Building a Broader Nano-network

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I. Introduction

Although there is a broadening social interest in the development of a powerful and general nanotechnology, the public discourse to date has largely avoided a comprehensive examination of its social dimensions, focussing instead on what is and is not scientifically possible. In this regard, much attention has been paid to the feasibility of Richard Feynman's famous 1959 vision, i.e., whether it is possible to manufacture complex molecules atom-by-atom.[1] Whether Feynman's hunch is correct – that "it would be, in principle, possible for a physicist to synthesize any chemical substance that a chemist writes down" – has been fiercely debated in the scientific literature and the popular press.

The most famous version of this debate, the recent point/counterpoint exchange between Richard Smalley and Eric Drexler,[2] illustrates a deep division within the nanotechnology community. Consider the following snippets:

Smalley: "The central problem I see with the nanobot self-assembler then is primarily chemistry. If the nanobot is restricted to be a water-based life-form, since this is the only way its molecular assembly tools will work, then there is a long list of vulnerabilities and limitations to what it can do. If it is a non-water-based life-form, then there is a vast area of chemistry that has eluded us for centuries … Please tell us about this new chemistry."[3]

Drexler: "[T]o visualize how a nanofactory system works, it helps to consider a conventional factory system. The technical questions you raise reach beyond chemistry to systems engineering."[4]

Smalley: "I see you have now walked out of the room where I had led you to talk about real chemistry, and you are now back in your mechanical world. I am sorry we have ended up like this. For a moment I thought we were making progress.

But, no, you don't get it. You are still in a pretend world where atoms go where you want because your computer program directs them to go there."[5]

Drexler: "Some chemists with careers tied to the old paradigm (based on random molecular motion in liquids) seem confused and threatened by this different and more powerful approach. … Members of the old guard instead have assured one another that MNT is 'an impossible, childish fantasy' — in short, that there is nothing to learn. Having failed to master the basic principles of MNT, they see its revolutionary promise and dangers as false, and try urgently to dismiss it."[6]

Smalley: "You and people around you have scared our children. I don't expect you to stop, but I hope others in the chemical community will join with me in turning on the light, and showing our children that, while our future in the real world will be challenging and there are real risks, there will be no such monster as the self-replicating mechanical nanobot of your dreams."[7]

The above compilation of *soundbytes* from the public exchanges between Smalley and Drexler over the past few years is not meant to provide full coverage, nor even a summary of their scientific positions. Quite to the contrary, these remarks were very purposefully selected to demonstrate that there are other things at play besides the testing of hypotheses – that this is not *mere* scientific discourse.

While this debate has been extremely influential within scientific circles, it is suggested that such discussion is not particularly useful in the broader policy arena. In our view, despite their good intentions, this is not the best way for prominent scientists to assist in the development of appropriate regulatory structures for nanotechnology. This type of rhetorical exchange is not the best enabler of sound policy and planning.

Although the development of sound social policy about a given technology must certainly commence with considerations about what is presently foreseeable, in this brief article we suggest that it is also important to contemplate possibilities that are not necessarily congruent with today's forecasts. We further suggest that scientific forecasting is itself an insufficient social safeguard against a technology said to have the potential to revolutionize our ability to control and manipulate matter. As an alternative, we propose, policy makers ought to embrace a foresight model that aims to develop a broader network of social participants in their deliberations about the future regulation of nanotechnology.

II. Mend the Gap

Policy-making is inherently a challenging task – a task made more difficult when faced with future uncertainties. In the face of rapid change, it is not good enough to simply debate about what we think is and is not scientifically possible *today*. Nor is it sufficient to state that "[t]here is no scientific evidence to support the notion that nanoparticles and nanotubes – the main components of many nanotech-based products – pose risks on human health and the environment."[8] While such statements, if true, are an important claim in advancing the argument that the perceived risks of nanotechnology are likely to be overestimated and overrated by mass media and the like, the policy debate does not and ought not to end with the conclusions of our science *de jour*.

