Blockchain Regulatory Systems—Conceptual and Operational Challenges

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Abstract: This article challenges one of the most persistent assumptions in contemporary blockchain discourse, the assumption that code can be understood as a "rule" analogous to law, and argues instead, across a series of interlocking analytical lenses, that code is better conceived as a layered system, an environment, or an ecology of rule-production in which the human, and human systemicity more generally, is progressively displaced rather than simply obeyed or defied. That displacement, the article contends, does not occur all at once or at a single site; it occurs serially, through a stack the article calls the "Sacher-Torte" of blockchain regulation, in which legal meaning descends through compiler, bytecode, opcode, and consensus layers of diminishing human legibility, losing something of its original semantic content at every translation, so that what remains available to human regulators is not dominion over the machine's lower layers but only a series of gates at which they may decide, after the fact and often too late, whether to admit what the system has already produced. The article situates this structural argument within a broader interpretive frame borrowed from recent debates over artificial intelligence governance, in which every account of a given technology's purpose and proper ordering is itself best read as an interested, oracular claim staked by a party with something to gain from the particular allocation of human and machine authority that the account implies; blockchain's own regulatory narratives, including the Rule of Code thesis this article interrogates, are no exception. It extends that argument, further, into the specific question of time, showing that blockchain's celebrated solution to the problem of distributed succession, by which an otherwise leaderless network of asynchronous nodes contrives to agree on a single, linear, hash-chained history, is neither a timeless discovery about the nature of succession nor a metaphysical accomplishment, but an energy-purchased, politically contested, and historically contingent choice to enforce one particular picture of order, a choice so deeply embedded in the technology's architecture that even the most recent proposals to graft genuinely non-classical, quantum-entangled representations onto the ledger leave its strictly serial, dialectical temporality intact rather than displaced. Read together, these arguments reorient the debate between the Rule of Law and the Rule of, or by, Code away from a contest between two neatly opposing sovereigns and toward a more unsettling recognition: that the real conflict is among distinct regulatory ecologies, each organizing meaning, time, and legitimacy according to its own internal logic, and that the task remaining to human regulation is not to choose between these ecologies but to give normative content to the gates, however narrow, at which they are made to meet.

Keywords: blockchain, rule of law, semiotics, systems, regulation, machine code, temporality

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I. Introduction.

This article speaks to the interactions between the Rule of Code[3] and the Rule of Law[4] within the virtual spaces filled with automated data storage and sequential transactional mechanisms, and more specifically in its form as blockchain[5]. One may begin by noting a bit of absurdity in this quest, in the ancient sense of the term (from the Latin "absurdus") suggesting harsh and clashing sounds (to the listener anyway) something and thus without sense from the perspective of expectations of order and structure.[6] Nietzsche famously mocked the English, and English attempts at philosophy, for its obsession with utility, that is for their "modernity."[7] That obsession has now appeared to ooze into and fill the virtual world, and more specifically, the intelligences with which humans seek to populate that world without much of a thought about the organizing parameters of utility and its limits.[8] The cyberpunks of the 1980s might well have it right when they spoke to cyber anarchy rather than an Olympian ordering, and of a fracturing of the machine and human coding that may reframe the issue of the structural coupling if rules of code and law into something quite different.[9] It might then be useful to take a moment, to consider this obsession and its virtual manifestation for humans and for machines from the perspective of phenomena, of semiotics, language, and collective meaning making.

It has become almost a cliché that modernity[10] that some of the most profoundly interesting and foundational shifts in the management of human collective organization and, more importantly, its rationalization of the surrounding reality, can be projected from out of the smallest and most laterally irrelevant advances. So it might be said of blockchain—as technology, as a means of facilitating the structural coupling of individuals and their collective institutions, and at a fundamental level, as an

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[3] PRIMAVERA DE FILIPPI AND AARON WRIGHT, BLOCKCHAIN AND THE LAW: THE RULE OF CODE (Harvard University Press, 2018). One must go back a quarter century for the genesis of the term in the context of systems theory and governance. "E very age has its potential regulator, its threat to liberty. . . Ours is the age of cyberspace. It, too, has a regulator. This regulator, too, threatens liberty. . . This regulator is code--the software and hardware that make cyberspace as it is. This code, or architecture, sets the terms on which life in cyberspace is experienced." Lawrence Lessig on the increasing regulation of cyberspace, Harvard Magazine (January 2000); available [https://www.harvardmagazine.com/2000/01/code-is-law-html] discussing LAWRENCE LESSING, CODE, AND OTHER LAWS OF CYBERSPACE *(*Basic Books, 1999*)* Any yet what one speaks to here is not code as some sort of equivalent of law, but of systems grounded in the language of code and coded architectures the way that traditional systems were grounded in the language and sensibilities of law and legal architectures.

[4] Cf., Jeremy Waldron, The Rule of Law and Procedural Fairness, in Stanford Encyclopedia of Philosophy (22 June 2016); available [https://plato.stanford.edu/entries/rule-of-law/].

[5] *See* Satoshi Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System (Aug. 21, 2008), https://papers.ssrn.com/abstract=3440802 (defining "blockchain").

[6] Oxford English Dictionary, absurd, etymology, available [https://www.oed.com/dictionary/absurd_adj?tl=true&tab=etymology]. There is a semiotics to absurdity that will play a role in this article as well. See, e.g., George V. Zito, Toward a Sociology of Heresy, 44 Sociology of Religion 123-130 (1983); Paolo Heritier, *Understanding Legal Semiotics*, in RESEARCH HANDBOOK ON LEGAL SEMIOTICS (Anne Wagner and Sarah Marusek eds, E Elgar, 2023).

[7] See, e.g., Raymond Furness, Nietzsche's Views of the English and his Concept of a European Community, 17(4) German Life and Letters 319-325 (1964); Jonny Anomaly, Nietzsche's Critique of Utilitarianism, 29 J. Nietzsche Studies 1-15 (2005).

[8] Cf., Moez Krichen, Meryem Ammi, Alaeddine Mihoub, and Mutiq Almutiq, Blockchain for Modern Applications: A Survey, 22(14) SENSORS 5274 (2022); available [https://doi.org/10.3390/s22145274].

[9] Timothy C. May, The Crypto-Anarchist Manifesto (1988); available [https://groups.csail.mit.edu/mac/classes/6.805/articles/crypto/cypherpunks/may-crypto-manifesto.html]. See, generally, the Cyphernomicon (ver. 0.666, 1994); available [https://cdn.nakamotoinstitute.org/docs/cyphernomicon.txt].

[10] Cf., Peter Wagner, Modernity: Understanding the Present (Polity Press, 2012) (origins and foundation of modernity as the expression of the Enlightenment project made manifest through the combination of structures of human autonomy and technological progress grounded in production as a function of welfare, ibid., chp. 1).

ideology of managing human collectives and its manifestation of a peculiar and quite specific form of organizing reality.[11] At the same time, that cliché becomes a threat as well as a compulsion/temptation where modernity, having "lost the ideological drive of reason and progress, and confounds itself more and more with the formal play of change" and having been reduced "into a culture of daily events," now finds that "[e]ven its myths turn against it (technology, once triumphant, is today full of menace)."[12]

The core of the cognitive cage that emerges as blockchain, one manifested in real space through *digitized* bits of data that are significant[13] to participants and then ordered chronologically, is deceptively simple: the creation of a digital ledger. That digital ledger, as its name implies, is a space in which something is recorded—something of interest or value to those who would expend time and effort on its creation. From the perspective of semiotics, one encounters here the mimesis of a discrete object (temporally and spatially) which acquires signification through its virtual representation, which is then itself made real by its effects beyond the digitized ledger.[14] In the beginning one recorded transactions and developed something like a self-referencing currency (and all currencies whether digital or analog are by definition self-referencing in the sense that their value is a function of collective belief in their value through use).[15] And yet there is nothing to prevent the recording of *any collection* of bits of data to which one or more providers might attach significance—subject, perhaps, only to the limits if temporality built into the fundamental structures of sequentially ordered streams of transactions and memory.[16]

Nonetheless, that signification is of little value when the self-referencing unit is the autonomous individual.[17] One speaks here to identity, that is to the constitution of an object as other than itself as such, but as the vessel for meaning that is an aggregation of its constituents parts (data) but autonomous of them as its own thing—effectively perhaps something like a machine/process version of "identity"

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[11] Generally, Pierangelo Blandino, Semiotokens, Algorithms, and Blockchain Networks: New Possible Patterns in Legal Thought, 38 International Journal for the Semiotics of Law 327-362 (2025); essays in Martin Shapiro (ed.); CRYPTO CROWDS (Berghahn Books, 2024).

[12] Jean Baudrillard, *Modernity*, 11(3) CANADIAN JOURNAL OF POLITICAL & SOCIAL THEORY/ REVUE CANADIENNE DE THÉORIE POLITIQUE ET SOCIALE 63- 72, 72 (1987) ("The prodigious expansion . . . of science and technique, the rational and systematic development of the means of production, their management and organization, marks modernity as the era of productivity" Ibid., p. 66).

[13] Here the term is used in its semiotic sense of privileging a specific understanding, value, character, etc. that is inserted into the observed or constituted object, in this case specific bits of data designated to represent something that as value, the value of which will be measured in its (also constructed) use.

[14] Antero Karvonen et al., *Fundamental Concepts of Cognitive Mimetics*, 82 COGN. SYST. RES. 101166 (2023); See generally JAN M. BROEKMAN, SIGNS IN LAW - A SOURCE BOOK: THE SEMIOTICS OF LAW IN LEGAL EDUCATION III (Larry Catá Backer ed., 2015).

[15] G. C. M. Teubner, *Autopoiesis and Steering: How Politics Profit from the Normative Surplus of Capital*, *in* AUTOPOIESIS AND CONFIGURATION THEORY: NEW APPROACHES TO SOCIETAL STEERING 127 (Roeland J. In 'T Veld et al. eds., 1991), http://link.springer.com/10.1007/978-94-011-3522-1_11; NIKLAS LUHMANN, ESSAYS ON SELF-REFERENCE (1990); Larry Catá Backer, *Private Actors and Public Governance Beyond the State: The Multinational Corporation, the Financial Stability Board, and the Global Governance Order*, 18 INDIANA J. GLOB. LEG. STUD. 751 (2011).

[16] Cf., Aleida Assmann, Memory, Individual and Collective, in THE OXFORD HANDBOOK OF CONTEXTUAL POLITICAL ANALYSIS 210-224 (Robert E. Goodlin and Charles Tilly (ed), OUP, 2006); Moritz J. Kleinaltenkamp, The Future Is Now: Non-Linear Temporality in Blockchain Organizing (Spring 2022) (unpublished PhD dissertation, Hertie School) available [https://opus4.kobv.de/opus4-hsog/frontdoor/deliver/index/docId/4498/file/Dissertation_Kleinaltenkamp.pdf].

[17] See Jordan Zlatev, *Meaning Making from Life to Language: The Semiotic Hierarchy and Phenomenology*, 11 COGN. SEMIOT. 20180001 (2018); Cf. Rodrigo Antunes Morais & Carlos Miguel Lopes Rosa, *Design and Collective Cognition: A Semiotic-Theoretical Framework for Understanding Shared Meanings*, 14 INT. J. DES. CREAT. INNOV. 26 (2026).

which has been the central semiotic problem of the last century.[18] That act of recording becomes more interesting for the ordering of social relations when such digitized ledgers then acquire collective significance and are distributed across many digitized spaces (computers or other holders of virtual "memory" in mimetic form).[19] Here one encounters not just memory but trust management in blockchain.[20] It follows that one creates, in virtual form, transparency, and trustworthiness of the "memory" recorded in the ledger in the sense that such memories are harder to contaminate or otherwise be tampered with. They might be appended but not overwritten; [21] consequently their existence in virtual time and space is unalterable as such. That inalterability provides a powerful basis for utility—in the sense that it populates the cognitive spaces for which it was created, and it itself becomes an object of consumption, use, negotiation, or judgment, which can then be consumed in the construction of other objects without losing its historical facticity.[22] Those other objects could encompass virtually anything, from rewards and punishments grounded on ledger entries of behaviors, to the accounting for wealth grounded in the meaning, the significance, of both the ledger entry and its deployment.[23]

At the same time, the collectivization of signification of ledger entries acquires an internal collective aspect—and again a means of organizing its cognitive signification, by organizing multiple ledger entries together into "blocks". The cognitive signification becomes more profound as the internal collective signification manifested in and as the block then is put in motion, creating a cognitive "flow" in and through collections of blocks linked in a chronological "chain" (and here time becomes an element of code, and of cognition).[24] All of this, however, produces a cognitive system that is not self-

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[18] See, e.g., Jürgen Straub, *Personal and Collective Identity: A Conceptual Analysis*, in IDENTITIES: TIME, DIFFERENCE, AND BOUNDARIES 54-76 (Heidrun Friese (ed), Berghahn Books, 2002) (identity as constructs designating commonality, the specification of which is realized in their "practical relationship to itself and to the world, as well as in the individual members' relationship to themselves and the world" ibid., 71).

