Anticipatory Governance: can we imagine a future scientific Ireland?

Padraig Murphy, Celsius Research Group, Dublin City University, Ireland

Prediction is very difficult, especially of the future.
Niels Bohr

These days, people seek knowledge, not wisdom. Knowledge is of the past, wisdom is of the future.
Vernon Cooper

[This is a draft version submitted for peer review. To cite, please view final document: Murphy, P. 2011. Anticipatory governance: can we imagine a future scientific Ireland? The Irish Review, 43 (43), pp. 37-48.]

Introduction: anticipating *sustainable* science futures

It would be a difficult task to reverse Irish people's passion for history and focus instead on the future. And perhaps we should not even try. But in this moment in Irish history, future uncertainties must at least have parity with the past in our collective imaginings. We can certainly use the past, to paraphrase Pascal, as a means to future goals. But there needs to be more effort made to scope out what the future can do for us.

Our imagining of the future is almost always technological. How long do you think you will live? What will the 22nd century be like? There is a future technological narrative for Irish policy too, that involves ICT, the biosciences and nanotechnology. Recession or not, the Irish Government intends to keep focusing on these key technologies, with particular emphasis on innovation, for a 'smart' or 'green' economy. The Government spent approximately €4.5 billion on science and technology between 1995 and 2005, with a sharp increase since the founding of Science Foundation Ireland in 2000[1]. The new European Commissioner for Science, Technology and Innovation Maire Geoghegan-Quinn has strongly indicated her determination to match European research excellence with entrepreneurship since taking up office in November 2009. The Strategy for Science, Technology and Innovation (SSTI) set out the roadmap (ibid.). Now, the task of 'translating', commercialising this research within society. Everything must change. Innovation, we presume, means everything changing. (How unproblematically we use this word, innovation.).

But this translation is predicated on an over-simplistic linear model of 'lab to market'. Not all these technologies have been easily translated in other societies; bio- and nanosciences are particularly divisive. How do we manage the process from research to product development differently, so that patenting is not the central objective and there is some sense, or indeed many senses, of sustainability? What about the risks these technologies bring? Can there be a sense of shared responsibility for science, with public input to public scientific expertise? And indeed can there be transparency, so that these actions are seen to be done? Can we really imagine what impact science will have on a future Ireland?

At this stage, it must be emphasised that prediction or futurism is not under discussion. Of primary interest is technology assessment, that is, evaluating the social acceptance of emerging and future technologies by invoking futures. It is not what might happen in the future but *what devices and practices are needed to use the future as a place of social action in the present*. Multiple potential futures can be created and negotiated, options opened and choices

made. What is also not of concern here is identifying 'black swan events', as economists call them, large, unexpected global events, because we know they *are* going to happen and they are difficult to predict. Risks are ever-present, and growing in our imaginings, constantly being constructed as described by contemporary social theorists such as Ulrich Beck[2, 3] and Anthony Giddens[4, 5]. This paper is concerned with socio-technical change, social and public response to emerging applications where there have been flashpoints, in such areas such as nuclear energy, embryonic stem cell technologies, nanotechnology, IT, even tangible technologies such as incinerators and new 'green framing' of fossil fuels. And then there are the new products of the everyday, gadgets with novelty and science fiction allure. Advertising borrows heavily from the sci-fi genre, playing with it. We now use sci-fi in an ironic way, creating a mock-modernism that never happened, and never will, but paradoxically *is* happening – in the sci-fi narratives of Sky+ box or Guinness adverts. We have brought the future forward already in Hollywood and visual culture.

