Volume **8** (3) 2026 https://doi.org/10.5204/lthj.4764

Adventures in the *Sociotechnical Umwelt:* Absences of Quantum Computing Imaginaries in Speculative Fiction and Technology Governance

Hin-Yan Liu
University of Copenhagen, Denmark

Abstract

This article stems from observing that, despite its surrounding hype, quantum computing has not been treated as the '*novum*' of speculative fiction leading to quantum computing's distinct absences within the cultural imaginary. Such absences are unique for technological governance, which is powerfully informed and directed by its surrounding cultural imaginaries, providing insight into the process of problem-*finding* in the governance endeavour.

We begin by separating out quantum computing from both quantum mechanics and other quantum technologies because the quantum signifier can muddy our analysis, especially since the latter are regular fixtures within the speculative fiction canon. I moderate my claim that quantum computing is absent in the speculative fiction canon by qualifying that its appearance usually serves as metaphorical portals into speculative worlds or as quasi-technological justifications to overcome significant technical and engineering hurdles in the narratives. To further reconcile this apparent contradiction between quantum computing's often literal presence in speculative fiction and my claim of its absences, we spend some time with three of Istvan Csicsery-Ronay's 'Seven Beauties of Science Fiction' to conclude that speculative fiction is not *about* quantum computing.

After setting out six observations from two absences I focus on problem-*finding* by way of affordances and adjacent-possibles that are illuminated through speculative fiction. As the absences of quantum computing imaginaries frustrate such endeavours, this lays the groundwork for the idea of *sociotechnical umwelt* which foregrounds the 'controlled hallucination' view of the human perceptual system. Here, the brain's predictions are calibrated by incoming sensory signals in a continuous error minimisation process. The analogy that I seek to draw is obviously that the process of technology governance advances through similar principles: that our cultural imaginaries developed and disseminated through speculative fiction is projected into, and subsequently conflated with, the problem-portfolio of a given technology, directing our regulatory responses accordingly.

I then contextualise this idea of the *sociotechnical umwelt* within Jack Balkin's 'salience' approach to technology governance and within the Collingridge Dilemma to indicate its immediate utility. Leveraging the centrality of perceptibility within technology governance, I deploy the *sociotechnical umwelt* as the outer limit of governability itself, and conclude with a plea for broadening the *sociotechnical umwelt* as a means of recognising latent harms.

Keywords: *Sociotechnical Umwelt*; Quantum computing; speculative fiction; problem-*finding*; sociotechnical imaginaries

Except where otherwise noted, content in this journal is licensed under a Creative Commons Attribution 4.0 International Licence. As an open access journal, articles are free to use with proper attribution. ISSN: 2652-4074 (Online)

© The Author/s 2026

Introduction

Quantum computing is odd.[1] Despite vast resources being poured into research and development aiming to unlock its allegedly revolutionary capabilities, and despite accompanying narratives that span from hope to hype,[2] efforts to envisage its future applications and impact remain nascent.[3] An example of the policy lag can be seen in the recent push for responsible Quantum Technologies,[4] versus for example, the much longer debates concerning responsible robotics,[5] and responsible artificial intelligence.[6] Why has quantum computing largely eluded the legal, regulatory, and governance debates that have generally tracked technological innovation in other arenas?

Some commentators suggest that the policy deficit for quantum computing can be accounted for by the purportedly early developmental stage, from a technological standpoint, that we find ourselves in at present.[7] In this article, I propose that the subdued law and policy debate on quantum computing is, instead, a direct corollary of the various *absences* of quantum computing in the speculative fiction canon.[8] Following the lead of Mitchell Travis and Kieran Tranter,[9] however, my aim is not to lay the fault at the feet of speculative fiction authors for their lack of imagination and engagement with the nitty-gritty of quantum computing futures. Instead, my aim in engaging with such absences in speculative fiction *as* the West's mythform[10] is to prise out otherwise elusive lessons for the broader project of technology governance. Indeed, speculative fiction may play a greater role than 'mere myth.' As Darko Suvin writes:

> Where the myth claims to explain once and for all the essence of phenomena, SF posits them first as problems and then explores where they lead to; it sees the mythical static identity as an illusion, usually as fraud, in the best case only as a temporary realization of potentially limitless contingencies.[11]

Such dynamic mythology strongly resonates with Ed Finn's proposition that speculative fiction might be the speculative laboratory of ideas for playing out possible and plausible futures, opening up problem-*finding* approaches that we discuss below.[12] These absences have truncated the cultural imaginaries of quantum computing infused futures in ways that have limited both our imagination and our concern for what quantum computing might herald.[13] Furthermore, I argue that the dearth of quantum computing policy discussion is an aberration in law and technology debates, which far from suffering a pacing-problem,[14] have generally been substantially, albeit subtly, influenced by cultural imaginaries flowing from the speculative fiction canon.[15] Indeed, in juxtaposing quantum computing against a backdrop of contemporary law and technology debates, I echo Kieran Tranter's proposition that legal scholarship and policy debate respond to the cultural imaginaries provided by

[1] In the spirit of resisting the 'weird' metaphor for quantum physics, Ball, Beyond Weird; See also, Meinsma, "Like a Coin Spinning in the Air," for metaphoric handles for quantum technologies.
[2] Karami, "The Quantum Hype in the Scientific Sphere."
[3] Notable contributions include, Atik, "Quantum Computing and Computational Law"; Hoofnagle, Law and Policy for the Quantum Age; Balarabe, "Quantum Computing and the Law"; Lukoseviciene, "Regulating Quantum Computers"; Nguyen, "Export Controls as Innovation Marketing?" Yet, as I hope to demonstrate, such treatment engages directly with the anticipated technical capabilities, rather than a more generalised set of concerns arising from the technological innovation as such.
[4] Schmidt, "Current and Future Directions for Responsible Quantum Technologies."
[5] Liu, "From Responsible Robotics Towards a Human Rights Regime."
[6] Voeneky, The Cambridge Handbook of Responsible Artificial Intelligence.
[7] Lukoseviciene, "Regulating Quantum Computers."
[8] This is a claim which I can only hope to substantiate in anecdotal rather than comprehensive terms. There are also obvious issues with the qualifiers that I have snuck in to make the claim more palatable, such as what qualifies a particular work to be in the canon or not, or what might constitute a significant treatment. It also suffers from any general negative claim, that even a single instance to the contrary can negate the entire claim. The point is not to get bogged down in the details, but to consider the lessons we can learn from a broad-brushstroke observation, and to work out what the exceptions might mean. I will use 'speculative fiction' as a synonym for 'science fiction,' and follow Ed Finn's loose definition of "useful stories about possible futures," Finn, "Step Into the Free and Infinite Laboratory of the Mind," 101.
[9] Travis, "Interrogating Absence," 24–25.
[10] Tranter, "The Speculative Jurisdiction," 818–20. See also, Chernyshova, "Science Fiction and Myth Creation in Our Age."
[11] Suvin, "On the Poetics of the Science Fiction Genre," 375.
[12] Finn, "Step Into the Free and Infinite Laboratory of the Mind."
[13] A different way of approaching this could be the hugely varied descriptions of what quantum computing might bring about, Lukoseviciene, "Regulating Quantum Computers," 4–10.
[14] Marchant, The Growing Gap Between Emerging Technologies and Legal-Ethical Oversight.
[15] For example, law and policy for artificial intelligence has been heavily influenced by its surrounding narratives, which is beginning to be more fully recognised. Hermann, "Beware of Fictional AI Narratives"; Hermann, "Artificial Intelligence in Fiction"; Cave, AI Narratives; Cave, Imagining AI.

speculative fiction,[16] rather than directly to the actual scope of technical prowess or technological application that is available at hand.

To be clear, the absences of quantum computing within the speculative fiction that constitute my core claim is not so much of a literal lack of presence within its works. Instead, where quantum computing does indeed make an appearance, it is neither the subject of the work nor is it integral to that work. I claim that, where quantum computing does feature within speculative fiction, it serves as plot devices that lend pseudo-plausibility to other technologies or capabilities that cannot otherwise be easily explained or accounted for in the process of fictive world-building. The metaphor here is one of quantum computing as a 'portal' technology that enables, catalyses, or otherwise justifies *other* spectacular technological breakthroughs.[17] While we dissect this in depth with reference to three of the Beauties of Science Fiction below,[18] a suitable entry point is provided by the Encyclopedia of Science Fiction entry for 'Quantum Computer':

> In sf, quantum computers provide a convenient shorthand for the kind of extraordinary computing power that may be required to sustain true AI, as in Greg Bear's Moving Mars (1994) with its QL (for quantum logic) "thinkers", or in Peter Watts's Blindsight (2006); or to tackle ultimate questions of Cosmology, as in The Zero Theorem (2013) directed by Terry Gilliam.[19]

Indeed, it may be precisely this association or imaginary that informs our hope and hype in quantum computing. In other words, we may think of quantum computing as the 'fairy dust' or 'secret sauce' that breaks current technological impasse, or waves away significant engineering obstacles, thereby embodying both technological break-through as well as the projected disruption that would ensue (most notably in the realm of cryptography with Shor's Algorithm[20]). The technical sophistication of quantum computing, as well as its association with the complexity of quantum mechanics, further accentuates the radical breakthrough imagery, lending an additional aura of mystique such that quantum computing become almost magical in their capabilities.[21] Many of the cultural imaginaries that do involve quantum computing often invoke it as a means of accessing parallel dimensions or alternate realities, via vague handwaving, to quantum mechanics and especially to what has become known as the 'many worlds interpretation of quantum mechanics.'[22] While these provide convenient plot devices or narrative drivers, these have tenuous connections at best with quantum computing capabilities as currently conceived, and do not engage with quantum computing, and as such, fail to engage with the consequences of quantum computing.

Understanding this exception of quantum computing imaginaries as paradigm-shifting technology embodies the metaphor of disruption. What is interesting about this form of cultural imaginary is that quantum computing is reduced merely to a narrative device for seamlessly suspending disbelief, but that this has nothing to do with the actual attributes or capabilities of quantum computing. This means that such cultural imaginaries are necessarily divorced from governance considerations because quantum computing is invoked in speculative fiction world-building to signal a radical departure from our own world rather than flagging an issue with the technology or its applications.

By deploying disruption as the core metaphor, we can gain insight into the dynamics of disruption posed by new technology, since much of what is touted as technology's disruptive impacts may more prosaically be described as 'displacement' when our perspective broadens.[23] What I mean by this is that many of the perceived disruptive effects of technological applications often boils down to their ability to displace settled social relations, and eminently those involving labour.[24] While this might appear as mere semantics, we did not have imaginaries that directly embodied disruptive technology as its core metaphor before quantum computing.

---

[16] Tranter, "The Speculative Jurisdiction"; Tranter, Living in Technical Legality.
[17] I owe this point entirely to Kieran Tranter in discussions during February 2025.
[18] Csicsery-Ronay, The Seven Beauties of Science Fiction.
[19] 'Quantum Computers' entry in The Encyclopedia of Science Fiction: https://sf-encyclopedia.com/entry/quantum_computers. Kieran Tranter and Sherryl Vint have generally confirmed this point in correspondence. We overlook the other allegory for quantum computers in the entry, namely 'sf speculation is that [quantum computers] may manipulate or allow transfer between Parallel Worlds.'
[20] Shor, "Polynomial-Time Algorithms for Prime Factorization."
[21] I am tempted to suggest that quantum computers play the role of the trickster in technological imaginaries, but this would lead the paper in an entirely different direction.
[22] The original paper setting out the idea is Everett, ""Relative State" Formulation of Quantum Mechanics." See more generally, Everett, The Many-Worlds Interpretation of Quantum Mechanics.
[23] Liu, "Artificial Intelligence and Legal Disruption."
[24] Danaher, Automation and Utopia.

