2. Nanotechnology and Dual-Use Dilemmas

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Nanotechnology development and the accommodation of risk

The abundant dual-use potential of nanotechnology arises from the fact it is not materials-specific in either the organic or the inorganic realms. At the nanometre scale, familiar materials can display altered, unexpected and/or amplified qualities including tensile strength, viscosity, conductivity and antimicrobial properties. Our ability to manipulate matter at the molecular and even atomic levels opens up a breathtaking range of possibilities in engineering, medicine, materials science, energy and computing, to list but a few. At the nanometre level (a nanometre is one-billionth of a metre, approximately the diameter of a strand of DNA), disciplinary boundaries between biology and chemistry have become indistinct; and novel techniques notwithstanding, nanobiotechnology is biotechnology conducted at the nano level.[1] Technological convergence—the project to create a 'single engineering paradigm' combining nanotechnology, information technology, biotechnology and cognitive science—is being actively pursued in both the United States and the European Union.[2] These developments have already extended our understanding of what science and technology can achieve.

Although the proponents of nanotechnology and technological convergence exalt the possibilities for human betterment, a great many malfeasant objectives and adaptations are not merely a logical possibility, but also a risk integral to their development and dissemination.

1 Many issues in nanoscience and nanotechnology turn on the practical aspects of disciplinarity, for proponents of nanotechnology, science educators and practising scientists themselves. See Wienroth, M. 2002, 'Disciplinarity and research identity in nanoscale science and technologies', in J. S. Ach and C. Weidemann (eds), *Size Matters*: *Ethical, Legal and Social Aspects of Nanobiotechnology and Nano-Medicine*, Lit Verlag, Berlin, pp. 157–77.

2 Roco, M. C. and Bainbridge, W. S. (eds) 2002, 'Converging technologies for improving human performance: nanotechnology, biotechnology, information technology and cognitive science', *National Science Foundation/ Department of Commerce-sponsored Report*, <http://www.wtec.org/ConvergingTechnologies>; Nordmann, A. 2004, *Converging Technologies—Shaping the Future of European Societies*, <http://www.ntnu.no/2020/pdf/final_report_en.pdf>.

Nanotechnology: Pace, promise and peril

The promise of nanotechnology might well be overstated in some quarters, but there can be no doubting the political importance that has accompanied and furthered its establishment. It is now sufficiently well embedded in research and industrial settings in more than 60 countries that the appearance of nanomaterials in a range of mundane consumer products is unremarkable.[3] Indeed, such is the rate of research breakthroughs and the development of new nanotechnology products and processes that our deliberative systems and established means of regulating them are already being outpaced.[4] The following, from a report on nanomaterials by the Royal Commission on Environmental Pollution, under its depiction of 'risk governance', can also be read with a view to our capacities to apply dual-use bioethics across the full span of nanotechnology and nanobiotechnology:

> [Currently], regulators face a Sisyphean task. Innovation is, or soon will be, driving new products onto the market at rates that are orders of magnitude faster than they can currently hope to manage with the resources at their disposal. We heard from one regulatory body that it was not even considering how to address third and fourth generation nanomaterials because they were fully occupied with those currently at the commercial stage. The magnitude of the task combined with constraints on resources tends to create an attitude of regulatory fatalism … One expert likened the challenge of risk governance in this field to that of shouting a warning to the driver of an express train as it thunders past.[5]

And, in the commission's view, what is true for regulatory deliberation also holds for public consideration more generally:

> There remains in our view a real question about whether the capacity for deliberation and (perhaps even more so) for public engagement in modern democracies is sufficient to sustain an approach that seeks to interrogate scientific and technological developments. The more specific the focus, the more numerous the cases will be, but as the focus becomes more generalized (looking at 'nanotechnologies' as a whole for example), the range of possible applications and implications threatens to make dialogue unmanageable. Informed and inclusive deliberation (however

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3 See the inventory of nanotechnology-based consumer products at The Project on Emerging Nanotechnologies, Woodrow Wilson Center, <http://www.nanotechproject.org/inventories/consumer/>.

4 Whitman, J. 2007, 'The challenge to deliberative systems of technological systems convergence', *Innovation*: *The European Journal of Social Sciences*, vol. 20, no. 4, pp. 329–42.

5 Royal Commission on Environmental Pollution 2008, *Novel Materials in the Environment*: *The Case of Nanotechnology*, <http://www.official-documents.gov.uk/document/cm74/7468/7468.pdf>, p. 66.