Contemporary writing in theories of practices and Science and Technology studies(STS) have placed particular emphasis on future-orientated scenarios and anticipatory workshops, developed with what were once known as 'lay-people', but are now seen as active members of public interest, specialists or non-specialists[6, 7]. There has been a—slight—move in policy-making in many countries, towards a more *social sustainable* approach to nano- and biotechnologies, sustainable energies, and health devices, that is, 'sustainable' in the sense of public acceptability and consumption, with some degree of collective 'responsibility' (we will look again later at what these two terms might mean regarding technology assessment). The embeddedness of STS in EU policy is reflected in the many social scientists of this persuasion working on high level policy reports[8, 9]. It is no surprise then to see terms such as 'reflexivity' and 'deficit model' filtering down into statements from science policy arenas. However, they have not yet spread across to other sections of social action. There are multiple sites of discourse of science and technology—business, organised civil society, science and innovation, policy, academic social sciences — each with vested interests in 'public engagement'. The higher education sector, and Irish scientists in particular, are making great strides to inform publics through education and outreach programs. However, there are assumptions about 'how the public might respond' inherent in education and outreach programs that need to be challenged—public engagement and indeed public dialogue with scientists and science policymakers must not be used as a noble ambition for its own sake. There needs to be defined parameters on who is involved in technology assessment and realistic expectations for public input. Without this, there are weaknesses regarding the impact of public involvement[10]. In an Irish context, there will always be 'stakeholders' from business but there also needs to be activists, teachers, non-experts of all kinds (that is, expertise relative to the technology under discussion) guiding and being guided by the processes of technoscience, preventing economic interests as the only agents for future change. Technoscience is the all pervading sets of innovation-led enterprise, seeing and selling science. Technoscience compels us to imagine present and future 'objects into which lives and worlds are built…imploded atoms or dense nodes that explode into entire worlds of practice'[11]. The science, technology and innovation agenda has huge power within the Irish context now, legitimised by science, relatively untouched by cutbacks (research programmes and infrastructure appear constant at any rate, whatever about research personnel).

Technoscience has a storyline. Emerging technologies are sometimes lumped together for the sake of communicating their societal impact but also because there is a Grand Theory for these technologies, the convergence sciences of 'nano-bio-info-cogno', or NBIC. There is a utopian narrative here that has been with us a long time, the myth of human mastery over nature using technology, and indeed mastery over the limitations of the human body itself, going back to the speculative writings of Thomas More[12, 13]. With such collaborative technologies come greater complexities, and thus greater disharmonies. Anticipatory governance then is imagining futures with sustainable technology acceptable to society. Sustainable economics experts have particular

phrases for the broad area: 'triple-bottom-line', '3BL', 'people planet profit', 'green marketing', 'eco-capitalism'. In the linkages between science studies and science policy, the term 'responsible innovation' has gained new currency. This paper also draws from an Environmental Protection Agency- funded project on Irish public responses to the discourses of nanotechnology. We will look briefly at the conceptualisation of anticipation, and also methodologies; there is a recent trend for foresight exercises[14-18]. The concepts and methods are of value to policymakers – that is, if it were possible to imagine our elected representatives allowing the input of shared visions, at least with regards to science, technology and innovation.

Different ways to imagine futures

It is useful to consider different methods that policymakers, business leaders, and social and natural scientists employ in envisioning future science and technology. First though, it is important to advocate two guiding concepts that are necessary for 21st century future planning for technology assessment, but which have not always been utilised: 1) a sense of the *aesthetic* and 2) adequate *representation*.

