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Grand Visions and Lilliput Politics: Staging the Exploration of the 'Endless Frontier'

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Abstract. The paper outlines a sociological analysis of politics and rhetorics accompanying the genesis of nanotechnology as the latest research policy priority. It gives an account of certain traits and events linked to the NNI initiative, being conceived of as 'gatekeeping activities' in relation to its emerging societal agenda. Further, it demonstrates how these become permeated by the self-replication controversy. In an attempt to situate the present appropriation of 'nano' also in a wider transformation, the paper proceeds by taking stock of the changing science-society relations. It reviews in passing some of the current debates on the new mode of knowledge production and the heralding of a 'scientific citizenship'.

1. Navigating the 'Spaces between'

"As 'the Hermes of modern scholarships' (*i.e.* a prominent interpreter of mediation, translation and multiplicity), the French philosopher Michel Serres has made the quest for connections between science and the humanities his lifelong mission."[1] There is in his understanding nothing like a smooth 'interface' between those two domains of human knowledge. There is sometimes communication, but also non-communication and static. Pursuing this, Serres has set himself the task of exploring landscapes which are rough, variable, baffling; where there are interesting 'spaces between'. The rough and unruly conditions of the North-West Passage here provide the key metaphor: "Between the hard sciences and the so-called human sciences the passage resembles a jagged shore, sprinkled with ice, and variable" (Serres 1981).

At the present stage of technoscience, sociologists, philosophers, ethicists and historians of science are to an increasing extent invited to set up or accompany expeditions heading towards those rough waters where nature and culture intersect. This can be traced back to a widened political recognition of the importance to open 'Pandora's Box of Science and Technology' before its stream of inventions is released to transform society on a full-scale. As an example for the broad-based demonstration of a new prospective policy, one could think here of the political mobilization in recent years for investigation and control of the nanoscale.

Whereas uncertainty, irregularities, and unexpected fractures permeate Serres' North-West Passage, the nano policies now launched by politicians, civil servants and other stakeholders are fueled by visions of smoothness and reliable navigation to safely steer clear of obstacles. The architects of current initiatives confidently declare that this time we will avoid future frictions, controversies and outbursts of public mistrust of science (such as

those experienced by geneticists or nuclear scientists) by "making everything right from the start".

Serres' metaphor may serve, I suggest, as a useful antidote to the current public and media appropriation of 'nano'. Although playing down roughness and glossing over unruly conditions may be inherent features of the political naiveté accommodating contemporary 'hypes' around emerging technologies, they should not be allowed too much leeway when it comes to the scholarly accounts of the intersections between the sciences and the humanities. No matter how very desirable smooth interfaces sometimes may appear, it remains the critical task of social scientists to recognize the existence and implications of 'the spaces between'.

From here, the paper proceeds as follows. As a first destination, some of the politics and rhetorics accompanying the genesis of the American National Nanotechnology Initiative (NNI) will be visited. This will therefore be about 'bringing nano in', or – echoing Coffin and King's smashing hit back in 1962 – about the invention of 'the Roco-motion'.[2] The next destination is the specific outgrowth of the NNI where the so-called 'societal implications' of 'nano' are to be looked into further. I am going to ask how this came about in the first place, but will also raise the more impertinent but still largely open question what kind of activities will be judged as appropriate in that realm, or: who will be allowed in there? In doing that, I will describe in some detail certain 'gatekeeping activities' that are safeguarding this new policy, including an attempt to reconstruct the key controversy underpinning this micropolitics.

Next there will be a short tour through some of the current debate on the science-society relation, by some referred to as the changing 'mode of knowledge production'. Certain social science constructs such as 'the public understanding of science' and 'scientific citizenship' will be introduced in an attempt to situate the present appropriation of 'nano' in a wider socio-political transformation. I finish this part by elaborating a bit the idea that for contemporary technoscience the so-called 'context of *implication*' is becoming as important as the 'context of *application*'. That offer links back to Serres, while also serving as a bridge to my sketch of things to consider when setting out to 'discover the nanoscale'.

2. Bringing 'Nano' in (the Invention of 'the Roco-motion')

"We offer next to nothing", reads the text on a poster facing those who enter the spacious hall of the new Nanoelectronics Centre at Chalmers Institute of Technology in Göteborg, housing one of the most advanced laboratories for nanometer-based research in Europe. That makes a good joke of course, a witty reference to the fact that just about everything in this minutely vibration-protected building, is under a spell of processes taking place at a scale 80000 times smaller than the width of a human hair. Also, anyone familiar with the recent flood of nano rhetorics can read the irony of that poster, since what indeed is being offered in this current outbreak of 'techno-babble' comes much closer to 'next to everything' than 'next to nothing'.

The stunning political success of the NNI has been embedded in rhetorics zigzagging between 'the glorious past' and 'the unique opportunity of today'. In the extensive material gathered during a series of workshops, there are references to legends like Vannevar Bush and his famous manifesto from the 1940s (Bush 1945), and to academic champions like Richard Feynman. But above all, it is humankind's present predicament which is said to require extraordinary action and commitment. Almost like a mantra, phrases are repeated such as "We are in an Age of Transitions, when we must move forward if we are not to fall behind". One here walks down a well-known road by claiming modern societies' dependence on scientists' authorative knowledge to sustain its citizens' welfare. Beyond that, one also embraces the idea that at certain points in history – such as this one – scientists have to

shoulder our common fate by grappling with risks: "At times, scientists should take great intellectual risks, exploring unusual and even unreasonable ideas, because the scientific method for testing theories empirically can ultimately distinguish the good ideas from the bad ones" (Roco 2001).