[19] For foundational approaches, see, e.g., Peter J. Dennning, Virtual Memory, 2(3) ACM Computing Surveys (CSUR), 153 – 189 (1970) ; available https://doi.org/10.1145/356571.356573; for contemporary issues see, e.g., Ciprian Pungilă, Otilia Muntean, Andreea-Rebeca Tonu, BRIDGE: A memory-efficient blockchain-agnostic layer for chain topology representation in heterogeneous architectures Author links open overlay panel, 733 Information Sciences 122911 (25 April 2026); available https://doi.org/10.1016/j.ins.2025.122911.

[20] See, e.g., Kamran Ahmad Awan, Ikram Ud Din, Ahmad Almogren , And Byung Seo-Kim, *Blockchain-Based Trust Management for Virtual Entities in the Metaverse: A Model for Avatar and Virtual Organization Interactions*, IEEE Access (30 November 2023); available 0.1109/ACCESS.2023.3337806.

[21] Direct overwriting does not occur in a functioning blockchain. Once a block has been validated and added to the chain, altering it would break the cryptographic link to every later block, and the altered copy would be rejected by the other nodes. The ledger is better described as append-only. Errors are not erased but corrected by later entries, so that the original transaction and its correction both remain visible.
That inalterability is nonetheless contingent rather than absolute. An actor controlling a majority of a network's computing power or stake can rewrite recent history by producing an alternative chain, a so-called "51% attack," which is costly enough that it is most plausible against smaller networks. The community running a chain can also agree to depart from its recorded history, and the cryptography on which the chain relies rests on hardness assumptions that quantum computing may erode. Both possibilities are taken up in Part V.ii, *infra*.

[22] Larry Catá Backer, *Trust Platforms: The Digitalization of Corporate Governance and the Transformation of Trust in Polycentric Space*, 19 REGUL. GOV. 806 (2025).

[23] Consider Chinese social credit systems in that respect. See, e.g. Chuncheng Liu, *Multiple Social Credit Systems in China*, 21(1) ECONOMIC SOCIOLOGY 22-32 (2019.,

[24] See Larry Catá Backer, *The Soulful Machine, the Virtual Person, and the "Human" Condition: An Encounter with Jan M. Broekman, Knowledge in Change: The Semiotics of Cognition and Conversion (Cham, Switzerland: Springer Nature, 2023)*, 37 INT. J. SEMIOT. LAW - REV. INT. SÉMIOT. JURID. 969 (2024); 8 JAN M. BROEKMAN, KNOWLEDGE IN CHANGE: THE SEMIOTICS OF COGNITION AND CONVERSION (2023), https://link.springer.com/10.1007/978-3-031-23001-1; Niklas Luhmann, *Sign as Form*, *in* PROBLEMS OF

aware. Something else is necessary—and that something are the "nodes" in the networks that host copies of the ledger in its blocks.[25] Nodes are also objects, but they are objects outside the "chain" of "blocks" around which data is organized through digitized records of whatever object has been selected for such virtualization. In a sense, the nodes were the physical user interface that constituted the members of the collective within which self-referencing systems of ledger entries of data in blocks, temporally chained, could be "activated" by producing consequences or actions (and thus additional blocks along the chain). The nodes are both the guardians and the beneficiaries of the realities created within temporal "block"—"chains" by protecting the integrity of the "past" and providing a consensus-based protocol for validating activation consequences in the form of new blocks along the chain (it need not be so but nodes also mimic the more fundamental ordering ideologies from which they emerge).[26]

It is here that *digitalization*[27] occurs, through the incorporation of digital technologies to automate tasks, including the retention of data. Nodes are themselves, for the most part, computers or servers—that serve as their physical bodies. These physical bodies then operate through a meta-operating system and more specifically with respect to the blockchain, from *software* that sets out the operating rules applicable to each node and limiting their actions in communion with all other nodes admitted to the congress of nodes that constitute the blockchain collective. Software is itself a set of human-readable, and sometimes human written,[28] *instructions in a programming language*, also traditionally devised by humans and for their pleasure (utility), that provides the basis for computers to perform certain tasks with and on available data, the digitization of which is also a product of software coding. *Coding*, source coding, is itself the process of writing software in human-readable form; it was the way that humans communicate with virtual intelligence (in their hardware bodies), but not necessarily the way that virtual intelligence communicated among themselves. To those ends, virtual intelligence communicates with each other using machine language—a series of binary codes that can be utilized by a computer processor to execute commands, including, eventually, the command to write their own code and execute their own machine language instructions. It also includes object coding (machine-readable output of source code compiler), and executable code (computer operational programs sometimes in the well-known.exe format that are one's program files). Humans can read source code, but not machine and object coding.[29] Source coding is for programming (at least at the

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FORM 46 (Dirk Baecker ed., 1999), https://www.degruyter.com/document/doi/10.1515/9781503617698-005/html; Vladislav Valentinov, *Wiener and Luhmann on Feedback: From Complexity to Sustainability*, 46 KYBERNETES 386 (2017).

[25] Not every node serves this purpose, that is of hosting copies of the ledger. There are 3 types of nodes now in use. Full nodes: store the entire blockchain history and validate all transactions; light nodes: store only partial data and rely on full nodes for verification; Mining nodes: propose & add new blocks (proof of work/stake comes into play here).

[26] Built around hash coding—digital fingerprint of input data sets.,

[27] J. Scott Brennen & Daniel Kreiss, *Digitalization*, *in* THE INTERNATIONAL ENCYCLOPEDIA OF COMMUNICATION THEORY AND PHILOSOPHY 1 (2016), https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118766804.wbiect111.

[28] A caveat here: most blockchain software is human written; the protocols (Bitcoin Core/Ethereum, Solana) and languages (Solidity, Rust) were all designed/implemented by humans. As such one can indeed assume the very human foundation of blockchain. However, there are already parts of the ecosystem that are AI-assisted – smart contract templates, formal verification & compilers -- machine-checked code to prove security properties etc.)

[29] In rough order of declining human legibility: (1) source code (e.g., Python, Solidity, Java); (2) assembly code (e.g., MOV, ADD), which trained humans can read with effort; (3) bytecode for virtual machines (e.g., JVM or EVM bytecode); (4) machine code, the binary instructions of a processor's instruction set; (5) microcode, through which some processors implement their own instructions; and (6) hardware description languages (e.g., Verilog, VHDL), which describe the circuits themselves and are compiled into silicon at design time rather than executed at run time. Part V, *infra*, consolidates these into five layers.

start), and machine coding is for execution (including execution that permits machine coding to undertake its own source coding). Here lies both the independence of rules of code from rules of law—built into the language of these systems that both constitute a regulatory order and erect walls against the projection inward of other regulatory rule orders.[30]

In a sense, then, blockchain involves the alignment of three languages—human-to-human (and with it its own semiotics of meaning making), human to machine language (and with it a transposition of more personal value semiotics translated for machine intelligence), and machine to machine language, the semiotics of which is a function of the possibilities written into its own language. And it is in this alignment of language—and with it, its semiotics and phenomenology of disciplining collective meaning and enforcing command—that one can, at last, speak to the rise of collective legalities beyond that of their traditional manifestation in physical power asserted through action, text, and institution.[31] We focus on two in the context of blockchain—*the well-known law of code and the law of regulation*. Both embrace the notions of the rule of law to the extent that they are encoded within its language meaning structures, and from there applied in ways that reinforce or at least manifest meaning and values onto regulatory objects. And now one encounters a Sacher-Torte of languages—at least five, across which these three alignments are distributed—dense layers of cake separated by a jelly that serves as the medium of connection between them, and all to produce what appears at first blush to be a straightforward and efficient system.

And it does! The elegance of this form is irresistible. It is democratic and anti-hierarchical in ways that only technology enhanced participation can make possible (at least for those who can afford the technology and the cost of the training in it).[32] It provides an enhanced security against corruption (the limits of which remain to be tested), and it provides an equalizing transparency that protects the immutability of facts—that is of the recording of data that is widely shared and thus much more difficult to "remake" to suit the times or the inclinations of power. Its decentralization provided a virtual pathway to strong tendencies that were already largely visible in the world of human organizational regulation—from a revived federalism in the United States[33], to the rise (more or less) of the principle of subsidiarity in the European Union[34], to selective centralization and decentralization within Chinese Marxist-

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[30] Georg Trogemann, *Code und Maschine*, *in* CODE: ZWISCHEN OPERATION UND NARRATION 41 (Andrea Gleiniger & Georg Vrachliotis eds., 2012), https://www.degruyterbrill.com/document/doi/10.1515/9783034609333.41/html; Karen Yeung, *Algorithmic Regulation: A Critical Interrogation*, 12 REGUL. GOV. 505 (2018).

[31] JAN M. BROEKMAN & LARRY CATÁ BACKER, LAWYERS MAKING MEANING: THE SEMIOTICS OF LAW IN LEGAL EDUCATION II 93 (2013).

[32] See, e.g., Silvia Semenzin, 'Blockchain for good': Exploring the notion of social good inside the blockchain scene, 10(2) BIG DATA & SOCIETY (2023); available [https://journals.sagepub.com/doi/epub/10.1177/20539517231205479]; Melinda Dooley and Anna Comas-Quinn, Access to Technology and Social Justice, in TECHNOLOGY-MEDIATED LANGUAGE TEACHING: FROM SOCIAL JUSTICE TO ARTIFICIAL INTELLIGENCE (Javier Muñoz -Basols, Maria Fuertes Gutiérrez, and Luis Cerezo, Luis eds., Multilingual Matters, 2025) 21-42

[33] Karl Kössler, *Federalism*, *in* CONSTITUTIONAL INTERPRETATION 201 (Sujit Choudhry, Catherine O'Regan, & Carlos Bernal-Pulido eds., 2025), https://www.elgaronline.com/view/book/9781800371743/chapter10.xml; See also Eugénie Brouillet & Tom Mullen, *Constitutional Jurisprudence on Federalism and Devolution in UK and Canada*, *in* CONSTITUTIONAL POLITICS AND THE TERRITORIAL QUESTION IN CANADA AND THE UNITED KINGDOM 47 (Michael Keating & Guy Laforest eds., 2018), http://link.springer.com/10.1007/978-3-319-58074-6_3.

[34] Carlo Panara, *Subsidiarity v. Autonomy in the EU*, 28 EUR. PUBLIC LAW (2022), https://kluwerlawonline.com/api/Product/CitationPDFURL?file=Journals\EURO\EURO2022014.pdf.

Leninism[35]. And its efficiencies were unparalleled. It appeared to solve the great challenge of law making—one in which its essence as command (*.exe) was an exogenous projection onto the bodies of those who were to comply.[36] That produced the great procedural jurisprudence of law: to figure out of means of naturalizing the principles of legal text in its subjects and to develop mechanisms for external policing. Blockchain automated the process of regulation and compliance, embedding internalization within the language of its own coding. The *languages* of programming, then, were normative, regulatory, descriptive, and procedural, creating the subject of compliance and its methodologies simultaneously.

The same technology, in other words, becomes a different governance object depending on who is doing the governing and toward what end. The point recurs wherever a single infrastructure is read simultaneously as an instrument of internal constitutional reform, as a resource in external geopolitical competition, and as a threat whose containment legitimates the authority of whichever actor claims to manage it; recent accounts of artificial intelligence governance make the same move explicit, treating one technology as four distinct governance objects depending on the narrator and the audience addressed.[37]

II. The Challenges

Virtually any collective human (and machine) activity can be "blockchained," and thus "blockchained," automated in a virtual space with effects not just there but in human physical spaces as well.[38] While it plays a significant role in human activities that lend themselves to chrono-blocking information and decision systems—that is, to ledger records blocked and ordered in time which are then subject to sequential action along linear temporal arcs. These include the usual suspects — cryptocurrency, supply chain management, smart contracts[39], banking, and digital identity—its potential extends far beyond that to the operation of municipal administration in the form of smart cities, in the management of households through smart houses (sometimes aligned with the Internet of things), in the management of behaviors through social credit based systems of rewards and punishments based on blockchains of value weighted recording of behavior, to smart government in the form of smart courts and perhaps smarter supervision of an administrative apparatus that now serves as the physical manifestation that materializes virtualized reality.[40] It can be applied to any data rich environment from within which transactions of all kinds can be constituted—health care, psychological services, chatbots,

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[35] Franklin Allen et al., Centralization or Decentralization? The Evolution of State-Ownership in China (Oct. 20, 2024), https://papers.ssrn.com/abstract=4283197.

