual work but also toward what may be called "democratizing auditing".

As Dominique Pestre has noted, organized "around words or expressions like governance, responsibility, transparency, accountability, sustainability, precaution, consensus, ethics, risk society, knowledge society, civil society, a new discursive order has emerged and spread" (Pestre 2007) – the order is one that responds to a society that has (allegedly) lost trust in its science and therefore takes measures to increase transparency and control. While each individual means of building up trust (again) can hardly be objected, it is characterized by a double face: the call for, e.g., transparency is, at the same time, a call for auditing – by more people, more institutions and by adding different means and procedures. Seen from this perspective, monitoring and governance by intellectual work is inevitably entrenched in forms of audit. So are we who participate in one or the other type of intellectual activity.

Michael Power pointed out that

> audits "make things auditable" (Power 1996) because they require individuals and organizations to be made visible in a manner which conforms to the audit process. This means that auditing actively stimulates the development of systems and the related forms of accounting for performance which make the control of control possible (Power 1997: 10).

In an analogous fashion, intellectual work operates by marking out landscapes of attention and acceptability which, albeit in a loose manner, serve as guidelines for deliberating, assessing and thus "making" an emerging technology.

> If ideas are understood as constituted in and through their articulation and use, we can see more clearly their treatment in contemporary regimes of accountability. It is not simply that pre-existing ideas are assessed and evaluated. Instead, audit cultures re-define and re-establish the very nature of ideas and their values. They do so through various processes of stripping, decontextualization and abstraction ... and through the introduction and use of technologies of measurement (Woolgar 2004: 452).

Intellectual work thus becomes part and parcel of governing complex technologies, may it appear as ELSI, futurology, or a blog hosted by interested citizens. In intellectual work as elsewhere "we observe, in short, the continual reflexive management of social organization boundaries and boundary relation" (Woolgar 2004: 453). Here, I fully emphasize Matthew Kearnes argument (this volume) that current proposals for developing accountability, transparency and credibility can be conceived of as techniques in the government of technoscience which modulate (yet, are not inconsistent with and thus further) liberal governance. As technology developments become more complex, intellectual activity not only diversifies but also participates in making it work. In so doing, intellectual work is a veritable instance of "government without government" (Rose and Miller 1992). Although the empirical execution of agoral intellectuality may be lamentable (see e.g. Davenport and Leich), its impact by closer inspection deplorable, and both extension and intensification of agoral intellectuality considered as nothing but staged talk – from a discourse analytical perspective, there is no such thing as "sheer talk" when it comes to *ELSIfication et al.* in the midst of audit societies. By way of diversifying intellectual work, society, that is, scientists, entrepreneurs, citizens, consumers, politicians ..., hence, we all become involved in governing an emerging technology – democratic values and requirements of control happily united in producing "vehicular ideas."

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