The grandiose scope of the NNI was from its outset manifested as nine 'Grand Challenges', wrapped in 'airy' and clearly under-socialized technological visions. Certainly this is no new phenomenon in conjunction with science policy. One could think of it as a necessary playing to the gallery, instrumental in drawing public attention to a new candidate for the policy top of the charts. In this case, however, instead of moderating the hype once the money was there, one escalated it. In December 2001, NNI-general Roco with the help of experts gathered for a workshop, to further inflate his bella donna. As the building blocks for all sciences are to be found at the nanoscale, one could, those experts claimed, by pulling down the barriers between the major provinces of contemporary science, accomplish radical improvements in human life. By chance, these provinces coincided with the four in-vogue areas *nano-bio-info-cogno*. Instead of four potent provinces there now came forth a fully irresistible NBIC empire. Only shortly after its public launch as the new 'endless frontier' then, 'nano' was recast as merely the precursor for the ultimate 'endless-ness' of the scientific endeavor (Roco & Bainbridge 2002).

The 'NBIC'-vision at once is making all scientific progress up to now look rather pale in comparison. 'Lilliput Politics' is clearly 'Grand Politics', and vice versa. There is simply no limit to what utopian qualities the synergistic combination of the NBIC provinces can add to the yet so imperfect world, to how truly powerfully they will be able to energize one another:

> Entirely new categories of materials, devices and systems for use in manufacturing, construction, transportation, medicine, emerging technologies, and scientific research […] engineered biological processes to manufacture valuable new materials […] a union of nanotechnology, biotechnology and computer science may be able to create "bio-nano processors" for programming complex biological pathways on a chip that mimic cellular processes. Virtual reality and augmented reality computer technology will allow scientists to visualize the cell from inside, and to see exactly what they are doing as they manipulate individual protein molecules and cellular nanostructures. […] a ubiquitous network that collects and offers diverse kinds of information in multiple modalities, every-where and instantly at any moment. (Roco & Bainbridge, 2002, p. 10)

Mastering molecular matters then, becomes a matter of empowering ourselves to be able to do whatever we can think of wanting to do. The alchemists after all got it right, only they didn't have the Dream Team we now have; a team saluted with a slogan by one of the participants of the NBIC workshop:

> If the *Cognitive Scientists* can think it
> the *Nano people* can build it
> the *Bio people* can implement it, and
> the *IT people* can monitor and control it. (Roco & Bainbridge, 2002, p. 11)

In a study of the remarkable biotechnology advance of the 1990s, Herbert Gottweis applies what he refers to as 'a poststructural analysis of policymaking and policy texts'. Traditionally, policy has been regarded within the frame of a realist epistemology which views policymaking as a struggle between rational actors, or as determined by institutional structures. By contrast, Gottweis puts forward an understanding of it as essentially constituted by narratives, which rhetorically stand for the interests of various groups in policymaking. Hence, in making objects governable, policy narratives draw their language from 'political metanarratives' such as modernization or international competition (Gottweis 1998).

Gottweis further proposed that science policy constructed from such rhetorical resources is successful only to the extent that it operates by also incorporating conflicting ideas as forms of legitimate difference. If it fails in doing so, public concerns developing into counter-narratives threaten to undermine the stability of policy decisions. Gottweis further claims that scientific language itself is metaphoric, symbolic and even poetic, and that it can be exploited as such. Symbolic objects like the gene, which are made only more multivalent as a result of their 'governability', thus participate in the process of surplus value production. This bears a close resemblance to the ideas on 'genetic fetishism' by science historian Donna Haraway: a relationship between human and nonhuman actors in a scientific network becomes mistaken for an unambiguous and 'corporeal' truth about 'life itself' (Haraway 1997, pp. 141-148).

A similar framing could, I argue, become of interest also for our attempts to approach the ongoing public reception and exploitation of 'the nanoscale'. How will 'governability' be produced in this field? What potent 'symbolic objects' could there be within nanoscience that are ready to become enrolled in metanarratives, and is there anything like a 'molecular fetishism' analogous to Haraway's genetic fetishism? And, in a more self-critical vein: to what extent and in what capacities can one expect social scientists to take part, and become co-opted by, a flourishing trade of nano narratives and nano counternarratives?

3. Making Nano 'Bene': The Societal Implications Thrust Area (SITA)

In addition to the 'Grand Challenges', NNI was composed of the 'Fundamental Research', 'Centres and Networks of Excellence', and 'Research Infrastructure' subprograms, and then also of the much more novel funding construct "Societal Implications and Workforce Education and Training" (NNI 2000a, pp. 11-13). 5-6% of the total NNI budget was allocated for this NSF-based construction of an annex to the nano skyscraper that was being built. Why did this extension of the standard policy toolbox come about in the first place?

Well, there has been no mystery or hush-hush whatsoever concerning that. The annex is there because of the determination of the NNI strategists not to repeat the mistakes of others. Neither are there any doubts about who those "others" are. They are the geneticists, being thought of as a troop of scientists badly suffering the consequences of failing to prepare for the societal reception of their research. The physical sciences have, as Eztkowitz has expressed the motives of the skyscraper constructors, "a need to find a way to emulate the success of the life sciences while avoiding the ethical and social problems that have emerged as genetically modified organisms hit the market" (Eztkowitz 2001). When a committee two years ago was given the assignment to assess the initial phase of NNI, the fifth subprogram was pointed out as an indispensable component of NNI (NRC 2002). It was at the same time relabeled as 'the societal implications thrust arena', or 'SITA'.[3]

The first two years of SITA activities (starting in September 2000) produced rather disparate and ad-hoc attempts to grasp the social problematic. Rather than develop social science informed approaches, the initial workshops invited any participant not suffering from too much self-criticism to fill the vacant construct 'societal implications' with any non-technical issue or more or less mundane management problem they could come up with. Those in charge of the SITA site were either committed not to bring mainstream social science into play, or did not know how to do so systematically.

