

REINVENTING THE FUTURE: FORESIGHT AND THE RISE OF NANOTECHNOLOGY

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Abstract

Within the forward view there are many indications of change processes, or what Dator calls 'tsunamis of change'. A highly developed capacity for foresight is capable of reading the signals of change, interpreting their significance and then using this knowledge to make decisions. However, most societies and organisations have not yet implemented effective foresight measures. Thus present and future generations remain vulnerable to the unforeseen effects of change. This paper takes up the theme of nanotechnology, explores some of its broad implications and then characterises it as a stimulus to applied foresight. It is hoped that this example will help to clarify the need for foresight as a social capacity.

The most interesting puzzle in our times is that we so willingly sleepwalk through the process of reconstituting the conditions of human existence.

L. Winner, *The Whale and the Reactor*, Univ. of Chicago Press, 1986, p 10.

Detecting Tsunamis and Signals of Change

The metaphor of tsunamis - waves of change - was coined by futurist Jim Dator to draw attention to a number of large-scale change processes bearing down upon us in the near future. ¹ If ignored, the impacts could reasonably be seen as destructive and destabilising. However, among the most basic concepts of foresight is that 'forewarned is forearmed'. ² If we are aware of such forces in the macro environment we can take account of them in the present. Hence, one of the most productive and useful things any organisation can do is to pay attention to relevant signals of change.

Many early signals of change are easy to miss in the early stages. The macro environment is constantly generating an infinite number of signals. But no individual or organisation can do more than attend to a very few of them. The profession of environmental scanning has developed to deal with this problem; that is, to answer questions about 'what should I/we be looking for' and 'how can we operationalise our search for signals, make them directly useful to our specific organisational needs'?

One of the most useful concepts that futurists try to communicate is that it is indeed possible to 'know' a surprising amount about the near-term future without falling into the trap of being naively predictive. This can seem like a contradiction. But the fact is that a combination of relatively recent 'software' and 'hardware' capabilities makes such knowledge widely available for perhaps the first time in history. Briefly these capabilities include the following.

* *Modern data-gathering and information systems* which make it possible to obtain and summarise vast amounts of raw data and to draw meaningful conclusions from it about real-world processes. The results can be published and made widely available around the world. ³

* The fact that *'knowledge' is not merely confined to the empirical (measurable) domain*. It also has other useful forms, which deal with qualitative, non-empirical phenomena (in such domains as law, ethics, judgement and interpretations). Some qualitative 'ways of knowing' are appropriate for developing a forward view. Bell has proposed the term 'critical realism' for this mode.⁴ What it produces is prepositional or interpretive knowledge.⁵

* The range of *concepts and methodologies of futures research* which describe phenomena in the macro environment so as to permit the construction (and continuing re-construction) of forward views.⁶

Through such means, environmental scanning, coupled with the careful analysis and knowledge-creation available within futures research 'opens out', and symbolically represents to our collective view, the arena of the near-term future. It is important to note that this arena (a) is indeed a construct and (b) that it must be constantly refreshed by new signals, new insights and new understandings. *The essence of the forward view is that it is dynamic, not static*. There is never, ever, a once-and-for-all view of the future. An annual strategic planning seminar or 'foresighting' exercise will not do. Specific institutional niches are required to permit continuous work. The key word here is 'process'. A viable forward view cannot be derived from one book, one individual (however well-respected) or even from a single futures method (such as scenarios, forecasting or Delphi). There is an essential discipline about creating forward views which has a lot to do with understanding the subtle process through which interpretive knowledge is created, validated and used. This construct - the forward view - has an essentially collective, even collegial aspect, which serves to integrate and check shared understandings on a wide scale.⁷ That is why individual 'gurus' should always be regarded critically and used with caution.