Rather, we must learn how to co-ordinate science and technology policy so that we can plan for alternative futures. This will involve broadening the debate beyond physicists, chemists and engineers. As the authors of a recent report noted:

> As the science of NT leaps ahead, the ethics lags behind. Activist groups have appropriately identified this gap, and begun to exploit it. We believe that there is danger of derailing NT if serious study of NT's ethical, environmental, economic, legal, and social implications does not reach the speed of progress in the science.[9]

Minding the gap is indeed an important first step. Mending it, however, is the more challenging next step.

In this section we briefly describe a well-known alternative to the point/counterpoint discourse approach that has been adopted by Smalley and Drexler. By reiterating this alternative approach, we hope to remind those interested in the ethics and science of nanotechnology that there are other discussions to be had. Rather than focussing primarily on competing scientific visions about the feasibility of molecular manufacturing, we hope to connect that discourse to existing techniques that have been used in other fields to identify and assess the bridge between our possible futures and the present.

What we are promoting is what one future studies author has described as:

> *a code to communicate between social actors in science, technology and society* … a combined analysis and communications process in which informed parties and stakeholders participate in a forward-looking exercise to identify the most important issues in the emerging S&T portfolio.[10]

Foresighting,[11] as it is sometimes called, is a methodology for examining the long-term future and finding answers for the present as a means of guiding technology policy. It represents an historical shift from short-term to long-term thinking; from past-oriented to future-oriented; from linear to non-linear 'system' thinking;[12] and from an either/or to a multiple option mindset.[13] It has been defined as:

> …the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging of generic technolo-

gies likely to yield the greatest economic and social benefits.[14]

This approach involves "[a] process by which one comes to a fuller understanding of the forces shaping the long term future … which should be taken into account in policy formulation, planning and decision making."[15]

'Foresighting' can be distinguished from 'forecasting'. Forecasting is the passive attempt to diagnose or predict future events.[16] Smalley's seminal *Scientific American* article[17], for example, merely forecasts that self-replicating nanobots cannot and will not be part of our future. Conversely, foresighting aims to actively change or create the future by linking it to the present. It focuses on the challenges of tomorrow, today. Thus, "the major difference between foresight and forecasting is that in forecasting the conclusions for today are missing."[18] The process of foresighting is premised on the assumption that the future is not fixed and that alternative futures exist.[19]

In the face of rapid change, it is not good enough to simply debate about what we think is and is not scientifically possible today.

Foresighting can be used in various ways. According to Slaughter, there are four major applications: "[i] assessing possible consequences of actions… [ii] anticipating problems before they occur … [iii] considering the present implications of possible future events … [and] [iv] envisioning desired aspects of future societies."[20] As the literature points out, foresighting as a tool for 'decision-shaping' rather than 'decision-making' offers many benefits including: engaging policy-makers and experts in actively planning for the future, identifying potential problems early, verifying expectations and examining trends, bringing people together to create a suitable future, strengthening existing networks, and educating the public on urgent future-related issues.[21]

Foresighting could have a positive impact on nanotechnology policy by providing a means for analyzing its broader social and economic implications. While some believe that nanotechnology has the potential to eliminate the problem of resource scarcity, others have pointed out that a technology which allows that 'anything can be made from anything' is sure to have an impact on our ecological systems.[22] Similar considerations will arise in the context of economics. For instance, unless nanotechnology offers a solution to the problem of inflation, we should not necessarily assume that near costless materials' production will necessarily result in decreased prices.[23] A foresighting methodology is needed to commence an assessment of nanotechnology's potential impact on these and other core socio-economic structures.

For example, certain visions of nanotechnology, if realized, could lead to significant economic disruption.[24] Substantially revised or perhaps even alternative economic systems might one day be required to ensure that the fruits of nanotechnology (like some of the information technologies that preceded it) are not short-lived. Similar considerations might be necessary to avoid a proliferation of existing disparities in wealth and power, and the creation of new divides between the haves and have-nots. All of these things indicate that we need to further develop a set of methodologies that will help us to identify and assess the bridge between our possible futures and the present.

III. Building a Broader Nano-Network

Scientific forecasting, conceptual modelling and the testing of hypotheses in the laboratory – though they are all key to a bright future – cannot provide sufficient social safeguards for a science said to have the potential to revolutionize our ability to control and manipulate matter. Mending the gap requires the development of a broader nano-network.