Were it not for the later inclusion of certain solid academic initiatives such as 'NIRT'[4], one could have ended up as manufacturers of some wishy-washy SITA-styled copies of the real thing – of 'Social Science Light-products', if you like. Or, employing a more nano-tuned metaphor: by coating the skyscraper with thin layers of societal, ethical and cultural concerns, one seemed to side with the macro-political calculation that it will acquire new properties and come out as more socially robust. As long as certain rules-of-

conduct were obeyed, and as long as those obeying them were people in possession of the proper credentials (academic, industrial, or political ones), any statement even if only remotely related to 'societal implications' was embraced as good as any other.

However, the conditional clause is important to notice here. The first few years of SITA exercises were in many ways open-minded and transparent, but in parallel some 'gatekeeping' also took place. Setting themselves the task of investigating the genesis of a new policy frontier of technoscience, philosophers, historians and social scientists have a specific obligation to further reflect upon gatekeeping activities. After all, by establishing and guarding the rules of access and authorization, such activities set the tone of how to frame the social here: at the point when the scientific nano community crosses the threshold of 'bringing visibility to the invisible', what can become voiced and made publicly and politically visible in the first place?

4. Gatekeeping at the Lowest (10^{-9}) Level (a Prolonged Social Drama)

In 2002 at a joint EU/NSF workshop in Italy, the American sociologist Mark Suchman initiated a discussion about the relation of nanotechnology to what he called 'governance regimes' which are defined as "the laws, rules and norms by which society manages interdependence and vulnerability" (Suchman 2002). Is there reason to believe, he asked, that this emerging technology poses any radical challenges to those regimes as we know them?

To come to grips with this, Suchman suggested one should first distinguish between issues concerning nano-materials and issues concerning nano-machinery, defined as follows:

> *Nanomaterials* arise from the manipulation of the nano-scale structure of macro-scale substances. It could for *e.g.* be wear-resistant polymers for tires, super-hard ceramics for drill bits, or ultra-fine membranes for filters. Nanotechnology is here primarily linked to chemical engineering and materials science.
> *Nano-machines* concern technologies of constructing nano-scale devices for operation in macro-scale environments; *e.g.* ultra-small in-vivo medical devices, miniaturized surveillance systems, or lilliputian mining and manufacturing equipment. This links nanotechnology to mechanical engineering and robotics.

Suchman argued that the enhanced performance of nano-materials does not in itself pose unprecedented challenges to society. Their potential is not a new phenomenon as mankind has developed many other transformative compounds, from glass to gasoline to plastic. Although nanomaterials may in some respects become revolutionary, they will still be "revolutionary in relatively familiar ways" (Suchman 2002, p. 96). Policy issues will arise from the performance of particular products, not from the inherent nature of nanotechnology per se. Case-by-case planning will represent a sufficient response. Applications are not likely to arrive any more simultaneously than those of, *e.g.*, semiconductors, synthetic polymers, or wireless telecommunications.

By contrast, when it comes to nano-machinery, Suchman's standpoint was that it threatens to confront society with policy issues which are as unprecedented as they are profound; it opens up "a genuinely new frontier". There are, he declared (by paraphrasing Feynman), "very few sheriffs at the bottom, to keep that room safe and productive" (Suchman 2002, p. 97). As currently envisioned, nano-machines would possess at least three distinctive properties each of which would generate novel issues of responsibility and control:

> *Invisibility*: nano-machines would be among the first complex constructions intentionally engineered to accomplish human purposes at a microscopic level, and their

> introduction into the technological armory would dramatically increase the potential for orchestrated covert activities;
> *Micro-locomotion*: (the ability to move through and within macroscopically solid matter): free ranging nano-machines will radically challenge our traditional understandings of macro-boundaries and barriers; fences, walls and even human skin are largely open space, at the nano-scale;
> *Self-replication*: as difficult as it may be to realize as of yet, self-replication will be a common attribute for any nanotech production passing market conditions, thus becoming socially significant; it poses profound challenges to human foresight and control, since without a carefully designed ready 'off switch', a population of self-replicating nano-machines could grow exponentially. (Suchman 2002, p. 97)

When introducing the proceedings published from this workshop, this line of thought was reviewed by the founder of the Roco-motion himself. After quoting the three traits of nano-machinery depicted as reasons for a deeper concern, the NSF official refuted Suchman by establishing:

> None of this exists. Literature reports new theoretically possible lifeforms, autonomous and self-replicating, but this is only science fiction. […] Moreover, the three above-mentioned characteristics refer to carbon-based chemistry, being *e.g.* relevant to viruses and studied under genomics. Thus, nanotechnology tools and approaches may be adopted, but substantially these aspects stay outside the development of nanotechnology as we intend it. (Roco 2002, p. 23)

This, in my eyes, reads like a rather remarkable piece of polemics. Maybe it is just a slip of the pen, or a bad day at work. It anyhow seems rather strange stating that 'none of this exists', when two of the three characteristics referred to are obviously inherent in the very definition of 'nano', and the third (self-replication), as pointed out by Feynman already, simply is a 'must' if nano is going to carry any significance for full-scale production. If you assure us it does not exist, some 80% or so of the grandiose NNI rhetorics vanish as well; and Roco would have to resign as the reigning nano policy champion, confessing he was never anything else but a (civil servant) top salesman of good old materials science and electronics, jazzed-up a bit.

According to my bluntly 'psychologizing' interpretation of this episode, a third person entered Roco's mind when he was faced with the word 'self-replication' in Suchman's paper, namely an 'enfant terrible' who was not wanted there – Bill Joy. Just a few months before the very first 'SITA' meeting, Joy had published an article launching a major attack on current technological development for being hazardous and way ahead of our ability to safely control the things we innovate. He specifically pointed out the risks of atom-sized self-replicating nano-machines ('nanobots'), and argued for a general moratorium (Joy 2000).

