Chapter 1

Introduction

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In science fiction, space and time warps are a commonplace.
They are used for rapid journeys around the galaxy,
or for travel through time.
But today's science fiction, is often tomorrow's science fact.
—Stephen Hawking [1]

There have been at least two watershed moments in the modern governance of emerging technologies, linked to issues of the embedding of those technologies in society. First, the tribulations of genetic modification (GM) technology, especially in agriculture in the 1990s, dealt a blow to the progressivist perspective of technologists and technology promotors. There were of course earlier debates about technology and society, such as in the

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nuclear sector as regards issues of safety and radioactive waste. Yet, even in the aftermath of such controversies, newly emerging technologies might have continued to have the benefit of the doubt and there was still room for promises of progress. The progressivist perspective may still be prevalent, but the promotors are more prudent now. Their 'social licence to operate' could no longer be seen as automatic, if it ever was. Second, the advent of nanoscience and nanotechnology in the early 2000s prompted new calls for specially adapted modes of governance. 'Responsible development' became a touchstone of law and policy in the field, which later evolved into the principle of Responsible Research and Innovation (RRI).

Of course, one reason why technological development may be contentious is that it is difficult to know where the 'optimal' balance lies between innovation and caution. Such questions are made all the more complex by issues of scientific and political uncertainty, and cross-generational, cross-national and cross-cultural differences in the values attached to technological progress. The idea that there can be a single 'correct' approach to new technologies has long been criticized as being unrealistic and undesirable. That is not to say, however, that there are not better and worse ways of dealing with technological advance, and embedding it in society.

This edited collection attempts to take stock of the governance of emerging technologies. It does so, not by offering a comprehensive overview of the governance arrangements for all major new technologies, but by identifying some of the main themes running through a small number of examples. For the most part, the collection draws on, and analyses examples from nanotechnology.[1] The edited volume highlights interesting and important issues as encountered by the contributors in their studies of, and experiences with, various applications of nanotechnology. But the book also looks forward, by commenting on the evolving patterns of technology governance and regulation, and by extending the analysis to other emerging technologies. Although the chapters vary in their approaches to technology, they share a central concern with the following issues.

[1]The edited volume grew out of the work being done in the Technology Assessment sub-program of the Dutch national nanotechnology R&D consortiums NanoNed and NanonextNL. See [2].

1.1 Novelty and Indeterminacy

Many aspects of emerging technologies are, by definition, new and uncertain, raising questions about whether and to what extent 'existing' governance arrangements continue to be fit for purpose.[2] The prospect of regulatory gaps often prompts exercises in forecasting, to create an 'anticipatory' evidence-base as it were, although the robustness of such policy-relevant knowledge (and its underpinning practices and assumptions) has frequently been called into question. Collingridge [4] introduced the idea of the 'dilemma of control', to describe the trade-off between regulating a technology when it is in its infancy (and then face the problem of a lack of evidence) and regulating a technology after it has become embedded in society (by which time it has become difficult to exert any influence over the pace and trajectory of the technology's further development). The dilemma cannot be 'solved' in any simple way, but it might involve strategies of 'hedging' and 'flexing' [5], and greater reflexivity.[3] The challenge, as perceived by policymakers and regulators, is to identify frameworks of governance that are stable, yet flexible, rooted in experience but also anticipatory, controlling and facilitative. Achieving this in conditions of severe uncertainty—and indeterminacy—is no easy task.

Indeterminacy goes deeper than uncertainty. Whereas uncertainty implies a lack of information, indeterminacy describes situations in which causal chains, networks and processes are open and defy prediction. Indeterminacy also creates a potentially greater space for projections about technologies, such as big promises about their future performance and societal effects—these promises give rise to particular visions of technoscientific progress. The early years of nanotechnology were full of references

[2]'Technological revolutions', philosopher James Moor reminds us, 'do not arrive fully mature' [3]. They take time to emerge, evolve and become embedded in society. Initially, the possibilities seem almost limitless; a new technology could develop in many different ways, along different trajectories, and directions.