> conducted) on a huge range of potential developments seems as distant a prospect as the resolution of many of the technical uncertainties identified elsewhere.[6]

The commission's concerns appear to be validated by the difficulties that have met the many efforts to engage interested publics in serious ethical as well as practical deliberations about the likely impacts and implications of nanotechnology-driven change:

> This commitment to 'upstream' public engagement raises many unresolved questions. At what stages in scientific research is it realistic to raise issue of public accountability and social concern? How and on whose terms should such issues be debated? Are dominant frameworks of risk, ethics and regulation adequate? Can citizens exercise any meaningful influence over the pace, direction and interactions between technological and social change? How can engagement be reconciled with the need to maintain the independence of science, and the economic dynamism of its applications?[7]

Even as these morally weighty yet essentially abstract considerations are being aired, however, the development of nanotechnology is forging ahead, with practical and moral implications that can only be guessed at, as the royal commission describes with respect to whether nanomaterials might pose serious risks to human health and ecosystem integrity.

> Determining the fate of novel materials is vital when assessing the toxicological threat they pose. Nanomaterials are illustrative of the challenge. Techniques for their routine measurement in environmental samples are not widely available, nor are we currently able to determine their persistence in the environment or their transformation into other forms. Laboratory assessments of toxicity suggest that some nanomaterials could give rise to biological damage. But to date, adverse effects on populations or communities of organisms *in situ* have not been investigated and potential effects on ecosystem structure and processes have not been addressed. Our ignorance of these matters brings into question the level of confidence that we can place in current regulatory arrangements.[8]

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6 Ibid., pp. 74–5.

7 Kearnes, M., Macnaghten, P. and Wilsdon, J. 2006, *Governing at the Nanoscale: People, Policies and Emerging Technologies*, Demos, London.

8 Royal Commission on Environmental Pollution, op. cit., p. 6. See also Morris, J., de Martinis, D., Hansen, B., Sintes, J. R., Kearns, P. and Gonzalez, M. 2011, 'Science policy considerations for responsible nanotechnology decisions', *Nature Nanotechnology*, vol. 6, pp. 73–7.

When set against the products and promise of nanotechnology, the very considerable risks and unknowns of the diffusion of nanomaterials might be expected to generate a great many dilemmas both at policymaking and at laboratory levels. Since these are not much in evidence either in public debate or in the momentum of nanoscientific advance, it is clear that the powerful interests involved and the expected gains and competitive advantages carry more weight than either ethical disquiet or practical concerns. Although this is hardly a novel position (of 30 000 bulk chemicals in use in the European Union, only 3000 or so have been formally assessed for health and environmental effects),[9] the moral significance and practical risks involved in nanotechnologies on present and planned scales cannot be regarded much as one might an incremental addition to an already chemicalised environment. After all, the 'transformative' qualities of nanotechnology have been much touted by its proponents, which accounts for the acknowledgment of serious ethical and societal implications that have found expression in the academic as well as policy and policy-related literatures.[10]

The acknowledged possibility of deleterious but unwanted outcomes of nanotechnology, however, in the form of kinds and degrees of toxicity—that is, a biochemical risk of a familiar sort, albeit perhaps on an exceptional scale—is not an end to the matter. It is in the realm of the many uses and adaptations of nanotechnology in practically every field of the physical and medical sciences and engineering that the larger dangers reside—and as part of them, the prospect of an explosion of dual-use issues. These are routinely gathered under the generic term 'societal implications', with 'ethical issues' often given freestanding consideration, by which it is unclear where military nanotechnology is (or should be) sited. After all, the research and development of military uses and adaptations of nanotechnology are by no means either merely prospective or peripheral to the establishment of nanotechnology. Although many of these are at least nominally defensive,[11] active research and already articulated war-fighting possibilities and other means of inflicting serious harm have not been

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9 Royal Commission on Environmental Pollution, op. cit., p. 50.

10 See, for example, Roco, M. C. and Bainbridge, W. S. (eds) 2001, *Societal Implications of Nanoscience and Nanotechnology*, Kluwer Academic Publishers, Dordrecht; Roco, M. C. and Bainbridge, W. S. (eds) 2007, *Nanotechnology: Societal Implications II: Individual Perspectives*, Springer, Dordrecht; 'The coevolution of human potential and converging technologies', *Annals of the New York Academy of Sciences*, vol. 1013 (May 2004); 'Progress in convergence: technologies for human wellbeing', *Annals of the New York Academy of Sciences*, vol. 1093 (2006); Banse, G., Grunwald, A., Hronszky, I. and Nelson, G. (eds) 2007, *Assessing Societal Implications of Converging Technological Development*, Edition Sigma, Berlin; Allhoff, F., Lin, P., Moor, J. and Wekert, J. (eds) 2007, *Nanoethics: The Ethical and Social Implications of Nanotechnology*, Wiley-Interscience, Hoboken, NJ.