From the unique example presented by the absence of quantum computing imaginaries, I develop the notion of *sociotechnical umwelts*: that we are capable of perceiving only a tiny slice of the possibilities and problems presented by a new technology. This derives by analogy from the perceptual bubbles inhabited by living organisms, who by virtue of their idiosyncratic sensory apparatus, can only perceive but a miniscule portion of the information available within their environment. The *sociotechnical umwelt* allows me to connect the functioning of the human perceptual system, driven primarily by projecting predictions that are subsequently calibrated by incoming sensory signals in a continual process of error minimalisation, to suggest that the cultural imaginaries provided by speculative fiction may play a similar role for technology governance. Speculative fiction defines our very ability to perceive the benefits and burdens that a technology arrays in front of us and dictates their salience[25] (conceived of as relative perceptibility) within problem-portfolios, and sets the scope and scale within which perception plays out.[26] I continue to contextualise the *sociotechnical umwelt* within Jack Balkin's salience approach to technology governance and the Collingridge Dilemma before suggesting that the *sociotechnical umwelt* may draw the line between Noam Chomsky's Problems and Mysteries that indicate the very boundary for the technology governance enterprise.

Quantum Computing as a Break-Through, Disruptive, and Portal Technology

While quantum computing is generally absent in the speculative fiction canon, there are two major exceptions. One involves its engagement with *quantum mechanics* with no plausible ramifications for technological governance (and if this turns out to be wrong, it will fall into the other exception anyway).[27] The other invokes quantum computing as a 'portal' technology – one that enables or catalyses other spectacular technological break-throughs.[28] The point here is that the appeal to quantum computing in such speculative fiction is primarily as a vehicle for world-building or for driving the narrative. As such, quantum computing is invoked to suspend disbelief and to midwife other technological developments, and so the commentary or critique that we can derive from such speculative fiction does not centre upon quantum computing or its implications. Where quantum computing does make an entrance in speculative fiction, it is often depicted as a pseudo-magical quasi-technological capacity:[29] one that, for example, justifies travel between parallel worlds,[30] faster-than-light travel, net-positive fusion, and time-travel in those fictitious worlds. Yet, depicting quantum computing as a 'portal' technology relegates its importance, since it can be plausibly substituted by advanced AI, supercomputing, or other technological bridge in the narrative, for example.

Importantly for our purposes, the 'portal' technology imaginary *does not* allow us to engage with the affordances of quantum computing nor does it open up exploration into adjacent-possibles for problem-*finding*. By literally opening up other, vastly different, technologically-driven worlds it diverts attention and exploration elsewhere, though it may allow us to engage with fiction in a speculative manner that would otherwise be fantasy, and therefore provide a gateway to engage with other technologically-driven worlds. The overarching point in these cultural imaginaries is not necessarily that quantum computing, *qua* quantum computing, is the key to such technological breakthroughs: rather the point is that 'quantum' strikes a delicate balance between being suitably scientific and appropriately mysterious as to qualify as a plausible narrative driver for the speculatively fictitious world at hand. As a means to other technologically-driven ends, technology governance skims over quantum computing quandaries.

An Example from Quantum Computing Export Controls

Anh Nguyen, writing in this Journal,[31] provides powerful support for this conclusion. She opens by asking 'Why are a host of states … imposing export controls on quantum computers with technical specifications (e.g., 2000 qubits) that are not yet realisable?'[32] She provides three narratives driving the ringfencing of quantum technologies: *sovereignty* ('The cutting-edge and transformative nature of QT has become the driving force behind export controls' ringfencing rationale to promote and protect a state's "sovereignty" over innovation resources vital to states' technological base');[33] *security* ('a cryptographically

[25] Balkin, "The Path of Robotics Law."
[26] Stanisław, Solaris, and accompanying commentary in Csicsery-Ronay, The Seven Beauties of Science Fiction, 66–68.
[27] Dihal, "New Science, New Stories."
[28] I owe this point entirely to Kieran Tranter in discussions during February 2025.
[29] Known as Clarke's Third Law, "Any sufficiently advanced technology is indistinguishable from magic" after Arthur C. Clark. Beech, The Physics of Invisibility, 189. I would add a distinction that a technological explanation seeks to underpin observed phenomena with scientific principles and engages plausible techniques consistent with physical laws, whereas appeals to magic simply request that we suspend disbelief.
[30] The "Quantum Computers" entry in The Encyclopedia of Science Fiction: https://sf-encyclopedia.com/entry/quantum_computers continues: 'Because quantum computers can be thought of as operating simultaneously in all the branching realities implied by the many-worlds interpretation of quantum theory, a tempting – though highly dubious – sf speculation is that they may manipulate or allow transfer between Parallel Worlds. This conceit is explored in such novels as Ian Watson's Hard Questions (1996) and Ian McDonald's Brasyl (2007).'
[31] Nguyen, "Export Controls as Innovation Marketing?"
[32] Nguyen, "Export Controls as Innovation Marketing?," 68.
[33] Nguyen, "Export Controls as Innovation Marketing?," 76–77.

relevant quantum computer – if realisable, could constitute a major security threat');[34] and the demonstrative *"Sputnik" Narrative* ('The innovative capabilities and potentials surrounding the imaginary of a [fault tolerant quantum computer] become the leitmotif of state's technology strategy').[35] She concludes that, 'Given that no full-fledged "useful" quantum technology exist, export controls become *tools of knowledge regulation.*'[36] Perhaps most telling of the lead that cultural imaginaries take over quantum technology regulation lies within Nguyen's 'security' narrative: 'Given the major military, information and cybersecurity implications of both quantum sensing and communication technologies, it is peculiar that these technologies have not been featured in recent [quantum technology] export control.'[37]

My interpretation of Anh Nguyen's quantum technology ringfencing is a combination of hype on the one hand,[38] and the absence of specificity within guiding cultural imaginaries on the other hand. The upshot is a cultural imaginary that lauds quantum computing as a keystone technological capability, but one which is unpopulated by specific potential- and problem-portfolios. Quantum computing is hyped up to be of critical importance for the future, but for reasons that we do not yet know.

Situating the Absences of Quantum Computing in Speculative Fiction through Three Beauties of Science Fiction

To build an analytical framework and to break down the vague claim of quantum computing's absences in the speculative fiction canon in analytically useful ways, I think we must meaningfully separate quantum *computing* from quantum *mechanics* or quantum *technologies*.[39] I will draw upon three of Istvan Csicsery-Ronay's 'Seven Beauties of Science Fiction'[40] to articulate the apparent paradox why treatments of quantum computing remain absent within speculative fiction despite the prevalence of quantum mechanics and quantum technology in both the canon and in the broader cultural imaginary. My aim is to demonstrate that speculative fiction engagement with quantum mechanics and quantum technologies are unhelpful for engaging with the legal, regulatory, and governance dimensions arising from or revealed by quantum computing. This is because such treatments do not specifically interrogate the specific problem-portfolios that quantum *computing* might herald, nor do they give form to the types of worlds that quantum computing might open up. What follows are necessarily brief sketches of three of the said Seven Beauties with a view to specifying more precisely both the nature and the contours of the absences of quantum computing in the speculative fiction canon.[41]

'First Beauty: Fictive Neology':

Istvan Csicsery-Ronay emphasises the role of the *new* in speculative fiction (which he underscored especially in the Second Beauty). In the context of the First Beauty, he introduces the idea of 'fictive *signa novi*':

> SF is distinct, in that its fictive neologies connote newness and innovation vis-à-vis the historical present of the reader's culture. They are fictive *signa novi*, signs of the new. In the real world, any design or fashion motif whose purpose is to refer to a "New Thing," whose meaning depends on its newness, is a sign of newness.[42]

Take a step back and consider that the use of 'quantum' well exceeds its literal meaning of 'a discrete quantity of energy proportional in magnitude to the frequency of radiation which it represents.'[43] This observation alone emphasises the use of 'quantum' not for any substantive meaning connoted by the word itself, but rather as an allegorical speculative fiction *signum novum* device: a signal the reader should thereafter suspend disbelief, and for example, accept the many-worlds interpretation of quantum mechanics.[44] In short, 'quantum' can be considered as a neologism signalling the invocation of a speculatively fictional world.

---

[34] Nguyen, "Export Controls as Innovation Marketing?," 77–78.
[35] Nguyen, "Export Controls as Innovation Marketing?," 78–79.
[36] Nguyen, "Export Controls as Innovation Marketing?," 79. Emphasis added.
[37] Nguyen, "Export Controls as Innovation Marketing?," 77.
[38] Nguyen, "Export Controls as Innovation Marketing?," 70–72.
[39] My thanks to an anonymous reviewer who pointed out that I should provide 'an indication of whether the science of quantum mechanics has featured in speculative fiction. That would situate the claims of quantum computing within historical and cultural context. For example, Philip Pullman's trilogy, His Dark Materials and his second trilogy, The Book of Dust, both feature quantum mechanics as part of the story.' I have also been referred to Alex Garland's television series "Devs" (2020) with similar deployments for quantum computing. Full disclosure: I have neither read Philip Pullman's work nor watched Alex Garland's series.
[40] Csicsery-Ronay, The Seven Beauties of Science Fiction.
[41] I keep to the original enumeration of the Seven Beauties for clarity.
[42] Csicsery-Ronay, The Seven Beauties of Science Fiction, 13. Emphasis original.
[43] The Oxford Dictionary of English, under "Quantum."
[44] After all, this is only just one possible interpretation but one which has captured and pervaded the public consciousness Everett, The Many-Worlds Interpretation of Quantum Mechanics.

Although Istvan Csicsery-Ronay contextualises such *signi novi* primarily within the use of new words and phrases, what is important is not the introduction of new words as such, but for our purposes his observation that:

> In most sf, semantic shifts are subtle and unmarked. They invite readers to supply the missing links themselves... SF readers expect to construct a world by supplying motivation and rationales for unfamiliar signs. Readers understand realistic stories of everyday terrestrial life by recognizing references to known experience. SF readers, by contrast, actively supply imaginary new referents that will give rational meaning to the implied science-fictional neosemes [which are 'semantic shifts of words and sentences that remain familiar in structure and appearance, but have been appropriated by imaginary new social conditions to mean something new'[45]].[46]

I can now be more specific in claiming the absences of quantum computing in the speculative fiction canon. Appeal to quantum mechanics and to quantum technologies pervade speculative fiction, but crucially these appeals operate as literary portals into speculatively fictitious worlds rather than engaging with the direct ramifications of quantum mechanics (which would be absurd given macrophysical reality which erases quantum effects) or of nascent quantum technologies more generally.