Instead of standing on the sidelines, cheering on a combative and adversarial scientific arm-wrestling match, diverse groups of social actors ought to assemble to examine potential profits and pitfalls of the technologies that miniaturize from as many different angles and perspectives as possible – with the aim of consensus building. As one Australian professor put it, true foresighting requires us to build an 'epistemic community' founded on "a number of principles around which the community members inter-subjectively construct a consensus."[25] These principles would include agreed-to methods and models for assessing and understanding causal relationships, common language and jargon, and political values concerning the policy implications and what policy choices should be preferred.[26]

Although some foresighting techniques currently employed in other contexts rely primarily on experts, many believe that a more complete methodology ought to include a broader range of participants from the social sciences, the humanities and the arts. The general public can and ought also to play a role in understanding and analysing the social implications of various foresighting activities. This type of active and inclusive participation not only generates excellent opportunities for public education and consultation about possible future events, but also enhances an expectation that "the rationality as well as the legitimacy of political decisions can be improved".[27] As Cuhls and Grupp point out,

> Discursive approaches make for more rationalized discussions, because they focus on the need to provide arguments. They introduce reasons as a standard for political discussion. Therefore, they correct the strategic (party) intellectuality and argumentative propaganda which is common in the public (mass media) confrontations.[28]

In contrast to the domain of experts – where it is possible, advertently or inadvertently, for researchers to promote their own ideologies, interests and agendas through the language of science – extending the nano-network to include laypersons and experts from relevant non-scientific disciplines would allow for greater political transparency. It might also promote a more informed and actively engaged public whereby "collective knowledge and the efficient performance of all actors in society and their capability to exchange information result in a steering resource similar to power or money."[29] An approach that creates a broader nano-network, involving other social actors in discussions and decision-making about the future regulation of nanotechnology, would enhance legitimacy and foster public trust.

IV. Conclusion

In the quest for knowledge, scientists, unlike elected officials, are not held responsible for safeguarding the public interest. They are not generally obliged to explore issues that extend beyond their own research interests,[30] nor are they required to consult with members of the public or others working beyond their own domains of expertise. Although most scientific policy is the product of negotiation and contestation,[31] such policies should not be determined primarily on the basis of contestations amongst scientists directly involved in the scientific or technological breakthrough in question. Just as progress in science is sometimes overshadowed by politics, policy choices surrounding the adoption or regulation of a particular science or technology can become clouded by the rhetorical assertions of particular scientific stakeholders. In the absence of a 'social contract' between scientists, government officials, and the public, heated exchanges between scientists must not become a policy maker's preoccupation.

Whatever place rhetoric might have in science, on its own, it is an ill-suited method for policy analysis – especially in fields where there is little consensus but great uncertainty. This is an increasingly significant consideration when one recognizes that scientific discourse is often used as a means of building powerful though divisive social networks. In the face of competition it is usually those scientific networks that are the most successful in translating their own interests on the largest scale that have the greatest impact on how a new technology is developed and implemented.[32] Likewise, the most powerful scientific networks can also have an impact on how such technologies are eventually regulated.

With this in mind, we ought to be very careful not to foster a divisive nano-network. It is suggested here that, in the face of scientific uncertainty, we ought to be oriented towards building a broader, more inclusive network that embraces actors from diverse sectors[33] and enables the development of an overlapping consensus in the shaping of future policy.

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1 Richard Feynman, "There's Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics" (Lecture given to the American Physical Society, California Institute of Technology, 29 December 1959), published in (1960) 23 Engineering and Science 22, reprinted in *Miniaturization*, Horace Gilbert, ed., (New York: Reinhold, 1961), online: Zyvex <http://www.zyvex.com/nanotech/feynman.html>.

2 Rudy Baum, "Nanotechnology: Drexler and Smalley make the case for and against 'molecular assemblers'" *Chemical & Engineering News* 81:48 (1 December 2003) 37, online: Chemical & Engineering News <http://pubs.acs.org/cen/coverstory/8148/8148counterpoint.html>.