Aesthetic is used here as Adorno intended —the phenomenon of *mimesis*, an imitation or doubling of social processes in art[19]. It is important to realise how fictive imagination coaxes out alternative pathways, for genomics, nanotechnology, nuclear and alternative energies, geo-engineering and other supposedly world-changing technologies (literally so in the later) and assessing where we are in the present. Fritz Lang's *Metropolis*[20] constructed a future that set the template for sci-fi visualisation, from *Forbidden Planet*[21] to *Star Wars*[22] to *Avatar*[23], all in a rich dialectic with 'real' technological progress. Indeed 'imaginaries' is now an accepted term within the social sciences for collective future planning and scenario-building of technologies. As O'Mathuna describes elsewhere in this volume, science fiction of all kinds undoubtedly plays its part in speculating futures, while realising the ethics and the aesthetics of the present (see also Erickson[24], Milburn[25] and Thurs[26] for explorations between science progress and science fiction). Jules Verne's fiction even had an element of prediction. But this is anticipating, rather than predicting. There is value in trying to come to grips with what Erickson[27] and Brown and Michael[28] call the sociology of anticipation, understanding the dynamics of expectation and how practices underpin communities of promise. There are important cultural skills to be acquired, relating the fictive to technological progress (and regress). Beck and Giddens talk of reflexive modernisation[29,30], where constructed risks and unknowns of progress (and even Donald Rumsfeld's 'unknown unknowns') come back to the gates of late modernity and demand to enter (even while Bruno Latour, another prominent STS radical, proclaims for those of us who claim to be within the technological *polis*, 'we have never been modern'[31]). Within Irish society maybe, just maybe, we are seeing a new appreciation for the aesthetics of future science through the presence of the popular Science Gallery, albeit with the governing practices of 'innovation' (What If… was an exhibition of future outlandish technologies hosted there in 2009).

While aesthetics are important, representation is doubly so—who or what is representing, or being represented, in the processes of technology assessment? In *Archaeologies of the future*, Frederic Jameson cautions about the politics of utopia, how it becomes totalising[32]. In a similar way, guiding visions can privilege consensus, leading to power inequities. While Jameson's point can be accepted, what is open to challenge is his Marxist notion of the ideology of utopia and its disrupting, distorting influence on 'knowledge'[33]. Empirical STS research has grounded these high notions; Irwin speaks of 'ethno-epistemic assemblages', where scientific knowledge and truth claims becomes situated in local contexts, bound up in cultural assumptions working on the borders of communities of practice in a specific area of science[34]. Brian Wynne, too, has been instrumental in challenging elite knowledge at the expense of tacit understandings of public action[35]. What has crucially been missing in Ireland is a public engagement necessary for technological debates to get the under-represented outside the innovation elite into both the active

processes of technological decision-making and into the public sphere. Imaginaries for nanotechnology future scenario planning for example involves many stakeholders, particularly what we might call 'non-expert publics', not 'the public', not only just the 'proximally interested' — those with opportunity or types of privilege to express an interest in scientific developments.

Traditional technology assessment procedures separate 'rational foresight analysis' from 'political decision-making'. This was the aim of one of the first institutions to look at this area, the US Office of Technology Assessment (OTA), which closed offices in 1995. The OTA would present how science would independently evolve, giving policymakers the information to plan around it. But in a sense, society was excluded, although it was a strategic initiative that left an important legacy. Outside of policy-driven technology assessment, science disciplines have their own future-orientated practices. In environmental science, Life Cycle Analysis (LCA), further separates science from politics. In this complex set of processes, the environmental impact of an object or substance is assessed throughout its 'life cycle'. In business, new 'greener' corporate social responsibility models use further multi-modal systems of analyses with acronyms such as PESTLE or STEEPLE, any variations of the words political, environmental, scientific, technological, legal or ethical Again, these de-contextualised processes tend to assume the 's' part, the 'social', is just one determinant. STS thinking considers the entire process socialised.

Future uncertainties have inspired many institutions in Ireland to initiate foresight exercises, including Dublin City University[36], and, indeed Forfas, the Government's own advisory body on science, technology and innovation[37]. What these foresight exercises have in common is presenting, with a modest cross-demographic representation of staff or interest groups, a series of scenarios from a rounded fixed point number of years in the future. From responses in workshops, trends, themes and drivers are typically identified. But are we effectively utilising the power of future imagination from less homogenous interest groups? Foresight models tend to construct roadmaps, using strong shaping of future pathways, engineered to a goal or a series of goals[38]. There are more open-ended models technology assessment that speak to sustainability, following the emergence of 'ethical and social implications of science and technology' (ELSI) in emerging technology foresight, and the importance for strategists to on speculate on public 'buy-in.' We will next examine two of these for the scientific area of nanotechnology, a particular common are for these new technology assessment methodologies.