'Second Beauty: Fictive Novums':

> If sf's language emphasizes neology, the sf novum emphasizes its *neo-logos*, the desire by readers to experience novelty not merely as entertaining ideas and techniques, but as an essential quality of fiction. Through the novum, the genre of sf is an engine for providing new concepts.[47]

The concept of fictive novums further displaces the treatment of quantum computing, even when invoked in works of speculative fiction, precisely because the quantum computer is *not* the novum. So what exactly is a novum?

> [T]he novum is the central imaginary novelty in an sf text, the source of the most important distinctions between the world of the tale and the world of the reader. To be "authentic," in Suvin's view, a novum must be immanent, scientifically apprehendable, and "*validated by cognitive logic*"[...] In practice, sf novums are the radically new inventions, discoveries, or social relations around which otherwise familiar fictional elements are reorganized in a cogent, historically plausible way.[48]

To illustrate that quantum computing, mechanics, and technology are not the substantive novums of speculative fiction, in the sense that its works unpack their ramifications, I would like to highlight novum archetypes (which may be critical to its role as the contemporary West's mythform):

> SF's novums tend to fall into certain classes that we might as well call archetypes. These archetypes are not irrational, ideological hypostases; they are dramatic abstractions of philosophical problems raised historically by theorists and practical inventors alike. They include the classic motifs of sf: extraterrestrial aliens; space travel (especially when enhanced by faster-than-light travel and cryonics); cyborgs and robots; artificial intelligence and A-life; rapid evolution/devolution; mutants; genetic modification and eugenics; prosthetic self-mastery and mastery over others; time travel; multiple realities; parallel and alternative universes; world catastrophe; telepathy; teleportation; precognition; utopia and dystopia. These archetypes fall into two main classes: plausible extensions of what is known, and fantastic extensions that would require new concepts of both scientific understanding and material laws to be taken seriously.[49]

In other words, works of speculative fiction explore and expound upon questions that are unrelated to the substantive problem-portfolio engendered by quantum computing. So where quantum computing does feature within the speculative fiction canon, it appears either as *a portal* to enter such fictive worlds or as *a justification* that enables us to enter and to explore the actual substantive novum represented within the overarching archetypes. This justificatory role merits further elaboration precisely because of quantum computing's ambiguous and ambivalent positionality that pseudo-plausibly bridges empirical scientific realities and those that speculative fictional works seek to explore:

> Many of sf's most typical novums are only ostensibly scientifically rational. Two-way time travel, telepathy, precognition, and communicating alternate universes are very difficult to formulate scientifically in the mesocosm of human existence. Yet they can be elaborated with consistency and coherence *as if* they were really possible ... Many marvellous things, however, can be explained as if they were rational, by converting the universe into a fictional game in which anything can

[45] Csicsery-Ronay, The Seven Beauties of Science Fiction, 19.
[46] Csicsery-Ronay, The Seven Beauties of Science Fiction, 22.
[47] Csicsery-Ronay, The Seven Beauties of Science Fiction, 57. Emphasis original.
[48] Csicsery-Ronay, The Seven Beauties of Science Fiction, 47; referring to Suvin, Metamorphoses of Science Fiction, 63.
[49] Csicsery-Ronay, The Seven Beauties of Science Fiction, 61.

> be posited to be a material process..., and any material process can be explained, using the proven rhetoric of scientific explanation.[50]

I hope that the approach through the novum has clearly illuminated the stark difference between the cameo *appearance* of quantum computing, or quantum mechanics and quantum technology, within works of speculative fiction, and the *treatment of novums* within such works which instead engage substantively with fundamentally different questions and challenges. Indeed, without recourse to fictive novums it would be easy to confuse and to conflate the appearance of quantum computing *within* works of speculative fiction as works of speculative fiction *about* quantum computing.

'Fourth Beauty: Imaginary Science':

If we consider quantum computing both as *signi nova* of speculative fiction thresholds, and as a means of possibly or plausibly justifying speculative fiction novums (that importantly for us, do not concern quantum computing as such), we should ask: why is 'quantum,' and especially quantum mechanics and quantum technologies, so often invoked within works of speculative fiction?:

> Science is sf's pretext. Every quantum-info-nano-bio-cyberastro-psycho-xeno-socio-physical infodump pumps up the illusion that sf stories are dramatizations of scientific knowledge. But even in the hardest of hard sf, sf's science is always figurative. It is an *image* of science, a poetic illusion disguising its illusionary status. The diegetic facts about the physics of onrushing asteroids or the biochemistry of consciousness may be ones that real-world scientists believe to be true. The theories that characters formulate, and the principles on which their worlds are constructed, may be ones that practicing scientists entertain. But within the frame of fiction, these are raw materials only. Many sf writers employ scientific ideas scrupulously. But there is no compulsion for them to do so. They use the language and history of technoscience to evoke the coherence and correspondence of the scientific worldview—but always with the freedom to violate, stretch, ironize, and problematize it. If actual science intends to increase human beings' freedom by augmenting their power over matter, sf makes both freedom and power the subject of play.[51]

Deploying (pseudo-)scientific rationales as narrative bridges into speculatively fictious worlds lends (pseudo-)plausibility in ways that distinguishes such worlds from 'mere' fantasy. I think it is this aspect that allows speculative fiction to serve in policy-relevant problem-*finding* capacities. This is because it enables, and then directs, play and exploration within the speculative and the hypothetical, rather than within the unbounded and purely fictive or the wholly fantastical. In this manner, speculative fiction can inform our cultural imaginaries associated with technologically-driven futures. To do so effectively in the technological governance realm, however, speculative fiction must engage its novums in ways which explore the ramifications of those embedding such technologies in human social worlds and engage with their rippling consequences.

Seven Words: Speculative fiction is not about quantum computing.

Istvan Csicsery-Ronay summarises the important roles played by our Three (of his Seven) Beauties:

> Just as neologisms unite two semantic/conceptual domains that are not "yet" combined in real usage, and as novums combine two historical-physical trendlines counterfactually, the fictive science of sf combines two cognitive/explanatory systems that real technoscience has not—yet.[52]

The upshot is that neologisms, novums, and fictive science extend our imagination in ways that allow us to engage with the perennial questions and ethical implications arising from new technologies by respectively signalling, estranging, and justifying the ludic laboratories created by speculative fiction. These represent modalities for expanding our *sociotechnical umwelt*.

Taken together, we can reconcile the presence of quantum computing (and even the quasi-ubiquity of quantum mechanics) within the speculative fiction canon harmoniously with my claim that these works do not meaningfully engage with quantum computing as such. This is because quantum computing both serves as a bridge into speculative fiction worlds (First Beauty fictive neology) and justifies such worlds back towards common reality (Fourth Beauty fictive science), and because quantum computing are not the substantive novums (Third Beauty fictive novum) explored in works of speculative fiction.

The paucity of speculative fiction *about* quantum computing have important qualitative impacts because the ensuing quantum computing cultural imaginaries become both impoverished (lacking in resolution and granularity) and truncated (shorn of range

[50] Csicsery-Ronay, The Seven Beauties of Science Fiction, 73. Emphasis original.
[51] Csicsery-Ronay, The Seven Beauties of Science Fiction, 111. Emphasis original.
[52] Csicsery-Ronay, The Seven Beauties of Science Fiction, 120.

and scope). Important consequences follow for technological governance due to its reliance upon widely propagated and richly textured corpus of speculative fiction literature.

Speculative Fiction and Problem-Finding

What I am trying to suggest is that the cultural imaginaries fostered and developed by speculative fiction are integral to problem-*finding* in technology regulation and governance.[53] Our ability to explore the potential problem-space opened up by new technologies and their applications are reliant upon the depth and detail of the stories that we tell, and are told, about those worlds suffused with technological consequences. I would go further to suggest that cultural imaginaries set: the perceptual boundaries for the potential problem space itself; the types of problems that we are able to identify; and the resolution through which we can perceive those problems. Cultural imaginaries prime us towards certain types of issues while blinkering us to others, and set the spatial and temporal scales at which we engage with those issues, with important ramifications for our *sociotechnical umwelt*.

Elsewhere, we have argued that the legally-disruptive effects of new technologies and their applications derive from their ability to shift the range of affordances, thereby altering the envelope of possibilities and limitations.[54] Despite this, however, orthodox law and technology approaches gravitate heavily towards problem-*solving*: retrospectively responding to the immediate, direct, and readily-perceptible issues that have arisen from earlier technological applications.

Among the limitations we had previously identified with strictly problem-*solving* approaches is a heavy reliance on over-narrow metaphors:[55]

> [W]here it comes to new technologies, problem-solving perspectives often, implicitly or explicitly, rely on drawing metaphors or analogies in order to fit a new problem or topic within the pre-existing boxes. Yet, as any given analogy or metaphor used to describe new technologies by necessity is incomplete, problem-*solving* perspectives that invoke them are necessarily partial and incomplete, and potentially even misleading, as they express only certain disconnected aspects of the overall challenge posed by the technology.[56]

Let me connect this observation to Darko Suvin's influential definition hinging upon cognitive estrangement whereby:

> SF is, then a literary genre whose necessary and sufficient conditions are the presence and interaction of estrangement and cognition, and whose main formal device is an imaginative framework alternative to the author's empirical environment.[57]

It is speculative fiction's ability to expand the range of metaphors and to contextualise the social impacts of technological applications that are clear and concrete contributions to problem-*finding* approaches to technology governance.[58] Speculative fiction helps us to explore the potential opportunity- and problem-space opened up by new and emerging technologies, and helps us to understand and unfold possible ramifications of their currently-foreseeable applications by centring upon characters who navigate worlds that are infused with hypothetical technological applications that are intertwined with possible social, political, and economic forces (as well as enmeshed with other horizon technologies).[59] For the purposes of *the sociotechnical umwelt*, this process renders perceptible problems that would otherwise remain opaque, but it also communicates these issues more viscerally through storytelling and character empathy engaging us beyond logic and rationality while expanding our sphere of concern as well. Speculative fiction, almost by definition, loosens the strictures of logic, legitimacy, and plausibility that is conducive to exploration and that confine more formal governance discourses and risk-analytic formulae.

This is not to say that speculative fiction is an unalloyed good for problem-*finding*. To the contrary, it can be powerfully misleading and distorting. The pervasiveness of its cultural imaginaries suffuse discourse and debate with metaphors and allegories that shape how we can think about new technologies and their applications. They spotlight issues that may *not be*

[53] Together with Matthijs Maas, we have previously proposed a problem-finding framework in Liu, ""Solving for X?"."
[54] Liu, "Artificial Intelligence and Legal Disruption."
[55] Liu, "Solving for X?," 4–5.
[56] Liu,, "Solving for X?", 4. Citations removed and emphasis original.
[57] Suvin, "On the Poetics of the Science Fiction Genre," 375. Emphasis removed.
[58] Sherryl Vint has pointed out to me, however, that speculative fiction has historically been less useful in drawing out the financial and economic aspects of the fictional worlds that have been portrayed in the canon. This may hamper speculative fiction's problem-finding utility because the portrayed imaginaries may miss out on important drivers and dynamics, such as monetisation of social media through attention-capture and advertising.
[59] Speculative fiction helps also to overcome technology governance's single-technology focus by extrapolating and entangling a range of different strands of technological development to generate emergent second-order ramifications.

pertinent in the real world at present, but which nonetheless make for a thrilling or captivating story.[60] In other words, while speculative fiction may broaden perspectives of the potential problem-space and make the issues it focusses upon more engaging, they may also be those that are the least relevant for technology governance.[61] Speculative fiction, explicitly or implicitly, sets the *umwelt* parameters for what we can and cannot perceive and communicate about when it comes to new and emerging technologies, as well as influencing how we are able to understand and evaluate them by setting the frames of discourse around them. In short, while speculative fiction can highlight and mainstream a range of possible technological futures, these may or may not be tethered to the issues that actually emerge as futures unfold in practice.