[3]This is taken up in Constructive Technology Assessment (CTA) by arguing that the harshness of Collingridge's dilemma is softened when considering that there are informal and formal assessments throughout the development of an emerging technology. In other words, instead of one big dilemma, there are many small dilemmas that can be addressed in concrete contexts. One should still be concerned about the path dependencies that might arise.

to the expected 'new industrial revolution', and to the 'alleviation of so many earthly ills' as the United States (US) Undersecretary of Commerce phrased it [6]. Such imagery may lead to developmental 'hype-cycles'—sometimes the promises are so far-fetched that they can only end in disappointment [7]. At the same time, there is also the possibility that 'big promises' (e.g. concerning the advantages of the nanoparticles and nanostructures) may trigger 'big concerns' (e.g. about health and environmental hazards). Again, it is important to maintain a sense of complexity, and to not assume that the answer lies solely in more or better risk assessments.

Historically, there has been a tendency to think about technology in terms of its associated 'effects', 'hazards', and 'risks' [8]. Over the years, various contributions from science-and-technology studies have highlighted the problems with such narrow framing of technology, and have shown how exercises in 'black-boxing' can conceal previously unacknowledged, but nonetheless important, subtleties and complexities. In this spirit, there is growing recognition in the academic and policy literatures that the 'facts' of technology may be contested and contingent, and that ambiguity can arise because technology cannot be separated from its constitutive social and political relations. The upshot is that technology amounts to more than a list of benefits and adverse consequences; there is more at play, including deeper social and political considerations, visions and values, risk-benefit calculations, trade-offs, and diverse knowledge and experiences, all of which can contribute to understandings of technological development. These are not static, nor are they consistent within one population, let alone across populations.

The interface between technology and policy-making is itself a source of uncertainty, not only in the sense that there are not always clear scientific answers directing policy action, but also because policy rules and practices themselves bring about novelty and change. This is particularly so where high-level policy commitments are made to becoming the 'world's leading knowledge-based economy' and to creating the 'Innovation Union' [9:5] by ensuring that innovative ideas are turned into new products and services.

Technological innovation rarely occurs independently of normative policy goals. Rather, law and policy can provide the

stimulant for rapid technological change, opening up new areas of uncertainty as a result. Equally, law and policy may act as a disincentive to technology investment and innovation, closing off potential pathways before they can begin to be explored.

1.2 Anticipation and Tentative Governance

There is a strong tradition in the policy literature of calls for 'evidence-based' decision-making, which is usually taken to mean that policies are to be underpinned by scientific facts—although, understandably, it bears a more fraught relationship with technologies so new that evidence is in short supply or deeply contradictory. More recently, it has become associated with the 'Better Regulation' agenda in the European Union (EU) [10] and individual Member States. For example, a United Kingdom Government report, titled *Modernising Government*, stated that

> This Government expects more of policy makers. More new ideas, more willingness to question inherited ways of doing things, better use of evidence and research in policy making and better focus on policies that will deliver long term goals (cited in [11:90]).

Invariably, new technologies, especially those bringing more disruptive forms of change, pose a challenge to the goals of Better Regulation. At the very least, new and disruptive technologies make it difficult to determine what sort of regulation would be 'better' or 'worse' in the circumstances. The question is how policy may be 'evidence-based' in conditions of partial knowledge and even ignorance.

The aim, therefore, is not just to act early but to act in ways that allow for reflection, revision and a degree of 'self-confrontation'. This has been captured by the notion of tentative governance [12]. This means—among other things—developing tools and approaches within the public and private sectors that are attuned to their own limits, contradictions, prior commitments, and potential roles in shaping new technological development.

Whereas the social sciences may in the past have been slow to provide reflexive analysis, the emergence of new technology is now seen as providing an opportunity for re-evaluation and for reflexively incorporating key insights into the technology's regulation and development. If nothing else, new technology

should give us pause for thought about the status quo of existing (not just prospective) arrangements for adapting to, and coping with, a changing technological world. But, one must ask, how often do policymakers, regulators and other relevant stakeholders stop to assess and evaluate such arrangements? Whose responsibility is it to engage in such activities? And what are the practical implications of doing so?