The case of nanotechnology

The allure of nanotechnology has always been its future orientation. Nanotechnology is considered work on the nanoscale, generally below 100 nm (100 x 1 billionth of a metre). Discourses have been built around a strong *leitbilder* or guiding vision, of Eric Drexler's nanonorobots and miniature devices roaming inside the body[39]. The utopia of Drexler has echoes of More's utopian predictions, while Bill Joy offers the dystopia of those same machines running amok[40], also represented in fiction by Michael Crichton's *Prey*[41] (some claim Heinlein's Waldo[42] or even Flann O'Brien's *The Third Policemen*[43] to be true originators of the nanotechnology mythology). While there are attempts to change the story of nanotechnology globally from one of almost magical promise in Drexlerian visions to one of mundane practicalities, technology and fiction still intermingle. Images accompanying *Irish Times* Innovation supplement of February 2008 contains a sinister looking artist's impression of nanobots corralling red blood cells and plaque through an artery. While future visions are necessarily utopian or dystopian, debates on nanotechnology tend to be divided simplistically into potential risks versus benefits

Let us examine two technology assessment models for wider public and conceptual involvement, based on STS that have a degree of overlap, one US-based, one European. In the US there is 'real-time' technology assessment, particularly clustered around the Centre for Nanotechnology and Society at Arizona State University (CNS-ASU). This model looks at future nanotechnology development in the context of strategic convergence sciences for radical

enhancement of human abilities. In deliberative activities, scenario workshops are set up explore future of medical diagnostics, such as the 'Doc-in-the-Box', with selected advocacy groups participating with ethicists, business leaders and scientists in looking at 'path dependencies' and obstacles to design and social acceptance[44]. Other field–work elements of this model use ethnography to examine scientists' on-site decision-making and reflexivity (a large family tree of research projects has grown in this area since Latour and Woolgar[45] and Law and Callon[46]). The real-time technology assessment approach may have limits to what actual impact 'ordinary citizens' might have on the product development process , although this largely depends on what stage of development deliberations occur at, or indeed what key decision-makers will be prompted into action. This is, however, the beginnings of deliberative innovation; there is, at least, the people and raw materials for the creativity supposed to be inherent to innovation, and also to expand both contextual understanding of science in society and public participation.

In Europe, Arie Rip's 'constructive' technology assessment also places itself within socio-technical scenarios since the 1980s[47].This approach is more established, drawing on multiple European disciplines – history, political science , philosophy, management theory, and sociology[48]. Rip claims his devices bring in 'social science fictions'[49]. His group call it 'modulation' between strategists and non-exerts , and identifying 'irreversibilities' where decisions are locked in, and where potential future pathways become more limited in endogenous, immanent science-in-the-making[50]. Often the processes explore the concentric development of a promising new field of science on one level (eg lab-in-a-cell), and on another level, a wider area on which a new technological development might impact (eg nanotechnology in food packaging)[51].

What these approaches have in common is their claim to increase the reflexivity of all participants in the research and development chain. A useful definition of reflexivity for technology assessment is borrowed from Ulrich Beck's reflexive modernisation' – *self-confrontation*[52]. This describes those ambiguities the risk society cannot so easily calculate and categorise and so the technoscientific system confronts itself through regularised risk assessment, NGO activities, public doubts, religious objections. At the individual level, 'enactors' in the process of technology development are being challenged, the tactics of the consumer/citizen being assimilated and yet changing the 'proper' strategies of scientific enterprise[53]. But traditional, internal-system risk assessment fails to capture all these 'bads' that may happen. They are part of the social construction of science and technology in society; yet despite their scientific bases, they are in the lap of *fortuna*, not the pathways of probability. Bringing the future into current thinking still uses today's instruments. We suppose that it can be anticipated, a future that follows today's pathways[54].