11 Kosal, M. E. 2009, *Nanotechnology for Chemical and Biological Defense*, Springer, New York; see also the MIT Institute for Soldier Nanotechnologies, <http://web.mit.edu/isn/>.

precluded.[12] Of the 13 US federal agencies which shared $1.6 billion under the US National Nanotechnology Initiative for 2009, the Department of Defense was allocated 28 per cent.[13]

Military uses and adaptations of nano-enabled products and processes are as yet not concentrated around dedicated means of offensive war-fighting or new weapons systems. Instead, the foreseeable nanotechnology developments most likely to be adopted for military purposes have a very wide range of applications: smart materials, micro-electromechanical systems, nanocomputing, robotics, micro-sensors and many more. Jurgen Altmann has noted that if 'the production facilities for raw material, feedstock, energy, and final products as well as the transport systems are themselves produced by' molecular nanotechnology, 'a very fast increase of the production and distribution of military goods is possible', and one possible outcome of this is that molecular nanotechnology 'production of nearly unlimited numbers of armaments at little cost would contradict the very idea of quantitative arms control and would culminate in a technological arms race beyond control'.[14] In any event, since the worldwide growth of nanotechnology research and development has been propelled by the expectation that it will usher in a 'new industrial revolution', an 'age of transitions' and other epoch-defining transformations, government sanction of nanotechnology developments has always had a strongly competitive edge—made all the more sharp now that it has been linked to conceptions/aspects of national security.[15] Realist fears inform the development of security dilemmas; and the dangers are already apparent: 'By taking cues from Moscow's centralized and opaque institutions, Washington risks misperceiving Russia's intentions and calculations … as well as prematurely locking into strategic competition. The result, if unaltered, could convert the promise of nanotechnology into a new realm of commercial rivalry and arms racing.'[16]

The perils of nanotechnology, however, are not limited to arms races of the sort that can, at least in principle, be addressed by dedicated arms-control initiatives.[17] There has already been concern over the comprehensiveness of the

12 Altman, J. 2006, *Military Nanotechnology*, Routledge, London. See also Shipbaugh, C. 2006, 'Offense-defense aspects of nanotechnologies: a forecast of military applications', *Nanotechnology*, pp. 741–7; Kharat, D. K., Muthurajan, H. and Praveenkumar, B. 2006 'Present and future military applications of nanaodevides', *Synthesis and Reactivity in Inorganic, Metal-Organic and Nano-Metal Chemistry*, vol. 36, pp. 231–5.

13 US National Nanotechnology Initiative, *Funding*, <http://www.nano.gov/html/about/funding.html> .

14 Altman, op. cit.

15 Vandermolen, LCDR T. D. 2006, 'Molecular nanotechnology and national security', *Air & Space Power Journal*, pp. 96–106.

16 Stulberg, A. N. 2009, '"Flying blind" into a new military epoch: the nanotechnology revolution, emerging security dilemmas, and Russia's double-bind', Paper presented at the International Studies Association Conference, February 2009.

17 Whitman, J. 2011, 'The arms control challenges of nanotechnology', *Contemporary Security Policy*, vol. 32, no. 1, pp. 99–115.

Biological Weapons Convention (BWC) and the Chemical Weapons Convention (CWC) relative to the malfeasant purposes to which nanomaterials and products can be put to use:

> Article 1 of the BWC prohibits the development, production, and possession of 'microbial or other biological agents, or toxins whatever their origin or method of production' … Assuming microbial or biological agents should be considered living things, can a toxin be something inorganic or artificially created? Since the phrase 'whatever their origin or method of production' relates to toxins because of the comma placement, it seems to include so-called mechanical devices that could result from mature nanotechnology. In this sense, one can argue that nanotechnology—particularly nanorobots—can be treated as a toxin if it causes harm similar to already known toxins. However, because the BWC seems to deal only with biological organisms or products thereof, a strong argument can be made that the artificially assembled products that nanotechnology would produce cannot possibly fit under the BWC. Perhaps the only way nanotechnology can fall under the BWC's prohibitions without a doubt is if it were used to artificially create replicas of known biological weapons or toxins. Only then would it clearly be covered since no difference would exist between the natural product and the 'artificial' version. However, nanotechnology as a field is much broader than these narrow 'biological replica' applications.[18]

Nanorobots are not first and foremost an arms-control issue, but a dual-use one, with the main lines of current research in the field dedicated to bio, industrial and medical nanorobots.[19] The wide applicability and adaptability of nano-enabled products and processes mean that their dual-use potential is more often than not clearly evident. For example, where a nano-enabled medical advance also holds the promise of more effective delivery of a chemical or biological agent for offensive purposes, one might expect this potential to find expression as a dilemma of considerable weight and intractability. Measured against the many considerable benefits that can arise from their many uses, however, are the research and development of any dual-use nano-development likely to present practising scientists, technologists or policymakers with a *dilemma*?

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18 Pinson, R. D. 2004, 'Is nanotechnology prohibited by the Biological and Chemical Weapons Conventions?' *Berkeley Journal of International Law*, vol. 22, no. 2, p. 298.

19 See the Special Issue of *The International Journal of Robotics Research*, vol. 28, no. 4 (April 2009): 'Current State of the Art and Future Challenges in Nanorobotics'.