The absence of a speculative fiction imaginary for quantum computing presents a useful counterweight for exploring the dynamics of the roles played by cultural imaginaries in technology governance debates,[62] since emerging technologies have been enveloped in speculative fiction throughout their development and deployment stages.

I propose that the general absence of cultural imaginaries for quantum computing from speculative fiction may hold important lessons for law and technology discourse as a whole, but that this may prove to be a double-edged sword. On one hand, it would be possible to neatly tailor the law and policy responses debates to the actual problems raised or revealed by quantum computing. This approach would be useful for direct, first-order, challenges that flow immediately from technological applications.[63] The effect could be a certain type of grounding for technological law and policy that encourage attention paid to actual and plausible impact, rather than engage in more hypothetical speculation. On the other hand, 'Science fiction is a free, infinite laboratory of the mind that allows its audience to envision possible futures *in context* … The craft of effective storytelling pushes authors and readers to play out second- and third-order consequences and to imagine the full context of a changed future.'[64] Speculative fiction enables us to imagine futures in greater resolution and to engage with greater interactional complexity in these futures. Speculative fiction also presents lower barriers to entry for debating futures, thereby promising greater inclusiveness and broader representation that may lead to more equitable and resilient responses. Yet, as we will see when we juxtapose quantum computing with artificial intelligence imaginaries, the potential for metaphors to take on a life of their own and to drive policy discussions looms large over such an approach.

The overall point that I want to make is that the general absence of cultural imaginaries for quantum computing futures itself provides a rare defamiliarising perspective that can reveal implicit and latent presumptions in law and technology debates. Speculative fiction has so infused our cultural imaginaries that it has become nigh impossible to entertain new and emerging technologies without their deep and tacit influence. If it is this cultural imaginary that informs our law and policy responses,[65] its general absence in the case of quantum computing may offer a rare glimpse into how to craft, and then to calibrate, a fundamentally different type of response. I offer this observation while remaining agnostic as to whether it is preferable or desirable to the dominant approaches to engaging with new and emerging technological capabilities.

It has become somewhat customary in such work to provide an explanation of what quantum computing is, how it works/is envisaged to work, before engaging with Shor's algorithm and its potential impact upon contemporary cryptography,[66] and Grover's algorithm increasing the efficiency of optimisation and machine learning tasks.[67] I will sidestep these stages here both because there are eminently better sources,[68] and because I think that engaging with the technical aspects would constitute a digression in this context.[69] My aim here is to engage with the futures that are enabled, restricted, or otherwise altered or influenced by quantum computing, so I need to focus our attention on the cultural imaginaries that inform the parameters of our law and policy debates.

[60] Isaac Asimov's infamous 'Three Laws of Robotics' provides the paragon example because it sets up for a thrilling story rather than proposing practical regulation and governance advice for robotics. Merely shifting the order of the Laws provides for very different worlds, as humorously illustrated in a comic by xkcd: https://xkcd.com/1613/.
[61] As an example, I would suggest AI Safety's emphasis upon human extinction risk posed by superintelligent AI, Liu, "Artificial Intelligence, Human Extinction." See generally, however, Bostrom, Superintelligence.
[62] Travis, "Interrogating Absence."
[63] For an overview of six categories of risks posed by quantum computing, see Lukoseviciene, "Regulating Quantum Computers," 12–16.
[64] Ed Finn calls this 'speculative specificity,' Finn, "Step Into the Free and Infinite Laboratory of the Mind," 99. Emphasis original.
[65] Tranter, "The Speculative Jurisdiction."
[66] Shor, "Polynomial-Time Algorithms for Prime Factorization."
[67] Grover, "A Fast Quantum Mechanical Algorithm for Database Search."
[68] For excellent overviews, see: Aaronson, Quantum Computing since Democritus; Bernhardt, Quantum Computing for Everyone; Hoofnagle, Law and Policy for the Quantum Age.
[69] See also the nuanced discussion as to how to introduce and engage with quantum computing for regulatory purposes, Lukoseviciene, "Regulating Quantum Computers," 4–10.

Six Observations from Two Absences

I am effectively building an argument out of two connected negatives, both of which are easy to challenge. The point of this article, however, is not to get bogged down in minutiae but rather to draw some larger lessons for law and technology: for this it may be necessary to step back and take in the whole.

If '[h]umans are much better at thinking about the future when we can also *feel* it, empathizing with future people who are living with the benefits and costs of particular innovations,'[70] then the absence of broadly shared cultural touchstones for futures infused with quantum computing constitutes a significant handicap. I suggest six outcomes.

First, it is difficult to know what to worry about when it comes to quantum computing. Compared to other allegedly revolutionary technologies, quantum computing has received relatively little policy attention. While it may be easy to discount this lack by noting its embryonic stage of development, it is worth recalling for example that Alan Turing had connected 'computing machinery' with the notion of thinking and 'intelligence' back in 1950 when digital computing was in its infancy.[71] This suggests that it is possible to think of adjacent potentials and problems in the abstract and in advance of requisite technological development and deployment. Instead, quantum computers have often been conceptualised merely as exceptionally powerful computers within works of speculative fiction which has then confined policy thinking within such metaphors.

Second, the lack of cultural imaginaries for quantum computing relative to other new and emerging technologies means that efforts at problem-*finding*[72] are more closely calibrated to the capabilities and challenges of quantum computing, rather than to received cultural imaginaries.[73] This represents the flipside from orthodoxy, potentially removing distraction from policy and governance debates. For example, early AI policy and governance debates have been heavily influenced by the cultural imaginary of autonomous weapons systems (often in the afterimage of the *Terminator* or the *Matrix*[74]) and continue to be overshadowed by claims of the AI threat of *human extinction*.[75] Similarly, as Kieran Tranter has argued, a raft of legislation banning *human* cloning followed successful *ovine* cloning with the birth of Dolly due to a pervasive cultural imaginary inherited from Aldous Huxley's *Brave New World* and the 'Frankenstein Myth.'[76] The point is that a rich corpus of speculative fiction can powerfully colour-in otherwise indeterminate sketches towards a world incorporating new technological applications. This may spotlight certain concerns that are compelling in a narrative setting, but which are poor indicators of manifest societal problems or how best to respond to them. A problematic example of this is readily found in the appeal to Asimov's 'Three Laws of Robotics' that continue to haunt policy debates across the digital technologies, despite these 'Laws' being clearly framed in a manner to drive a thrilling narrative rather than to inform actual regulatory responses.[77]

Third, while the tight nexus between innovation and policy response might appear as an unalloyed good, I would suggest that the lack of cultural imaginary hampers both the range and scope of problem-*finding* endeavours. There is a strand of legal scholarship that emphasises the technological attributes of new and emerging technologies in a way that leans towards technological determinism. Ryan Calo has exemplified this approach in his search for a technology's 'essential qualities' as a

[70] Finn, "Step Into the Free and Infinite Laboratory of the Mind," 99. Emphasis original.
[71] To be fair, it may have been an easier association to make at a time when a computer was a job description rather a technological artefact. Turing, "Computing Machinery and Intelligence." And while there have been analogous claims that consciousness in the brain is underpinned by quantum functions, such claims have been poorly received and heavily criticised. Stuart, "Quantum Computation in Brain Microtubules?"
[72] Liu, "Solving for X?"
[73] See for example the threat modelling and scenario planning in Hoofnagle, Law and Policy for the Quantum Age, ch. 8.
[74] Human Rights Watch, Losing Humanity; Anderson, "Law and Ethics for Robot Soldiers."
[75] See the Center for AI Safety's "Statement on AI Risk": 'Mitigating the risk of extinction from AI should be a global priority alongside other societal-scale risks such as pandemics and nuclear war.' https://www.safe.ai/work/statement-on-ai-risk. While AI may pose a range of global catastrophic, and potentially even existential, risk it is difficult to conceive of how AI may threaten human extinction (which can be considered an extreme subset of existential risk) outside of a couple of hypothetical thought-experiments. Yet, despite the absence of credible pathways to human extinction from AI threats, this still overshadows debate on AI policy. For my critique, see Liu, "Artificial Intelligence, Human Extinction, and Other Stories."
[76] Tranter, Living in Technical Legality, 17–42.
[77] One can critique the application of Asimov's 'Three Laws' at multiple levels. For example, they are more aligned to principles rather than laws since they would be impossibly indeterministic and therefore inoperable. But more importantly, however, it is not clear how these laws came about and why what would effectively be a constitutional transplant be justified and operational in this context. How did the underlying priorities and values come to become enshrined? What were the political processes that brought these about? What about restrictions, limitations, and conditions? These are just some considerations that highlight the rhetorical and narrative use of the fictious regulation that caution against application in the real world.

guide to identifying the legal issues that might arise.[78] I suggest that such an approach will prove to be overly restrictive and brittle because the envelope of affordances will shift with time, development, application, and interaction and because there will be economic and social drivers and restrictions that will shape the law and policy landscape that ensues.[79]

Engaging with cultural imaginaries is imperative for problem-*finding* because of what Ed Finn calls, 'speculative specificity' because in 'centering characters – people – instead of technologies, writers have to offer concrete answers to those nagging questions which can be so easy to gloss over when an invention or discovery exists only as a concept.'[80] Emphasising the characteristics and capabilities of a technology, especially when it is still emerging, detracts from its applications, set within its social context, and the interactional dynamics that determine its problem portfolio.

Fourth, I suggest that while these characteristics might make for more tightly targeted regulatory interventions, another consequence is that such responses will be much more brittle and likely to miss the mark. This may bifurcate problem-identification and response. On one hand there will be a cluster of readily identifiable problems that flow from the foreseeable: in the case of quantum computing this would include Shor's and Grover's Algorithms eroding contemporary cryptography. Yet, because these are foreseeable impacts, it is possible to avert the problem by crafting responses before widespread implementation invokes those problems.[81] On the other hand, because it is easier to legitimate and justify responses to foreseeable problems this might lead both to a false sense of control and security involving the emerging technology, and to marginalising other approaches attempting to engage with the potential problem-space. By concentrating on the immediate consequences of quantum computing innovation and application, obvious problems will receive due regard, and this is important, but such responses will probably overlook interaction effects and be blinkered to the broader and deeper consequences that follow.

Effectively, the question becomes: why speculate about hypothetical problems when there are concrete issues that need to be addressed? What I find interesting about foreseeability is that it cuts in drastically different directions. Take the case of artificial intelligence governance: Spanning from AI Ethics concrete issues include both the direct and immediate (fairness, accountability, and transparency, for example) through to what appear to be the long-term hypothetical represented by AI Safety (The Centre for AI Safety's statement on AI risk touting human extinction seems to be the high-water mark,[82] but this includes the category of existential and global catastrophic risks more generally). The difference in these two types of foreseeable issues arguably derives from the availability of cultural imaginaries. The wealth of AI in speculative fiction that has implicated AI applications with threats to humanity, making this sort of risk both perceptible and salient and therefore within the realm of the foreseeable, if arguably implausible. This may account for apparently disparate threads in contemporary AI governance that do not appear in the quantum computing discourse.