Unfortunately, however, many institutions and large social formations either have no provision for creating forward views or they have inadequate and defective ones - such as conventional, inward-looking strategic planning units which may legitimately be regarded as 'fossils' of the industrial era. Some corporations spend quite large sums of money either 'buying in' the latest methodology or in developing their own in-house capabilities. But in surprisingly few cases are they willing to question, let alone clearly perceive, the effects of the collective 'paradigm blindness' created by unquestioned values, adherence to defective economic theories and, most commonly of all, by deeply ingrained corporatist ideologies.⁸ It is no wonder that much corporate work is bland and unconvincing: it takes its shape and meaning from a very simplified world - what Wilber aptly termed the industrial 'flatland'.⁹ On the other hand, if you look at, say, government and educational systems, what you find are systems that are essentially run according to the under-dimensioned dictates of short-term politics and mainstream economics, both of which arguably have crippling defects and cascading unintended side-effects. As presently constituted, neither politics nor economics are capable of contributing much of value to a viable forward view. They are unfortunately part of the problem. We and all generations to follow are therefore subject to far greater levels of hazard and uncertainty than are strictly necessary.

The upshot is that, as the quote from Winner suggests at the head of this paper, we are in the process of reconstituting the conditions of human existence. But we (that is our major institutions and formations) are generally not paying attention. The purpose of this paper is to use the example of nanotechnology to show why, and to some extent how, we could and should be paying attention.

Early signals of nanotechnology

During many seminars and speaking engagements I have often been surprised at how few people have ever even heard of nanotechnology. So what were the early signals? One was provided by Richard Feynman at a talk at the Christmas 1959 meeting of the American Physical Society during which he argued that there was ‘plenty of room at the bottom’, meaning that there were scales of miniaturisation that had not, at that time, been seriously considered.¹⁰ The ‘basic concept of nanotechnology was later articulated in a conference paper by Taniguchi at an engineering conference in Tokyo in 1974.¹¹ Many other events could be cited thereafter. But by far the clearest signal was the publication in 1986 of K. Eric Drexler’s groundbreaking book *Engines of Creation*.¹² This, for the first time, clearly laid out the stunning new perspective that nanotechnology promised to create. Since then there have been many other books, conferences, the formation of Drexler’s own Foresight Institute (FI) and more recently the creation of a web site designed to facilitate discussion and dialogue about possible effects and implications.

To such empirical signals could also be added a number of science fiction (SF) short stories and novels which employed the notion of ‘the very small’ in a variety of dramatic ways. One early story is James Blish’s classic short called *Surface Tension*, in which a number of improbably-shrunken humans battle it out on the micro-scale with various microorganisms.¹³ The notion was later popularised in Asimov’s novel *Fantastic Voyage* and the film derived from it. More recently an anthology of short stories and scientific comment explicitly about nanotechnology was published under the heading of *Nanodreams*. Some of the best contemporary SF portrays nanotech as a significant force in near-future societies.¹⁴ Hence, scientific and imaginative notions of ‘the very small’ have been around for some years. But the implications of technologies developed and applied at this level remain widely unappreciated.

What is Nanotechnology and Why is it Significant?

Nanotechnology is a potentially very powerful suite of new technologies, which seem likely to flow from the confluence of a number of streams of existing technology and research, such as those outlined below.

* Understanding, duplicating and adapting natural microbiological processes such as protein synthesis (the so-called ‘wet’ side of nanotechnology from which all organisms are created).

* Molecular engineering; that is, the construction of tiny machines, atom by atom, that can synthesise complex structures of any size from simple raw materials.

* As part of the above, continuing research on micro computing leading to the progressive enhancement and radical miniaturisation of computing capacity.

A key concept in this perspective is that of the ‘replicating assembler’. It is envisaged as a tiny machine that will reproduce itself many times to bring about, or catalyse, other processes such as the construction of an engine or a spare body part. How these tiny machines will be controlled and kept from overrunning certain limits has certainly been addressed, but remains unresolved. However, the perspective offered by nanotechnology is stunning. Engines will be grown in vats; space suits will be like a second skin, flexible and highly versatile; tiny machines will float in human bodies enabling cell repair and perhaps control over aging. It may even become possible to thaw out cryogenically frozen people and restore them to life. (One of the slogans of nanotech is ‘long life in an open world.’) Communication, security, access to information and media will all be via tiny ‘personal assistants’ either hung on the body, disguised as decoration (jewelry, glasses) or

even implanted within it. The ‘cyberpunk’ novels of William Gibson have depicted some aspects of such a future, but they are very much in the dystopian mode.¹⁵

Drexler himself recently suggested a few ‘highlights’ of the development and application of nanotech.