Ethics, applied ethics and dual-use dilemmas

Implicit in the idea of a dual-use dilemma is that the beneficent purposes and/or uses of a technology are roughly equal to the potential harm that could be brought about by pernicious applications. If harmful and destructive uses for a developing scientific or technological advance can be foreseen but are not expressed, or not expressed as a *dilemma*, the dual-use potential will not be sufficient on its own to necessitate the kinds of deliberation (scientific, managerial, legal, political) that will regulate, slow, modify or halt the development in question. Subsequent concerns about risks and dangers then become post-facto legislative and law-enforcement matters. Similarly, regulatory initiatives such as export bans to dangerous regimes or to untrustworthy end users do not address dilemmas, but arise from cost and risk/benefit analyses.

Within established scientific and technological arenas, real and potential dual-use dilemmas are not abstract: their 'visibility' in every sense is conditioned by some combination of political priorities; inter-business and international competitive impulses; patterns of public and private financing; and by the narrowness of specialist research that can contribute to, rather than exhibit, dual-use potential. Acknowledging this does not oblige one to subscribe to one or another form of technological determinism, but it takes into account that the proclaimed benefits on the plus side of dual use can serve promotional purposes (of which, beware nano-hype);[20] and that they are rarely if ever wholly disinterested. As discussed further below, these and related considerations narrow the range of actors likely to perceive or to voice dual-use dilemmas, as well as the circumstances when they will be able or likely to do so. At the same time, although many kinds of moral significance and forms of ethical predicament can follow in the wake of scientific and technological advances, these do not all take the form of dilemmas; there are, for example, detailed, ethical arguments both for and against various forms of human enhancement through genetic engineering.[21]

As a general consideration, dual-use dilemmas leave open the question of the affected and/or responsible agent—who or what experiences the dilemma—and indeed, whether such dilemmas are framed in ethical rather than, or in addition to, prudential considerations. For the purposes of this argument, it can be assumed that any dilemma arising from the possible misapplication of biological knowledge will entail practical dangers of considerable moral significance. We

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20 Toumey, C. 2004, 'Nano hyperbole and lessons from earlier technologies', *Nanotechnology Law and Business*, vol. 1, no. 4, pp. 397–405; Berube, D. M. 2006, *Nano-Hype: The Truth Behind the Nanotechology Buzz*, Prometheus Books, Amherst, Mass.

21 Harris, J. 2007, *Enhancing Evolution: The Ethical Case for Making Better People*, Princeton University Press, Princeton, NJ; Sandel, M. J. 2007, *The Case against Perfection: Ethics in An Age of Genetic Engineering*, Belknap Press, Harvard, Mass.

can read as much into the definition of 'dual-use research of concern' proposed by the US National Science Advisory Board for Biosecurity: 'research that, based on current understanding, can be reasonably anticipated to provide knowledge, products, or technologies that could be directly misapplied by others to pose a threat to public health, agriculture, plants, animals, the environment, or materiel.'[22] Moral unease, however, is never automatically congruent with estimates of the practical significance of possible dangers; and it is in the nature of a dilemma that countervailing considerations are of roughly equal weight. In addition, countervailing considerations in life-science dual-use conundrums—that is, those that bolster the case for either the positive or the negative aspects of the dual use to be determined—most often entail structural considerations. This is because of the range of powerful interests involved and because the encompassing arenas are international and/or global.

The application of bioethics or ethical reasoning more generally is not a matter of informed individuals unfailingly applying knowledge to circumstance; and this applies to scientists no less than to any other moral agents.[23] In his comprehensive study of scientists whose research was furthered by collaboration with the Nazi regime, John Cornwell depicts the striking similarity of pressures facing scientists then and now: 'The greatest pressures on the integrity of scientists are exerted at the interface between the professional practice of science and the demands of award-giving patrons.' The narrative of scientific collaboration with the Nazi regime reveals 'the pressures of hubris, loyalty, competition and dependence leading to compromise. In the final analysis the temptation was a preparedness to do a deal with the Devil in order to continue doing science.'[24]

Even when there is no obvious devil in the form of a psychopathological regime, scientific research can but rarely be understood as 'pure' in the sense that it can wholly be abstracted from the potential for pernicious uses; and ethical concerns are embedded in risk/benefit calculations that do not present in clear, dichotomous form. So it is that particular cases of the dissemination of biological knowledge through open, peer-reviewed publication can be seen as posing grave risks of misuse;[25] but at the same time, there is no enthusiasm for general prohibitions on scientific exchanges, on which so much beneficent advance depends, and for which there is no commanding legal reach.[26] It follows that in

22 National Science Advisory Board for Biosecurity (NSABB) 2008, 'Frequently asked questions', <http://www.biosecurityboard.gov/faq.asp#1>.