Fifth, there are radical differences in terms of inclusivity throughout the arc of technological development and deployment, but this may be especially stark when it comes to discourse on risk and regulation. Technology policy debates tend to involve epistemic communities of established experts and specialists working within institutional structures that may incentivise engagement with the set of foreseeable problems discussed above. This may mirror Planck's Principle, as told by Thomas Kuhn:

> Max Planck, surveying his own career … sadly remarked that "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it."[83]

Speculative fiction, however, is inherently inclusive thereby broadening not only the range of voices in a direct sense, but also the range of possible issues and topics that can be engaged. This becomes especially important when it comes to allegedly revolutionary technologies, because parts of the problem-portfolio may be opaque to certain people yet impose disparate impacts upon others. The broader range of voices, perspectives, and approaches offered by speculative fiction may be conducive to problem-*finding* in ways that orthodox technological policy approaches are unable to fulfil.

---

[78] Calo, "Robotics and the Lessons of Cyberlaw."
[79] A part of this came out in Jack Balkin's response, see Balkin, "The Path of Robotics Law."
[80] Finn, "Step Into the Free and Infinite Laboratory of the Mind," 99.
[81] One way of putting this is that foreseeability provides a foothold into the information problem limb of the Collingridge Dilemma, Collingridge, The Social Control of Technology.
[82] 'Mitigating the risk of extinction from AI should be a global priority alongside other societal-scale risks such as pandemics and nuclear war.' Emphasis added, and available at: https://safe.ai/work/statement-on-ai-risk
[83] Kuhn, The Structure of Scientific Revolutions, 150.

Sixth, despite the appearance of broader inclusivity, anthropocentric perspectives are effectively concentrated and ossified. This is because speculative fiction narratives have a tendency to privilege human characters over the more-than-human.[84] While this is not an inherent limitation for speculative fiction, it seems to represent an outer edge of what it is reliably capable of delivering. So, while speculative fiction may expand the bounds of inclusivity for human beings, it may still marginalise other agents and patients from the participatory process. This raises the general point that speculative fiction also faces strong limitations in what it can foresee and engage with.[85]

Problem-*Finding* through Speculative Fiction: Affordances and Adjacent-Possibles

One way of framing the potential contribution that speculative fiction can make to the project of problem-*finding* is through the concept of 'adjacent-possibles.'[86] As adapted to our context by Ed Finn:

> Science fiction and science are both engaged in exploring the *adjacent possible*: the worlds we might be able to reach from our present configuration of science and society. Writers and researchers scour the literature, looking for ideas that might be combined or extended in novel ways, and both groups are in the business of creating new stories or new concepts that might change the world.[87]

That is, instead of engaging with the issues that are revealed by the direct technological innovations in quantum computing and their applications (those that are merely 'adjacent'), speculative fiction and other imaginary futures and worlds enable engagement with second-order 'adjacent-possibles.' There are several differences: a difference of methodology, approach, and tolerance; the possibility to engage with combinations and emergent technologies, processes, and outcomes; and to adopt different vantage points when considering governance approaches.

Thinking about governance through a speculative fiction framework throws up the possibility for different affordances, and their effects, to be recognised. There are, however, strong probabilities that those affordances and effects will prove to be distractions for governance for several reasons. Mainly, it is neither the explicit intention nor the purpose of speculative fiction to foresee and predict the future, and the factors that drive a compelling narrative are unlikely to map neatly onto problems that will emerge. Also, it is worth noting that the scope of the possible will necessarily exceed the scope of the plausible, which itself will be greater than the scope of the probable.[88]

With quantum computing, the foreseeable affordances seem to be largely restricted to eroding contemporary cryptographic techniques, but the lack of speculative fiction has hampered our vision as to its other potential impacts. Contrast this with the early concerns voiced about autonomous weapons systems at a time when these were technologically plausible but remained largely hypothetical.[89] Popular cultural imaginaries are dominated by *The Terminator* and *The Matrix*, and the 'Killer Robot' is a stock character in speculative fiction so galvanising momentum towards a *pre-emptive* prohibition was a viable strategy to advocate.[90] This was premised upon their purported inability to comply with the obligations imposed by International Humanitarian Law (IHL),[91] overlooking the obvious legal conclusion that means and methods of warfare that cannot fulfil IHL obligations cannot be legally deployed, thereby rendering redundant any prohibition based solely upon this rationale.[92] It also

[84] Notable exceptions to the anthropocentric perspective are the three latest novels by Richard Powers, although these may not be classified as works of speculative fiction, Powers, The Overstory; Powers, Bewilderment; Powers, Playground. Becky Chamber's 'Monk and Robot' series stands out as an epitome of inclusivity in the canon. The series comprises of Chambers, A Psalm for the Wild-Built; and Chambers, A Prayer for the Crown-Shy.

[85] The personal computer is notably absent from the speculative fiction canon, which Kieran Tranter usefully pointed out to me in conversation. Sherryl Vint has also described to me how we imagined some of the things we might like or be able to do with the new social media, but had no capacity to envisage how monetising through advertising would lead to a preference for, and indeed an optimisation for, engagement time that has spurred knock-on effects including polarised cultures, the return of fascism, and fractured attention-spans. On this last point, see generally, Zuboff, The Age of Surveillance Capitalism.

[86] Björneborn, "Adjacent Possible."

[87] Finn, "Step Into the Free and Infinite Laboratory of the Mind," 99. Emphasis original.

[88] For an accessible overview of the 'P-model,' see Voros, "The Futures Cone, Use and History." For greater context, see Figure 4 and surrounding text, Voros, 'Big History and Anticipation,' 434–37. See also Dunne, Speculative Everything, ch. 1.

[89] See generally, Bhuta, Autonomous Weapons Systems. There is elasticity in the concept of 'autonomous' which serves to bridge the speculatively fictional and the technologically immanent.

[90] Human Rights Watch, Losing Humanity.

[91] For analysis as to how autonomous weapons systems might comply with IHL, see. Anderson, "Law and Ethics for Robot Soldiers" It is worth noting the subtle, yet effective, shift of reference by the term 'Robot Soldiers' rather than 'Killer Robots'; Anderson, "Adapting the Law of Armed Conflict to Autonomous Weapon Systems."

[92] Liu, "Categorization and Legality of Autonomous and Remote Weapons Systems"; Liu, "Refining Responsibility."

overlooked the fact that there has only been a single precedent for a pre-emptive prohibition on new weaponry: the 'blinding laser weapon,'[93] itself seemingly a weapon from the pulp pages of speculative fiction. The cultural imaginary of the Killer Robot was mobilised to oppose the autonomous weapons system, rather than in response to the actual threat, impact, or effect of such systems.

This provides a good example showing that speculative fiction imaginaries do not necessarily provide a good guide for governance. To the contrary, the powerful cultural imaginaries that hang over autonomous weapons systems have placed blinkers that restrict our ability to engage with the fuller range of affordances provided by new technologies. Rather than an overly-narrow obsession over autonomous weapons systems deploying kinetic weaponry on a traditional battlefield in the image of the Killer Robot, however, a significant portion of the problem-space seems to be occupied by the prospect for military and strategic applications of artificial intelligence,[94] and autonomous capabilities in cyber operations,[95] to name just two.[96] The autonomous weapons systems example shows us the flip side: powerful and pervasive dominant cultural imaginaries that focus our fear, (mis-)directing our attention to a specific subset of issues that then distort our governance responses to new, emerging, or speculative technologies.

Where does this leave us? On one hand, the absence of quantum computing imaginaries has curtailed and truncated our ability to engage with its policy and governance implications; on the other hand, the overbearing Killer Robot narratives have cornered regulatory responses to autonomous weapons systems to limited considerations. What about the vast space in between these positions?

Let's go back to Ed Finn, who sought:

> [T]o understand how AI is depicted in contemporary science fiction. We were hoping to learn whether the speculative side of our cultural imaginary on AI has better answers for what kinds of stories we should be telling, as policymakers try to understand and regulate these rapidly evolving tools. The answer? Nobody knows what AI is — even in fiction, where the author can make all the decisions about how the world works. The AI systems we studied in fiction were ambiguous in terms of their agency, their boundaries or extent of operations, the question of who owned or controlled them, etc. Little wonder that we collectively have such a poor grasp of what AI means in the real world, much less how to manage it.[97]

This highlights just how slippery AI can be, and not just for those seeking to govern its applications. Yet, a similar observation can be made for quantum computing, that 'nobody knows what quantum computing is,'[98] but the stark difference is its absence from the speculative fiction canon and therefore the lack of associated cultural imaginary. The signal is difficult to discern from the noise in the former, while the signal is difficult to detect in the silence of the latter.

Perhaps the point is that the affordances of a technology depend not just upon the characteristics of its applications and how these are plugged into social, political, and economic systems, but also on how we perceive them through the filters of shared cultural imaginaries. As Ed Finn again points out: 'Policy and technology decisions are deeply informed by adjacent possible

[93] Carnahan, "The Protocol On "Blinding Laser Weapons." It is worth noting the limited military utility: 'Meanwhile, there was also a growing sense that a true "blinding" laser, that is, an antipersonnel weapon that cannot kill or injure except by causing severe eye damage, was not militarily necessary,' 487. Emphasis original.

[94] Maas, "Innovation-Proof Governance for Military AI?"; Maas, "How Viable Is International Arms Control for Military Artificial Intelligence?."

[95] Buchan, "Autonomous Cyber Weapons and Command Responsibility."

[96] Questions raised by autonomous weapons systems are just one nexus where artificial intelligence, as a general multipurpose technology, intersects with the military and security apparatus. One way to think about this is to consider where the powerful information processing capabilities of artificial intelligence would make the most impact in the military and strategic realm. From this perspective, autonomous weapons systems replacing combatants in the battlefield would not appear to be a priority since AI would be more usefully incorporated within the decision-making echelons at brass level. This would present very different sets of concerns, including human beings placed under the loop (that is, that human beings would be subjugated to military command by AI, or at least extremely heavily influenced by its decision-making processes). See generally for different framings, Liu, "From the Autonomy Framework."

[97] Finn, "Step Into the Free and Infinite Laboratory of the Mind," 102.

[98] In homage to Richard Feynman's infamous quip 'I think I can safely say that nobody understands quantum mechanics,' Feynman, The Character of Physical Law, 129. My point here is that akin to Ed Finn's observation about AI, quantum computing can be many things understood through different metaphors and analogies but we still do not know what quantum computing is as such. But note: 'The mathematical and quantum mechanical foundations of [quantum technology] are theoretically sound and have been experimentally proven. As such, [quantum technology] is not a speculative technology; however, because of these engineering hurdles, the field is still exploratory and uncertain,' Nguyen, "Export Controls as Innovation Marketing?" Citation omitted.

futures that science fiction offers up.'[99] The deluge of law and policy work on artificial intelligence, juxtaposed against the silence of quantum computing counterparts reflects exactly this.

Speculative fiction may be useful for diversifying the adjacent possibles for new and emerging technologies and how these may be applied. Yet, its utility for problem-*finding* may be severely curtailed because the social, political, and economic dimensions remain tethered to those that are accessible, familiar, and salient to its readers and audience. So speculative fiction sets up adjacent possibles when it comes to shiny new technologies, it but often remains mired merely within the first-order adjacent when it comes to the social ramifications of such developments.

Sociotechnical Umwelts

This unique combination in quantum computing is the launchpad for our adventures into '*sociotechnical umwelts.*'[100] My idea in a nutshell is that speculative fiction's imaginaries render perceptible only a minute subset of potentials, possibilities, and problems from the full panoply of sociotechnical futures. These imaginaries launch vectors for the future technology governance, but they also set blinkers veiling alternative approaches that have not been expressed in the speculative fiction canon. This means that absences within the cultural narrative will cast long shadows into technology governance.

Ed Yong contextualises the *umwelt*:

> Every animal is enclosed within its own sensory bubble, perceiving but a tiny sliver of an immense world. There is a wonderful word for this sensory bubble – *Umwelt*. It was defined and popularized by the Baltic German zoologist Jakob von Uexküll in 1909. *Umwelt* comes from the German word for "environment," but Uexküll didn't use it to refer to an animal's surroundings. Instead, an Umwelt is specifically the part of those surroundings that an animal can sense and experience – its perceptual world.[101]

Unlike the physical differences in animal perceptual systems that underpin the diversity of individual *umwelts*, however, it is a metaphorical analogy that I draw upon here. It builds upon an earlier idea we proposed that technologically-driven legal disruption engages with the affordances and signifiers that new technologies open up.[102] In this vein, the absence of quantum computing imaginaries has provided the necessary defamiliarisation revealing that affordances and signifiers differ not only upon 'objective' attributes or concrete applications, but may also present themselves in differential fashion depending upon sociotechnical imaginaries that both direct and obscure perceptibility.

To do this, I must distort slightly the meaning of *umwelt* from its original focus upon animal *perception* to instead represent *sociotechnical perceptibility*. And to do this, I connect this ability to perceive to the priming of the human perceptual system and the processes of prediction and projection, followed by calibration and grounding through sensory input. Anil Seth calls this view of perception 'controlled hallucination.'[103] It involves the brain constantly making predictions about the world which incoming sensory signals subsequently tether to their external causes.[104] 'In this view, perception happens through a continual process of *prediction error minimalisation*'[105] whereby the brain's predictions are adjusted to the sensory signals it receives to increase the probability of accuracy for future predictions. Anil Seth emphasises that:

> The third and most important ingredient in the controlled hallucination view is the claim that perceptual experience… is determined by the content of (top-down) predictions, and not by the (bottom-up) sensory signals. We never experience sensory signals themselves, we only ever experience interpretations of them.[106]

Taking together this detour into perception, I suggest that a *sociotechnical umwelt* concerns the set of *a priori* expectations regarding a technology (its artefacts, applications, processes, and interactions) sculpted by and inculcated into a society via its cultural imaginaries (speculative fiction as the West's mythform). I argue that it is this *sociotechnical umwelt* that directs regulatory attention by rendering perceptible only certain problem- and potential- portfolios. Indeed, Kieran Tranter might have hinted at this *sociotechnical umwelt* approach when emphasising the anticipatory possibilities of the future:

---

[99] Finn, "Step Into the Free and Infinite Laboratory of the Mind," 103.
[100] An analogy I draw from von Uexküll, Foray into the Worlds of Animals and Humans.
[101] Yong, "How Animals Perceive the World"; Yong, An Immense World, 5. Emphasis original.
[102] Liu, "Artificial Intelligence and Legal Disruption," 224–31.
[103] Seth, Being You, 82.
[104] See also, Clark, The Experience Machine. Andy Clark and Anil Seth are both members of the Sussex Centre for Consciousness Science.
[105] Seth, Being You, 83. Emphasis original.
[106] Seth, Being You, 83.

> Technology is considered a problem that warrants legal exegesis because it is anticipated that a technology, or the popular discussion of a potentially emergent technology, will affect the future. Therefore, legal scholarship on technology is kind of an applied futurology – its starting point is images of technological futures that call for law. This is a speculative activity, a creative process of looking at what is and projecting, imaging and dreaming what *could be*.[107]

Applying Anil Seth's 'controlled hallucinations view' to the cultural imaginaries that we clothe new and emerging technologies with, we get the notion that these imaginaries are the hallucinatory predictions that are projected forth, and that the sensory input feedback sometimes calibrates these regulatory responses. Colin Picker provides three historical examples of such anticipatory projections (each example with rich speculative fiction imaginaries):

> [I]n the 1960s scholars conceived a "centre of the earth treaty" to deal with expected technologies that would exploit subterranean resources. Similarly, scholars also considered the need for a weather modification treaty to deal with the expected technology associated with cloud seeding and a set of principles to deal with the first human contact with extraterrestrials. *However, as these technologies and many others came to naught, so too did the scholars' proposed international regimes*.[108]

Within this context, Kieran Tranter's rich account of first-generation space law in the wake of Sputnik I demonstrates in detail the regulatory projections from pulpy space opera to refined law reviews that have failed to materialise.[109] Such regulatory projections contextualise Anh Nguyen's observed paradox of quantum technology ringfences despite lack of proven capabilities that repeat this familiar refrain:

> The mathematical and quantum mechanical foundations of [quantum technology] are theoretically sound and have been experimentally proven. As such, [quantum technology] is not a speculative technology; however, because of the engineering hurdles the field is still exploratory and uncertain.[110]

The core difference that sets the regulatory projections for quantum computing apart from earlier technologies (especially in the 1960s) is the availability and detail of the cultural imaginaries from speculative fiction. With the prevalence of space opera, even 'the modest achievement of launching an artificial satellite takes on *prophetic* proportions,'[111] whereas the absence of quantum computing imaginaries leaves a void in the ability to cast detailed regulatory projections.

The *sociotechnical umwelt* reveals the peril and promise of cultural imaginaries surrounding technological development. Technologies accompanied by rich speculative fiction traditions provide plentiful opportunities for regulatory daydreaming, but these might be mainly misleading. While this is clear in retrospect for technologies that never materialised, it is more subtle for quotidian technological applications where their ubiquity veils the apportionment of benefits and burdens, or demarcates harms from injuries as I hope to explore below.

My recourse to perception in unfolding the *sociotechnical umwelt* holds one further insight in the example of *pareidolia*:

> For humans – and some other animals – the significance of faces means that our brains come preloaded with strong face-related prior expectations. This is why we all tend to see faces in things … And because we all do it, we typically don't think of pareidolia as hallucination.[112]

Indeed, as Carl Sagan has famously recounted pareidolia in the Man on the Moon and the Face on Mars,[113] the phenomenon is both prevalent and persistent. Pareidolia reveals a certain amount of inevitability: even though we may consciously 'know' that there is no face, we still erroneously *experience* faces within everything we see. By analogy, even if we come to know full well that our cultural imaginaries inaccurately distort the concerns that we project into the future, speculative fiction-fuelled hallucinations may continue to drive our experiences of what we are able to see in those futures and therefore continue to influence our regulatory responses to new technologies. Furthermore, connecting to the sixth of my observations above,

[107] Tranter, "The Speculative Jurisdiction," 820. Emphasis original.
[108] Picker, "A View from 40,000 Feet," 194–95. Emphasis added.
[109] Tranter, "The Magnitudes of Law and Science Fiction." Referring to Haley, "The Law Of Space-Scientific and Technical Considerations"; and Gorove, "On The Threshold Of Space."
[110] Nguyen, "Export Controls as Innovation Marketing?," 71. Citations removed.
[111] Tranter, "The Magnitudes of Law and Science Fiction," 23–24. Emphasis added to underscore prospective orientation enabled by a rich cultural imaginary.
[112] Seth, Being You, 123.
[113] Sagan, The Demon-Haunted World, 43–59.

pareidolia underscores the emphatically anthropocentric orientation of the *sociotechnical umwelt* where human possibilities and human problems hold the monopoly on both perceptual projections and sensory calibrations into the future.

Contextualising the *Sociotechnical Umwelt* within Technology Governance

The idea of the *sociotechnical umwelt* may well be lurking within at least two ideas guiding technology governance: Jack Balkin's focus upon salience[114] and the Collingridge Dilemma.[115]

Jack Balkin responded to Ryan Calo's proposal that technologies possess 'essential qualities,'[116] with the dynamic and contingent notion of 'salience' by asking:

> What problems does a new technology place in the foreground that were previously underemphasized or deemed less important? What aspects of human activity or of the human condition does a technological change foreground, emphasize, or problematize? And once technology moves a certain problem or a certain feature of our lives from the background to the foreground of our concern, what are the consequences for human freedom?'[117]

The *sociotechnical umwelt* may well be the gatekeeper for what qualifies within the contingent and fluctuating concept of salience. As Balkin writes: 'What seems particularly important and salient about technology changes over time as people work with and through new technology';[118] and 'As we innovate socially and economically, what appears most salient and important about our tools may also change.'[119] Because the concept of salience is integrally connected with perception, it is a good candidate to be guided by the sociotechnical perceptibility of problems that is represented by the *sociotechnical umwelt* (and may indeed amount to much the same thing). If this is true, then understanding the *sociotechnical umwelt* may provide a conceptual pathway towards engaging with salience beyond a general, and largely retrospective, descriptor of the evolving issues within technology governance.

More importantly, it reasserts salience as a perceptual process in the 'controlled hallucination' sense. Salience in this sense need not be a rational and objective representation of the problem-portfolio presented by a new technology, and indeed is unlikely to be because salience represents the emphatically *individual human* angle. Salience in this context might be reduced to little more than speculative fiction imaginaries echoed through changing collective concerns.

David Collingridge's dilemma is worth setting out in the original because it deals precisely with the interlocking processes of prospective projection and responsive calibration:

> The root of the manifest difficulties with which the control of technology are beset is that our technical competence vastly exceeds our understanding of the social effects which follow from its exercise. For this reason, the social consequences of a technology cannot be predicted early in the life of a technology. By the time undesirable consequences are discovered, however, the technology is often so much part of the whole economic and social fabric that its control is extremely difficult. This is the *dilemma of control*. When change is easy, the need for it cannot be foreseen; when the need for change is apparent, change has become expensive, difficult, and time consuming.[120]

From the perspective of the *sociotechnical umwelt* the 'information problem' is an obvious approximation to the hallucinatory projection part of the perceptual process. The 'power problem' is more subtle: its articulation also lies within the *sociotechnical umwelt* in terms of the problems that it can encompass. A different way of putting this is that, amongst an implausibly vast potential problem space, a certain collection of problems are identified and recognised as being problems (and the subset of problems worthy of addressing at that). The rest, lying beyond sociotechnical perceptibility, remain unrecognised even as issues in the first place.[121]

[114] Balkin, "The Path of Robotics Law."
[115] Collingridge, The Social Control of Technology.
[116] Calo, "Robotics and the Lessons of Cyberlaw."
[117] Balkin, "The Path of Robotics Law," 46–47.
[118] Balkin, "The Path of Robotics Law," 47.
[119] Balkin, "The Path of Robotics Law," 49.
[120] Collingridge, The Social Control of Technology, 11. Emphasis original.
[121] See by analogy, Veitch, Law and Irresponsibility, 85–92.

Concluding Thoughts: Realms of Ungovernability Beyond the *Sociotechnical Umwelt*

The *sociotechnical umwelt* might mark the outer limits of governability itself because it may not be possible to govern that which cannot be perceived. I propose two approaches: Scott Veitch's 'Law and Irresponsibility;[122] and Noam Chomsky's Problem/Mystery distinction.[123]

Reframed thus, Scott Veitch's rhetorical question: 'What registers in law as a wrong? This question has a deceptively simple answer: what registers in law as a wrong is a breach of the law'[124] opens doors across fractal scales.[125] I want to focus upon the term 'registers' because this is the perceptual term that elevates the *sociotechnical umwelt* to becoming the arbiter of *injury* (from 'in-juria,'[126] in contradistinction to unrecognised harm). Indeed, the *sociotechnical umwelt* perspective reveals the general conceptual notion of perceptibility of injury itself, rather than any particular injury that is extracted from harm as such. Indeed, the idea of *sociotechnical umwelt* may provide the conceptual sophistication necessary to elaborate this perception and recognition of injury from harm, since each sociotechnical system possesses different perceptibility thresholds and different constellations of perceptibility.

The human wrongs brought forth by AI that systemically circumvent human rights protections provide an excellent example,[127] which took Sue Anne Teo's appeal to the allegory of 'slow violence' from the literature around environmental harms to explicate:[128]

> *Observability*, *perceptibility* and intentionality are elements that commonly feature on accounts of violence. 'Slow violence' is however an alternative framing, presenting violence as being attritional in nature, namely one that takes place gradually and slowly.[129]

She draws upon Rob Nixon's exposition of 'slow violence' that lays out a different, temporally-oriented aspect, that further informs the *sociotechnical umwelt*:

> By slow violence I mean a violence that occurs *gradually and out of sight*, a violence of delayed destruction that is *dispersed across time and space*, an attritional violence that is typically *not viewed as violence at all*. Violence is customarily conceived as an event or action that is immediate in time, explosive and spectacular in space, and as erupting into instant *sensational visibility*. We need, I believe, to engage a different kind of violence, a violence that is neither spectacular nor instantaneous, but rather *incremental and accretive*, its calamitous repercussions playing out across *a range of temporal scales*.[130]

By weaving Rob Nixon's emphasis upon 'slow violence' into the technology governance literature, Sue Anne Teo has extended the *sociotechnical umwelt* concerning the harms leveraged by AI that have hitherto resisted recognition as human rights violations. Crucially, she did not expose substantively *new* harms imposed by AI: instead, she shifted the parameters of perceptibility to encompass different scales of time and severity.

This underscores the obvious observation that we cannot govern what we cannot perceive. The *sociotechnical umwelt* sets the boundary for the very prospect of governability itself.

A different way to approach this is through Noam Chomsky's famous distinction between 'problems' and 'mysteries':[131] where *Problems* 'appear to be within the reach of approaches and concepts that are moderately well understood' and *Mysteries* 'remain as obscure to us today as when they were originally formulated.' I suggest that the *sociotechnical umwelt* demarcates the division between the two: ungovernable mysteries that lay beyond perceptibility and remain intractable, and regulatory problems that, being perceptible, engage policy and scholarly debate that might lead to regulatory responses. While the problem-*finding* approaches that I alluded to above work through searches via adjacent-possibles, these need to be

[122] Veitch, Law and Irresponsibility.
[123] Collins, "Chomsky's Problem/Mystery Distinction."
[124] Veitch, Law and Irresponsibility, 92.
[125] Describing Szolem Mandelbrojt's work and coining of the term, see Gleick, Chaos, 98. See generally, 90-103.
[126] Veitch, Law and Irresponsibility, 86.
[127] Liu, "The Digital Disruption of Human Rights Foundations"; Liu, "AI Challenges and the Inadequacy of Human Rights Protections"; Teo, "How Artificial Intelligence Systems Challenge the Conceptual Foundations."
[128] Teo, "Artificial Intelligence."
[129] Teo, "Artificial Intelligence," 2265. Emphasis added.
[130] Nixon, Slow Violence and the Environmentalism of the Poor, 2. Emphasis added.
[131] Chomsky, "Problems and Mysteries in the Study of Human Language."

supplemented with approaches with less path-dependencies. To revisit Mitchell Travis and Kieran Tranter's meditation on the meaning of absences in speculative fictions I touched upon above, there may indeed be justifiable critiques whereby 'the limited imagining … in science fiction shows a fault with the creators of science fiction.'[132] That said, there may be certain technologies that, unlike quantum computing, provide more amenable foundations for storytelling with the demonstrated ramifications for technology governance.

If this idea holds, a key task for technology governance involves both expanding (in an absolute sense), and altering (shifting the vantage point, the frames of reference, and the sensory apparatus deployed) the *sociotechnical umwelt*s in order to increase the overall ambit of governance. Yet, as these are activities that fall beyond the traditional purview of legal scholars and policy analysts it seems likely that this work will remain largely untouched.

It is the unique absence of quantum computing imaginaries, that coupled with the amorphous hype around its potential possibilities, enabled our adventures into the *sociotechnical umwelt*. We have seen the ramifications that follow from the stories that we are told about a technology both for technology governance and for establishing the outer limits of governability of technology. *Sociotechnical umwelts* reinforce the bridge between the cultural narratives of speculative fiction and regulatory responses to emerging technologies that have previously been established[133] through specific pathways within the variations in perceptions and differences in perceptibility. Beyond differentials in the regulatory responses to different technologies as a function of their treatment in the speculative fiction canon, *sociotechnical umwelts* indicate hard limits to the project of technology governance that may never be overcome.

Acknowledgement
This work was supported by the Independent Research Fund Denmark Grant 0257-00010B. I would like to express my sincere gratitude to the care and attention that earlier drafts received from Kieran Tranter and the editorial team and the three anonymous reviewers which pushed me to continually revise and refine this article. All views, and remaining errors, are mine alone.

AI Disclosure Statement
This article is a purely human endeavour and I would like to emphasise that no artificial intelligence applications of any kind were used at any stage of the thinking, research, writing, and editing process.

[132] Travis, "Interrogating Absence," 24.
[133] Tranter, "The Speculative Jurisdiction."

Bibliography

Aaronson, Scott. *Quantum Computing Since Democritus*. Cambridge University Press, 2013.

Anderson, Kenneth, Daniel Reisner and Matthew Waxman. "Adapting the Law of Armed Conflict to Autonomous Weapon Systems," *International Law Studies, US Naval War College* 90 (2014): 386–411. https://digital-commons.usnwc.edu/ils/vol90/iss1/3/.

Anderson, Kenneth and Matthew Waxman. "Law and Ethics for Robot Soldiers." *Policy Review* 176 (2012). https://scholarship.law.columbia.edu/faculty_scholarship/1742.

Asimov, Isaac. "Runaround." In *I Robot*, 25-48. New York: Gnome Press, 1950

Atik, Jeffery and Valentin Jeutner. "Quantum Computing and Computational Law." *Law, Innovation and Technology* 13, no 2 (2021): 302–24. https://doi.org/10.1080/17579961.2021.1977216.

Balarabe, Kasim. "Quantum Computing and the Law: Navigating the Legal Implications of a Quantum Leap." *European Journal of Risk Regulation* (2025): 1–20. https://doi:10.1017/err.2025.8.

Balkin, Jack M. "The Path of Robotics Law." *California Law Review Circuit* 6 (2015): 45–60. https://www.californialawreview.org/online/the-path-of-robotics-law.

Ball, Philip. *Beyond Weird: Why Everything You Thought You Knew about Quantum Physics Is Different*. The Bodley Head, 2018.

Beech, Martin. *The Physics of Invisibility*. Springer, 2012.

Bernhardt, Chris. *Quantum Computing for Everyone*. The MIT Press, 2019.

Bhuta, Nehal, Susanne Beck, Robin Geiβ, Hin-Yan Liu and Claus Kreβ, eds. *Autonomous Weapons Systems: Law, Ethics, Policy*. Cambridge University Press, 2016.

Björneborn, Lennart. "Adjacent Possible." In *The Palgrave Encyclopedia of the Possible*, edited by V. P. Glăveanu. Palgrave Macmillan, 2020. https://doi.org/10.1007/978-3-319-98390-5_100-1.

Bostrom, Nick. *Superintelligence: Paths, Dangers, Strategies*. Oxford University Press, 2014.

Buchan, Russell and Nicholas Tsagourias. "Autonomous Cyber Weapons and Command Responsibility." *International Law Studies* 96, no 1 (2020). https://digital-commons.usnwc.edu/ils/vol96/iss1/21/.

Calo, Ryan. "Robotics and the Lessons of Cyberlaw." *California Law Review* 103 (2015): 513. https://www.jstor.org/stable/24758483.

Carnahan, Burrus M., and Marjorie Robertson. "The Protocol On 'Blinding Laser Weapons': A New Direction for International Humanitarian Law." *American Journal of International Law* 90, no 3 (1996): 484–90. https://doi:10.2307/2204074.

Cave, Stephen and Kanta Dihal, eds. *Imagining AI: How the World Sees Intelligent Machines*. Oxford University Press, 2023.

Cave, Stephen, Kanta Dihal and Sarah Dillon, eds. *AI Narratives: A History of Imaginative Thinking about Intelligent Machines*. Oxford University Press, 2020.

Chambers, Becky. *A Prayer for the Crown-Shy: A Monk and Robot Book*. Tor Publishing Group, 2022.

Chambers, Becky. *A Psalm for the Wild-Built*. Tor Publishing Group, 2021.

Chernyshova, Tatiana. "Science Fiction and Myth Creation in Our Age." *Science Fiction Studies* 31, no 3 (2004): 345–57. https://doi.org/10.1525/sfs.31.3.345.

Chomsky, Noam. "Problems and Mysteries in the Study of Human Language." In *Language in Focus: Foundations, Methods and Systems: Essays in Memory of Yehoshua Bar-Hillel*, edited by Asa Kasher. Springer Netherlands, 1976. https://doi.org/10.1007/978-94-010-1876-0_15.

Clark, Andy. *The Experience Machine: How Our Minds Predict and Shape Reality*. Penguin Books, 2024.

Collingridge, David. *The Social Control of Technology*. Frances Pinter, 1980.

Collins, John. "Chomsky's Problem/Mystery Distinction." In *A Companion to Chomsky*, edited by Nicholas Allott, Terje Lohndal, and Georges Rey. John Wiley & Sons, Ltd, 2021. https://doi.org/10.1002/9781119598732.ch36.

Csicsery-Ronay, Istvan. *The Seven Beauties of Science Fiction*. Wesleyan University Press, 2012.

Danaher, John. *Automation and Utopia: Human Flourishing in a World without Work*. Harvard University Press, 2019.

Dihal, Kanta. "New Science, New Stories: Quantum Physics as a Narrative Trope in Contemporary Fiction." In *Representations of Science in Twenty-First-Century Fiction*, edited by Nina Engelhardt and Julia Hoydis. Palgrave Macmillan, 2019. https://doi.org/10.1007/978-3-030-19490-1_4.

Dunne, Antony and Fiona Raby. *Speculative Everything*. MIT Press, 2013.

Everett, Hugh. " 'Relative State' Formulation of Quantum Mechanics." *Reviews of Modern Physics* 29, no 3 (1957): 454–62. https://doi.org/10.1103/RevModPhys.29.454.

Everett, Hugh. *The Many-Worlds Interpretation of Quantum Mechanics*. Edited by Bryce S. DeWitt and Neill Graham. Princeton University Press, 1973.

Feynman, Richard. *The Character of Physical Law*. MIT Press, 1985.

Finn, Ed. "Step Into the Free and Infinite Laboratory of the Mind." *Issues in Science and Technology* 41, no 2 (2025): 99–103. https://doi.org/10.58875/KCMI9739.

Gleick, James. *Chaos: Making a New Science*. Vintage, 1997.
Gorove, Stephen. "On The Threshold Of Space: Toward A Cosmic Law." *New York Law Forum* 4, no 3 (1958): 305–28. https://doi.org/10.1007/978-3-7091-4414-5_13.
Grover, Lov K. "A Fast Quantum Mechanical Algorithm for Database Search." *Proceedings of the Twenty-Eighth Annual ACM Symposium on Theory of Computing* (New York, USA), 1996, 212–19. https://doi.org/10.1145/237814.237866.
Haley, Andrew. "The Law Of Space-Scientific and Technical Considerations." *New York Law Forum* 4, no 3 (1958): 262–74. https://digitalcommons.nyls.edu/nyls_law_review/vol4/iss3/3/.
Hermann, Isabella. "Artificial Intelligence in Fiction: Between Narratives and Metaphors." *AI & Society* 38, no 1 (2023): 319–29. https://doi.org/10.1007/s00146-021-01299-6.
Hermann, Isabella. "Beware of Fictional AI Narratives." *Nature Machine Intelligence* 2, no 11 (2020): 654–654. https://doi.org/10.1007/s00146-021-01299-6.
Hoofnagle, Chris Jay and Simson L. Garfinkel. *Law and Policy for the Quantum Age*. Cambridge University Press, 2022.
Human Rights Watch. *Losing Humanity: The Case Against Killer Robots*. Human Rights Watch and International Human Rights Clinic, 2012. https://www.hrw.org/report/2012/11/19/losing-humanity/case-against-killer-robots.
Karami, Muhammad Unggul and Julia Cramer. "The Quantum Hype in the Scientific Sphere: Expectations of the Future of Quantum Technology in Peer-Reviewed Literature." *Digital Society* 5, no 2 (2026): 28. https://doi.org/10.1007/s44206-026-00269-z.
Kuhn, Thomas S. *The Structure of Scientific Revolutions*. University of Chicago Press, 1970.
Liu, Hin-Yan. "Categorization and Legality of Autonomous and Remote Weapons Systems." *International Review of the Red Cross* 94, no 886 (2012): 627-652. https://doi:10.1017/S181638311300012X.
Liu, Hin-Yan. "Refining Responsibility: Differentiating Two Types of Responsibility Issues Raised by Autonomous Weapons Systems." In *Autonomous Weapons Systems - Law, Ethics Policy*, edited by Nehal Bhuta, Susanne Beck, Robin Geiß, Hin-Yan Liu, and Claus Kreß. Cambridge University Press, 2016. https://doi.org/10.1017/CBO9781316597873.014.
Liu, Hin-Yan. "From the Autonomy Framework towards Networks and Systems Approaches for 'Autonomous' Weapons Systems." *Journal of International Humanitarian Legal Studies* 10, no 1 (2019): 89–110. https://doi.org/10.1163/18781527-01001010.
Liu, Hin-Yan. "The Digital Disruption of Human Rights Foundations." In *Human Rights, Digital Society and the Law: A Research Companion*, edited by Mart Susi. Routledge, 2019. https://doi.org/10.4324/9781351025386-6.
Liu, Hin-Yan. "AI Challenges and the Inadequacy of Human Rights Protections." *Criminal Justice Ethics* 40, no 1 (2021): 2–22. https://doi.org/10.1080/0731129X.2021.1903709.
Liu, Hin-Yan. "Artificial Intelligence, Human Extinction, and Other Stories." Paper presented at Legal Responses to the Existential Threat Posed by Artificial Intelligence, Chinese University of Hong Kong. 2025.
Liu, Hin-Yan, Matthijs Maas, John Danaher, Luisa Scarcella, Michaela Lexer and Leonard Van Rompaey. "Artificial Intelligence and Legal Disruption: A New Model for Analysis." *Law, Innovation and Technology* 12, no 2 (2020): 205–58. https://doi.org/10.1080/17579961.2020.1815402.
Liu, Hin-Yan, and Matthijs M. Maas. " 'Solving for X?': Towards a Problem-Finding Framework That Grounds Long-Term Governance Strategies for Artificial Intelligence." *Futures* 126 (2021): 102672. https://doi.org/10.1016/j.futures.2020.102672.
Liu, Hin-Yan, and Karolina Zawieska. "From Responsible Robotics Towards a Human Rights Regime Oriented to the Challenges of Robotics and Artificial Intelligence." *Ethics and Information Technology* 22, no 4 (2020): 321–33. https://doi.org/10.1007/s10676-017-9443-3.
Lukoseviciene, Aurelija. "Regulating Quantum Computers: Insights into Early Patterns and Trends in Academic Regulatory Conversations on the 'Quantum Revolution.'" *Law, Innovation and Technology*, 2025. https://doi.org/10.1080/17579961.2025.2469350.
Maas, Matthijs M. 'How Viable Is International Arms Control for Military Artificial Intelligence? Three Lessons from Nuclear Weapons'. *Contemporary Security Policy* 40, no 3 (2019): 285-311. https://doi.org/10.1080/13523260.2019.1576464.
Maas, Matthijs M. "Innovation-Proof Governance for Military AI? How I Learned to Stop Worrying and Love the Bot." *Journal of International Humanitarian Legal Studies* 10, no 1 (2019): 129–57. https://doi.org/10.1163/18781527-01001006.
Marchant, Gary, Braden Allenby, and Joseph Herkert, eds. *The Growing Gap Between Emerging Technologies and Legal-Ethical Oversight: The Pacing Problem*. The International Library of Ethics, Law and Technology 7. Springer, 2011.
Meinsma, Aletta Lucia, W. Gudrun Reijnierse and Julia Cramer. "Like a Coin Spinning in the Air: The Effect of (Non) Metaphorical Explanations on Comprehension and Attitudes towards Quantum Technology." *arXiv*. 2026. https://doi.org/10.48550/arXiv.2506.10539.
Nguyen, Anh. "Export Controls as Innovation Marketing? Sociotechnical Imaginaries in the Ringfencing of Quantum Technologies." *Law, Technology and Humans* 7, no 1 (2025): 68–83. https://doi.org/10.5204/lthj.3777.

Nixon, Rob. *Slow Violence and the Environmentalism of the Poor*. Harvard University Press, 2011.
Oxford Dictionary of English, Oxford University Press Second Edition (revised) 2005
Picker, Colin B. "A View from 40,000 Feet: International Law and the Invisible Hand of Technology." *Cardozo Law Review* 23, no 1 (2007): 149–219. https://larc.cardozo.yu.edu/clr/vol23/iss1/6.
Powers, Richard. *Bewilderment*. W.W. Norton & Company, 2022.
Powers, Richard. *Playground*. W.W. Norton & Company, 2024.
Powers, Richard. *The Overstory*. W.W. Norton & Company, 2019.
Sagan, Carl. *The Demon-Haunted World: Science as a Candle in the Dark*. Ballantine Books, 1997.
Schmidt, Adrian, Alexandre Artaud, Arsev Umur Aydinoglu, Astrid Bötticher, Rodrigo Araiza Bravo, Maria Luisa Marilu Chiofalo, et al. "Current and Future Directions for Responsible Quantum Technologies: A ResQT Community Perspective." *Ethics and Society* 20, no 3 (2026). https://doi.org/10.1007/s11569-026-00522-2.
Seth, Anil. *Being You: A New Science of Consciousness*. Faber and Faber, 2021.
Shor, Peter W. "Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer." *SIAM Review* 41, no 2 (1999): 303–32. https://doi.org/10.1137/S0097539795293172
Stanisław, Lem. *Solaris*. 1970; Faber and Faber, 2016.
Stuart, Hameroff. "Quantum Computation in Brain Microtubules? The Penrose–Hameroff 'Orch OR' Model of Consciousness." *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences* 356, no 1743 (1998): 1869–96. https://doi.org/10.1098/rsta.1998.0254.
Suvin, Darko. *Metamorphoses of Science Fiction: On the Poetics and History of a Literary Genre*. Peter Lang, 2016.
Suvin, Darko. "On the Poetics of the Science Fiction Genre." *College English* 34, no 3 (1972): 372–82. http://www.jstor.org/stable/375141.
Teo, Sue Anne. "How Artificial Intelligence Systems Challenge the Conceptual Foundations of the Human Rights Legal Framework." *Nordic Journal of Human Rights* 40, no 1 (2022): 216–34. https://doi.org/10.1080/18918131.2022.2073078.
Teo, Sue Anne. "Artificial Intelligence and Its 'Slow Violence' to Human Rights." *AI and Ethics* 5 (2025): 2265–80. https://doi.org/10.1007/s43681-024-00547-x.
Tranter, Kieran. "The Speculative Jurisdiction: The Science Fictionality of Law and Technology." *Griffith Law Review* 20, no 4 (2011): 817–850. https://doi.org/10.1080/10383441.2011.10854722.
Tranter, Kieran. *Living in Technical Legality: Science Fiction and Law as Technology*. Edinburgh University Press, 2020.
Tranter, Kieran. "The Magnitudes of Law and Science Fiction." In *Cultural Legal Studies of Science Fiction*, edited by Alex Green, Mitchell Travis and Kieran Tranter. Routledge, 2024.
Travis, Mitchell, and Kieran Tranter. "Interrogating Absence: The Lawyer in Science Fiction." *International Journal of the Legal Profession* 21, no 1 (2014): 23–37. https://doi.org/10.1080/09695958.2014.946932.
Turing, Alan. "Computing Machinery and Intelligence." *Mind* LIX, no 236 (1950): 433–60. https://doi.org/10.1093/mind/LIX.236.433.
Uexküll, Jakob von, Marina von Uexkull and Joseph D. O'Neil. *Foray into the Worlds of Animals and Humans: With A Theory of Meaning*. University of Minnesota Press, 2010.
Veitch, Scott. *Law and Irresponsibility: On the Legitimation of Human Suffering*. Routledge-Cavendish, 2007.
Voeneky, Silja, Philipp Kellmeyer, Oliver Mueller and Wolfram Burgard, eds. *The Cambridge Handbook of Responsible Artificial Intelligence*. Cambridge University Press, 2022.
Voros, Joseph. "Big History and Anticipation." In *Handbook of Anticipation: Theoretical and Applied Aspects of the Use of Future in Decision Making*, edited by Roberto Poli. Springer International Publishing, 2019.
Voros, Joseph. "The Futures Cone, Use and History." *The Voroscope*, February 24, 2017. https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/.
Yong, Ed. *An Immense World: How Animal Senses Reveal the Hidden Realm Around Us*. Bodley Head, 2022.
Yong, Ed. "How Animals Perceive the World." *The Atlantic*, 2022. https://www.theatlantic.com/magazine/archive/2022/07/light-noise-pollution-animal-sensory-impact/638446/.
Zuboff, Shoshana. *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power*. Profile Books, 2019.