The extent to which law and regulation provide opportunities for reflexivity in this context is much debated. For one thing, it is a well-rehearsed argument that law struggles to keep up with technological innovation. If law marches with technological progress, it is 'in the rear and limping a little'.[4] The problem has been described as the potential 'disconnect' [13] and/or 'pacing problem' [14] between technological development and regulatory frameworks, where there are genuine questions as to whether a particular new technology falls within the letter and spirit of existing regulatory provisions. Where there are plausible gaps, law—in the form of legislative intervention—is often said to be too slow to respond. It is a well-documented feature of law-making processes that they can be unwieldy and bureaucratically cumbersome mechanisms for dealing with rapidly evolving and contested technological futures, and with the wider social implications lying outside conventional issues of 'risk'. At a fundamental level, law is concerned with resolving uncertainty and it deploys various tools to achieve that goal including, for example, the burden of proof and evidentiary presumptions to bridge the gap between knowns and unknowns. These traditional legal norms can become less straightforward to apply when confronted with novel and open-ended circumstances. As Richard Posner observes:

> Law is the most historically oriented, or if you like the most backward-looking, the most 'past-dependent,' of the professions… It is suspicious of innovation, discontinuities, 'paradigm shifts', and the energy and brashness of youth [15:573].

Given the potential limits of conventional legal responses to new technology, there have been calls for new approaches to governance. Although the idea of 'new governance' is not a settled one, it tends to signal a shift away from hierarchical, command and control regimes to more varied techniques of regulation.

[4]Justice Windeyer, *Mt Isa Mines v. Pusey* (1970) 125 CLR 383.

These techniques are usually described as less rigid and less prescriptive than those deployed under traditional regulatory frameworks—and, because of this, they may lend themselves to the more experimental and more reflexive governance of emerging technologies.

1.3 Change, Re-Interpreted and Re-Negotiated

A focus on governance opens up space both within, and beyond, traditional structures and institutional frameworks for further analysis. A recurring theme in this collection is change, be it technological, scientific, social, or political change, and the governance frameworks, principles and behaviours that emerge or are adapted as a consequence. There is a sense that governance may be better suited than traditional legal approaches to dealing with change and uncertainty because it is less committed to specific, uniform outcomes (e.g. such as those contained in precise legal standards), and entails more agile and process-oriented techniques (e.g. using more inclusive and discursive approaches to decision-making). It is in these governance spaces that policies and practices on new technology may be more openly re-interpreted and re-negotiated as experiences unfold.

In this sense, technological development can bring about more than a one-off change; it can induce multiple shifts throughout its social embedding. One example might be the initial polarization of responses to a particular hi-tech product during its early stage of development or commercialization, but a subsequent softening of views as the product becomes more 'mainstream'. The opposite is, of course, also possible. The rhetoric of technoscientific innovation is often framed in sharply dualistic terms—technology is either a saint or sinner, revolutionary or evolutionary, continuous or discontinuous, liberating or enslaving. Other dualisms that infuse the debate include: stagnation or change, heedlessness or precaution, individual or collective, regulated or unregulated, public or private, global or local, poverty or wealth, potential or actual, control or chaos, power or helplessness, upstream or downstream, expert or lay, transparent or opaque, reversible or irreversible.

While not unique to technology, such dichotomies have the potential to obfuscate the issues and short-circuit central debates

[16]. Over time, as a technology becomes embedded, such dualisms are less easily sustained, since issues, patterns and relations emerge in more complex and kaleidoscopic ways. For example, in the case of nanotechnology, the traditional division of moral labour—between on the one hand technology developers and promoters, and on the other hand regulatory agencies and concerned groups—has become blurred, paving the way for better integrated approaches to decision-making. By developing insights into the complexities of processes of and approaches to embedding new technologies into society, and by feeding those insights back into governance arrangements, the overall aim is to build-in prolonged moments of reflexivity.