23 Whitman, J. 2010, 'When dual use issues are so abundant, why are dual use dilemmas so rare?' Research report for the Wellcome Trust project 'Building A Sustainable Capacity in Dual Use Bioethics', <http://www.dual-usebioethics.net/>.

24 Cornwell, J. 2004, *Hitler's Scientists*: *Science, War and the Devil's Pact*, Penguin, London, p. 462.

25 Indicative examples are listed in Institute of Medicine and National Research Council 2006, *Globalization, Biosecurity and the Future of the Life Sciences*, The National Academies Press, Washington, DC, pp. 53–4.

26 Marchant, G. E. and Pope, L. L. 2009, 'The problems of forbidding science', *Science and Engineering Ethics*, vol. 15, pp. 375–94.

such instances, the moral and/or prudential reasoning of individual researchers, publishers and concerned institutions will be informed and conditioned by larger interests and concerns, many of which provide the basis on which particular dual-use dilemmas are generated—in this case, the maintenance of an open epistemic community that will support the range of biological sciences integral to twenty-first-century life. The cases of nanotechnology and technological convergence have been conceived and established not only in ways that highlight the beneficent potential (subtitles of key works include 'technologies for human wellbeing' and 'for improving human performance'), but that also depict 'ethical concerns' and 'societal implications' more as challenges to be dealt with than as outcomes to be avoided.

It is against this background that we must set the potential of bioethics to identify, articulate and address dual-use issues in the life sciences. What needs to be borne in mind is that, in common with other specialist forms of applied ethics within the life sciences (neuro-ethics, nano-ethics, and so on), dual-use bioethics operates *within* fields of endeavour that are engines for generating dual-use issues; it does not bring ethical scrutiny to bear on its own operating environments. In one sense, this is as it should be: subfields of ethics are delimited and specialist—that is their strength, particularly as the issues they engage increase in number and complexity. Yet the growth of specialist, applied ethics in the life sciences also has the effect of signalling the ethical validity of fields they are established to scrutinise, however many dual-use issues they seem set to produce. As the number and kind of ethical quandaries arising from far-reaching scientific and technological advances proliferate, attention naturally focuses on actual or impending difficulties, rather than on the conditions that produce them. Of course, the relationship between medicine and medical ethics is largely unproblematic in this regard, the much larger compass of modern biosciences and bioethics less clearly so, since enterprises such as genetic engineering remain contested in themselves and not merely in respect of some of their particulars or applications. Nanotechnology is still more vexed.

Yet at the same time, there is a great deal of developed-world government anxiety that, 'ethical and societal implications' notwithstanding, nothing should seriously impede the entrenchment and furtherance of nanotechnology and envisioned forms of technological convergence for which it is the foundation.[27] Hence the assertion in the path-breaking US National Science Foundation/Department of Commerce (NSF/DOC) report on converging technologies that '[p]rogress can become self-catalyzing if we press ahead aggressively; but if we hesitate, the barriers to progress may crystalize and become harder to

27 Fisher, E. and Mahajan, R. L. 2006, 'Contradictory intent? US federal legislation on integrating societal concerns into nanotechnology research and development', *Science and Public Policy*, pp. 5–16.

surmount'.[28] Similarly, the principal EU report on nano-led convergence set out the plan for forging ahead despite acknowledging that each of the likely characteristics of converging technology applications 'presents an opportunity to solve societal problems, to benefit individuals, and to generate wealth. Each of these also poses threats to culture and tradition, to human integrity and autonomy, perhaps to political and economic stability.'[29]

Still more remarkable is the following assumption contained in the NSF/DOC report: 'The ability to control the genetics of humans, animals and agricultural plants will greatly benefit human welfare; widespread consensus about ethical, legal and moral issues will be *built into* the process.'[30]

Such a starkly instrumentalist understanding of ethical deliberation was characterised by Paul Ramsey more than 30 years ago:

> We need to raise … ethical questions with a serious and not a frivolous conscience. The man of frivolous conscience announces that there are ethical quandaries ahead that we must urgently consider before the future catches up with us. By this he often means that we need to devise a new ethics that will provide the rationalization for doing in the future what men are bound to do because of new actions and interventions science will have made possible. In contrast a man of serious conscience means to say in raising urgent ethical questions that there may be some things that men should never do. Good things that men do can be made complete only by the things they refuse to do.[31]

The reassurance in the EU report that '[e]nlightened exploitation of discoveries in' nanotechnology, biotechnology, information technology and cognitive science 'will humanize technology rather than dehumanize society'[32] also has the effect of making ethical deliberation appear capable of precluding dilemmas. Moreover, it appears that the task of practitioners in the social sciences and humanities is to act as guides across the space between anxious publics and prepared arenas, if not fixed ends. The following (also from the EU document cited above) on nano-facilitated technological convergence outlines their roles:

> The broadly transformative potential of [technological convergence] sets limits to [its] public acceptance. The pace of the diffusion of new technologies is constrained by the pace [at which we accept] and, if so, accommodate them. Here the social sciences and the humanities are

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28 Roco and Bainbridge, 2002, op. cit., p. 3.