A proposal offered by the Environmental Protection Agency (EPA) STRIVE funded project with which I was involved was to go beyond either/ or risk and benefits analysis and reflect instead on the *heteroglossia* in the many texts across policy, news coverage and non-expert discussions on nanotechnology, or what certain sociologists and discourse analysts call 'dialogicality'[55]. There have been many attempts at obtaining consensus in 'public opinion' initiatives for nanotechnology —'nanojuries', 'nanodialogues', consensus conferences. The complexity of nanotechnology is such that consensus on any aspect has to be impossible (many contributing scientist would say a unifying 'nanotechnology' does not even exist, but consists of cross-linking disciplines).

Ireland's attempts at technology assessment, NanoIreland, carried out in the mid-2000s did not deliver on it promise to scope out the terrain in any real sense The concern is, where economic voices are over-represented, foresight becomes weak. Two lobby groups for nanotechnology, Integrated Nanoscience Platform for Ireland (INSPIRE), Competence Centre for Applied Nanotechnology (CCAN) promote a strategic national nanotechnology agenda, the latter an initiative supported by Enterprise Ireland and Industrial Development Agency (IDA). The agenda for these communities of practices is the removal of these 'nano-fictions' from

nanotechnology discourse. This is a tall order of course, given the fictive imaginings of nanotechnology.

Futurescaping: what we need to do to imagine science futures

The main question is - how do we address a society and economy that is unsustainable and that will have an aging population? Politics has not provided the answer; in any event, Ireland has had a serious, and widening, gap between politics and citizenship. Emerging sciences are developing strongly as political processes in their own right, allied to economy. The first problem to address then is *transparency*. Can we open science out, acknowledging its 'messiness' regarding funding mechanisms, framing and subjectivities, all of which are publicly discussed now since 'climategate'? We must accept we have post-normal processes of science, as Jerry Ravetz calls them, already socialised, already politicised, caught in networks of business, education interests and civil society. The British system currently facilitates, even in a notional way, public participation in science governance. Perhaps this is because there is now a litany of failed socioscientific issues in the UK where science is pointedly portrayed as a fixed entity of power and mistrust. (BSE, MMR, genetically modified crops, the invasion of Iraq on the back of allegedly erroneous scientific evidence, and more recently, the leaking' of East Anglia University climate change emails). In Ireland 'science' or 'technology' is not explicitly seen as the focus of such debates, although it must be integral to them when one considers abortion, embryonic stem cells, and the GM food debates. Here, socioscientific debates are seen as epistemological matters that can be resolved, rather than issues of power and democracy. That now has to change. We can have an Irish way of doing this. If Schumpeter-type processes of innovation have been identified to lead us to a more 'Enlightened' future, then let us in some way, accept this state of affairs. There may be better ways, but let us work with this and accept that we have no current political choice; we have decided collectively how to get out of recession

This then is the second problem to address—it must be a *responsible* innovation. This is perhaps a doubly unproblematised phrase, but the expression can be defined. While many other nano- and emerging technology governance initiatives around the world have either oversight programmes or a strong, or notional, sense of 'moral governance' on issues of risk, health, sustainability and ethics (see the Human Genome Project, the National Nanotechnology Initiative, The Nanotechnology Industries Association), Irish technology assessment has thus far failed to address the area of risk except in the instrumentalist practices of the toxicological sciences.