- * Near-flawless products at minimal cost
- * Carbon-based (read diamond-based) materials with roughly 70 times the strength-to-density ratio of space shuttle aluminum
- * Computers able to perform a billion instructions per second while using 100 billionths of a watt and occupying about the volume of a bacterium
- * As a consequence, almost certainly the ability to develop genuine machine intelligence
- * The ability to undertake really complex tasks such as molecular repair of tissue, and really large tasks, like relativistic interstellar flight
- * Re-chargeable batteries that actually work
- * (And) any of the above for roughly the cost of design plus the cost of raw materials¹⁶

It is tempting to dismiss much of this as technophilic fantasy. But there are at least four reasons why such a response would be wrong. First, Drexler and his colleagues clearly know what they are talking about. While some of the visions do depend on significant technical leaps, they are also based on real science and engineering know-how. Second, and to his credit, Drexler does not try to pull the wool over our eyes. One chapter of *Engines of Creation*, called 'Engines of Destruction', explores some of the many possible dangers. Third, he has made an essential connection between innovation and foresight. He argues that the benefits of technology and the pressure of competition impel us forward. But as the pace quickens, so the likelihood of a fatal error grows. Since we cannot slow the pace of change, he suggests, we must do more to encourage the growth of foresight. This will enable us to direct the process of technical change in safer directions. Finally, taken not as a single forecast but *as a series of signals*, the development of nanotechnology has gained a level of credibility that cannot be reasonably ignored.

Of course, no one knows exactly when the different aspects of nanotechnology will be implemented, or even what level of implementation will occur in each sub-field. But what is increasingly clear is that as work in progress continues to develop, we will certainly begin to see the ‘first fruits’ before too long. Forecasts for implementation vary, but many cluster around 2015-2040 which, given the magnitude and extent of likely impacts, is not far off.

Some Implications of Nanotechnology

Given the broad spread of techniques, technologies and processes gathered under the

heading of nanotechnology, it is notoriously difficult to forecast specific technical applications. However, that is not the purpose of this paper. Instead I want to explore some of the broad social and cultural implications.

1. *The end of scarcity?*

A successful, broad-spectrum implementation of nanotechnology would completely revise our current notions of resource scarcity, and manufacturing costs would fall very steeply indeed. This is due to the fact that once ‘anything can be made from anything’ manufacturing essentially becomes a software problem. Once the instructions to direct molecular assemblers have been created, the mechanism can run over and over again, just as it already does in many existing biological processes, producing perfect, or near-perfect, copies. However, nano-enthusiasts seldom distinguish between the end of *resource scarcity* (and hence physical limits to growth) and the much more difficult issue of *cumulative impacts* on the already over-stressed global ecology. Nor should we assume that because manufacturing costs decrease that the sale price of products would also be low (as witnessed, for example, by the present inflated retail prices of CDs). Still, the prospect of highly efficient solar collectors could perhaps do much to head off a looming energy crisis in the mid-21st century, as well as to moderate the impacts of the continued use of coal, oil and nuclear power.

2. **The end of farming, manufacturing, forestry and related industries?**

One of the revolutionary aspects of nanotechnology is the way that it promises to replace the traditional ‘bulk’ technologies of the industrial era with an entirely new generation of ‘molecular’ technologies. This would not only eliminate manufacturing industry as we know it. It would also eliminate the rural sector: farms growing food and forest plantations growing wood. If we want beef or chicken meat we would be able to grow large slabs of it in vats. Cattle and chickens would no longer be needed. Equally, we would be able to synthesise wood with exactly the characteristics that we require for particular purposes, instead of ‘making do’ with nature’s random variations and imperfections. Clearly the implications for rural communities land use and regional economies would be profound.

3. **Social, cultural and economic impacts**

It is difficult to imagine a non-dystopian wired society in which each individual is theoretically equipped with miniaturised versions of the very best of today’s communication and information technologies (CIT) and more at very low cost. It is equally difficult to assess the multiple impacts on: shopping, entertainment, education, families and so on because the context would be so transformed. But we could certainly expect a range of very major impacts. For example, I doubt if the institution of schooling, which developed in the middle industrial period to serve the limited needs of that time, would survive in its present form. Forward thinkers such as Seymour Papert already envisage the passing away of the school and the rise of a new class of advisers or mentors in place of old-style teachers.