3 *Ibid.*

4 *Ibid.*

5 *Ibid.*

6 "Is the Revolution Real?", online: Foresight Institute <http://www.foresight.org/NanoRev/istherev.html> at "Why is MNT still controversial amongst chemists" ff.

7 Baum, *supra* note 2.

8 Emmanuelle Schuler, "Perception of Risks and Nanotechnology" (2004) 12:3 Health L. Rev. [also in this edition], online: TU-Darmstadt – Institut für Pholosophie <http://www.ifs.tu-darmstadt.de/phil/Schuler.pdf>.

9 Anisa Mnyusiwalla, Abdallah Daar & Peter Singer, "'Mind the Gap': Science and Ethics in Nanotechnology" (2003) 14 Nanotechnology R9, online: California Council on Science & Technology <http://www.utoronto.ca/jcb/pdf/nanotechnology.pdf>.

10 Quoted in Jan Kozlowski, "Adaptation of Foresight Exercises in Central and Eastern European Countries" (Paper presented to the United Nations Industrial Development Organization's Regional Conference on Technology Foresight for Central and Eastern Europe, 4-5 April 2001), online: UNIDO <http://www.unido.org/userfiles/kaufmanC/Koslowskipaper.pdf> at 13 [emphasis added].

11 The first time the term "foresight" was used in a book in the context of science and technology policy was in 1984 by John Irvine and Ben Martin in their book *Foresight in Science: Picking the Winners* (London: Dover Frances Pinter, 1984). See generally Richard Slaughter, "A Foresight Strategy for Future Generations" (1997) 29:8 Futures 732; Richard Slaughter, "Foresight beyond Strategy: Social Initiatives by Business and Government (1996) 29:2 Long Range Planning 156; Richard A. Slaughter, *The Foresight Principle: Cultural Recovery in the 21st Century* (London: Adamantine, 1995) [Slaughter, *Foresight Principle*]; Richard Slaughter, "The Knowledge Base of Futures Studies as an Evolving Process" (1996) 28:99 Futures 799; Denis Loveridge, "Foresight and its Emergence" (1998), online: Policy Research in Engineering, Science and Technology <http://les.man.ac.uk/PREST/People/Staff/Denis_Loveridge.html>; Ben Martin, "Technology Foresight: Capturing the Benefits from Science-Related Technologies" (1996) 6:2 Research Evaluation 167; Ben Martin, "Foresight in Science and Technology" (1995) 7:2 Technology Analysis & Strategic Management 139 [Martin, "Foresight in Science"]; OECD, "Technology Foresight: A Review of Recent Government Practices" (1995); Hariolf Grupp & Hal Linstone, "National Technology Foresight Activities Around the Globe—Resurrection and New Paradigms" (1999) 60 Technological Forecasting and Social Change 85.

12 *Supra* note 10. As Kozlowski points out "it is no coincidence that foresight was born in the 1970's when the development of the system approach was accelerated." In the early 1970's, several key systems books were published: Jay Forrester, *World Dynamics* (Cambridge: MIT Press, 1973); George Klir, *Trends in General System Theory* (New York: Wiley-Interscience, 1972); and Mario Bunge, *Treatise on Basic Philosophy,* vol. 4 (Dordecht, Boston: Reidel, 1979).

13 *Ibid.*

14 Martin, "Foresight in Science", *supra* note at 140.

15 Joseph Coates, "Foresight in Federal Government Policy Making" (1985) Futures Research Quarterly 1 at 10.

16 Kerstin Cuhls, "Can Foresight as a Policy Instrument Contribute to Technology Policy in Less Favoured Regions?" (Poster paper presented to the Euroconference on Technology Policy and Less Developed R&D Systems in Europe, 17 October 1997), online: INTECH Publications <http://www.intech.unu.edu/publications/conference-workshop-reports/seville/cuhls.pdf>.

17 Richard Smalley, "Of Chemistry, Love and Nanobots" *Scientific American* 285 (September 2001) 76 at 77 [Smalley, "Of Chemistry"].