This brings us to the third problem to address: we must make science *sustainable*. Emerging technologies such as genetic engineering and nanotechnology are being 'greenwashed' while paradoxically being challenged by 'non-government organisations' such as Greenpeace[57] and the ETC Group[58]. Ireland needs a new sense of what could be progress, a new humility in acknowledging that we know the boundaries are leaky, and that includes the false dichotomies set up around nature v culture, environment v society. Beck has said 'what is 'natural' is now so thoroughly entangled with what is 'social' that there can be nothing taken for granted about it anymore'[59]. The human urge is still to demarcate and dichotomise. But there is a blurring or destruction at nature/society borders, a move towards *assemblages* in the study of the constructed/natural environment. The STS trend is to explore 'relational' concepts of science, nature and society in patterns of discourse rather than dualist ones, in pursuit of futures with 'the common good'. This means being socially sustainable, as in the sustaining of objects and concepts formed and accepted in all societies. The Irish Government must energise this process. The technology assessment models described here can be elevated above mere focus groups, workshops or internet forums (although integral methodologies) to the level of ground-up policy-making. Is it too utopian to ask that one day soon there is such a participative democracy making in-roads in support of a creaking representative one? A new Irish Health and Sustainable

Technologies Forum might be a good starting point on a macro level, a national conversation on the future of convergence and climate change technologies. This would present a plurality of futures, a 'futurescaping' of possibilities that can be engaged with at all levels, not mired in the economics-speak and buzzwords we now associate with innovation culture, that drive out voices of the marginalised and the aesthetic. It can be difficult for any one of us to take a step outside our 'thought communities', as early sociologist of science Ludwik Fleck once called them[60], to get an 'external' view of science, to see how the practices of science policy self-construct and are shaped.

References

1. Ireland, Department of Enterprise, Trade and Employment. *Strategy for Science, Technology and Innovation, 2006-2013* (Dublin: Stationery Office, 2006), p22.
2. Ulrich Beck. *Risk Society: Towards a New Modernity*. Trans. by M. Ritter (London: Sage, 1992).
3. Ulrich Beck 'The Reinvention of Politics: Towards a Theory of Reflexive Modernisation', in U. Beck, A. Giddens and S. Lash (eds.), *Reflexive Modernisation: Politics, Tradition and Aesthetics in the Modern Social Order.* (Cambridge, UK: Polity Press, 1994) pp1-55.
4. Anthony Giddens *Modernity and Self-identity: Self and Society in the Late Modern Age* (Cambridge, UK: Polity Press, 1991).
5. Anthony Giddens 'Risk, Trust, Reflexivity', in U. Beck, A. Giddens and S. Lash (eds.), *Reflexive Modernisation: Politics, Tradition and Aesthetics in the Modern Social Order.* (Cambridge, UK: Polity Press, 1994) pp184-215.
6. D. H. Guston and D. Sarewitz 'Real-time Technology Assessment' *Technology in Society*, vol. 24, 2002, pp93-109.
7. J. Schot and A. Rip 'The Past and Future of Constructive Technology Assessment, *Technological Forecasting and Social Change*, vol. 54, 1997, pp251–268.
8. Ulrike Felt, Brian Wynne, Michel Callon, Maria Eduarda Gonçalves, Sheila Jasanoff, Maria Jepsen, Pierre-Benoît Joly, Zdenek Konopasek, Stefan May, Claudia Neubauer, Arie Rip, Karen Siune, Andy Stirling and Mariachiara Tallacchini. *Taking European Knowledge Society Seriously*. *Report of the Expert Group on Science and Governance, to the Science, Economy and Society Directorate, Directorate-General for Research, European Commission.* (Brussels, Belgium: European Commission, 2007).
9. Alfred Nordmann *Converging Technologies – Shaping the Future of European Societies: a Report for HLEG: Foresighting the New Technology Wave*. (Brussels: European Commission, 2004)
10. Jasber Singh, *Polluted Waters: the UK Nanojury as Upstream Public Engagement*. [Online]. Discussion paper, 2005, p11.Available from http://www.nanojury.org.uk/pdfs/polluted_waters.pdf. [Accessed 3 March 2010]
11. Donna Haraway *Modest_Witness@Second_Millennium. FemaleMan©_Meets_OncoMouse™: Feminism and Technoscience* (London and New York: Routledge, 1997), p11.
12. Barbara Adam and Chris Groves *Future Matters: Action, Knowledge, Ethics*. (Leiden, NL/ Boston, US: Brill, 2007), pp66-70, citing Thomas More, *Utopia*, (Harmondsworth, UK: Penguin, 1516).
13. Fredric Jameson *Archaeologies of the Future: the Desire called Utopia and other Science Fictions* (London/New York: Verso, 2005) citing Thomas More, *Utopia.*
14. Irish Council for Science Technology and Innovation. *Technology Foresight Ireland: Life Sciences Panel*. [Online], 1999.Available from http://www.forfas.ie/icsti/statements/tforesight/health/execsumm.htm [Accessed 3 March 2010].
15. Forfás. *Shaping our Future: Ireland 2025 - Strategic Policy Requirements for Enterprise Development.* (Dublin: Forfás, 2009).
16. Sheila Moorcroft *Managing our Destiny in Uncertain Times…: DCU Foresight Report* (Dublin: Dublin City University/Research For Tomorrow, Today, 2008)