Equally, retailing, shopping, office work, the range of uses and functions that comprise cities would all be drastically altered. Who would need to go shopping if they could deposit some raw material into a ‘nano-constructor’ and program it to synthesise whatever they needed? What possible use would shopping malls and multi-level car parks have in an age of unparalleled material abundance?

Much here depends on how the different aspects of nanotechnology are implemented and by whom. One of the less attractive aspects of miniaturisation is the likely growth of surveillance. As is already the case with mobile telephones that can be, and are, tracked from location to location, we may end up never knowing if our activities are being recorded or not.

As noted, another major area of potential impact is on health, the control and repair of body functions and parts, and greater control over the aging process. Research in these related areas is controversial; but to take only one aspect - to date our predilection for 'death control' measures (i.e. medicine, health care, hospitals) has in no way been matched by our ability to bring birth control into balance with it. Another big advance in the former that was not matched by appropriate responses in the latter would exacerbate an already unstable situation by accelerating overall population growth.

But this is still only scratching the surface. Considering some of the other organisational and human implications, Ed Regis asks:

how (would) you handle the disruption of the world economy caused by a technology that provided unlimited material goods automatically, at virtually zero labour cost, and with negligible costs for raw materials: What would happen to giant corporations once nanotechnology really got rolling? How (would) you cope with the mass unemployment promised by the arrival of fully automated molecular manufacturing? What were people going to do with their lives - what were they going to do, period - when physical labour was no longer a necessity, when they could look forward to living for hundreds of years in perfect health and perpetual youth? ¹⁷

These are all good questions. Yet what is interesting from the accounts I have seen of the possible impacts of nanotech is the way they seem to overlook questions of power and control.

4. Power and control in the nanotech future

What has been widely overlooked in the nanotech debate so far is that *with each new leap forward in technical power there is a corresponding potential for exploitation and control*. As C. S. Lewis put it some years ago (and in the gendered language of the time) 'what we call man's power over nature turns out to be a power exercised by some men over other men with nature as its instrument.' ¹⁸ With nanotechnology there is clearly a new dimension of power and hence a whole new range of opportunities for organisations and groups to use and abuse that power. This is not yet something that has been widely aired. For example, one hesitates to imagine what the military are already planning with nanotechnology, let alone criminals, guerilla organisations, aggrieved minorities and so on.

While a wide range of possible benefits could certainly emerge from the successful implementation of nanotechnology, it is also clear that with present economic structures, political divisions, the presence of various long-running conflicts in the world and the growing gaps between the 'haves' and the 'have nots' on the one hand, and the very limited effectiveness of, e.g., conflict resolution and applied social ethics on the other, that the advent of nanotechnology may very likely exacerbate existing inequities and create many new dilemmas and problems.

The world trade system as it presently functions has led to increasing social and economic polarisation. Without re-constituting economic frameworks and modifying present-day geo-politics, new forms of technology may not be other than temporary 'solutions'. Again, while it is true that existing forms of corporations may themselves be under threat, the elites that run them are unlikely

to passively allow their power and prestige to decay. They are much more likely to explore and implement new forms of power and control. Such issues require urgent collective attention.

The nanotechnology problem, and responses to it

The nub of the nanotechnology problem is that most of its proponents are convinced that it is coming, so we'd better prepare for it as best we may. Notions of inevitability, novelty and *technical* innovation are found throughout the nanotech discourse. It is obvious that the underpinnings of a new world are being created. But what kind of world is it, and how are the fundamental choices to be made? These issues are genuinely difficult to grasp. Drexler's response was to set up the Foresight Institute, a non-profit corporation founded to help prepare for future technologies by research, public education and institutional development. A basic goal of the FI is to help develop several related organisations, which will share a common focus on the problems and opportunities posed by nanotechnology. To this end, the FI publishes news, essays and information. It serves as a networking forum and a source of suggestions for projects in a variety of related areas: computer software, media resources, molecular graphics, political action and tertiary teaching, to name but a few.

Clearly this is a major initiative and an important embodiment of the foresight rationale. In principle Drexler is right: the prospect of such radical and far-reaching changes means that careful foresight work is essential. But there are some weaknesses in this particular application of the principle. For example, the FI cannot be said to be working solely in the public interest (however defined) because it has chosen an advocacy role. The FI documents I have seen are as concerned to establish the scientific and engineering basis of nanotechnology as they are to encourage debate about it. This arguably represents a confusion of roles, which pre-empts some of the most important questions (eg. do we really *need* such a radically de-stabilising suite of technologies?) So there appears to be a barely concealed determinism driving the whole nanotech perspective. As noted, proponents seem to take the view that such developments are all but inevitable; the public should become involved in 'guiding' their application. But such a view begs the deeper question about this apparent inevitability and takes as unproblematic a frame of reference, which is congruent with an out-dated US-centred geopolitical view. The implications of nanotech in a multi-polar world seem not to have been seriously considered.

Given the long time frames applied to the technology, these oversights arguably represent a failure of imagination: the politics are static, the technology rips ahead. In this view, it does not occur that such a prior commitment actually *obscures* the kind of reconceptualisation, which would make the technology itself more problematic, less inevitable. This also illustrates one of the traps that detracts from much popular futures work: technology occupies the high ground but the worldview, with its hidden assumptions, commitments and agendas, is tucked away out of sight, unavailable and unregarded. Here is a powerful argument for the use of distinct *levels of analysis* in the forward view. I have elsewhere proposed three: the empirical, the social/regulatory and the worldview/value levels.¹⁹ If we considered the nanotech phenomenon on each of these it would be much easier to tease out hidden dangers, ideological issues and those associated with obscured worldview commitments.

At the empirical level it is easy to be carried away by optimistic perceptions of abundance and the promise of quite new technical options. But there is insufficient attention to the costs of nanotech and to the centrality of other levels of understanding and response. At the social/regulatory level, there will clearly be a need for new rules and regulations to guide the development of nanotech in socially sanctioned ways. But the deeper point is the presently

unsatisfied structural need for an applied foresight capacity in the wider society and culture.²⁰ Without such a capacity, allied to robust and effective social ethics, it is possible that the challenge of the 'Nanotech revolution' could become irresolvable, leading to historically unprecedented upheavals and breakdowns: social, economic and ecological. At a still deeper 'worldview/values' level, a more profound and worrying imbalance is that which clearly exists between these rapidly-developing technical capacities on the one hand, and our slow, even faltering, progress towards social maturity, or wisdom, both individual and collective.²¹ A whole realm of analysis awaits attention here. It would focus on the ways that present formulations of nanotech emerge from, and depend upon, features of the Western worldview that are neither universally true, nor universally useful. Yet 'other' worldviews are certainly capable of providing the grounding for highly and usefully divergent futures. As such they should be considered as a significant part of the range of possibility ahead and of the wider latitude for understanding and choice that are certainly available.²² Due to space restrictions I will here comment only on the second of these levels.

Nanotechnology as a stimulus to applied foresight

Human societies developed out of a context, which is genuinely and radically different from the world picture before us at the end of this century. But they have not yet come to grips either with the transformations in progress or those moving steadily into view. I have chosen the theme of nanotechnology because it is one, and only one, of the many powerful forces moving out of the future and toward us with the force of a tidal wave, or tsunami. What fascinates me is that *the means to detect and respond to such forces exists - but those means are hardly being used*. In other words, the social investment in foresight is inadequate to the task. By 'means' I refer to:

- * the wider use of environmental scanning capabilities;
- * the application of other futures concepts, tools and methods; and
- * the routine use of these to create evolving overviews of the near-future context.²³

I conclude that it is difficult to see how individuals, organisations or societies can expect to achieve a difficult, many-layered, challenging, complex and, let us admit, dangerous, transition to a new century and era without rapidly taking up some of these capacities and integrating them into everyday practice.

The alternative is to passively wait for the 'tsunamis of change' to hit. But it is increasingly clear what the consequences of that would be. We should not stand idly by and let new dimensions of hazard, risk and uncertainty steadily accumulate until they constitute major threats to the well-being of present and future generations. The whole point of foresight implementation is to reduce hazards, risks and uncertainties to acceptable levels. The question is will we do this? Or will we again permit the impersonal forces of history drive our children and theirs through yet more savage social learning experiences?

The macro future seems to be delicately poised between foresight and experience. The more we apply the former the less need we fear the latter. But it seems that human societies at their present stages of development remain unresponsive to the challenges of the near-term future. In other words, they still 'need' powerful learning experiences before they will act. So the dynamics of world history in the 21st century will be played out within the dialectical interplay of foresight and experience, and all future generations are hostages to the outcome.

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