1.4 This Collection

There is a plethora of newly emerging and potentially disruptive technologies. Nanotechnologies. Synthetic biology. Additive manufacturing (AM) or three-dimensional (3D) printing. Unmanned aerial vehicles. And gene editing using CRISPR-Cas9 techniques. Each of these technological domains was, at one time or another, found only in the imagination of science fiction writers, on the pages of their manuscripts, and in the creativity of movie director's minds as they sought to bring these visions to the big screen. And while travel through time may still fall within the realm of science fiction, certain other technological possibilities, as chapters of this volume illustrate, are part of today's science fact.

What they also build on is what we, as a collective, can learn from consequences of the 'magic mineral' asbestos, the widespread use of ozone-depleting chlorofluorocarbons, environmental exposure to polychlorobiphenyls, and the human health and environmental hazards of lead in paint and petrol [17]. This does not, of course, mean that mistakes will no longer be made in determining suitable regulatory and governance responses to techno-scientific innovation. For one thing, Sir John Meurig Thomas reminds us of the fallibility of predictions of scientific and technological advances [18]. This does not make the attempt to predict the future a purely academic exercise, but it does highlight that many important discoveries are often influenced by a range of (often unpredictable) external factors, including

political, commercial, societal and ethical pressures. Consequently, new technologies and their products will experience periods of under- and over-regulation [19], although we might not be in a position to make such judgments without the benefit of hindsight. This raises important questions about how to approach and evaluate the regulatory, ethical and social dimensions of a given technology as, and when, it emerges.

The chapters in this collection consider these questions; they are divided into three parts. *Part 1—Variety in the Governance of Newly Emerging Technologies* (Chapters 2–7) examines governance issues arising from newly emerging technologies generally. In Chapter 2, van Lente and Rip examine the co-evolution of science, technology and science in order to identify recurrent governance patterns for emerging technologies. The authors highlight the significance of 'early warnings' and 'early signalling' as aids to policymakers and technology developers, as well as the orientation towards Grand Challenges in the policy discourse.

In Chapter 3, Dorbeck-Jung and Bowman explore different modes of governance—precautionary, anticipatory and responsive—that have been employed in addressing real work regulatory challenges posed by nanotechnologies, and the uncertainties thereof. Their chapter dwells on the notion of effectiveness, and the inability to measure effectiveness in an environment characterized by an absence of (known) harms.

Notions of uncertainty, innovation and potential hazards are threads that similarly run through van de Poel's chapter (Chapter 4). He observes that society is 'the laboratory in which new technologies are tried out'. Van de Poel suggests that as it is not possible to mitigate all potential risks associated before a new technology and/or its products enter the market, we should embrace the concept of experimentation once a technology reaches the market and is embedded within it. Careful and deliberate design of experiments allows for real world experimentation, the results of which can then be employed to address the very challenges presented by the technology.

The notion of the *disembedded* future, one that 'tames' an uncertain future by imposing certain logics of decision at the expense of a broader ethics of care, is explored by Groves in Chapter 5. Developing more 'care-full' practices, accordingly to Groves, depends on, among other things, making space for the

virtues and goals of RRI. With RRI now a cross-cutting theme of EU policy in areas of science and technology, an understanding of how ethical and moral issues play into innovation, and its embedding in society, is fundamental to ensuring the goals of RRI are achieved.

In Chapter 6, Rip introduces a novel element in de-facto governance, the division of moral labour, as it specifies roles and responsibilities that have been settled over time. As is clear from the discussion in Chapter 5 (Groves) and Chapter 7 (Shelley-Egan and Lucivero), it can also a productive focus for discussing the governance of new technologies. Rip discusses how the roles and responsibilities are being articulated for nanotechnology.

Shelley-Egan and Lucivero (Chapter 7) focus on the notion of ethical reflexivity and responsibility as applied to emerging technologies. In their chapter the authors ask whether, and how, RRI and institutional reflexivity might be built into scientific practice, notwithstanding the absence of formal regulation (particularly, hard law) to that effect. Again, as with other chapters in the book, the focus is very much on developing more ethically sensitive ways of effectively governing a technology without resorting to traditional legal mechanisms.