17. Patrick Crehan *Teagasc 2030 - A Case Study in Foresight: Reinventing the Irish Agro-Food Knowledge System*[online] , 2009 Available from http://www.cka.be. [Accessed 3 March 2010].
18. CIRCA Group Europe Ltd. and the Conference Heads of Irish Universities *Technology Foresight and the University Sector*, 2000. Available from http://www.iua.ie/publications/documents/publications/2000/Report_15.pdf. [Accessed 3 March 2010].
19. Theodore W. Adorno. *Aesthetic Theory*. Translated by C. Lenhardt. (London/Boston/Melbourne/ Oxfordshire, UK: Routledge and Keegan Paul, 1984).
20. *Metropolis* [Film]. Directed by Fritz Lang. Germany: Universum Film (UFA), 1925.
21. *Forbidden Planet* [Film]. Directed by Fred M. Wilcox. USA: Metro-Goldwyn-Mayer (MGM), 1956.
22. *Star Wars: Episode IV – A New Hope* [Film]. Directed by George Lucas. USA: Lucasfilm, 1977.
23. *Avatar* [Film]. Directed by James Cameron USA/UK Twentieth Century-Fox Film Corporation, 2009
24. Mark Erickson 'Small Stories and Tall Tales: Nanotechnology, Science Fiction and Science Fact' in A. R. Bell, S. R. Davies and F. Mellor (eds.), *Science and its Publics*. (Newcastle : Cambridge Scholars Publishing, 2008), pp135-156.
25. C. Milburn 'Nanowarriors: Military Nanotechnology and Comic Books'. *Intertexts*, vol. 9, 2005 pp77-103.
26. D. P. Thurs 'Tiny Tech, Transcendent Tech: Nanotechnology, Science Fiction and the Limits of Modern Science Talk'. *Science Communication* vol. 29, 2007, pp65-95.
27. Mark Erickson 'Small Stories and Tall Tales', p136.
28. N. Brown and M. Michael. 'A Sociology of Expectations: Retrospecting Prospects and Prospecting Retrospects' *Technology Analysis & Strategic Management*, vol. 15, 2003, pp1-18.
29. Ulrich Beck 'The Reinvention of Politics'
30. Anthony Giddens 'Risk, Trust, Reflexivity'
31. Bruno Latour *We Have Never Been Modern* Trans. By C. Porter. (Essex, UK: Pearson Education, 1993).
32. Fredric Jameson *Archaeologies of the Future*
33. *ibid.*
34. Alan Irwin and Mike Michael, M. Science, Social Theory and Public Knowledge. (Maidenhead, Berks: Open University Press, 2003)
35. B. Wynne. 'Misunderstood Misunderstandings: Social Identities and Public Uptake of Science' *Public Understanding of Science*, vol. 3, 1992. pp281-304.
36. Sheila Moorcroft *Managing our Destiny in Uncertain Times*
37. Forfás *Shaping our Future*
38. Arie Rip and Haico te Kulve 'Constructive Technology Assessment and Socio-technical Scenarios', in E. Fisher, C. Selin, and J.M Wetmore (eds.) *The Yearbook of Nanotechnology and Society: Volume 1: Presenting Futures*. (New York: Springer, 2009), pp49-70.
39. K. Eric Drexler. *Engines of Creation: the Coming Era of Nanotechnology*. (New York : Anchor Books/Doubleday,1986).
40. Bill Joy. *Why the Future Doesn't Need Us.* [Online].*Wired* vol 8, 2000. Available from http://www.wired.com/wired/archive/8.04/joy.html [Accessed 8 March 2010].
41. Michael Crichton *Prey* (New York: HarperCollins, 2002)
42. Robert A. Weinlein. *Waldo/Magic Inc*. (Del Rey).
43. Flann O'Brien *The Third Policeman* (London: Flamingo,1993)
44. Cynthia Selin, *Real-time Technology Assessment: Anticipation and Deliberation* Presentation to CNS-ASU Workshop - S.NET: Society for Nanoscience and Emerging Technologies, 8 September, 2009.
45. Bruno Latour and Steve Woolgar *Laboratory Life:The Construction of Scientific Facts* (Princeton, NJ: Princeton University Press, 1986)

