Toward Anticipatory Governance: The Experience with Nanotechnology

Risto Karinen
David H. Guston[1]

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 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 for-

[1] Support for this chapter provided in part by the US National Science Foundation cooperative agreement # 0531194. Any findings, conclusions, or opinions are those of the authors and do not necessarily represent the National Science Foundation.

mulations 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 forthcoming, 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.[2] Increasing numbers of consumer products utilizing nanotechnologies have emerged; as of October 2008, more than 500 nanotechnology-based products or product lines were available in the consumer market.[3]

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 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.

[2] http://www.nano.gov/html/about/funding.html, (13-08-08).

[3] According to the Wilson Center Project on Emerging Nanotechnologies. http://www.nanotechproject.org/44, (13-08-08).

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.[4] 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. 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.

[4] 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).

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,[5] 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 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

[5] 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.

network in 2005.[6] 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.[7] 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.

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.[8] 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.

---

[6] 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.

[7] 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, (27-01-08).

[8] See National Nanotechnology Initiative: FY 2009 Budget and Highlights, http://www.nano.gov/NNI_FY09_budget_summary.pdf, (13-08-08).

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.[9] 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 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.[10]

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:

[9] 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).

[10] 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.

> "*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.[11]

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 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" (Spi-

[11] Personal communication with the authors: 2 January 2008.

nardi and Williams 2005: 61). Roadmaps can also be understood as scripts staging the scene and setting the tempo of production (Selin 2007).[12]

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,

[12] For more on roadmaps in nanotechnology, see Johnson (2007)

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 2008), 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,[13] 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).

8 REFERENCES

Anbari, F. T. and Y. H. Kwak (2004), 'Success factors in managing six sigma projects', *Presented at the Project Management Research Institute Conference,* July, London. http://home.gwu.edu/~kwak/Six_Sigma_PMI_2004.pdf, (30-12-07).

Anderson, B. (2007), 'Hope for nanotechnology: anticipatory knowledge and the governance of affect', *Area* **39**(2): 156-165.

Anderson, B., M. Kearnes, and R. Doubleday (2007), 'Geographies of nano-technoscience', *Area* **39**(2): 139-142.

Baechler, G. (2001), 'Conflict transformation through state reform' in *Berghof Handbook for Conflict Transformation.* http://www.berghof-handbook.net/uploads/download/baechler_handbook.pdf, (30-12-07).

Barben, D. (2006), 'From 'acceptance' to 'acceptance politics': Towards an epistemological shift in the analysis of public understanding of science and technology', *Presented at the annual meeting of the Science and Democracy Network.*

Barben, D., E. Fisher, C. Selin, and D.H. Guston (2008), 'Anticipatory governance of nanotechnology: foresight, engagement, and integration' in E. J. Hackett, O. Amsterdamska, M. Lynch, and Judy Wajcman (eds.), The Handbook of Science and *Technology Studies,* Third Edition, Cambridge (Mass.): MIT Press, pp. 979-1000.

---

[13] 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. The findings were not yet available for this chapter (Selin in preparation).

Bennett, I. and D. Sarewitz (2006), 'Too little, too late?: research policies on the societal implications of nanotechnology in the United States', *Science as Culture* **15**(4): 309-325.

Biermann, F. and K. Dingwerth (2004), 'Global environmental change and the nation state', *Global Environmental Politics* **4**(1): 1-22.

Bimber, B. (1996), *The politics of expertise in Congress: The rise and fall of the Office of Technology Assessment*, Albany: State University of New York Press.

Bimber, B. and D. H. Guston (eds.), (1997), 'The end of OTA and the future of technology assessment', *a special issue of Technological Forecasting & Social Change* **54**(1-2).

Blackler, F. (1995), 'Knowledge, knowledge work and organizations: an overview and interpretation', *Organizational Studies* **16**(6): 1021-1046.

Brown, N., B. Rappert, and A. Webster (2000), *Contested futures: A sociology of prospective techno-science*, Aldershot: Ashgate Publishing.

Berne, R. (2006), *Nanotalk: Conversations with scientists and engineers about ethics, meaning, and belief in the development of nanotechnology*, Mahwah (NJ): Lawrence Earlbaum Associates, Publishers.

Bush, V. (1945), *Science The Endless Frontier: A Report to the President*, reprinted by the National Science Foundation (1990): Washington, DC.

Caldwell, L. (2002), 'Public Administration – The New Generation' in E. Vigoda (ed.), *Public Administration: An Interdisciplinary Critical Analysis*, New York: Marcel Dekker Inc., pp. 151-76.

Cook-Deegan, R. (1994), *The Gene Wars. Science, Politics, and the Human Genome*, New York: WW Norton & Company.

Doubleday, R. (2007), 'Risk, public engagement and reflexivity: Alternative framings of the public dimensions of nanotechnology', *Health, Risk and Society* **9**(2): 211-27.

Drexler. E. (1986), *Engines of creation: the coming era of nanotechnology*, New York: Anchor Books.

Eigler, D.M. and E.K. Schweizer (1990), 'Positioning single atoms with a scanning tunnelling microscope', *Nature* **344**(6266): 524-526.

Feltmate, B.W. (1993), *Barriers to Achieving Sustainable Development in North America: Historical Naivety, Media Limitations, and non-Anticipatory Governance*, Ottawa: National Library of Canada.

Feynman, R. (1959), 'There's plenty of room at the bottom', *A talk given at the annual meeting of the American Physical Society at the California Institute of Technology*, 29 December.

Fisher, E. and R. Mahajan (2006), 'Nanotechnology legislation: contradictory intent?: US federal legislation on integrating societal concerns into nanotechnology research and development', *Science and Public Policy* **33**(1): 5-16.

Gilmour, J. B. (1995), *Strategic disagreement: Stalemate in American politics*. Pittsburgh: University of Pittsburgh Press.

Grin, J., H. van de Graaf, and R. Hoppe (1997), *Technology Assessment through Interaction: A guide*, Den Haag: Rathenau Instituut.

Gupta, A. (2001), *Searching for Shared Norms: Global Anticipatory Governance of Biotechnology*, Doctoral dissertation, Yale University.

Gupta, A. (2003), 'The role of knowledge flows in bridging North-South technical divides' in *Knowledge Flows and Knowledge Collectives: Understanding the Roles of Science and Technology Policy in Development*, Washington, DC: Center for Science, Policy and Outcomes, pp. 99-130. http://www.insme.it/documenti/CSPO_Rockefeller_Vol1.pdf#page=99, (30-12-07).

Gupta, A. (2004), 'When global is local: negotiating safe use of biotechnology' in S. Jasanoff and M.L. Martello, *Earthly Politics: Local and Global in Environmental Governance*, Cambridge (Mass.): MIT Press, pp. 127-48.

Gupta, A. (2006), 'Problem framing in assessment processes: the case of biosafety' in R.B. Mitchell, *Global Environmental Assessments: Information and Influence*, Cambridge (Mass.): MIT Press, pp. 57-86.

Guston, D. H. (2007), 'The Center for Nanotechnology in Society at Arizona State University and the Prospects for Anticipatory Governance', in N. M. de S. Cameron and M. E. Mitchell (eds.), *Nanoscale: Issues and perspectives for the nano century*, Hoboken (NJ): Wiley, pp. 3377-92.

Guston, D. H. and D. Sarewitz (2002), 'Real-time technology assessment', *Technology in Society* **24**(1-2): 93-109.

Hartzog, P.B. (2004), *21st Century Governance as a Complex Adaptive System*. http://panarchy.com/Members/PaulBHartzog/Papers/21st%20Century%20Governance.pdf, (30-12-07).

IRGC (2006), '*Nanotechnology Risk Governance*', White Paper 2, (authors: Renn, O. and M. Roco), Geneva.

Johnson, A. (2007), 'Top-down science: The role of roadmaps in the development of nanotechnology', at Chemical Heritage Foundation-Wharton Symposium on Nanotechnology, Philadelphia.

Joy, B. (2000), 'Why the future doesn't need us', *Wired* 8(4): 238-262.

Kearnes, M. and P. MacNaughten (2006), 'Introduction: (re)imagining nanotechnology', *Science as Culture* **15**(4): 279-290.

Kim, E. S. (forthcoming), 'Directed evolution: An historical exploration into an evolutionary experimental system of nanobiotechnology, 1965-2006', *Minerva*.

Kingdon, J.W. (1995), *Agendas, alternatives, and public policies*, 2nd edition, New York: Harper Collins.

Kuzma, J. (2007), 'Oversight Policy for Agrifood Nanotechnology: Bridging Science, Risk and Society', *Presented at the annual meeting of the American Association for the Advancement of Science*, San Francisco.

Lindblom, C.E. (1959), 'The science of muddling through', *Public Administration Review* **19**(2): 59-79.

Lyall, C. and J. Tait (eds.), (2005), *New modes of governance: developing an integrated policy approach to science, technology, risk and the environment*, Aldershot: Ashgate.

MacNaughten, P., M.B. Kearnes, and B. Wynne (2005), 'Nanotechnology, governance, and public deliberation: what role for the social sciences?', *Science Communication* **27**(2): 268-291.

Maynard, A. (2006), 'Nanotechnology: the next big thing, or much ado about nothing?', *Annals of Occupational Hygiene Advance Access*, October: 1-12.

McCray, W. P. (2005), 'Will small be beautiful? Making policies for our nanotech future', *History and Technology* **21**(2): 177-203.

Mendoza, M. L. and E. T. Gonzalez (2002), 'Between good management and good governance: the case of the Phillipine quality award for the public sector', *Presented at Asia Pacific Conference on Governance: From Crisis to Reform.* http://www.goodgovernance-bappenas.go.id/publikasi_CD/cd_penerapan/ref_cd_penerapan/download/unfolder/GOOD MGMT%20(Between%20Good%20Management%20and%20Good%20Governance).pdf, (30-12-07).

Mody, C. (2006), 'Corporations, universities, and instrumental communities: commercializing probe microscopy, 1981-1996', *Technology and Culture* 47(1):56-80.

National Academy of Sciences (NAS) (1969), 'Technology: processes of assessment and choice', *Committee on Science and Public Policy*, Washington, D.C.: National Academy Press.

Roco, M. (2004), 'The US national nanotechnology initiative after 3 years (2001-2003)', *Journal of Nanoparticle Research* **6**(1): 1-10.

Roco, M. (2006), 'Keynote Address', *Presented at the Centre on Nanotechnology and Society First Annual Nano-Policy Conference*, National Press Club, Washington, DC.

Sarewitz, D. and D. H. Guston (2005), 'New frontiers of technology assessment', Presented at *Nanotechnology: Science, economy, society*, Marburg, Germany.

Sarewitz, D. and N. Woodhouse (2004), 'Small is powerful' in A. Lightman, D. Sarewitz, C. Desser (eds.), *Living with the genie: essays on technology and the quest for human mastery*, Washington D.C.: Island Press, pp. 63-84.

Schot, J. and A. Rip (1997), 'The past and the future of Constructive Technology Assessment', *Technological Forecasting and Social Change* **54**(2): 251-268.

Schwartz, P. (1991), *The art of the long view: the path to strategic insight for yourself and your company*, New York: Doubleday/Currency.

Sclove, R.E. (1995), *Democracy and technology*, New York: The Guilford Press.

Selin, C. (2007), 'Expectations and the emergence of nanotechnology', *Science, Technology & Human Values* **32**(2): 196-220.

Selin, C. (forthcoming), 'Negotiating plausibility: intervening in the future of nanotechnology', *Science and Engineering Ethics.*

Selin, C. (2008), *The future of medical diagnostics*, Centre for Nanotechnology in Society at Arizona State University working paper.

Selin, C. (in preparation), *The future of anticipatory governance*, Centre for Nanotechnology in Society at Arizona State University working paper.

Smits R., A. Leyten, and P. den Hertog (1995), 'Technology assessment and technology policy in Europe: new concepts, new goals, new infrastructures', *Policy Sciences* **28**(3): 271-299.

Smits, R., R. van Merkerk, D. Guston, and D. Sarewitz (2008), 'The role of TA in innovation policy', Innovation Studies Utrecht Working Paper Series 0801, http://www.geo.uu.nl/isu/pdf/isu0801.pdf (12-08-08).

Spinardi, G. and R. Williams (2005), 'The governance challenges of breakthrough science and technology' in C. Lyall and J. Tait (eds.), *New modes of governance: developing an integrated policy approach to science, technology, risk and the environment*, Aldershot: Ashgate, pp. 45-68.

Steelman, J. (1947), *Science and public policy (5 vol)*, Washington, DC: US Government Printing Office.

Taniguchi, N. (1974), 'On the basic concept of nano-technology' in *Proceedings of the International Conference of Production Engineering*, Vol. 2, Tokyo: Japan Society of Precision Engineering.

Toffler, A. (1970), *Future Shock*, New York: Random House.

van der Heijden, K. (2005), *Scenarios: the art of strategic conversation*, Chichester: John Wiley & Sons.

van Lente, H. and A. Rip (1998), 'The rise of membrane technology: from rhetorics to social reality', *Social Studies of Science* **28**(2): 221-254.

Vig, N. and Paschen, R. (2000), *Parliaments and technology: development of technology assessment in Europe*, Albany: State University of New York Press.

Wildavsky, A. (1984), *The politics of the budgetary process*, 4th edition, Glenview (IL): Scott Foresman and Co.