29 Nordmann, op. cit., p. 4.

30 Roco and Bainbridge, 2002, op. cit., p. 5 (emphasis added).

31 Ramsey, P. 1977, *Fabricated Man*: *The Ethics of Genetic Control*, Yale University Press, New Haven, Conn., pp. 122–3.

32 Nordmann, op. cit., p. 99.

> needed to inform and accompany [technology convergence] research and to serve as intermediaries. They should create settings within which science and technology researchers on the one hand and the various publics on the other, can learn from each other.[33]

Such a position does not invalidate the many genuine and methodologically scrupulous efforts that have been made to engage both working scientists and the general public in dialogue about the risks and uncertainties of nanotechnology,[34] whether or not one agrees that the metaphor 'moving the debate upstream' adequately captures the degree to which debate is constrained by political, research, industrial and military developments already well advanced—and the degree to which advocates of nanotechnology foresee the compass and role of ethical deliberation. As depicted in the NSF/DOC report, the nanotechnology 'effort should have many stakeholders in education, healthcare, pharmaceuticals, social science, the military, the economy and the business sector, to name a few. No less than a comprehensive national effort will be required.' In addition, M. C. Roco, widely regarded as the founding father of the US National Nanotechnology Initiative, has recounted the efforts made in the 1990s to ensure widespread, interlocking social and institutional momentum behind the establishment and acceptance of nanotechnology:

> The US National Nanotechnology Initiative was conceived as an *inclusive process* where various stakeholders would be involved. In 1999 we envisioned a 'grand coalition' of academic, industry, governments, states, local organizations, and the public that would advance nanotechnology … Creating a chorus of approval for nanotechnology, from 1990 to March 1999 was an important preliminary step.[35]

Two considerations arise from the history of how nanotechnology has been introduced, institutionalised and consolidated. First is the difficulty any individual is likely to face in apprehending, acknowledging and voicing ethical concerns over dual use that run counter to a prevailing ethos of tightly interlocked institutions and interests. One need not subscribe to Daniel S. Greenberg's judgment that '[a]n infinity of researchable topics renders science insatiable for money and increasingly indiscriminate in ways to get it',[36] which depicts a corroded ethos, but leaves open the possibility for the ethical

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33 Ibid., p. 18.

34 For example, see Rogers-Hayden, T. 2007, 'Moving engagement "upstream"? Nanotechnologies and the Royal Society and Royal Academy of Engineering's inquiry', *Public Understanding of Science*, vol. 16, no. 3, pp. 345–64; Kearnes, M., Macnaghten P. and Wilsdon, J. 2006, 'Governing at the nanoscale: people, policies and emerging technologies', Demos, London; and Nanologue.net, 2006, <http://www.nanologue.net/>.

35 Roco, M. C. 2006, *National Nanotechnology Initiative—Past, Present and Future*, <http://www.nano.gov/NNI_Past_Present_Future.pdf> (italics in original).

36 Greenberg, D. S. 2001, *Science, Money and Politics*: *Political Triumph and Ethical Erosion*, University of Chicago Press, Chicago, p. 463.

deliberation and moral courage of individuals. As psychologist Philip Zimbardo has observed, however, '[m]ost of us have a tendency both to overestimate the importance of dispositional qualities and to underestimate the importance of situational qualities when trying to understand the causes of other people's behavior'.[37] Zimbardo distinguishes between dispositional, situational and systemic causes of behaviour; and although his interest is in trying to account for cruel, inhumane and violent behaviours, his professional experiences, ranging from the Stanford Prison Experiment to Abu Ghraib trial testimony, illustrate how difficult it is for individuals to maintain and enact an oppositional ethical position against a powerful, prevailing expectation. If, as quoted above, the proponents of nano-led technological convergence foresee that 'widespread consensus about ethical, legal and moral issues will be built into the process', the practical prospects for dual-use bioethics will rest on levels of moral courage unsupported by the records of social psychology or history.

Second, it might reasonably be asked whether, if ethicists and bioethicists are stakeholders in a nano-led technological convergence initiative, they can also bring ethical scrutiny to the enterprise itself. There is a strong case for nonconformity with the functional roles that some advocates of nanotechnology foresee for the social sciences and humanities:

> We object to the narrow apprehension that the function of the humanities and the social sciences consists only of achieving public trust concerning nanotechnology. We believe that philosophy and ethics have a critical function regarding the implementation of new technologies, which for instance encompasses asking fundamental questions such as, What impact will this new technology have on humanity? What is a good life? Will this new technology affect the realization of a good life? What kind of society do we want? and How does this new technology relate to that kind of society? (And the list could easily be extended.)[38]