Part 2—Promises, Politics and Particularities of Nanotechnologies looks explicitly at the applications of nanotechnology, in order to tease out the different lessons from, and perspectives of, the technology's entry into the market. As this section of the book discusses, governance arrangements (broadly defined) for nanotechnology-based products have now emerged and are not confined to the nation or supranational level; they are now also part of the transnational landscape.

The focus of Chapter 8 is on nano-based sensor technologies. In this chapter, te Kulve and Konrad explore the governance tools that have developed by producers and users of the product as a result of their ongoing interactions; so-called 'demand-side' governance. Their chapter illustrates a deepening and widening of new governance spaces, including those that are developed from the ground up through less formal means, and that go beyond the obvious domains of state-centred rule-making.

In their chapter, Konrad and Palavicino (Chapter 9) make the argument that expectations or imaginaries of the future, and not just technologies per se, may themselves be governed. This might

happen, for example, through the discursive politics of innovation, as a particular technological future may be framed in terms that define its benefits broadly but its hazards narrowly.

The volume then shifts to an examination by Kica and Wessel (Chapter 10) of public-private and private governance schemes involving international standard-setting bodies and non-governmental organizations. Their chapter raises important questions relating not just to where governance activities occur and by whom, but also about the normative basis of such actions. How *should* governance work be distributed?

A common theme among the chapters in this part of the book is the need for collaboration between relevant stakeholders. In her chapter, Reichow (Chapter 11) continues to build on this premise by looking at the ways that business associations, firms and the government have shaped, and are shaping, the occupational health and safety regulatory framework addressing nanomaterials. By looking specifically at two jurisdictions—Germany and the US—Reichow is able to show the level of influence that can be wielded by non-state actors. Moreover, her chapter provides a clear illustration of the variety of governance tools that might be deployed in response to nanotechnology, including information exchange between state and private actors.

Together, these four chapters provide insight into less conventional approaches to the development of governance regimes, and how important and influential non-state actors can be. Such practices shall no doubt continue to evolve along with the emergence of new technologies; how successfully different actors are will depend, so it would seem, on the level of power they have at their discretion, who they seek to influence, and the public values and societal expectations associated with the technology and its products.

Part 3—Looking to the Future of Disruptive Technologies speculates as to just how society may respond to the next wave of emerging technologies. In Chapter 12, Marin focuses on the metamorphosis of the drone; a technology that was developed by, and for, the military that has now found its way into the civilian world. Within the context of this chapter, Marin explores the ethical, legal and social issues created by the use of drone technologies for border surveillance activities in the US and

the EU. The analysis presented by Marin paints a picture of rapidly decreasing privacy, in which the deployment of drones 'changes border surveillance and makes it more pervasive and subtle'. She argues that drones should be considered a 'game changer' within the context of such applications, and that careful consideration must be given to the ways that data may be collected and used.

AM, or so-called 3D printing, has been described as a disruptive technology. In Chapter 13, Delvenne and Vigneron explore the history and use of AM/3D printing today, and paint a detailed picture of the way in which the technology could be employed across all societal domains. The chapter speaks to the seemingly limitless possibilities offered by the technology, and the ways in which AM/3D printing could transform systems of trade, alter global political dynamics, and shift power in ways that we can barely comprehend at this time. Their chapter challenges the reader to contemplate who the potential winners and losers are likely to be, and the ramifications thereof to individuals and society more generally.

In the final chapter (Chapter 14), Bowman, Stokes and Trump explore the tendency and implications of resorting to existing regulatory regimes when faced with a new technology, in this case a particular application of synthetic biology. Here, the authors examine the potential risks and benefits of relying on the regulatory *status quo,* and ask if there are better approaches to bringing a technology to market—especially one that involves such a high degree of scientific uncertainty.

1.5 In Conclusion

In this edited volume, we are taking stock of what has been learned about governance of emerging and possibly disruptive technologies. There has been a lot of learning in practice, including some trial and error. Our contributors build on that, but have also tried to identify important issues and approaches that deserve to be further developed and applied. We invite our readers to think with us, and join in this further development and application.

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