46. John Law and Michel Callon 'The Life and Death of an Aircraft: a Network Analysis of Technical Change, in W. Bijker and J. Law (eds.) *Shaping Technology / Building Society: Studies in Sociotechnical Change*. (Massachusetts: MIT Press, 1992), pp21-52.
47. Rip and te Kulve 'Constructive Technology Assessment and Socio-technical Scenarios'
48. Schott and Rip 'Constructive Technology Assessment'
49. *op.cit.* p49
50. Bruno Latour *Science in Action : How to Follow Scientists and Engineers through Society*. (Cambridge, US: Harvard University Press, 1987)
51. Rip and te Kulve, p51.
52. Ulrich Beck 'The Reinvention of Politics', p5.
53. Michel de Certeau *The Practice of Everyday Life*. Trans. by S.F. Randall. (Berkeley and Los Angeles: University of California Press, 1984).
54. Barbara Adam and Chris Groves *Future Matters*
55. Norman Fairclough *Analysing Discourse: Textual Analysis for Social Research* (London and New York: Routledge, 2003).
56. Jerry Ravetz. The 'Post-normal Science of Safety', in M. Leach, I. Scoones, and B. Wynne (eds.) *Science and Citizens: Globalisation and the Challenge of Engagement*. (London and New York : Zed Books, 2005)pp43-53.
57. A.H Arnall *Future Technologies, Today's Choices - Nanotechnology, Artificial Intelligence and Robotics: Technical, Political and Institutional Map of Emerging Technologies.* [Online]. (London: Greenpeace Environmental Trust, 2003). Available from http://www.greenpeace.org.uk/MultimediaFiles/Live/FullReport/5886.pdf. [Accessed 22 February 2010].
58. ETC Group. *The Big Down - Atomtech: Technologies Converging at the Nanoscale*. [Online].Winnipeg : ETC Group, 2003. Available from http://www.etcgroup.org/upload/publication/171/01/thebigdown.pdf. [Accessed 8 February 2010]
59. Ulrich Beck 'Preface', in U. Beck, A. Giddens, and S. Lash. (eds) Reflexive Modernisation: Politics, Tradition and Aesthetics in the Modern Social Order. Cambridge, UK: Polity Press, pp vi-viii.
60. Ludwik Fleck. Genesis and Development of Scientific fact. (Chicago and London: University of Chicago Press, 1979[1935]).
61. , 2003, pp1-18.