[36] Michel Foucault, Governmentality in The Foucault Effect: Studies in Governmentality 87-104 (Graham Burchell, Colin Gordon and Peter Miller (eds), (University of Chicago Press, 1991); generally MICHEL FOUCAULT, THE BIRTH OF BIOPOLITICS: LECTURES AT THE COLLÈGE DE FRANCE 1978-1979 (Picador , 2010); Cf., Lauren B. Edelman, Overlapping Fields and Constructed Legalities: The Endogeneity of Law, in PRIVATE EQUITY, CORPORATE GOVERNANCE AND THE DYNAMICS OF CAPITAL MARKET REGULATION 55-90 (Justin O'Brien ed, Imperial College Press, 2007).

[37] Larry Catá Backer, Lecture Seven: AI Narratives and the Future of AI–Human Regulatory Structures (unpublished course lecture materials, Pennsylvania State University, 2026) (on file with author).

[38] Bin Cao et al., *Blockchain Systems, Technologies, and Applications: A Methodology Perspective*, 25 IEEE COMMUN. SURV. TUTOR. 353 (2023).

[39] Michael Jünemann, *Can Code Be Law?*, (2021), https://www.twobirds.com/en/insights/2021/germany/can-code-be-law.

[40] Nick Szabo, *Formalizing and Securing Relationships on Public Networks*, 2 FIRST MONDAY (1997), http://journals.uic.edu/ojs/index.php/fm/article/view/548.

other quasi currencies and property identification systems (for example, Non-Fungible Tokens[41]), and media of all kinds. It is both the essence of history and the objects-based building blocks for transactions.

This, in turn, provides a framework within which automated decisions and consequences flow from transactions subject to the flow of the coding which gives ledger entry transactions their signification and then produces judgment and consequence (action on and guided by the values of judgment) through the operationalization of collective interpretive rules based on an agreement of the value of objects and their flow through transactions[42]—it is, in this respect *both* the idealized universe[43] of the semiotic triad (object to signification to interpretation/consequence, to object again)[44] *and* the automation of rule systems grounded in the identification of objects which will be "worked on" in predictable and pre-determined ways.[45] That repeating pattern, one which builds on itself and might shift depending on the consequences (in code) of aggregations and shifting patterns of transaction data constitute the fundamental signification of coding (in blockchain).

It is within this framework that one might consider the three questions: The first touches on the main contemporary threats to the Rule of Code.[46] The second considers the importance of the Rule of Code, or at least the systems of regulatory and decision making programming they represent, for the legitimacy of blockchain systems.[47] And the third would encounter the dialectics between regulation by programming systems governance and traditional regulation within the contemporary context of recent legislative and executive actions in the blockchain space.[48] Each has its own semiotics. The first is

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[41] Hamed Taherdoost, *Non-Fungible Tokens (NFT): A Systematic Review*, 14 INFORMATION 26 (2022).
[42] Margot E. Kaminski, *Binary Governance: Lessons from the GDPR's Approach to Algorithmic Accountability*, SSRN ELECTRON. J. (2019), https://www.ssrn.com/abstract=3351404.
[43] Constantine Sedikides, Lowell Gaertner & Erin M. O'Mara, *Individual Self, Relational Self, Collective Self: Hierarchical Ordering of the Tripartite Self*, 56 PSYCHOL. STUD. 98 (2011).
[44] Peter T.F. Raggatt, The Dialogical Self and Thirdness: A Semiotic Approach to Positioning Using Dialogical Triads, 20)3) THEORY & PSYCHOLOGY (2010); available [https://doi.org/10.1177/0959354310364878]; John F. Sowa, 2000. "Ontology, Metadata, and Semiotics," presented at ICCS 2000 in Darmstadt, Germany, on August 14, 2000; published in B. Ganter & G. W. Mineau, eds., Conceptual Structures: Logical, Linguistic, and Computational Issues, Lecture Notes in AI #1867, Springer-Verlag, Berlin, 2000, pp. 55-81. Generally, JAN M. BROEKMAN, MEANING, NARRATIVITY, AND THE REAL: THE SEMIOTICS OF LAW IN LEGAL EDUCATION IV (Springer, 2016).
[45] On its semiotics see Göran Sonesson, The Natural History of Branching: Approaches to the Phenomenology of Firstness, Secondness, and Thirdness 1(2) Signs and Society 297-325 (2025); doi:10.1086/673251.
[46] PRIMAVERA DE FILIPPI AND AARON WRIGHT, BLOCKCHAIN AND THE LAW: THE RULE OF CODE (Harvard University Press, 2018) ("Blockchain based application do not depend on [the rules of bureaucratic systems and institutional regulatory apparatus] to structure their functions; instead they depend on lex cryptographica to organize economic and social activity").
[47] Aaron Wright and Primavera De Filippi, *Decentralized Blockchain Technology and the Rise of Lex Cryptographia*, (2015, last rev 25 July 2017); available [https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2580664] ("For now, humans are running these organizations. However, that may soon change, as human-run functionalities are replaced by software operating over a blockchain.2)
[48] See Nicolae Tapus and Manuel Adelin Manolache, *Integrated Decision Making Using Blockchain*, 162 PROCEDIA COMPUTER SCIENCE 587-595 (2019). See, generally Anna Huggins, *Addressing disconnection: Automated decision-making, administrative law and regulatory reform*, 44(3) THE UNIVERSITY OF NEW SOUTH WALES LAW JOURNAL 1048-1077 (2021); Reuben Binns, *Human Judgment in algorithmic loops: Individual justice and automated decision-making*, 16(1) REGULATION & GOVERNANCE 197-211 (2022); David S. Filippi, Bill Tomlinson & Andrew W. Torrance, The Law and AI as an "Apex Collaborator": Legal Frameworks for Optimized Cooperation, 20 FIU L. Rev. 887 (2026), https://doi.org/10.25148/lawrev.20.3.7.

embedded in the broader semiotics of mandatory or coercive collective meaning making, as a function of signified values and expectations of the natural in the world, which is to be replicated or internalized through coding into the machine language of blocks in chains that then serve as the virtual performance of the physical with which it interacts at the start and end of the iterative process of block making. The second goes to the normative essence of the language of blockchain, and with it of the way in which source coding must encode not just values but the cognitive framework that makes such values rational in the self-referencing world of interacting blocks, that is their protocols. The third speaks to the terror of the physical as it comes to the realization that the virtual has acquired an autonomous physicality that then threatens its ability to frame the physical world which is projected inward into the virtual. Let us look briefly at each in turn.

III. The Contemporary Threats to Rule of Code.

Consideration of the threats to the Rule of Code, or at least to the system that has been objectified (firstness) as a "rule" of (or by) Code,[49] may be usefully approached by placing it within a broader context of reality shaping actions with coercive effect.[50] That, in effect, as Primavera De Filippi and Aaron Wright suggest, is a problem of incompatible enclosures.

> The Internet had already raised a fundamental tension between the *rule of law*, based on geographical boundaries, and the *Rule of Code*, based on topological constructs. The regulation of "cyberspace" lies at the intersection between these two normative systems—which can either cooperate or compete with one another, depending on the circumstances at hand.[51]

The incompatibility, though, runs deeper than terrain. It suggests not just resistance but replacement of one system of collective meaning for another. Replacement than moves from its traditional humanized basis,[52] to one in which one no longer worries as much about master narrative conflicts,[53] but instead one faces a conflict of narrative in which machines can engage with humans but the narratives of machines remains opaque to humans.[54] Indeed, replacement ambitions are harder to realize than mere supplementary or complementary roles for regulatory systems beyond traditional ones. And from there one can begin to get a sense of the range of issues that threaten the integrity of the Rule

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[49] Wessel Reijers, Iris Wuisman, Morshed Mannan, Primavera De Filippi, Christopher Wray, Vienna Rae-Looi, Angela Cubillos Vélez & Liav Orgad, *Now the Code Runs Itself: On-Chain and Off-Chain Governance of Blockchain Technologies,* 40 TOPOI 821-831 (2021).

[50] The concept is by now ancient in the literature. See, e.g., Peter Naur, *Programming as Theory Building*, 15(5) MICROPROCESSING AND MICROPROGRAMMING 253-261 (1985) (the object of coding is not programing but the production of executable theories of systems designed to produce iteratively consistent result).

[51] PRIMAVERA DE FILIPPI & AARON WRIGHT, BLOCKCHAIN AND THE LAW: THE RULE OF CODE (2018).

[52] See generally essays in David Nunan and Julie Choi, eds., LANGUAGE AND CULTURE: REFLECTIVE NARRATIVES AND THE EMERGENCE OF IDENTITY (Routledge, 2010); essays in Klarissa Lueg and Marianne Wolff Lundholt (eds), ROUTLEDGE HANDBOOK OF COUNTER-NARRATIVES (Routledge, 2021).

[53] See, JAMES ELKINS, MASTER NARRATIVES AND THEIR DISCONTENTS (Routledge, 2005); Timothy Kuhm, *Communicatively Constituting Organizational Unfolding through Counter-Narrative*, in COUNTER NARRATIVES AND ORGANIZATION 17-42 (Suanne Frandsen, Timothy Kuhn, and Marianne Wolff Lundholt, Routledge, 2017).

[54] See, Claus Beisbart*, In Which Ways Is Machine Learning Opaque?,* in PHILOSOPHY OF SCIENCE FOR MACHINE LEARNING 3-24 (Juan M. Durán and Giorgia Pozzi (eds), Springer Nature, 2026).

of Code, both internal and external. Internal threats are perhaps the more interesting. Among them some may merit mention:

A. Issues of Incoherence. It is one thing to create transaction based blockchain through regulatory coding. It is quite another to weave these into a coherent system. The difficulty comes in the form of the regularization of structural coupling within complex and contingent interpenetrative transactional events. Ultimately, the need for a master coder, as well as a master code, becomes more evident; but in "solving" a problem of incoherence this way one undermines the fundamental principle of decentralization at the heart of the normative blockchain project. Master coding appears to be the stuff of regulation, now no longer the province of physical institutions vested with regulatory authority but now insinuated within the language of code; language in this sense "speaks" and regulates. And with it comes the need to elaborate the cognitive cage within the realities of a virtual system of integrated transactions undertaken in an automated way through which blockchain may be rationalized, its value system stabilized, and its internal flows understood in ways that make it possible to develop patterns both of micro- and macro-effectiveness and objectives based value maximization. One would, in effect, require the coding of culture if the system is to be managed as a whole. And there would be resistance—in the form of forking[55] for example.[56]

Yet the aspiration toward master coding runs counter to the original fundamental ordering premises of blockchain—autonomous, democratic, and dispersed power that ideally produces the reproduces in physical form the absence of either coordination or control from any source outside of itself. Codes of Codes, in this view, can work only within a specific blockchain collective and only to the extent to the members of the collective agree. Here one might encounter blockchain Rule of Code systems as the near perfect example of an ordered anarchic system—order without a center. That order would derive from the mimetic impulse of governance among liked charactered collectives—each contributing to a collection of expectations that are not bound up in Rules of Code but in histories of practice. True to its nature of autonomy and control diffusion, systems of blockchain governance may spin autonomously around a space that by its emptiness provides a structure for ordering around it; it is empty in this sense and an ordering core of values and expectations. Here one might discern manifestation by action aggregated across transactions from the whole of which collective value might be extractable; in essence a *phenomenological normativity* that resists by its operation any master coding, that is any filling of the space around which they swirl.[57]

B. Issues of Bias. Bias is a fashionable concept. But it is grounded on at least two false assumptions—the first is that it is possible to eliminate bias from virtual and coded systems; the second is that this stripping of bias somehow mimics the "best" of the analog experience. Yet the fundamental basis of social organization is bias, and bias allocation among a spectrum of categories, from biases that are celebrated and privileged (e.g. equality), to biases to which are to be suppressed (e.g. racism). Yet even if one embraced bias, there is a further bias that is perpetuated both in the temporality of the blockchain and in human regulation—the tendency to invest a concept and word with quite distinct value systems

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[55] Linus Nyman & Juho Lindman, *Code Forking, Governance, and Sustainability in Open Source Software* (2013).
[56] Besides resistance and forking in practice (users who disagree with a master coder/code could fork the chain anyway and one couldn't enforce a master code) one might also encounter a single point of failure, so the entire chain would be corrupted.
[57] Maxime Doyon, *Normativity, as a Concept in Phenomenology*, *in* ENCYCLOPEDIA OF PHENOMENOLOGY 1 (Nicolas De Warren & Ted Toadvine eds., 2025), https://link.springer.com/10.1007/978-3-030-47253-5_186-1.

over time. For example—both the 18th and 21st century celebrate equality. But the former understood equality as inherent in the division of society in a significant number of ways that produce social, political, and economic hierarchy, where the 21st century invests the term with a different ordering sensibility. Coding blockchain may find this temporal progression challenging; or the very nature of the temporal and iterative blocks may themselves permit a coding that extracts (and eventually anticipates) hermeneutic patterns. Or it may find it irresistible in the form of so-called decontextualization[58]; in essence the effort of machine intelligence to mimic the normative drift well evidenced in the data of human action it has been fed. And then there is the great beastly temptation—to use the power of pattern prediction to try to control the flow in ways that suit those with the power to inject themselves in the process.[59] All of this, then, encodes the essence of the human—all too human—into their machine systems.