This argument has purchase as a matter of professional orientation, but still greater meaning within contexts that contain such as the following, which concerns the prospect of a nanotechnology-enabled battlefield in which soldiers 'could be accompanied by machines capable of making their own decisions' (again, from the NSF/DOC report):

> [C]ognitive scientists can do research on how a cyborg system makes decisions about what constitutes a legitimate target under varying conditions, including [the] amount of information, how the information is presented, processing time, and the quality of the connection to

37 Zimbardo, P. 2007, *The Lucifer Effect*: *How Good People Turn Evil*, Rider, London, p. 8.

38 Ebbsen, M., Andersen, S. and Besenbacher, F. 2006, 'Ethics in nanotechnology: starting from scratch?' *Bulletin of Science, Technology and Society*, vol. 26, no. 6, p. 453.

> higher levels of command. Practical ethicists can then work … with cognitive scientists to determine where moral decisions, such as when to kill, should reside in this chain of command … Practical ethicists and social scientists need to act as stand-ins for other global stakeholders in debates over the future of military nanotechnology.[39]

None of the above diminishes the importance of awareness and ethical engagement of dual-use potentials by practising life scientists and by applied ethicists, but it does contextualise it. Where, one might ask, are the ethicists and their awareness of the dual-use potential of nanotechnology? We surely know enough in outline about the practical potential and hoped-for applications of nanotechnology (and the considerable efforts being expended to secure them) to recognise them as morally weighty and ethically challenging matters. In respect of dual-use bioethics as it applies to nanotechnology, moral engagement with the project might best be thought of as pre-emptive rather than speculative. Contrary to this, Alfred Nordmann has argued:

> Ethical reflection of science and technology typically reacts to issues that present themselves in the form of classical dilemmas, actual and current predicaments, or hypothetical cases. In the case of reproductive technologies, for example, ethical discussion has proven its relevance by being very close on the heels always of novel techniques. In contrast, nanotechnologies develop a tool-box for technological development. As such they prepare the ground for a technical convergence at the nanoscale. By enabling such a convergence, nanotechnologies create a methodological challenge in that ethical engagement with presenting issues becomes displaced by a perceived need to proactively engage emerging issues. Lay and professional ethicists are only beginning to meet this challenge.[40]

To characterise nanotechnological developments as a 'toolbox', however, and to assert that the ethical challenges presented at this stage are 'methodological' are to abstract them from their social, political and economic contexts, which shape their purposes and drive their momentum. In short, this line of argument insulates nanotechnological developments from ethical scrutiny. But the political sanction and investments that have directed the nanotechnology enterprise have brought about a proliferation of new dual-use issues and have extended or hybridised familiar ones. The weight and competitive orientation of the interests involved have also established it on foundations shot through

39 Roco and Bainbridge, 2002, op. cit., p. 370.

40 Nordmann, A. 2007, 'If and then: a critique of speculative nanoethics', *Nanoethics*, vol. 1, no. 1, p. 34.

with moral and practical risks both profound and pervasive. These are hardly propitious operating conditions for the scope and efficacy of either nano-ethics or dual-use bioethics as applied to nanotechnology.

Dual use and dual-use dilemmas in nanotechnology

As we have seen, even at this early stage of development, the thoroughgoing international commitment to nanotechnology research and practical applications has brought about a condition in which new scientific breakthroughs, novel materials and processes and technological adaptations of nanotechnology are coming on stream at speeds and with complex interrelations that challenge professional comprehension at the community level. These have already begun to outpace our wider deliberative systems—including our means of ethical scrutiny. To this we can add the studied reluctance of nanotechnology's many advocates to engage ethical deliberation outside a framework in which ethical considerations are but one of a set of 'issues' in a scientific and technological progression that must not lose its inertia. This has been the case from the start, as the following two examples illustrate. The first, a report by the US National Research Council in 2002, explained why there was then a paucity of social science research on the 'societal implications' of nanotechnology: 'There appear to be a number of reasons for the lack of activity' in social science research on societal implications.

> First and foremost, while a portion of NNI [National Nanotechnology Initiative] support was allocated to various traditional disciplinary directorates, no funding was allocated directly to the Directorate of Social and Behavioral and Economic Sciences, the most capable and logical directorate to lead these efforts. As a consequence, social science work on societal implications could be funded in one of two ways: (1) it could compete directly for funding with physical science and engineering projects through a solicitation that was primarily targeted at that audience or (2) it could be integrated within a nanoscience and engineering center.[41]

More recently, the US National Nanotechnology Initiative's funding opportunities for 'societal implications' in fiscal year 2010 are typical (and, it should be added, only slightly above 1 per cent of the total disbursement):

41 National Research Council (NRC) 2002, *Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative*, Committee for the Review of the National Nanotechnology Initiative, Division on Engineering and Physical Sciences, National Research Council, National Academies Press, Washington, DC, p. 34.