18 Kerstin Cuhls quoted in Jan Kozlowski, *supra* note at 14.

19 According to this definition, it is difficult to imagine members of Smalley's network engaging in foresighting around the social implications of molecular assemblers since they think them to be impossible.

Whether Drexler's network is in fact truly engaged in the practice of "foresighting" as described above is less easily determined. As stated above, the process of foresighting is premised on the assumption that that the future is not fixed. Drexler has repeatedly spoken of "The Coming Era of Nanotechnology." Likewise, the Foresight Institute states its mission in terms of preparing for "the coming ability to build materials and products with atomic precision." To his end, Feynman is usually quoted for the view that this is "a development which I think cannot be avoided". According to the Foresight Institute, "[t]he current world-wide surge in nanotechnology research reinforces his conclusion.", online: Foresight Institute <http://www.foresight.org/>. Operating on the assumption that molecular manufacturing is *inevitable* (although it is not entirely clear that this is what the Foresight Institute is doing) would undermine the foresighting methodology in precisely the same way that the assumption that molecular manufacturing is *impossible* does. Both approaches risk shaping future possibilities that might otherwise be avoided or, alternatively, risk the omission of future possibilities that might otherwise be considered.

20 Slaughter, *Foresight Principle*, *supra* note at xvii.

21 Ron Johnston, "The State and Contribution of International Foresight: New Challenges" in European Commission IPTS-JRC eds., *The role of Foresight in the Selection of Research Policy Priorities Conference Proceedings,* Report EUR 204006 EN, online: Turkish Academy of Sciences <http://www.tuba.gov.tr/FS-ResPrior%20eu.pdf> at 99.

22 Richard Slaughter, "Reinventing the Future: Foresight and the Rise of Nanotechnology", online: World Futures Studies Federation <http://www.wfsf.org/docs/SLAUGHTER.pdf> (discusses several socio-economic implications of advanced nanotechnology).

23 In fact, in the early stages of nanotechnology, costs of goods and services will increase because they will likely carry a surtax to allow nano-innovators to recoup research and development expenditures. See David Berube, "Nanosocialism" *NanoTechnology Magazine* 2:4 – 2:8 (April to August 1996), online: University of South Carolina English Faculty <http://www.cla.sc.edu/ENGL/faculty/berube/nanosoc.htm>.

24 *Ibid.* See also Christine Peterson, "Molecular Manufacturing: Societal Implications of Advanced Nanotechnology" Testimony given to the U.S. House of Representatives Committee on Science (April 9, 2003), online: House Committee on Science <http://www.house.gov/science/hearings/full03/apr09/peterson.htm>.

25 Johnston, *supra* note at 110.

26 *Ibid.*

27 L. Heenan as quoted in Kristen Cuhls & Hariolf Grupp, "Status and Prospects of Technology Foresight in Germany after Ten Years", online: Japanese National Institute of Science and Technology Policy <http://www.nistep.go.jp/achiev/ftx/eng/mat077e/html/mat077ae.html>.

28 *Ibid.*

29 *Ibid.*

30 Which very often includes goals beyond "the pursuit of truth" – such as securing for their institutions large research grants, patents and other forms of intellectual property.

31 As Stephen Ball states: "Policy-making is inevitably a process of bricolage: a matter of borrowing and copying bits and pieces of ideas from elsewhere, drawing upon and amending locally tried and tested approaches, cannibalizing theories, research, trends and fashions and not infrequently flailing around for anything at all that looks as though it might work" (Stephen Ball, "Educational studies, policy entrepreneurship and social theory" in Roger Slee & Gaby Weiner, eds., *School Effectiveness of Whom? Challenges to the School Effectiveness and School Improvement Movements* (London: Falmer, 1988) at 127.

32 See *e.g.* Latour's forthcoming book, *Actor Network Theory – A Personal Guide to Sociology* (Oxford: Oxford University Press).

33 Including academia, industry, and the public arena: Brian Rappert, "Rationalizing the Future?: Foresight in Science and Technology Policy Co-ordination", online: The University of York SATSU <http://www.york.ac.uk/org/satsu/OnLinePapers/Brian/Futures.htm>.