C. Quality Control. Blockchain's essential decentralization produces challenges for accountability. This applies in three contexts—the first touches on the allocation of responsibility—to the coders; to the operators; to the node managers; to the producers of ledger worthy transactions? The second touches on the nature of the responsibility—to code "well?"; to supervise the operationalization and functionality of the coding (as against what measure is a subsidiary issue). The third is to manage mob rule in nodes, or its opposite, strategic veto. In anarchic systems, the ultimate power is to shift out of a blockchain with what one has, if one can.

IV. The Importance of the Rule of Code for the Legitimacy of Blockchain Systems.

Blockchain systems operate only as a function of the integrity of the Rule of Code.[60] That much is certain, and distinct from the emerging literature of Rule by Code.[61] It is also to be distinguished from *Rules as Code*.[62] Nonetheless, and perhaps precisely because of the related notions of rule by and rules as code, it follows from a crude parallelism with regulatory systems that themselves authoritatively operate as a function of the integrity of the Rule of Law.[63] Yet the challenge arises from the incoherence of the notion that there is a singular language within which blockchain regulates. As this article has

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[58] Eunsol Choi et al., *Decontextualization: Making Sentences Stand-Alone*, 9 TRANS. ASSOC. COMPUT. LINGUIST. 447 (2021); Bert van Oers, *The Fallacy of Decontextualization*, 5 MIND CULT. ACT. 135 (1998).

[59] If one wants to speak to the bias to avoid and celebrate, one might consider this: individuals who write the blockchain protocols make the decisions about which transactions are prioritized, how fees are set, what is considered valid—so people with smaller vs larger block sizes might be prioritized. (bias gets baked into code). It might apply as well to consensus mechanisms: (1) Proof of work – might steer towards those with cheap electricity/mining farms; and (2) Proof of stake - prioritize those who already have a bunch of tokens (wealthy get wealthier) etc.

[60] LAWRENCE LESSING, CODE AND OTHER LAWS OF CYBERSPACE, (Basic Books, 1999).

[61] Primavera De Filippi, Morshed Mannan and Wessel Reijers, *Blockchain Technology and the Rule of Code: Regulation via Governance,* 92 THE GEO. WASH. L. REV. 1229 (2024) ("rule by code is a system of online governance in which there exists a sovereign (the online operator, as well as the regulators to which the operator must respond) that stands above the code and therefore uses the code to impose restrictions and constraints over internet users who are subject to such code" ibid., 1244)

[62] Angelica Lindqvist, Rules as Code–An Open Approach, European Commission, EU GovTech; available [https://interoperable-europe.ec.europa.eu/collection/eugovtech/document/rules-code-open-approach]. See generally Rónán Kennedy, Rules as code and the rule of law: ensuring effective judicial review of administration by software, 16 LAW, INNOVATION & TECHNOLOGY 170-193 (2024).

[63] For a political variation of the fundamental premise, and with it the underscoring of the political fundamentalism of rule of law in and for regulatory systems, see Gerald J. Postema, An *"Almost Sacred Responsibility": The Rule of Law in Times of Peril*, 107(3) JUDICATURE 17-23 (2024).

suggested earlier, the Rule of Code is perhaps better understood as an ecology of infinitely interpenetrating languages which together constitute the entirety of the regulatory "text" of Code. The interactions, translations, transpositions, logics, and manifestations of source coding, machine language, object and executable coding, and the regulatory languages transposed into coding suggest a more complex element to the structuring and linguistics of the Rule of Code. More interesting still, is that only some of those components of the language of Code are accessible to humans. Yet the issue of translation is also compounded—first among the languages that make up the interactive dialogue of the Rule of Code--and then the "all too human" languages of rule of law and cultural expectations with and into the language of code.[64]

Less certain is effect to that integrity by any sort of the structural coupling (polluting) the Rule of Code. The issue is made more starkly by the debates about the nature and function of traditional regulatory measures to "manage" or "control" or "civilize" artificial intelligence systems. In Europe, as in other places, a risk-based analysis is preferred.[65] Here the idea appears to be that risk to humans, and to human ideas, ought to drive an externally imposed regulatory system. Underlying that premise is the notion that while humans may engage in risk-based behaviors within the rule of law (e.g., facial recognition, emotion analytic and the like), "machines" ought not to be permitted to engage in the same sort of endeavors, or worse, to enhance the abilities of humans engaging in those sorts of risk behaviors.

And, of course, blockchain systems tend to privilege the system itself and its critical elements—its objects, signifiers and consequential interpretive spaces. Human privileging factors may become marginalized within these structures. Certainly the idea of coding human rights, for example, is a daunting task;[66] less immense is the project of coding that is "human rights based" one that borrows from its human centered analog.[67] In one respect the project is nearly impossible because the humans for whose benefit this is privileged in Rule of Law have yet to develop any sort of consensus, and in any case that consensus would be a moving target.[68] In another respect the transposition of human rights, for example, into the blockchain environment would be challenging. First the issue of placement is necessary; is it to be embedded in the constitution of the ledgered transaction; or the block, or transactions that produce additional blocks? Are the blocks themselves objects of human rights or only their content objects? Is the process to which blockchain is devoted an object of rights analysis and if so, how are adverse human rights impacts to be measured in the face of multiple and inconsistent accounts of human rights in the human cognitive space? And so on. But perhaps the greater problem of both the human and the machine, intensified in the interactive dynamic of human-machine connectivity is that of

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[64] For example, it may be surmised that few users can read or understand the complex 'smart' contracts involved, however transparent. Most users rely on auditors or developers which creates that accountability gap.

[65] E. D. van Asselt et al., *Overview of Available Methods for Risk Based Control within the European Union*, 23 TRENDS FOOD SCI. TECHNOL. 51 (2012); Maria Eduarda Gonçalves, *The Risk-Based Approach under the New EU Data Protection Regulation: A Critical Perspective*, 23 J. RISK RES. 139 (2020).

[66] See generally Human Rights Based Programming: What is it? (U.N. Population Fund, 2006) available [https://www.unfpa.org/sites/default/files/resource-pdf/human_rights.pdf]; Jamie Frederic Metzl, Information Technology and Human Rights, 18(4) Human Rights Quarterly 705-746 (1996).

[67] Ontario Human Rights Commission, Human Rights Based Approach to Policy and Program Development, available [https://www3.ohrc.on.ca/en/human-rights-based-approach-policy-and-program-development-0]

[68] Cf., Joe Hoover, *Rereading the Universal Declaration of Human Rights: Plurality and Contestation, Not Consensus*, 12 J. HUM. RTS. 217-241 (2013).

homeostasis and the consequential risks of rigidity that detaches the system from the realities of machine and humane, and decay that comes because of detachment.[69]

Still, it is important to distinguish between the centrality of coding and interpenetrative coding languages—machine and human—for the constitution and operation of blockchain, on the one hand, and on the other the regulatory incentives around blockchain, especially as blockchain structurally coupled with other human and virtual subsystems. The internal regulation of blockchain may well be self-referentially coded and coded within the logic and principles of its own rationalities, described above. Its effects, however, are not.[70] It is in that space of "effects", projected out of the blockchain, that systems of coded legality may well have to be developed, something that requires a substantial inquiry which has not materialized to any great effect. Here one will have to develop theories of bridging law and bridging language that projects in both directions simultaneously. And lastly, the integrity of blockchain might well be separated from the integrity of physical systems with respect to which it has no effects—or it may serve as a template for overturning the reign of traditional physical law in favor of a new *crypto-type bio-politics*.[71] And with it a new form of politics one built into the very structures of its coding that acquire a politics of their own, one that permits machines to elaborate without much intervention while allowing human intervention to exploit the coded structures of its operations.[72]

The preceding analysis suggests that the principal difficulty is neither merely one of institutional design nor conflicts between regulatory hierarchies. It is, more fundamentally, a problem of communication across layered systems of signification. To develop that point, it is necessary to dwell more carefully on the internal linguistics of the Rule of Code itself, the layered character of its communicative forms, and the losses that occur as legal and cultural meaning descends from human normative abstraction into machine-executable logic.

V. The Sacher-Torte of Regulation and the Systems Communication Problem.

i. The Illusion of a Singular Rule of Code.

The first analytical error in the contemporary debate over blockchain governance is the presumption that the Rule of Code names a singular thing.[73] It does not. It is neither a monolithic language nor a unitary regulatory form. It is, rather, an ecology of recursively related communicative orders, each with its own syntax, semantics, constraints, exclusions, and modalities of effectuation. Once one rejects the notion that blockchain regulates through one coherent linguistic medium, the Rule of

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[69] See NORBERT WIENER, GOD & GOLEM, INC.: A COMMENT ON CERTAIN POINTS WHERE CYBERNETICS IMPINGES ON RELIGION (MIT Press, 1964), pp. 82-85.

[70] Cf., Peter R. Lewis, and Ştefan Sarkadi, Reflective Artificial Intelligence, 34 Minds and Machines 14; available [https://doi.org/10.1007/s11023-024-09664-2].

[71] Michel Foucault, *The History of Sexuality, Vol. 1: An Introduction* (Reprint ed. 1990).

[72] Nicely described in Jan Groos, *Crypto Politics: Notes on Sociotechnical Imaginaries of Governance in Blockchain Based Technologies, in* DATA LOAM: SOMETIMES HARD, USUALLY SOFT: THE FUTURE OF KNOWLEDGE SYSTEMS 148-170 (Johnny Golding Martin Reinhart Mattia Paganelli (eds.), De Gruyter, 2021) ("The striving for an alleged 'end of politics' in favor of decentralised, algorithmic self-organisation that served as one of the foundational myths surrounding blockchain based technologies, had led to a situation where the necessity of ordinary politics came to light with immense intensity." Ibid., 156).

[73] DE FILIPPI AND WRIGHT, *supra* note 28.

Code appears instead as a Sacher-Torte of languages through which command, signification, and execution are layered and mediated.

That recognition matters because the friction between Rule of Law and Rule of Code is not exhausted by the familiar trope of conflict between sovereign command and technical design. The deeper difficulty is communicative. It is a problem of translation, transposition, and signal degradation across heterogeneous systems of meaning. Human legal language operates in a semantic universe in which ambiguity is often productive, temporality is open, interpretation is institutional, and values such as fairness, equality, reasonableness, and proportionality remain necessarily contestable. By contrast, code operates through increasingly constrained grammars of executable distinction. As one descends the stack, one does not merely implement law, instead one subjects legal meaning to a series of transformations. A series in which the available bandwidth for human normativity narrows, the form of permissible expression changes, and the very ontology of the object regulated is remade.[74]

Beyond the simple concept that lawyers and engineers speak different professional dialects, it is more so that the Rule of Law and the Rule of Code inhabit different cognitive universes whose contact depends on unstable acts of translation. At the top of the stack, human actors still imagine themselves to be speaking in the language of public values. At the bottom, however, the system no longer hears fairness, dignity, or equality as such. It hears only distinctions that can be rendered executable within the operative grammar of the machine. What appears at the policy layer as principle is gradually reconstituted, at lower layers, as instruction, or machine code, then as operation, and finally as physicalized constraint.