> Research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, workforce, educational, ethical, and legal implications ($5.78 million). The application of nanoscale technologies will stimulate far-reaching changes in the design, production, and use of many goods and services. Factors that stimulate scientific discovery at the nanoscale will be investigated, effective approaches to ensure the safe and responsible development of nanotechnology will be explored and developed, and the potential for converging technologies to improve human performance will be addressed. The Nanotechnology in Society Network will extend its national and international network.[42]

A second difficulty is that the range of uses of nanotechnology is so extensive and the promise so considerable that 'dual use' will not accurately or fully capture the likely relationship between promise and peril. This is particularly compelling in the case of nano-facilitated medical advances. For example, in an experiment that shows great promise for treating brain cancer in humans, University of Washington researchers have been able to cross the blood–brain barrier in mice. 'Until now, no nanoparticle used for imaging has been able to cross the blood–brain barrier and specifically bind to brain-tumor cells. With current techniques doctors inject dyes into the body and use drugs to temporarily open the blood–brain barrier, risking infection of the brain.'[43] But the possibilities of nano-facilitated drug-delivery systems[44] extend greatly beyond the precise imaging of brain tumours, particularly with respect to malign applications of neurobiology.[45]

Third, the very adaptability of nanotechnology makes a determination of dual use at early stages of development very difficult, or introduces the possibility at a threshold that is below that required for a genuine dilemma. For example, in the following, it is very unlikely that a scientist engaged in the development of nanowires would regard the full span of their possible applications as posing an ethical dilemma:

> University of Arkansas researchers have created assemblies of nanowires that show potential in applications such as armor, flame-retardant fabric, bacteria filters, oil cracking, controlled drug release, decomposition of

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42 National Nanotechnology Initiative (NNI), *Funding Opportunities, at NSF in FY 2010*, <http://www.nsf.gov/crssprgm/nano/core10_nsf_wta_nni.doc>.

43 'Nanoparticles cross blood–brain barrier to enable "brain tumor painting"', *University of Washington News*, 3 August 2009, <http://uwnews.org/article.asp?articleid=51245>

44 Suril, S. S., Fenniri, H. and Singh, B. 2007, 'Nanotechnology-based drug delivery systems', *Journal of Occupational Medicine and Toxicology*, vol. 2, no. 16, <http://www.occup-med.com/content/pdf/1745-6673-2-16.pdf>.

45 Wheelis, M. and Dando, M. 2005, 'Neurobiology: a case study of the imminent militarization of biology', *International Review of the Red Cross*, vol. 87, no. 859, pp. 1–16.

> pollutants and chemical warfare agents. This two-dimensional 'paper' can be shaped into three-dimensional devices. It can be folded, bent and cut, or used as a filter, yet it is chemically inert, remains robust and can be heated up to 700 degrees Celsius.[46]

In all probability, nanotechnology dual use—that is, malign possibilities and pernicious applications as readily achievable as beneficent ones—will continue to feature in research and development programs ranging across the physical and medical sciences, but will rarely appear as dual-use *dilemmas*. The way in which the nanotechnology and technological convergence enterprises have been structured indicates faith at the policymaking level that the worrying developments or applications of nanotechnology can be dealt with on a case-by-case basis, which essentially relegates dual-use conundrums to considerations of risk. There is nothing in the way that nationally supported nanotechnology programs have been initiated and sustained that acknowledges ethical quandaries of a structural kind; and similarly, nor is it the case, as the Fink Report of 2004 asserts, that '[b]iotechnology represents a "dual use" dilemma'.[47] Genuine dilemmas are incapacitating—and there is little to suggest that our individual and collective ethical unease over the biotechnology and nanobiotechnology prospects will inhibit these enterprises, despite the number and range of dual-use possibilities they will continue to generate.

In order for dual-use potentials to be recognised and publicised as matters of social concern and public policy, dual-use bioethics in nanotechnology will need to be sited as far as possible 'upstream', towards current political initiatives and research and development commitments. But the malign possibilities are too wide-ranging in kind and too numerous to be dealt with as and when a genuine dual-use dilemma appears. Indeed, bioethics and nano-ethics will find little argumentative purchase in highlighting dual use if they concentrate on the apprehension of dilemmas. After all, when set against the already extant dual-use potential of nanotechnology, the number of expressed dilemmas is exceedingly rare.[48] What are required are ethical studies that regard the nano-enterprise from 'outside' or 'above', which will provide a context for, and inform, applied ethical studies, such as bioethics and nano-ethics can provide.

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46 US National Nanotechnology Initiative, 2006, <http://www.nano.gov/html/research/home_research.html>.

47 Committee on Research Standards and Practices to Prevent the Destructive Application of Biotechnology, National Research Council of the National Academies 2004, *Biotechnology Research in An Age of Terrorism* [Fink Report], The National Academies Press, Washington, DC, p. 15.

48 Whitman, 2010, op. cit.