Bill Joy touched a sore spot, of course, and did so right on the eve of something big. In principle though, his unexpected attack offered the best of opportunities to test the NNI guidelines for 'how to cope with public reactions' that were outlined in the program declarations. They prescribed that one should adopt an open, liberal and rational attitude; something like 'no bans and no blinders, instead: include, listen, analyze and learn'. But that was not exactly how Joy's ideas in fact were dealt with during SITA's opening workshop.

Hence, several of its participants devoted the larger share of their presentations to the refutation of all the major elements of Joy's dystopian analysis. Attracting the greatest attention perhaps, Nobel Laureate in nano chemistry Richard Smalley used most of his time to outline his 'fat and sticky fingers rebuttal' of nanotechnology's alleged risks (see below).[5] Throughout the conference Joy came to serve as something of a joke, really, although quite an annoying one. I heard no one trying to analyze *why* it was that he had come up

with such a hair-raiser. After all, being a respected expert himself, Joy was not exactly the madcap or nerd type of guy.

There seem to have been two programs operating in parallel here. One prescribes 'listen emphatically to everybody', and try to grasp the wider context and motives explaining a person's views – that is, the official SITA rule-of-conduct. Then there is a second *un*authorized program saying that it is sometimes okay to skip that empathy a bit, and go straight to the arguments, and if you don't fancy them, please feel free to smash them into pieces. Actually, an informal authorization was given to this approach during that first workshop, when one participant to the obvious liking of many of the present SITA colonists frankly stated: "The rub in exploring the borderlands is finding that balance between being open-minded enough to accept radical new ideas, but not so open-minded that your brains fall out!"

I suggest that Roco when again reading about 'self-replicating' somehow recalled this event, that he became 'Joy-phobic' and did not manage to keep up the broad-minded approach when commenting upon Suchman's in fact not so very provocative piece.[6] If that really was part of a general strategy (or instinct, for that matter) by the NNI coordinator to nip in the bud any radical anxiety associated with nano technology, then 'reality' has not been particularly nice to him ever since he slammed shut that door.

First, it was reopened by Pat Mooney at a prestigious conference on 'Sustainability in a Global Perspective' in Stockholm. The head of the ETC group unleashed a storm of radical nano critique, in relation to which Suchman (and even Joy) stands out merely as a subtle breeze.[7] Next, the American science fiction and screenwriter Michael Crichton served the same purpose by publishing his novel *Prey* (Crichton 2002); and then in 2003, believe it or not, Prince Charles ended centuries of absence and brought royalty back into the business of science politics through his 'Grey Goo Alarm'.[8] So there certainly seem to be many more Joy-boys 'out there'; apparently risking their brains to fall out…

With all due respect for the knowledge and dedication of these people (including, of course, His Royal Highness), they are still not representing the front-line in this combat. As suggested already, Roco's harsh rebuttal of Suchman seemed to be modeled after Smalley's treatment of Joy two years earlier. Although Joy at that time was the official target, it is hard to escape the conclusion that Smalley, when claiming that self-replication was impossible because nature itself does not provide enough room at the nanoscale for the plethora of 'fingers' that this would require, was also addressing someone who argued something very similar 41 years earlier – the legendary physicist Richard Feynman.

There is a slight problem here, namely that two highly prominent scientists in making a similar inquiry whether replicating things at the nanoscale is feasible or not, arrived at exactly the opposite conclusion. Indeed, Feynman's speech and paper in 1959 was called 'There is plenty of room at the bottom' (Feynman 1959). Why is that a problem? Surely it is not forbidden nor uncommon that one Nobel laureate rebuts another; in fact, having done so convincingly on some important issue, is often exactly why he or she is awarded the prize.

The problem is a different one. It concerns the overall legitimation for the current level of government spending on nanoresearch. Before this boom there were already innovative areas within, *e.g.*, materials science and microelectronics with the potential to produce nanoscale knowledge advancing the engineering project. Still, there can be no doubt that 'the Feynman legacy' – with its key thesis of the feasibility of human-controlled molecular assembling – provided the basis upon which extensive public promotion of nanotechnology was erected. To corroborate this, there were several references to the Feynman thesis in the public announcement of the NNI by former president Clinton in 2000, as well as in the bulky documentation (much of it written or commissioned by Roco) accompanying its initiation.

This of course does not impose any obligation on Smalley to be loyal. Notwithstanding his position as one of the major beneficiaries of the program, he could as a 'free academic' still choose to call into question the legacy of the field's intellectual founding father. But, there is here another component, perhaps causing a problem for Smalley. Hence, to judge from his public statements on the self-replication thesis from 1999-2003, there seems to be a certain lack of consistency in his arguments. Appearing before the US Senate in 1999, and more recently in a talk before a White House Council (Smalley 2003), he endorsed the Feynman thesis from 1959. On various occasions apart from the one cited above he refuted it quite energetically.

To no surprise for those monitoring nanotechnology also long before Clinton lent it public fame, there is one person, in particular, who has been carefully monitoring Smalley's positions on this issue. This someone is not an observer like anyone else, but a key player, in fact the third link in the front-line of this controversy: K. Eric Drexler. He is the person who can lay claim to having first drawn attention to Feynman's radical molecular manufacturing vision by publishing *Engines of Creation* in 1986. Smalley has, of course, been fully aware of Drexler's position as the prime spokesperson for the grandiose potential of nanotechnology. After having 'rehearsed' his lines by taking on Joy at that SITA opening workshop, he directly addressed Drexler and the Feynman thesis which "has inspired the nanotechnologists everywhere" in the following year in a widely read journal (Smalley 2001).

According to Smalley, for self-replication to take place at the nanoscale, the small assemblers (also 'nano-machines', 'manipulators', 'nanobots') which are to perform that task must have 'many tiny fingers' – to be precise, one per moving atom. With all the manipulators needed to have complete precision in and control over the chemistry, assembling 'atom-by-atom' as it were, these tiny fingers amount to such a great number that there isn't enough room in the nanometer-size region to accommodate them. Self-replication is simply impossible in our world, he concluded, adding: "To put every atom in its place – the vision articulated by some nanotechnologists – would require magic fingers."

In an open letter to Smalley in 2003, Drexler rebutted this argument. He denied that the assemblers proposed by himself and others during two decades of work on molecular manufacturing have or need those 'Smalley fingers' (Drexler 2003a, p. 1). Accordingly, all the problems with 'fat fingers' and 'sticky fingers' dwelled upon in Smalley's argumentation are of no relevance whatsoever. Not only does Drexler here accuse his critic for repeatedly having "publicly misrepresented my work"; he also constructs a 'straw man', one which he then goes on to attack.

Recently, Drexler essentially repeated this rebuttal of Smalley. This time, however, he devoted more space to demonstrate that not only has he been misrepresented, but also Feynman and his famous 1959 thesis (labeled 'the original nanotechnology vision' in an NNI promotional brochure from 1999). Feynman, he emphasized, never assumed or talked of any need to "separately grab and guide many neighboring atoms simultaneously" (Drexler 2003b). His thesis hence cannot be affected by any Smalley fingers. In response to the Nobel laureate chemist's denial of Feynman's core claim ("'There's plenty of room at the bottom.' But there's not *that* much room." [Smalley 2001]), Drexler insisted: "The Feynman thesis stands."

Drexler also elaborated on the 'pattern of ambiguity or inconstancy' in Smalley's public appearances; the one I cited above. By comparing excerpts from several speeches and relating those to the different contexts within which they were given, Drexler seeks to demonstrate the variability in Smalley's positions regarding the original nanotechnology thesis, accusing him of engaging in 'promotional rhetoric' (Drexler 2003b, p. 6). Further, he ascribes the worry for a backlash as the motive for this engagement, quoting his combat-

ant: "we should not let this fuzzy-minded nightmare dream scare us away from nanotechnology" (Smalley 2000, p. 116).

The price that Smalley has to pay to extinguish this nightmare – namely to proclaim Feynman's thesis false – is not only unacceptable for Drexler (to him, this thesis *is* nanotechnology). He also finds the very idea of trying to calm public fears misguided and dangerous. Ever since reintroducing Feynman's vision in 1986, he has maintained that molecular manufacturing based on the nanomachinery of living systems is "a technology of unprecedented power" and always associated with "commensurate dangers and opportunities" (*e.g.*, Drexler 2003b, p. 2). Both should be addressed. Nanoreplicators are feasible, thus their control is a most legitimate concern. Drexler finishes off his rally by charging that Smalley is getting himself into deep water:

> Continued attempts to calm public fears by denying the feasibility of molecular manufacturing and nanoreplicators would inevitably fail, placing the entire field calling itself 'nanotechnology' at risk of a destructive backlash. (Drexler 2003b, p. 8)

I have no intention to intervene in this controversy "itself", *i.e.*, by taking a position myself on whether self-replication is feasible or not. I lack the natural science background needed, and I lack the motive for doing so, as this is an outline of the *social* framing of the problem. Things are a little different when it comes to Drexler's second point, Smalley's alleged inconstancy. It is true that my illiteracy could also play a part here by impairing my ability to judge whether the positions taken are as incompatible as Drexler claims. On the other hand, those speeches address 'the public' which include me as a layperson in relation to natural science. So, here my view at least should count. This view is also informed in the sense that I have studied the documents fairly close; and I have already indicated that inconsistency is also my 'verdict'.

As regards Drexler's third point, namely how to act in relation to public worries on science-related risks, I can lay claims of having some expertise, since my academic field (Science and Technology Studies – STS) represents quite some work on that. In the light of those findings, I would argue that Drexler's message to Smalley is very much 'on track'. His point that public concerns cannot be suppressed by denying any rational reason for them is empirically well-founded. Anyone following the 'infected' debates related to bioscience during the last decade could confirm this. Smalley's standpoint on how to kill off fuzzy-minded nightmares appears out-of-date. By contrast, Drexler practiced deliberate forms of knowledge production long before they became 'politically correct': along with his appropriation of Feynman's legacy in the mid 80ies, he founded the Foresight Institute to organize workshops, chat groups, newsletters, etc, focusing on the wider societal, political and ethical implications of nano technology (including dystopian ones such as uncontrollable 'nanobots').

Bringing this section to a conclusion, I will recapitulate the controversy not so much in the idealistic or pure terms in which scientists tend to represent themselves, but instead as the staging of what anthropologists sometimes call 'a social drama'. It all started when Smalley, after having smashed Joy's appeal into pieces, decided to also take on Drexler, and indirectly Feynman himself. As these two were already symbolically present during his attack on Joy, one could say in favor of Smalley that it was 'intellectually honest' of him not to stop his rebuttal short of the real targets. And he did what he had decided to do with great force.

Consider for example the metaphorical language he mobilized, the one involving 'fat and sticky fingers' (those which Drexler with contempt refers to as 'the Smalley fingers'). That language vigorously conveys the message that there is a true drama taking place at the very core of nature. My God! – it's just everywhere around us, in the inner realms of every element of our physical world. Although we cannot actually see them, there are here lots

and lots of fingers, unruly and adhesive fingers which constantly stick fast to each other, creating a muddle of everything. Not only do the atoms and molecules inhabiting that chaos get captured by heaps of entangled tiny fingers. They at the same time ensnare those humans who by their scientific imagination inhabit this place: the famous Feynman and Drexler, his controversial disciple of our days. It threatens to suffocate not only them, but at once also their vision of a giant leap forward for one of mankind's proudest creations: engineering.[9]

As dramatic and powerful as this may seem, critical questions whether Smalley created something of a mess for himself pop up. First, he has come out in public as having contradicted himself, on a point fundamental for the nano mobilization policy to which he has been committed for the last few years. Secondly, I suggest that he might have missed a good opportunity here. If the major motive behind his engagement has been his worry that significant obstacles might be imposed on the nanoscience community, then, instead of getting a public controversy going, Smalley could have been more efficient by approaching Drexler as a potential ally; 'politically', although not scientifically.

The catch here is that although Drexler and Joy make bedfellows when it comes to their belief in self-replication as a real possibility, they certainly do not when it comes to the implication of that. Whereas the latter argued for a moratorium, Drexler has for many years advocated full speed ahead, both when it comes to developing the technology *and* when it comes to scrutinizing the ugly sides of molecular self-assembly. He represents a third position here, different from Smalley's siding with the traditional (default) option to sweep uncomfortable stuff under the carpet, and from Bill Joy's 'agonistic' advice to force scientists to put on the brakes.

As Smalley staged the social drama, this third option was 'sacrificed' for the sake of a public scientific controversy, perhaps right at the point when it was most called for. No doubt he stands more than a fair chance of coming out as the winner of the rally; if not for the superiority of his scientific arguments, but because of the great suspicion that his antagonist has encountered from the science community long before this particular drama already (Fogelberg & Glimell 2003). However, the choice in this case may not be between winning and loosing, but between victory and a Pyrrhic victory. 'Gatekeeping', then, may sound like a straightforward activity, but, apparently, it may soon turn into a rather tricky business; no matter whether those practicing it are clever civil servants or people rewarded the most prestigious of scientific prizes.

5. The Changing Mode of Knowledge Production

Reflections on the present formation of nanotechnology policy can be usefully situated, I suggest, in the vivid research on the changing 'science and public relationship'. What I have brought to attention so far stems exclusively from American events, but the ideas below are mainly of European origin. They are part of a general debate rather than specifically related to how nano policies evolve in Europe (an account of which is outside the scope of this paper). Nonetheless, the connection between this section and the former ones may not be that far off. Already joint EU/NSF workshops have been arranged, catalyzing perhaps the advent of a 'euro-roco-motion'. What now follows could therefore be read as an act of stocktaking preparing for the encounter of that hybrid with European political traditions.[10]

A recurrent claim in the current debate is that we are witnessing the emergence of a new mode of knowledge production. Science and society are understood to be accelerating towards each other rendering conventional ways of analyzing them in isolation from one another irrelevant. The distance between science and society collapses into their mutual embrace and varying depths of entanglement (Elam & Bertilsson 2003). This new intimacy

has been described as, *e.g.*, evolving practices of '*contextualized knowledge production*' (Gibbons et al 1994), an all-inclusive engagement in '*collective experiment*' (Callon 1999), or the defining predicament for '*post-normal science*' (Ravetz 1999). Broader participation means that controversy is just as likely as consensus to come along with innovation. As science helps expand the scale and scope of innovation processes in society, so it helps expand the scale and scope also for potential disagreement. By adding new ingredients to collective experiment, "science does not promise to put an end to politics, it only serves to *enlarge politics further*" (Latour 1998).

The European Union appears to be a governmental context particularly well disposed to the forging of a new 'social contract' between science and society. The construction of active forms of *'scientific citizenship'* in support of knowledge-based communities is now gaining recognition as of vital importance for the European project. It can be described as the idea that citizens should not just be generally informed about science, but also actively engaged in the process of scientific and technological change (Irwin 2001). The current interest in scientific citizenship has arisen as the commitment to the 'Enlightenment model' of science and society relations has declined. That model postulated that the only scientific citizens are the scientists themselves. For science to produce proper scientific knowledge, it must live in a 'free state' or republic, disentangling and purifying itself in a domain apart from the rest of society; a cosmology mirrored as "science is the goose that lays the golden egg, but only under suitably autonomous circumstances" (Elam & Bertilsson 2003).

Also in line with the Enlightenment model, it is only natural that communication between science and society is one-way. First, scientists develop new matters of fact, then others in command of suitable scientific training disseminate these facts to society, without society being given the opportunity to talk back to science. As the lines of communication between science and society are now subject to radical reconstruction, that regime can be seen to give way to a range of alternatives for the future 'democratic governance' of science.

This shift is usually seen as synonymous with the development of the Public Understanding of Science (PUS) movement, establishing itself some ten years ago. Innovations which should have found a place in society as a matter of course were seen as being blocked by ignorant and irrational patterns of resistance. The solution to this stalemate was to focus on 'science literacy'. PUS was to engage in a missionary work into the everyday lives of ordinary citizens enabling them to gradually acquire an enlarged, but still restricted, scientific citizenship.

In recent years, the PUS movement has become more prepared to take seriously a lack of public confidence in science and technology. From fighting public ignorance and resistance, it is gradually rededicating itself to the task of securing public *consent* for the carrying out of radical new science-based combinations. PUS also increasingly is associated with deliberative modes of democracy originating out of the work of Jürgen Habermas and John Rawls:

> The ideals of equality between scientists and non-scientists and of informed public debate as the preconditions for forging socially sustainable public policies need to be translated into new processes of deliberative democracy. (Durant 1999, p. 317)

Deliberative democracy is here viewed as a science-friendly model of democracy; one which scientists can embrace not only because it helps make science more democratic, but also because it helps make democracy more scientific. However, the suspicion has also been voiced that by producing 'better' citizens through experiments that value rationality, deliberative democracy is a politics played out on the scientists' home turf. It can be accused of promoting a vision of innovations without real adversaries. This speaks against the cultural logic of democratic politics. It abstracts 'the political' out of politics, implying that

conflicts can be reduced to a competition of interests that can be harmonized through rational argumentation (Mouffe 2000). A strong reliance on deliberative fora to the exclusion of other forms of political expression in the construction of virtuous scientific citizens, may prove counter-productive in the long run. Tools of deliberation will be turned into tools of hegemony, not of rationality.

In a similar vein, Sheila Jasanoff has recently discussed the dedication of producing consent in relation to risks (Jasanoff 2002). She notices that even in the adversarial US environment, there has been an eagerness for processes such as consensus conferences to foster cooperation among disparate parties – 'Getting to yes' has become a paramount goal. But as uncertainties mount and as science impinges upon the most intimate, even sacred, aspects of human life, it is no longer wise to assume that societies will or should always agree upon the instruments of governance. Jasanoff argues that, instead, a diversity of approaches can acknowledge that within modernity's complex socio-technical formations, safety comes from the heterogeneity of our accommodations with risk. Rather than seeking consensus, it may be more fruitful for authorities to learn how to foster 'informed dissent' about risk among knowledgeable publics.

According to Jasanoff, much of the analytical ingenuity of science policy has been directed toward devising predictive methods like risk assessment, cost-benefit analysis or climate modeling. For her, these represent *'technologies of hubris'*, achieving their power through claims of objectivity and by systematically overstating what is known about risks while downplaying uncertainty and conflict. There is instead a need for *'technologies of humility'*, capable of incorporating unforeseen consequences, plural viewpoints and mutual learning.

Another strand of thinking that bears a relation to Jasanoff's argument is Michel Gibbons' discussion about the distinction between 'context of application' (c-o-a) and 'context of implication' (c-o-i) (Gibbons 1999, Nowotny *et al.* 2001). 'Contextualization', he claims, is at the core of what 'rethinking science' is all about; denoting an endeavor that must embrace the planned or predictable applications of scientific research as well as its unknown implications. Thus, if science is to secure a new social contract with society and produce the *socially robust knowledge* which will be required, it must take it upon itself to become fully familiar with the larger 'c-o-i' surrounding every major program of science-based innovation. To try to take into account the 'c-o-i' of a research area is, Gibbons emphasizes, something very different from coming to terms with its immediate 'c-o-a'. It typically demands a much more thorough 'reflexivity', going far beyond a 'forward look' or a 'technology foresight' exercise.

Neither Gibbons nor Jasanoff is particularly helpful in guiding us how to actually 'address the unknown'. Perhaps Gottweis' method of looking deeper into the narratives and rhetorical resources mobilized in science policymaking here could be of some help for moving from applications to implications. To exemplify, while the so far dominant application orientation of technology assessment has mobilized metanarratives focusing on constructs like prosperity and progress, one could imagine a turn towards contexts of implication to evoke alternative narratives and counternarratives exploring phenomena such as viability and accountability.

Our need for thoroughly reflective practices is of course no news for any 'true humanist'. It is just that so very little of it has been channeled in the direction of science and technology. Is that really about to change now? Are Gibbons and others in the contemporary debate sensing a significant historical shift, when claiming that contexts-of-implication is what counts from now on? If only some of that would become the case, I imagine that Serres – although fully aware of the difficulties involved – would be pleased after devoting so much effort to prepare for navigating the roaring waters of the North-West Passage. One might also recall here C.P. Snow and his well-known manifesto on the 'the two cultures' (Snow 1963). In my reading, and reframing it in Gibbons' terms, the gap

(Snow 1963). In my reading, and reframing it in Gibbons' terms, the gap depicted by Snow reflected his deep concern over how a 'c-o-a focus' of modern science and technology was about to establish a hegemony, excluding crucial human experiences and values from the agenda. The envisioned 'c-o-i turn' could bring these back to the fore. So Snow would be pleased, too.

Or would he not? Could it be that the current appeal for 'c-o-i' does *not* represent a radical rethinking of the role of science in our society, after all, but that it prescribes instead a way to *preserve* the contextualization of science merely in the limited terms of 'applications'? Is it perhaps in line with what Gottweis talked of, namely the incorporation of conflicting ideas as forms of legitimate difference – in other words, developing 'c-o-i' analyses in terms determined by the old 'c-o-a establishment'? Without surrendering to cynism, social scientists have to be open also to this possibility; remaining essentially skeptical or methodologically agnostic when investigating the motives of new policies and practices.

6. Rounding-off: Discovering the Nanoscale while Constructing it

Adding the last piece to this nano mosaic, I will expand a bit my last commentary on the role of the social scientist. Again I will draw on a typology put forward by Mark Suchman, this time categorizing four policy agendas or ambitions for social studies of nanotechnology:

> The most modest agenda is simply *observation*, carefully tracking the emerging field and cataloging its impacts, without necessarily intervening to divert its course. Somewhat more actively, social science might facilitate *communication*, allowing nanoscience researchers to explain technical capabilities and limitations to the general public and, equally importantly, allowing the general public to explain social needs and concerns to the research community. Building on both observation and communication, social science might also assist in *remediation*, helping to control and repair any undesirable side-effects of the nanotechnology enterprise before they become too severe. Finally, and most ambitiously, sound social research might actually encourage creative *restructuring*, taking advantage of the sweeping novelty of nanotechnology in order to envision new social institutions – laboratories, disciplines, firms, markets, professions, and states – that would be more flexible, open and egalitarian than the old regimes that they would replace. (Suchman 2002, p. 99)

As Suchman himself underlines, these agendas are interrelated, and accordingly the boundaries between them could easily become blurred. Although the model holds the first two agendas to be 'modest' ones, whereas the last two are more 'ambitious', this is not necessarily how they always come out. Being affiliated with the constructivist science studies tradition, I could testify that 'observation', the most modest one of the four agendas, indeed can be perceived as not only immodest sometimes, but highly controversial (compare the 'Science Wars' triggered by observations of how the 'politics of epistemology' permeate also the sacred core of science).

A pragmatic reading of the model, coming dangerously close to an anticlimax perhaps, could suggest that it may anticipate the emergence of different social-science based nano cohorts that group themselves around the foci of observation, communication, remediation, restructuring, while largely developing their own research methodologies. In this paper I tried to draw attention to some highly explicit and some more tacit practices (lumped together as 'Lilliput Politics') that are possibly conditioning or mapping the agendas for those cohorts in the making. Trivial as that may be for many readers, politics is here not confined to a White House or Brussels macro phenomenon. Instead politics is multi-

facetted and kaleidoscopic, extending its presence and impact all the way down to the 10^{-9}-bottom of human knowledge.

Recognizing this, we should be ever so attentive on how the course of politics may affect our various accounts of the nanoscale world. That does not in my thinking imply that those accounts should rest on a moralist or political footing per se. It is both feasible and desirable to pursue a combined approach – where we remain agnostic and symmetrical in designing our investigations, and at the same time ever so sensitive to political processes when reflecting further upon the accounts that are produced by our investigations. That sensitivity must also include 'the nano imprints' we ourselves will make. When people from the social or human science camps set out on expeditions to the nanoscale regions they will certainly not merely 'discover' those realms of science and its practitioners. They will also construct them while making them visible, which then includes their politics.

Notes

[1] Quote from www.nwe.ufl.edu/sls/abstracts/botta.html. See also e.g. Brown, S.D. (2002) and for some abstracted material used: www.studyoftime.org/weiwert/PV_SERR.HTM.

[2] Mihail Roco chairs the National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology (NSET), and is a Senior Advisor for Nanotechnology at the National Science Foundation. He also directs research opportunities in mechanical and chemical processes, and coordinates the NSF programs on academic liaison with industry (GOALI). Prior to joining the NSF, Roco was Professor of Mechanical Engineering at the University of Kentucky (1981-1995). He is the key architect of the National Nanotechnology Initiative, and coordinated the preparation of the National Science and Technology Council reports on Nanotechnology (NSTC, 1999) and National Nanotechnology Initiative (NSTC, 2000). Roco in 1999 received the U.S. National Society of Professional Engineers and NSF joint award 'Engineer of the Year'.

[3] The committee organized by the National Research Council was set up at the request of officials in the White House National Economic Council. SITA was assessed in highly positive terms: "… it may be a policy exercise after which future policy initiatives will be modeled; … a model for our times. We can use it over and over again if we do it right!" As a field still in its infancy, nanotechnology provides a unique opportunity for developing a fuller understanding of how technical and social systems actually affect each other: "… a relatively small investment in examining societal implications, has the potential for a big pay-off." Source: NRC 2000.

[4] This refers to the NSF-sponsored Nanotechnology and Interdisciplinary Research Initiative at the University of South Carolina in Columbia.

[5] The basic arguments of that rebuttal and the use of the anthropomorphic metaphor 'finger' to characterize the manipulator function of the mechanical nano-sized robot implied in self-replication can be traced back to a talk Smalley gave at a conference in Houston, Oct 1996. For more details, see Fogelberg and Glimell 2003, pp. 20-22. (The seminal argument, in Smalley's own words, is also available online at http://discuss.foresight.org/critmail/sci_nano/4584.html)

[6] This was not entirely so, however. Roco did pay lip service to the SITA rule-of-conduct even while rebutting Suchman. Hence, in between the two strong rejections quoted, *i.e.*, in place of the ellipsis between 'fiction' and 'Moreover', the missing text should be: "However, sociologists warn that even if the construction of such entities/machines/beings might be impossible, from a sociologist perspective they already 'exist'. Indeed, the perception of risk can exist even if the risk itself does not, and vice versa. Consequently, analysis and communication based on rationality are indispensable" (Roco 2002, p. 23).

[7] The ETC Group (formerly RAFI) is an international civil society organization based in Winnipeg, Canada. It is dedicated to the conservation and sustainable advancement of cultural and ecological diversity and human rights. The combined themes of Erosion (cultural as well as environmental); Technology; and Concentration (of corporate power) form the framework for the Group's work. Its recent report on nanotechnology (ETC 2003) was sponsored by the Dag Hammarskjöld Foundation.

[8] See, *e.g.*, "Brave new world or miniature menace? Why Charles fears grey goo nightmare", *The Guardian*, April 29, 2003; and "Nanotech Un-gooed! Is the Grey/Green Goo Brouhaha the Industry's Second Blunder?", *etc group Communique*, July/Aug 2003.

[9] This is not to say of course that Smalley is the only one mobilizing strong or seductive metaphors here; neither Feynman nor Drexler hesitate to draw on one's imagination. The emotional engagement one can sense in Smalley's metaphorical language has its equivalence in an emotional reading of Smalley from

Drexler's side. His undisguised feelings of disgust when confronted with 'the tiny fingers theory' erupt, I suggest, out of a profound relationship with the physicist legend on trial here.

[10] For the next few pages I am greatly indebted to Mark Elam. For a more thorough account of the contemporary debate on public engagement with science, see Elam & Bertilsson 2003.

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