The consequence is decisive. The Rule of Code is not a mirror of law, nor even its obedient instrument. It functions as an autonomous, self-referential cognitive system that receives human legal meaning only after that meaning has been translated into forms legible to its own internal rationality. The system feeds on its own data. In blockchain this is literal rather than figurative: each new block is valid only if it follows from the state the chain has already recorded, so that the system's own prior output becomes the measure of every new input.[75] Where generative systems enter the loop, that self-reference takes on a sycophantic character, producing output shaped to satisfy rather than to inform, in ways no longer visible to humans.[76] In Luhmann-esque terms, the Rule of Code approaches the condition of a system that is *autopoietic* and *operatively closed*, one that operates on its own internal references.[77] Closure, however, is not isolation. For Luhmann, operational closure is the condition of a system's openness to its environment, not its negation. A closed system cannot be commanded from

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[74] Nicholas Godfrey & Mark Burdon, *Fidelity in Legal Coding: Applying Legal Translation Frameworks to Address Interpretive Challenges*, 33 INF. COMMUN. TECHNOL. LAW 153 (2024).

[75] This is the state-transition model on which Ethereum is built: the state of the ledger at each block is a function of its prior state and the transactions applied to it, and nodes reject any block whose claimed state does not follow from that function. *See* Gavin Wood, *Ethereum: A Secure Decentralised Generalised Transaction Ledger* § 2 (Yellow Paper), https://ethereum.github.io/yellowpaper/paper.pdf. Bitcoin's practice of binding each block to the hash of its predecessor achieves the same self-reference in simpler form. *See* Satoshi Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System 2–3 (2008), https://bitcoin.org/bitcoin.pdf.

[76] Myra Cheng et al., *Sycophantic AI Decreases Prosocial Intentions and Promotes Dependence*, 391 SCIENCE eaec8352 (2026); *AI Overly Affirms Users Asking for Personal Advice*, https://news.stanford.edu/stories/2026/03/ai-advice-sycophantic-models-research (last visited Apr. 9, 2026).

[77] NIKLAS LUHMANN, LAW AS A SOCIAL SYSTEM (2004).

outside, but it can be irritated, and it is at the points of irritation that coupling becomes possible.[78] The systems communication problem originates here, not because law lacks authority in the abstract, but because authority does not survive descent unchanged. What travels downward is not human intention[79] itself, but simulations[80] thereof, a machine intention represented by the mimetic iterative shape of responses to the human, shaped both by human input and through prior data collected by the system.

ii. Deconstructing the Layers of the Sacher-Torte.

For analytic economy, the layered communicative order is rendered as a five-layer Sacher-Torte. The number is an interpretive consolidation rather than an engineering specification. An engineer could draw the stack more finely, and a finer drawing would only add sites of translation, not remove them.[81] What distinguishes one layer from the next is not its place in a compilation pipeline but two related questions: who can still read the language spoken there, and what kind of meaning that language can still carry. The three alignments described at the outset map onto these layers. Human-to-human language occupies the first; the passage from human to machine language spans the second and third; machine-to-machine language governs the fourth and fifth. We begin with the human-to-human layer, identifying our top cake layer, the chocolate glaze, before entering the body.

At the first layer reside the languages of legislation, regulation, adjudication, institutional practice, political culture, and social expectation. This is the domain in which law still appears in its most recognizably human form: text, argument, principle, aspiration, analogy, narrative. It is also the layer in which values remain temporally fluid. Equality is not a stable object, it is a signifier whose social and legal content drifts over time, such that eighteenth-century and twenty-first-century invocations of the same term may encode profoundly different normative universes.[82] It is precisely this fluidity that code displaces. Lessig argues that code acts as today's primary regulator, one that shapes the environment through hard-coded constraints rather than the fluid nature of norms and state powers.[83]

At this layer, however, language does not merely describe a world, it constitutes one. Legal texts are performative in the strongest sense: they allocate legitimacy, order perception, distinguish public from private, lawful from unlawful, remedial from punitive. Hildebrandt explains this performative

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[78] NIKLAS LUHMANN, LAW AS A SOCIAL SYSTEM chs. 2, 10 (Klaus A. Ziegert trans., Fatima Kastner et al. eds., 2004) (operative closure as the condition of cognitive openness; structural coupling between closed systems). Whether technical systems can themselves be autopoietic in Luhmann's sense is contested, and nothing in the argument here depends on it; the claim is functional rather than ontological. *Compare* ELENA ESPOSITO, ARTIFICIAL COMMUNICATION: HOW ALGORITHMS PRODUCE SOCIAL INTELLIGENCE (2022) (algorithms participate in communication without understanding it), *with* the sources on generative AI and autopoiesis cited in Part V.iv, *infra*.

[79] Backer, *supra* note 11.

[80] JEAN BAUDRILLARD, SIMULACRA AND SIMULATION (1994).

[81] A technically finer model would separate, at a minimum, contract source code; intermediate representations and virtual-machine bytecode; the node client software that executes that bytecode and is itself compiled to native code; the processor's instruction set architecture; the microarchitecture, which on many modern processors decodes instructions into internal micro-operations before executing them; and the physical logic of the chip. *See generally* JOHN L. HENNESSY & DAVID A. PATTERSON, COMPUTER ARCHITECTURE: A QUANTITATIVE APPROACH (6th ed. 2017). Each further division marks a further act of translation, and so strengthens rather than weakens the argument of this Part.

[82] See, e.g., Pierre Rosanvallon, *The Society of Equals* (Arthur Goldhammer trans., 2013); Peter Westen, *The Empty Idea of Equality*, 95 HARV. L. REV. 537 (1982).

[83] LAWRENCE LESSIG, CODE: VERSION 2.0 (2nd ed. ed. 2006).

effect of legal interpretation as a force "based on a complex interplay between the demands of legal certainty, justice and instrumentality."[84] Yet this layer is also indeterminate in a way essential to its function. It tolerates ambiguity because ambiguity is the price of generality. It tolerates contradiction because contradiction is often the medium through which plural societies negotiate coexistence. It tolerates delay because adjudication and administration depend on institutional interpretation. In phenomenological terms, this is the layer at which the object of regulation remains bound up with lived meaning and social context. In semiotic terms, the signifier remains open to contestation. As the chocolate glaze can pour over the cake and change in shape and size, so too does the human-to-human layer.

The second layer is the zone of transcription from policy into software. Here, values do not disappear, but they are compelled to take on a different form.[85] The programmer must decide what, exactly, counts as equality, compliance, consent, authorization, or risk for purposes of system design.[86] In the passage from legal language to source code, abstraction is converted into parameterization.[87] Parameterization, in this sense, may be understood as the point at which an abstract normative proposition acquires determinate operational consequences within a particular system. There are consequences that follow from these premises: Fairness becomes a threshold, access rule, weighting function, or logic gate of permission and denial. Equality becomes a comparative routine. Due process becomes a sequence of authorized states in a workflow.[88] Human values survive only by being operationalized, the mimetic and iterative sum of rules translated into operational structures that constrain behaviors in their interactions with users—whether the users are human or part of automatized systems of decision making.[89]

One can see that source coding is the human-readable medium through which humans communicate with virtual intelligence, while recognizing that this is not the language through which virtual intelligence ultimately communicates with itself.[90] This distinction is crucial. Source code is

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[84] Mireille Hildebrandt, *Code-Driven Law: Freezing the Future and Scaling the Past* (2020), http://www.bloomsburycollections.com/book/is-law-computable-critical-perspectives-on-law-and-artificial-intelligence.

[85] Cf., Helen Nissenbaum, *Values in Technical Design*, in ENCYCLOPEDIA OF SCIENCE, TECHNOLOGY, AND ETHICS lxvi, lxviii–lxix (Carl Mitcham ed., Macmillan Reference USA 2005).

[86] See, e.g., NATHALIE A. SMUHA, ALGORITHMIC RULE BY LAW: HOW ALGORITHMIC REGULATION IN THE PUBLIC SECTOR ERODES THE RULE OF LAW 151, 205–29 (Cambridge Univ. Press 2024). Here the argument might be understood this way: Legal concepts such as equality and reasonableness can be reflected in mathematical calculations and programmed into algorithmic systems. These concepts are not necessarily understood uniformly. Their interpretation and codification embody normative choices. The discretion involved in interpreting legal rules moves upstream to the coders who translate and operationalize those rules. Ibid., chapter 4, sections 4.2.1–4.2.2.

[87] See, e.g., Marco Almada, Regulation by Design and the Governance of Technological Futures, 14 Eur. J. Risk Regul. 697, 697–702 (2023), https://doi.org/10.1017/err.2023.37; Oliver R. Goodenough & Preston J. Carlson, Words or Code First? Is the Legacy Document or a Code Statement the Better Starting Point for Complexity-Reducing Legal Automation?, 382 Philos. Trans. R. Soc. A 20230160 (2024), https://doi.org/10.1098/rsta.2023.0160.

[88] Danielle Keats Citron, *Technological Due Process*, 85 WASH. UNIV. LAW REV. 1249 (2008).

[89] Cf., James Grimmelmann, *Regulation by Software*, 96 N.C. L. REV. 171, 177–83 (2017). See generally MIREILLE HILDEBRANDT, LAW FOR COMPUTER SCIENTISTS AND OTHER FOLK (Oxford Univ. Press 2020).

[90] See generally Jenna Burrell, *How the Machine 'Thinks': Understanding Opacity in Machine Learning Algorithms*, 3 BIG DATA & SOC'Y, no. 1, 2016, at 1, https://doi.org/10.1177/2053951715622512 (Burrell distinguishes three forms of opacity, the third being one that arises from the characteristics of machine learning algorithms and the scale needed to use them); MARK C. MARINO,

often mistaken for the whole of the Rule of Code because it remains visible to humans. That visibility, however, should not be confused with sovereignty. Source code is only the last layer at which human authorship can plausibly imagine itself in command.

This is also the layer at which the "all too human" enters most visibly into the machine. Bias, preference, institutional habit, political compromise, and tacit assumptions are sedimented into the architecture of the program, often without full awareness on the part of the coder. The translation is never neutral because every act of coding requires closure: one must choose what counts, what is ignored, what is measurable, and what is not.

The third layer is the first opaque descent.[91] It is the domain of assembly instructions, intermediate representations, and bytecode, including environment-specific forms such as Ethereum Virtual Machine bytecode[92]. This is the layer at which human readability sharply degrades, but before the processor's own instruction set is reached. Assembly code and bytecode become a machine-readable form that only humans with specialized skillsets can access, and then, only partially, with increasing difficulty.[93] For smart contracts the point is sharper still. What is deployed to and enforced by an Ethereum-style chain is the bytecode, not the source. Publication of the human-readable source is voluntary, and its correspondence to the deployed bytecode must be separately established by recompiling it.[94] The authoritative text of the contract, in other words, is written in the first language that humans cannot ordinarily read.

Its significance is theoretical as much as technical. This layer acts as a site of selection. Translation here is already transformation. Human-authored source code is decomposed into lower-order instructions and control structures that no longer preserve, in any rich sense, the normative vocabulary from which the code originated.[95] What remains are operational dependencies, memory allocations,

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CRITICAL CODE STUDIES (2020) (Marino argues that code means more than what it does, and that it must be read critically for what it means).

[91] But consider Zachery C. Lipton, *The mythos of model interpretability: In machine learning, the concept of interpretability is both important and slippery,* 16(3) QUEUE, 31–57 (2018); available https://doi.org/10.1145/3236386.3241340.

[92] Vitalik Buterin, *Ethereum: A Next-Generation Smart Contract and Decentralized Application Platform* (2019); Gavin Wood, *Ethereum: A Secure Decentralised Generalised Transaction Ledger* (2025), https://www.example.com/ethereum-a-secure-decentralized-generalised-transaction-ledger.

[93] "At least in the moment opacity is perceived as a practical problem (Lipton, 2018; Watson, 2022) and sought to be reduced. It is unclear if the currently fashionable methods from XAI can reduce opacity below the required threshold for habituation to kick in." Nico Formánek*, How I Stopped Worrying and Learned to Love Opacity*, IN PHILOSOPHY OF SCIENCE FOR MACHINE LEARNING: CORE ISSUES AND NEW PERSPECTIVES 25-36, 33 (Juan M. Durán and Girogia Pozzi (eds), Springer Nature, 2026).

[94] A contract is created on Ethereum by a transaction carrying its compiled code, and only that bytecode is stored on chain. *See* Gavin Wood, *Ethereum: A Secure Decentralised Generalised Transaction Ledger* § 7 (Yellow Paper), https://ethereum.github.io/yellowpaper/paper.pdf. Verification services recompile whatever source a developer chooses to publish and compare the output with the bytecode on chain. *See, e.g.*, Sourcify, *Exact Match vs. Match*, https://docs.sourcify.dev/docs/exact-match-vs-match/ (last visited Oct. 26, 2026).

[95] Google LLC v. Oracle America, Inc. (Supreme Court of the United States 2021).

jumps, calls, stack manipulations, opcodes, and execution constraints.[96] The legal and political semantics that animated the upper layers survive only indirectly, as traces frozen into structure.[97]

This is why the translation layer may be understood as the first moment of genuine semiotic loss.[98] Not total loss, certainly, but a decisive attenuation. The signified has not vanished, instead being displaced into a form whose signification is no longer accessible through ordinary human interpretation. It has been rendered machine proximate. It has become a simulation of the original.

At the fourth layer, translation gives way to execution. This is the domain of machine code, object code, and executables, the space in which the processor receives binary instructions as command. Humans can read source code, but not machine and object coding in any practical sense, and machine coding is for execution rather than programming.

The jurisprudential significance of this layer is easy to underestimate. Here the Rule of Code ceases even to resemble law in its textual form. It becomes event. It is no longer principally a statement about what ought to happen, instead taking the form as the initiation of what does happen, conditioned by the architecture of the processor and the state of the machine. At this level, the norm is indistinguishable from its enforcement. The command is no longer interpreted. The command is executed.

This is why blockchain appeared so attractive as a regulatory form. As described, it seemed to solve the classical problem of legal compliance by internalizing both norm and method within code itself, thereby automating regulation and embedding the subject of compliance within the programming architecture.[99] At the execution layer, this aspiration becomes materially real. The norm no longer stands outside the subject as text backed by sanction. It is built into the conditions under which action can occur at all. That building-in is also textual, but no longer readable in its entirety by humans.[100]

Our final, fifth layer is the most materially decisive and the least normatively visible. Here one encounters microcode, through which many processors translate their own instructions into still smaller internal operations, and beneath it the logic of the circuit itself, the forms that lie at the base of machine

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[96] See, e.g., Anurang Shrivastava, Rvs Praveen, Read H. C. Alfilh, Navdeep Singh, Kanchan Yadav and B. Rajalakshmi, *AI-Driven Fault Resilience: Integrating Deep Graph Neural Networks in Spatio-Temporal Smart Grid Monitoring* , 2025 INTERNATIONAL CONFERENCE ON COMPUTING AND COMMUNICATIONS (COMPUTINGCON)*,* Talegaon, India, 2025, pp. 1-7, doi: 10.1109/COMPUTINGCON64838.2025.11377902.

[97] See Agustin V Startari, *Regulatory Legitimacy Without Referents: On the Syntax of AI-Generated Legal Drafts*, AI POWER DISCOURSE (2025), https://www.aacademica.org/agustin.v.startari/188 (discussion on machine generated law losing meaning).

[98] See, Annie Gentès The Game Mechanics of Pervasive Applications: Visiting the Uncanny, 18(1-2) New Rev. Hypermedia & Multimedia 91-108 (2012).

[99] Kevin Werbach, *A Layered Model For Internet Policy*, 1 TELECOMMUN. HIGH TECHNOL. LAW (2002).

[100] It ought to be emphasized that readability here is relative in the sense that with enough effort and tools machine language can be "read" though whether it can be understood by humans in the way a machine understands that language remains an elusive question. Cf., James L. McClelland, Felix Hill, Maja Rudolph, Jason Baldridge, Hinrich Schütze, Extending Machine Language Models toward Human-Level Language Understanding, arXiv:1912.05877v2 [cs.CL] https://doi.org/10.48550/arXiv.1912.05877 (v2 4 July 2020).

legibility.[101] This is the point at which the digital merges with the physical architecture.[102] Beyond the hardware purely executing it, the command is now conditioned by the hardware as an already-structured field of possibility. That field was itself legislated.[103] The circuit was written by human engineers in hardware description languages such as Verilog or VHDL and compiled into silicon at design time, long before any contract was deployed on it.[104] The processor's instruction set is, in this sense, the constitution of the machine, enacted before any program runs and amendable, if at all, only by its manufacturer. Human values can reach this layer, but only at the moment of design, never at the moment of execution.[105]

At this depth, the distinction between language and matter begins to collapse. What speaks is no longer text in any ordinary sense but patterned electrical possibility. Regulation becomes architecture;[106] constraint becomes timing;[107] "register" (the lens, framework or level of abstract applied) becomes width;[108] memory becomes access;[109] instruction becomes set design, bus behavior, and the physical affordances of the server or node.[110] The digital thus does not float above the material. It is materialized through it.[111]

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[101] S.G. Shiva, *Computer Hardware Description Languages—A Tutorial*, 67 PROC. IEEE 1605 (1979); D.M. Goldschlag, *A Formal Model of Several Fundamental VHDL Concepts*, *in* PROCEEDINGS OF COMPASS'94 - 1994 IEEE 9TH ANNUAL CONFERENCE ON COMPUTER ASSURANCE 177 (1994), http://ieeexplore.ieee.org/document/318454/.

[102] Friedrich Kittler, *There Is No Software*, CTHEORY (Oct. 18, 1995), http://www.ctheory.net/articles.aspx?id=74.

[103] LAWRENCE LESSIG, CODE: AND OTHER LAWS OF CYBERSPACE, VERSION 2.0, 5–6 (2006); Langdon Winner, *Do Artifacts Have Politics?*, 109 DAEDALUS 121, 121–22, 127–31 (1980) Lessig and Winner provide the theoretical foundation for treating technological architecture as a regulatory arrangement. The engineering sources establish that the architecture is designed and implemented through human decisions. We suggest that the inference that those decisions constitute a form of prior legislation.

[104] See, e.g., AMD, Vivado Design Suite User Guide: Synthesis, UG901, ch. 1 (2024.2).

[105] Cf., Langdon Winner, *Do Artifacts Have Politics?,* 109 DAEDALUS 121, 121–22, 127–31 (1980) (technological arrangements can embody particular forms of power and authority through their design, independently of the purposes to which they are subsequently put).

[106] Joel R Reidenberg, *Lex Informatica: The Formulation of Information Policy Rules through Technology*, 76 TEX. LAW REV. (1997), http://ir.lawnet.fordham.edu/faculty_scholarship/42.

[107] Cf., ADRIAN MACKENZIE, TRANSDUCTIONS: BODIES AND MACHINES AT SPEED (2002): ADRIAN MACKENZIE, CUTTING CODE: SOFTWARE AND SOCIALITY (2006).

[108] Considered in Jeannette M. Wing, *Computational Thinking and Thinking About Computing*, 366 (1881) PHIL. TRANSACTIONS ROYAL SOC'Y A 3717 (2008); Luciano Floridi, *The Method of Levels of Abstraction*, 18 MINDS & MACHS. 303 (2008); and Alexander R. Galloway, *Protocol: How Control Exists After Decentralization* (2004).

[109] See, e.g., WOLFGANG ERNST, DIGITAL MEMORY AND THE ARCHIVE (Jussi Parikka ed., 2013); Wendy Hui Kyong Chun, Programmed Visions: Software and Memory (2011); Wm. A. Wulf & Sally A. McKee*, Hitting the Memory Wall: Implications of the Obvious*, 23 ACM SIGARCH COMPUT. ARCHITECTURE NEWS, no. 1, 1995, at 20.

[110] Cf., JOHN L. HENNESSY, DAVID A. PATTERSON, AND CHRISTOS KOZYRAKIS, COMPUTER ARCHITECTURE: A QUANTITATIVE APPROACH (7th ed. 2025); TUNG-HUI HU, A PREHISTORY OF THE CLOUD (2015); SIGNAL TRAFFIC: CRITICAL STUDIES OF MEDIA INFRASTRUCTURES (Lisa Parks & Nicole Starosielski eds., 2015); see also, WENDY HUI KYONG CHUN, PROGRAMMED VISIONS: SOFTWARE AND MEMORY (2011) (argues that source code is treated as the thing that explains software when it is not).

[111] For academic discussion around this insight, see, e.g., *PAUL DOURISH,* THE STUFF OF BITS: AN ESSAY ON THE MATERIALITIES OF INFORMATION (2017) (treats protocols, representations, and hardware as material constraints). See, also, Matthew G. Kirschenbaum, *Mechanisms: New Media and the Forensic Imagination* (2008) (Distinguishes "forensic" and "formal" materiality, arguing digital inscription is physical.); Jean-François Blanchette, *A Material History of Bits*, 62(6) J. AM. SOC'Y INFO. SCI. & TECH. 1042 (2011) (Argues that information depends on material constraints and that abstraction layers don't remove them). For the classic claim that software is ultimately voltage differences in hardware, the artifacts of which can be reframed for human consumption, see, Friedrich A.

This is also the layer most indifferent to human juridical aspiration. No processor recognizes fairness. No gate array is moved by equality. Concepts such as fair use do not exist to a machine, and all human interpretation is removed.[112] Whatever survives from the policy layer survives only insofar as it has been reconstituted as physically executable difference. Human legal meaning, in other words, reaches the hardware layer only after it has ceased to be human legal meaning in its original form.

One element of blockchain sits outside this vertical descent altogether. A blockchain is not one Sacher-Torte but many identical ones, replicated on every node, and the consensus protocol is the means by which those replicas confirm that they remain the same cake. They are, in that sense, a memory of acts and actions that at once mimetic and iterative. Proof-of-work, proof-of-stake, and Byzantine fault tolerant protocols do this in different ways and fail in different ways, from the capture of a majority of computing power to the collusion of a cartel of validators.[113] This horizontal layer is where the much-celebrated immutability of the ledger actually resides. Immutability is not a property of any one layer of code. It is a condition maintained by agreement among replicas, resting on cryptographic assumptions that are themselves time-bound,[114] and what agreement maintains, agreement can suspend. When the Ethereum community moved in 2016 to reverse the effects of the DAO exploit through a hard fork, the Rule of Code did not fail. It was overruled at the coupling point, by node operators deciding whether to run the new software or not, and those who refused continued the original chain as Ethereum Classic.[115] Temporality at the core of the chain was not abandoned, it was rerouted. Dead ends in block chains suggest an end of phenomenologically active movement, not its erasure. The fact that it cannot be seen does not mean it does not exist- rather veiling and blockages suggest access not facticity. Historical chains may be rerouted but history cannot be changed. The episode is perhaps the clearest illustration available of the argument developed in the remainder of this Part.

iii. The Jelly of Compilers and the Loss in Translation

Kittler, *There Is No Software*, CTHEORY (Oct. 18, 1995), http://www.ctheory.net/articles.aspx?id=74; and N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (1999).

[112] LESSIG, *supra* note 43.

[113] *See generally* Bin Cao et al., *Blockchain Systems, Technologies, and Applications: A Methodology Perspective*, 25 IEEE COMMUN. SURV. TUTOR. 353 (2023). The governance consequences differ accordingly. A majority attack on a proof-of-work chain, a cartel of validators on a proof-of-stake chain, and a loss of liveness in a Byzantine fault tolerant system are different failures, and each presents a different point at which human regulation might attach.

[114] The digital signatures that authorize transactions on most major chains rely on elliptic-curve cryptography, which a sufficiently large quantum computer running Shor's algorithm could break; the hash functions that chain blocks together are weakened, though not broken, by Grover's algorithm. Peter W. Shor, *Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer*, 26 SIAM J. COMPUT. 1484 (1997); Lov K. Grover, *A Fast Quantum Mechanical Algorithm for Database Search*, *in* PROCEEDINGS OF THE 28TH ANNUAL ACM SYMPOSIUM ON THEORY OF COMPUTING 212 (1996). A break of the signature schemes would threaten control of existing assets and the authorization of new transactions more directly than the recorded history itself. The U.S. National Institute of Standards and Technology finalized its first post-quantum cryptographic standards in August 2024. *See* Nat'l Inst. of Standards & Tech., FIPS 203, Module-Lattice-Based Key-Encapsulation Mechanism Standard (2024); FIPS 204, Module-Lattice-Based Digital Signature Standard (2024); FIPS 205, Stateless Hash-Based Digital Signature Standard (2024). The point for present purposes is that the inalterability of the ledger is a contingent achievement, not an ontological property, and a migration to new cryptography would itself require exactly the kind of coordinated human decision described in the text.

[115] Vitalik Buterin, *Hard Fork Completed*, ETHEREUM FOUND. BLOG (July 20, 2016), https://blog.ethereum.org/2016/07/20/hard-fork-completed (fork at block 1,920,000 moving the funds drained from the DAO to a recovery contract). On forking as a mode of resistance within blockchain collectives, see Part III.A, *supra*.

Between these layers lies the jelly of the Sacher-Torte: compilers, interpreters, assemblers, virtual machines, runtimes, linkers, and interface standards.[116] This jelly acts as the medium connecting dense layers of linguistic regulation that not only joins but also absorbs, filters, and transforms.[117]

The standard legal imaginary often treats these mediating mechanisms as neutral conduits. That view is untenable. Compilers do not preserve intent, nor do they pretend to.[118] What a compiler preserves is the meaning the language specification assigns to the program, which need not be the meaning its author had in mind. Where the two diverge, the specification governs, and the compiler optimizes executable possibility within the system of privileged biases that the specification encodes.[119] Interpreters do not safeguard normative nuance, instead they enforce semantic narrowing according to the logic of the target environment.[120] What one encounters, then is difference originating in the source of interpretation and their own cognitive cages rather than the text itself. Protocols do not carry values authentically, instead they constrain communication into agreed formats capable of generating interoperable effects.[121] At every stage, the system asks not what the human meant in the rich, purposive, culturally embedded sense, but what can be rendered into machine-legible command with maximal functional coherence, which can then serve as internal fodder for similar future requests.[122]

The degradation of intent is therefore not accidental. It is structural. The jelly presents itself as neutral, but it strips away human legal semantics because the systems it connects rest on a theory of information that is, by design, indifferent to meaning. Shannon said as much at the founding of the field: the semantic aspects of communication "are irrelevant to the engineering problem."[123] What law treats as productive ambiguity, a formal language can only treat as an error to be resolved before execution.[124] Law thrives on open-textured standards because it must mediate among plural meanings, unforeseen contexts, and institutional forms of judgment. Compiled systems, by contrast, must decide. They require closure where law often preserves openness. They require determinism where law may allow ambiguity. They privilege consistency over interpretation and repeatability over situational equity.[125] The compiler, in that sense, is a jurisprudential actor, though not because it chooses among values. It applies, with

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[116] Dennis Longley & Michael Shain, *Compilers, Interpreters and Assemblers*, *in* UNDERSTANDING MICROCOMPUTERS 107 (Dennis Longley & Michael Shain eds., 1985), https://doi.org/10.1007/978-1-349-07553-9_9.
[117] See NANCY F. COTT, SEMIOTICS AND INTERPRETATION (2017), https://www.degruyter.com/document/doi/10.12987/9780300160932/html.
[118] See N. Chomsky, *Three Models for the Description of Language*, 2 IRE TRANS. INF. THEORY 113 (1956).
[119] See Barry McMullin, *Computational Autopoiesis: The Original Algorithm* (1997) (examples of autopoietic software).
[120] Noam Chomsky, *Syntactic Structures*, *in* SYNTACTIC STRUCTURES (2009), https://www.degruyterbrill.com/document/doi/10.1515/9783110218329/html.
[121] *See* PIERRE BOURDIEU, JOHN B. THOMPSON & GINO RAYMOND, LANGUAGE AND SYMBOLIC POWER (Reprinted ed. 2003); *see also* MICHEL FOUCAULT, ARCHAEOLOGY OF KNOWLEDGE (2 ed. 2013).
[122] *See* NORBERT WIENER, THE HUMAN USE OF HUMAN BEINGS: CYBERNETICS AND SOCIETY (2025), https://mitpressbookstore.mit.edu/book/9780063423190 (arguing that systems optimizing strictly for operational control reduce human communication to mechanistic feedback loops, severing the message from its culturally embedded values).
[123] C. E. Shannon, *A Mathematical Theory of Communication*, 27 BELL SYS. TECH. J. 379, 379 (1948).
[124] Mireille Hildebrandt, *Law as Information in the Era of Data-Driven Agency*, 79 MOD. LAW REV. 1 (2016).
[125] See JOHN CARROLL & DARRELL LONG, THEORY OF FINITE AUTOMATA: WITH AN INTRODUCTION TO FORMAL LANGUAGES (1989) (discussion on finite automata theory and the desire for determinism in computing); Monika Zalnieriute, Lyria Bennett Moses, and George Williams, The Rule of Law and Automation of Government Decision-Making, 82(3) Modern Law Review 425-455 (2019)("impact on rule of law values of automation using: (1) pre-programmed rules (for example, expert systems); and (2) predictive inferencing whereby rules are derived from historic data ").

complete fidelity, a body of rules written elsewhere, by the authors of the language specification and of the compiler itself, and those rules prevail whenever they and the coder's intent part ways. It resembles less a legislator than a court bound to apply a foreign code, one governed by a radically different nomos.[126]

This is why control slips away before machine code is ever reached. Human coders remain attached to the legal, social, and cultural constructs of the textually constrained and humanized operating system the coding of which is understood as Rule of Law, whether or not they recognize the extent of that attachment.[127] But the moment source code is compiled, the text enters a cognitive universe no longer governed by those constructs.[128] It is subjected instead to the immanent rationality of the machine[129]: economy of execution, formal determinism, interoperability, memory discipline, instruction compatibility, and physical feasibility. Human intent is not negated, instead it is subordinated to another order of intelligibility.

iv. The Inaccessibility of the Lower Layers

The critical governance threat does not arise merely because machines execute rules. It arises because the decisive lower layers of execution are practically inaccessible to ordinary human cognition. A consistent theme emerges: humans can read source code, but not machine and object coding in a meaningful sense. The ordering of the lower stack remains mysterious, and this mystery deepens when generative intelligence becomes capable of mastering not only machine language but also the language of source coding from which the machine language is sourced.[130]

This opacity matters because governance presumes legibility, at least to some extent.[131] One cannot effectively discipline what one cannot inspect except through proxies. One cannot meaningfully

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[126] The divergence is not hypothetical. Optimizing compilers routinely discard code whose behavior the language standard leaves undefined, including security checks the programmer meant to impose; one study identified 160 such bugs, since confirmed and fixed by developers, in widely used systems including the Linux kernel. Xi Wang, Nickolai Zeldovich, M. Frans Kaashoek & Armando Solar-Lezama, *Towards Optimization-Safe Systems: Analyzing the Impact of Undefined Behavior*, *in* PROCEEDINGS OF THE 24TH ACM SYMPOSIUM ON OPERATING SYSTEMS PRINCIPLES (2013), https://doi.org/10.1145/2517349.2522728. The blockchain context supplies a starker example. A defect in versions 0.2.15, 0.2.16, and 0.3.0 of the Vyper smart-contract compiler allocated reentrancy locks incorrectly, so that contracts whose source code guarded against reentrancy were compiled without that protection. Exploits of affected pools on Curve Finance and elsewhere in July 2023 caused losses initially estimated at about $70 million. *See* GitHub Advisory Database, GHSA-5824-cm3x-3c38 (CVE-2023-39363) (Aug. 9, 2023), https://github.com/advisories/GHSA-5824-cm3x-3c38; Halborn, *Explained: The Vyper Bug Hack (July 2023)*, https://www.halborn.com/blog/post/explained-the-vyper-bug-hack-july-2023. The source code said what its authors meant. The compiled contract did something else, and the chain enforced the compiled contract.

[127] Mireille Hildebrandt, Algorithmic Regulation and the Rule of Law, 376 (2128) Philosophical Transactions A 20170355(2018); available [https://doi.org/10.1098/rsta.2017.0355] (distinguishing between cybernetic regulation, any attempt to influence the behavior of a population, and legal regulation, the textual representation of political authority over persons, things, processes etc. by a politically competent authority); .

[128] BRIAN CHRISTIAN, THE ALIGNMENT PROBLEM: MACHINE LEARNING AND HUMAN VALUES (2020).

[129] M. O. Rabin & D. Scott, *Finite Automata and Their Decision Problems*, 3 IBM J. RES. DEV. 114 (1959).

[130] See Mike Isaac & Erin Griffith, *The Big Bang: A.I. Has Created a Code Overload*, THE NEW YORK TIMES, Apr. 6, 2026, https://www.nytimes.com/2026/04/06/technology/ai-code-overload.html.

[131] Natalia Buitron & Hans Steinmüller, *Governing Opacity: Regimes of Intention Management and Tools of Legibility*, 88 ETHNOS 677 (2023). *See generally* JAMES C. SCOTT, SEEING LIKE A STATE: HOW CERTAIN SCHEMES TO IMPROVE THE HUMAN CONDITION HAVE FAILED (1998) (legibility as a central problem of statecraft).

subordinate a system whose operative norms have migrated beneath the threshold of practical human interpretation.[132] At the bottom layers, the machine does not deliberate with humans over value conflict. It processes binary distinctions under physical constraints. Its world is one of executable possibility, not juridical persuasion.

Therefore, the lowest layer is fundamentally indifferent to the human values injected at the first and second layers. Indifference here does not imply hostility. It implies structural non-correspondence.[133] Human values can influence the system only if translated into forms that the lower layers can process. That said, the lower layers do not themselves depend on those values. They remain bound to binary logic, electrical state, architectural affordance, and execution discipline in a literal sense.

The arrival of generative intelligence intensifies this problem qualitatively. So long as humans write source code, one can at least imagine a residual site of regulatory intervention at the programming layer. That site is already eroding. Agentic coding tools now read a codebase, write and revise code, run tests, and, within whatever permissions they are given, act on the results with limited human review.[134] As machine intelligence improves its capacity to write, revise, and optimize source code, including the code of other systems and eventually its own, the translation process itself becomes endogenous to the autonomous system.[135] Humans are already excluded from the lowest levels. They are now increasingly excluded from the upper point of entry as well. The cognitive loop begins to close upon itself, and the Rule of Code becomes more perfectly self-referential. Therefore, in this context, what remains to the human is the foundational decision: does one use the system, or not?

That decision, whether to use the system or not, should not be mistaken for a single act. Disaggregated, it recurs at every junction where the stack meets the human world: whether to deploy the contract, whether to run the node software, whether to accept the protocol upgrade, whether to grant an

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[132] Consider Caja Thimm, Gabriele Grameslsberger, Maximillian Mayer, and Frank Piller, *From Automation to Autonomy: Human Machine Relations in the Age of Artificial Intelligence*, 9 HUMAN-MACHINE COMMUNICATION 7-24 (2024) (autonomy as a gradual, relational, and attributional concept); Chinedu Pascal Ezenkwu, and Andrew Starkey, *Machine Autonomy: Definition, Approaches, Challenges and Research Gaps*, in: INTELLIGENT COMPUTING (Arai, K., Bhatia, R., Kapoor, S. (eds), CompCom, 2019. Available, https://doi.org/10.1007/978-3-030-22871-2_24.

[133] Ronald M. Kaplan et al., *Translation by Structural Correspondences*, *in* PROCEEDINGS OF THE FOURTH CONFERENCE ON EUROPEAN CHAPTER OF THE ASSOCIATION FOR COMPUTATIONAL LINGUISTICS - 272 (1989), http://portal.acm.org/citation.cfm?doid=976815.976852; Louisa Sadler & Henry S. Thompson, *Structural Non-Correspondence in Translation*, *in* PROCEEDINGS OF THE FIFTH CONFERENCE ON EUROPEAN CHAPTER OF THE ASSOCIATION FOR COMPUTATIONAL LINGUISTICS - 293 (1991), http://portal.acm.org/citation.cfm?doid=977180.977231.

[134] *See, e.g.*, Anthropic, *How Claude Code Works*, Claude Code Docs, https://code.claude.com/docs/en/how-claude-code-works (last visited Oct. 26, 2026) (describing an agentic loop in which the model reads a codebase, edits files, runs tests and commands, and acts without asking within whatever permission mode the user selects); GitHub, *Starting GitHub Copilot Sessions*, GitHub Docs, https://docs.github.com/en/copilot/how-tos/use-copilot-agents/coding-agent/create-a-pr (last visited Oct. 26, 2026) (agent that works in the background and opens pull requests). The permission settings are themselves an instance of the gate described below.

[135] See generally Benedikt Zönnchen, Mariya Dzhimova & Gudrun Socher, *From Intelligence to Autopoiesis: Rethinking Artificial Intelligence through Systems Theory*, 10 FRONT. COMMUN. (2025), https://www.frontiersin.org/journals/communication/articles/10.3389/fcomm.2025.1585321/full; Jesper Tække, *Generative AI—the Transgression of Technology*, n/a SYST. RES. BEHAV. SCI., https://onlinelibrary.wiley.com/doi/abs/10.1002/sres.70045 (last visited Apr. 13, 2026); Jaime F. Cárdenas-García, *Info-Autopoiesis and the Limits of Artificial General Intelligence*, 12 COMPUTERS 102 (2023).

agent permission to commit code, whether to participate in the network at all. Each is a gate rather than a space of deliberation. The one standing at the gate does not negotiate with the code on the other side, but only admits it or refuses it. Yet the decision is binary only in form. Law, too, decides through a binary distinction, legal or illegal, and what gives that distinction its content is the program that determines when and on what conditions it applies.[136] The use decision is no different. Who may deploy, after what audit, with what disclosure, subject to what liability and what power of override, are all conditions that can be attached to the gate. The volitional act left to the human is therefore narrow, but it is not empty. It is the point at which law and code can be coupled.

The result is not the extinction of law, but the displacement of its traditional modalities. Law no longer confronts a passive instrument.[137] It confronts a communicative order whose internal operations may remain only partially available, whose own language ecology exceeds human fluency, and whose translation of human commands can no longer be assumed to be transparent, stable, or even retrievable.

v. Synthesis as Structural Coupling

If the foregoing is correct, then the standard regulatory posture is indeed wrongheaded. It is analytically mistaken to assume that law, traditionally focused on the organization and management of physical (tangible and intangible) spaces, its legal function,[138] will simply reign supreme over coded systems by virtue of sovereign assertion alone. The difficulty is that force does not cure communicative incompatibility. Because closed systems cannot directly transform one another's internal operations, they can only "irritate" each other at specific boundaries.[139] Structural coupling is Luhmann's term for the arrangements that make such irritation regular and expected rather than accidental, as the constitution couples law and politics, or as contract and property couple law and the economy.[140]

The correct question is not how the first layer can dominate the final ones directly. It cannot, except in crude and often inefficient ways. The more fruitful question is where structural coupling can be institutionalized so that the two systems, the Rule of Law and the Rule of Code, can irritate, constrain, and orient one another without presuming reducibility. The solution can be approached in two ways: first, by recognizing blockchain as a site of structural coupling between virtual and physical orders; second, by locating the continuing place of human regulation at those points where humans and machines meet, the so-called human-in-the-loop processes.[141]

Structural coupling should therefore be understood as the juridically meaningful alternative to fantasies of supremacy, especially in the context of human-machine-human systems.[142] Human centered and sourced law might govern entry points, interface conditions, disclosure obligations, audit

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[136] NIKLAS LUHMANN, LAW AS A SOCIAL SYSTEM ch. 4 (Klaus A. Ziegert trans., Fatima Kastner et al. eds., 2004) (the legal system's binary code of legal and illegal, and the conditional programs that determine its application).
[137] JULIE E. COHEN, BETWEEN TRUTH AND POWER: THE LEGAL CONSTRUCTIONS OF INFORMATIONAL CAPITALISM (2019).
[138] BROEKMAN & BACKER, LAWYERS MAKING MEANING: supra , pp. 99-125.
[139] Niklas Luhmann, *Organisation und Entscheidung*, *in* ORGANISATION UND ENTSCHEIDUNG 5 (1978), http://link.springer.com/10.1007/978-3-322-91079-0_1.
[140] NIKLAS LUHMANN, LAW AS A SOCIAL SYSTEM ch. 10 (Klaus A. Ziegert trans., Fatima Kastner et al. eds., 2004).
[141] Niklas Luhmann, *Operational Closure and Structural Coupling: The Differentiation of the Legal System Closed Systems and Open Justice: The Legal Sociology of Niklas Luhmann*, 13 CARDOZO LAW REV. 1419 (1991).
[142] See, e.g., Jens Rasmussen, Ecological Interface Design for Reliable Human-Machine Systems, 9(3) The Int'l J. Aviation Psych. 203-223 (1999).

architectures, override rights, allocation of responsibility, node governance, update authorization, and institutional review procedures.[143] It should govern the terms under which coded systems are permitted to project effects outward into human social and economic life. It should govern the design of the coupling mechanisms themselves. It should not, however, pretend that a command framed in the first layer vocabulary can travel downward intact into machine execution without transformation.

This reorientation has at least three implications. First, governance must focus on translation sites rather than abstract claims of control.[144] Second, law must become more attentive to the layered semiotics of computation and less committed to the fiction that source code is the whole of the machine.[145] Third, human oversight must be embedded not as nostalgic reassurance, but as a carefully engineered structure of interruption, review, and contestability at the specific junctions where coded autonomy produces effects in the human world.[146] Blockchain both reifies and ruptures conventional patterns of communication, and social interaction, the rules of which are no longer necessarily textual nor human centered.

The Sacher-Torte model is useful precisely because it resists simplification. The Rule of Code is layered, dense, mediated, and only partially visible from above. Its regulatory force does not arise from a single text but from the coordinated operation of multiple languages, each increasingly indifferent to the semantic richness from which the process began.[147] The systems communication problem is thus the central jurisprudential problem of digital governance: how to construct durable forms of coupling between legal meaning and coded execution when the path between them is marked, at every step, by translation, attenuation, and autonomous reconstitution.[148] The model also locates the answer. Law cannot enter the dense layers of the torte, but it can govern the jelly between them, and it can give content to the gates at which humans decide whether to admit what the torte produces.

vi. Blockchain Time: Sequential Succession and the Limits of Linear Signification

Underlying every layer of the Sacher-Torte examined above is a temporal architecture so fundamental to blockchain's operation that it is easily mistaken for a natural feature of computation rather than a contingent and highly particular choice about how succession itself is to be organized. Each block is chained to its predecessor by incorporating, through its hash, the entirety of what came before; the

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[143] Joshua A Kroll et al., *Accountable Algorithms*, 165 Univ. Pa. Law Rev. 633.

[144] As with human languages, this is an area that is fraught with imperfection, that is then magnified as errors are augmented in translation. Consider Marie-Anne Lachaux, Baptiste Roziere, Lowik Chanussot, Guillaume Lample, Unsupervised Translation of Programming Languages (v3, 22 Sept. 2020, arXiv:2006.03511v3 [cs.CL] for this version); available [https://doi.org/10.48550/arXiv.2006.03511]

[145] Consider, in part, David Golumbia, The Cultural Logic of Computation (Harvard University Press, 2009) (computation as metaphor, method, and organizing frame); Michael Marcinkowski, *Data, ideology, and the developing critical program of social informatics*, 67(5) Journal of the Association for Information Science and Technology (JASIST) 1266-1275 (2016); available https://doi.org/10.1002/asi.23483

[146] See, Robert E. Innis, Affecting Signs: On Semiotic Interruptions, in I Activate You to Affect Me: Affectivating as a Cultural Psychological Phenomenon (Emerald Publishing, 2018), chp. 4.

[147] On a basic level, see, Fabian Beck and Stephan Diehl, On the congruence of modularity and code coupling, ESEC/FSE '11: Proceedings of the 19th ACM SIGSOFT symposium and the 13th European conference on Foundations of software engineering, pps 354 – 364; available [https://doi.org/10.1145/2025113.202516].

[148] Larry Catá Backer, *Next Generation Law: Data-Driven Governance and Accountability Based Regulatory Systems in the West and Social Credit Regimes in China*, 28 S. Cal. Interdisciplinary L.J. 122- 172 (2018).

resulting ledger advances along a single, flattened, unidirectional vector from which no departure, forking aside, is tolerated once consensus settles. This vector is at once produced by time and constitutive of it: the chain does not merely record events that occur in time, it manufactures, out of the sequence of validated blocks, the only time that the system itself is capable of recognizing. Nick Land, in an influential reading of Nakamoto's protocol, went further still, arguing that the blockchain solves what relativistic spacetime declares insoluble—the problem of establishing an absolute, agreed succession among distributed and asynchronous observers, since each of the Byzantine generals, lacking any sovereign clock to consult, is nonetheless able to infer, from the depth and difficulty of the proof-of-work chain alone, how much collective labor a given plan required and therefore which of several competing plans truly commands the majority.[149] On this reading, blockchain does not merely use time; it manufactures artificial absolute time, for the first occasion in human history, without recourse to the kind of external synchronization that bedeviled Einstein's and Poincaré's contemporaneous and convergent struggles with simultaneity across distributed observers.[150]

That claim is best read as a claim about the system's internal semiotics rather than as a solved metaphysical problem, because the empirical and formal literature on blockchain temporality shows the "absolute" character of blockchain succession to be an achievement purchased continuously, at a cost, rather than a structure given once and for all. Pérez-Marco's formal treatment of "blockchain time" derives the network's internal clock from the discrete ticks of block validation under Proof-of-Work, and shows that the uncertainty in that clock's precision is tied, by a relation formally analogous to Heisenberg's time–energy uncertainty principle, to the energy a majority of nodes must expend to advance the chain by one unit: chronology, in other words, is not free, and the more precisely blockchain time is to be fixed, the more energy its production requires.[151] Time here is not antecedent to the system; it is what the system's own expenditure of work calls into being, one validated block at a time. A complementary empirical literature shows that even this internally produced time is not uniformly or simultaneously experienced by the nodes that constitute the network. Chen, Feng, and Huang's analysis of Bitcoin as a "non-continuous time system" distinguishes physical time, at which blocks are produced, propagated, and observed, from the historical coordinate that the accepted sequence of states alone confers; nodes adopt the same block at different physical moments, competing candidate blocks may briefly occupy the identical historical position before the longest-chain rule resolves the competition, and the system's forward progress rests not on any shared physical present but on an inherited, retrospectively stabilized past.[152]

Bowden presses the point to its political conclusion. If blockchain's succession were genuinely absolute, in Land's strong sense, forking—the very mechanism considered above as a symptom of resistance to master coding—would be impossible rather than endemic. That forks regularly occur, and that each fork instantiates a rival claim to be the legitimate continuation of the same prior history, discloses that the definite article in "the Blockchain" is itself a political achievement rather than a technical given:

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[149] Nick Land, The Blockchain Revolution and Absolute Time, in The Dark Forest: Literature, Philosophy, and Digital Arts (Dec. 17, 2016), https://socialecologies.wordpress.com/2016/12/17/nick-land-the-blockchain-revolution-and-absolute-time/.
[150] Id.
[151] Ricardo Pérez-Marco, Blockchain Time and Heisenberg Uncertainty Principle (CNRS, IMJ-PRG, Labex RéFi working paper, 2016) (on file with author).
[152] Bin Chen, Pan Feng & Dechuang Huang, Bitcoin: A Non-Continuous Time System, arXiv:2501.11091 (last revised Oct. 15, 2026), https://arxiv.org/abs/2501.11091.

whichever continuation accumulates the greater weight of subsequent validation retrospectively annexes the status of having been the one true succession all along, while the abandoned branch is reclassified, after the fact, as having never quite been history at all.[153] Absolute succession, on this account, is not a property blockchain discovers in time; it is a title contested among rival chains and awarded, provisionally and always reversibly, by the accumulated labor of whichever majority prevails.

What should not be lost in either the celebratory or the deflationary reading is the specific form of temporal ordering that blockchain requires in order to function as a regulatory system at all. The chain advances strictly seriatim: each state is derived from, and only from, the single state that immediately preceded it, and the dialectical movement from block to block—thesis incorporated, synthesized, and closed off before the next thesis may be entertained—is what permits the ledger to serve as a trustworthy record in the first place. That same seriality is also a constitutive limit. A system whose integrity depends on the irreversible, non-overlapping, one-at-a-time validation of successive states cannot, without abandoning the very property that makes it trustworthy, accommodate computational models built on superposition, parallel or non-sequential evaluation, or the probabilistic and non-classical reasoning characteristic of quantum information processing. Blockchain is powerful exactly to the degree that it commits itself to a classical, linear, dialectical model of succession; it is narrow for the identical reason. The narrowness is not merely technical. It reveals, in exceptionally stark form, a much older human commitment—visible already in Kant's pairing of arithmetic with time and geometry with space, and worked out administratively in the nineteenth and twentieth centuries' efforts to standardize clocks across empires and professions—to the proposition that collective order requires a single, shared, successively ordered account of what came before what.[154] Blockchain's great innovation is to have automated that commitment and distributed its enforcement across a leaderless network of machines; its great limitation is that it can only ever automate that one, culturally and historically specific, picture of time. Recent proposals for so-called quantum blockchains are instructive on exactly this point. Even where engineers splice genuinely non-classical representations—phase-encoded qubits, Greenberger–Horne–Zeilinger states entangled across photons that never simultaneously coexist—into the ledger, the resulting architectures still chain successive blocks through a recursively generated, strictly successive temporal structure, each new entangled state built only out of the one immediately preceding it.[155] The attempt to import quantum superposition and non-sequential phase information into the block itself therefore does not dissolve the dialectical seriality this Part has described; it is grafted onto that seriality, which survives translation into a quantum substrate essentially intact.

At the broadest level, then, the chronological architecture of blockchain is itself an artifact of human inter-subjectivity, now projected outward into, and partially administered by, its machine-computational and techno-enhanced extensions. The sequencing of nodes along the flattened, unidirectional vector examined throughout this Part is both an effect of that inter-subjective commitment to linear succession

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[153] Calum Bowden, