

Ideas in Progress

Paper Number 30

Nanotechnology: its potential as the ‘next industrial revolution’ and its social consequences

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The series constitute ‘ideas in progress,’ after the notion described by I.J. Good in ‘The Scientist Speculates.’ Good also describes ideas about ideas as ‘partly baked ideas’ believing that “... it is often better to be stimulating and wrong than boring and right.” While the papers do not take this tenet as an excuse for licence at the expense of rigour, they are exploratory and the ideas may change as a theme is developed over time.

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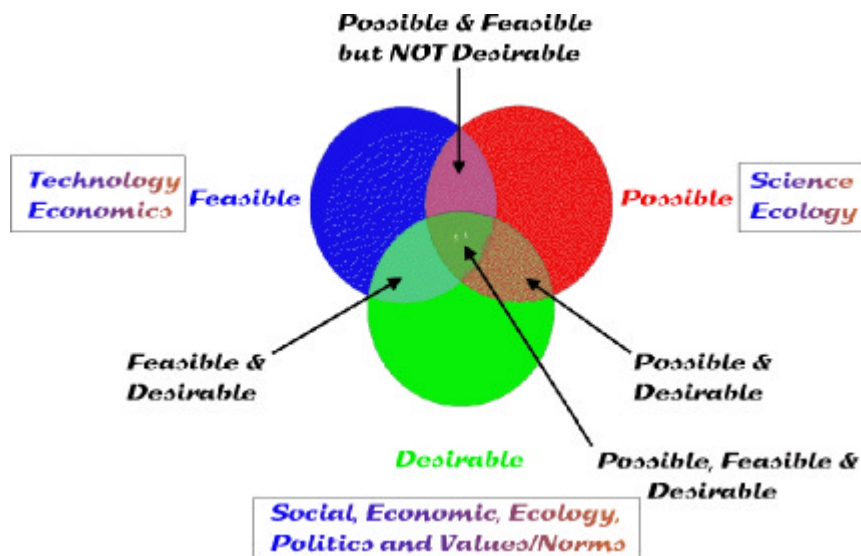
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'Nanotechnology' has been hailed as characterizing the next 'industrial revolution.' If that is the case there will be, if there are not already, major consequences for future industrial and social development globally. The importance of nanotechnology is not limited to populist visions of new wonder artifacts; it is a view promulgated by the scientific and technical community to a degree of exaggeration that is unhelpful, as neither its ideas nor their embodiment are entirely new, Feynman having indicated the possibilities in a classic lecture in 1959 ('There's Plenty of Room at the Bottom' in which he outlined the possibilities of making artifacts nanometre scale (10^{-9} of a metre)).

The first essential step is to 'kill' the notion of 'nanotechnology' - it simply does not exist. What is real is science, technology and engineering at the nanometre scale, the order of magnitude anticipated by Feynman, and they were born at the moment of his 1959 lecture. Nano-scale artifacts are becoming more widely manufactured, but it has to be remembered that nano-scale science has been commonplace in biology and chemistry, especially organic synthesis, for many decades but not under that name. However, the possible influences of nano-scale science and technology on the structure of industry, the economy and society needs discussion now if an unquestioning exploitation of new science and technology for wealth creation and competitiveness, which at the same time influence society and ways of living with many working practices and other aspects of life, is to be avoided. In other fields, such as computer and communication technologies, their exploitation has gone unchallenged and has often resulted in contentious influences on the quality of life and ways of living. Many of these influences, such as the loss of cultural diversity, computer based crime, loss of privacy and increasing surveillance, were foreseen¹ but were ignored until many years had passed. Similarly, research had established limitations to the desire to use the new communications means², such as e-mail and its variants, long before the recent wild investment in the 'new economy.'

Whether nano-scale artifacts will be the basis of the 'next industrial revolution' can be examined through the discussion of three interrelated questions:

- ***What may science make possible at nano-dimensions?*** The question here is a dual one of what are the limits of science? and what do we know about the science of limits?³ Here the key must be to piece together a broad description of where the frontiers of fundamental science lie and the directions in which they are moving: without that the discussion becomes meaningless
- ***What may become feasible as nano-scale artifacts?*** Technology and engineering at nano-scale defines the *feasibility* of designing and creating nano-artifacts. On occasions inventions may enable the creation of nano-scale artifacts before the underpinning science is established⁴. Later innovations, with their connotation of the widespread use of a nano-scale manufacturing process or service provision, will enable the market demand for nano-scale artifacts to be met
- ***What nano-scale artifacts are desirable?*** Desirability covers that area of contention where people discuss and argue about which artifacts may be acceptable to and be expected by society. Desirability, is then the last and the most socially oriented of the three interrelated questions of possibility, feasibility and desirability that will influence the evolution of nano-artifacts acceptable to society. It may also turn out to be the most important.



The ideas involved can be readily appreciated from the adjacent Venn diagram where the important central area denotes what is possible, feasible and desirable at any point in time. Other important overlaps between possibility, feasibility and desirability are also clear and indicate how with time there is a migration towards the central area where the three components coalesce.

Having cast 'nano- technology' into its real components of nano-scale science, technology and engineering, the primary and necessary feature of integration of many themes in them into systems for the creation of artifacts, remains hidden. The first attribute of any nano-scale artifact is *systems integration*. There are already signs of systems integration becoming a pervasive characteristic of the manufacturing and service industries. Some nano-scale systems are already in use, for example in accelerometers. Much of organic synthesis, for example of pharmaceuticals or drug delivery systems, might also be thought of as falling within the realm of nano-scale science and technology. Similarly, materials science and technology, particularly for electronics and biomimetics, would also fall within the the nanometre field. The second pervasive characteristic of the nano-scale is its *linear scale* (dimensions lie between 0.1 and 100 nm). What further separates these artifacts from their forerunners is systems integration at a scale where *quantum physics* and *electronic structure* begin to exert their influences. Creating artifacts with these characteristics is unlikely to follow present design and production methods as these are underpinned by Newtonian science.

The combination of the systemic nature of nano-artifacts with their physical dimensions will also enable them to perform tasks and to be used in circumstances unfamiliar to and perhaps unnoticed by society. Once the presence of nano-artifacts has become known it does not follow that they will be attractive to or accepted by society. Past process, product and service failures have demonstrated society's hesitancy in accepting new artifacts and this is being repeated now in aspects of GMO's, stem cell research, genetics and some forms of gene therapy. The need to create informed debate then becomes clear.

The social aspects of nano-artifacts are often forgotten. The present is, perhaps, a defining moment for industry, investors, regulators and others providing the opportunity to examine the reality and potential (or otherwise) of nano-artifacts as the harbinger of the next industrial revolution or the next stock market bubble.

Organisationally, the future development of nano-scale science and technology, and dependent artifacts will involve:

- Companies concerned with developing nano-artifacts and production processes
- Investors in nano-scale ventures including venture capital companies, ‘business angels’ and others concerned with the initial financing of start-up and similar companies
- Major investment houses
- Stock market analysts as their influence on investment directions is considerable
- Regulators; pressure and single issue groups with social and ethical concerns, and concerns for sustainable development (antagonism to ‘nanotechnology’ is already being expressed by some of these groups)
- Research Councils, university researchers and those concerned with public policy for the financing of science and technology in both the UK and wider
- Those people concerned with the management of intellectual property
- Serious journalists and media representatives (e.g. from The Economist, The Financial Times and other quality broadsheet newspapers, TV channels broadcasting quality documentary programmes)
- Society at large

For all the foregoing reasons research will be needed to build a coherent and in-depth understanding of:

- What is involved in the creation of nano-scale artifacts and businesses based on them
- Its likely future directions in relation to the problems of living in the modern and future world, using Maxwell’s philosophy of wisdom which addresses this question specifically
- How nanotechnology may create wealth and enable improvements in the quality of life, particularly with regard to sustainable development
- Where the current centres of excellence in nanotechnology are located and what they do
- The investment paths, which by implication mean product and market opportunities, to, if possible, enable the exploitation of nanotechnology to occur in a reasonably orderly way avoiding the ‘bubble’ phenomenon so frequently associated with investments in unfamiliar high technology

The methods used will depend heavily on the concepts of systems with a special emphasis on the notions of self-organization and relevant concepts from ecology. It will be necessary to:

- Both extend and challenge the current perception that ‘nanotechnology’ will provide the basis of a new industrial revolution
- Create of a body of information about the location of centres of global excellence in nano-scale science, technology, engineering and the socio-economic acceptance of new pervasive technologies (if possible) in a way to enable network analysis of the data collected and the establishment of quantitative measures of the importance of nodes of excellence in the network
- Bring together stakeholders in the creation of nano-artifacts to promote widespread

and realistic understanding of nano-artifacts to facilitate government and industry policy making for the orderly development of nanotechnology as a potential engine for socioeconomic and sustainable development

- Informing the investment, user and policy communities of the possible ways nano-artifacts may develop. The purpose of this is to promote orderly rather than chaotic investment to avoid the “bubble” phenomenon often associated with the exploitation of unfamiliar science and technology, such as has already occurred in biotechnology, genetics, IT, communications and media which hampers concrete developments and destroys considerable resources

Epilogue

Nano-scale artifacts and the principles of their creation are likely to make themselves felt through *dematerialisation*⁵, the application of the *principle of parsimony*⁶ and the phenomenon of *disintermediation*⁷ all of which have significance for *sustainability and sustainable development*. Nano-scale artifacts will also be conditioned by the notions of *fitness for purpose*, *value* and *risk*⁸. For these reasons alone it is important that the possible influences of this growing field on the structure of industry and the economy begins to be discussed now. Doing so may avoid a future situation paralleling current and past patterns of unquestioning exploitation of new technologies and their excessive promotion in ways that cause unachievable investor expectations.

Notes

1. Loveridge, D. “Computers and You,” *Futures*, December, 498-503, 1983
2. Research conducted at The Institute for the Future demonstrated this round about 1972
3. I am indebted to John Barrow for the notion of the limits to science and the science of limits which in turn are related to Alvin Weinberg’s ideas concerning *trans-science*
4. Such as the role of dendrimers in the formation of monodispersed gold nano-particles
5. Dematerialization is a common notion in industrial design where the emphasis might simply be described as ‘doing more with less’ - these notions now need much wider application
6. The principle of parsimony is an outgrowth of the notions embodied in ‘Occam’s razor’ - see Sober, E. “The principle of parsimony,” *Brit. Jnl. Phil. Sci.*, 32, 145-156, 1981
7. Disintermediation refers to a set of notions described by Hawken, P. “The Next Economy,” Holt Reinhart Winston, 1983
8. The interaction of these three parameters has been developed by Loveridge, D. “Technology choice - game, set or match?” *Proc.of Conference on “Managing R&D into the 21st. Century,”* Manchester, 14-16th. July, 1997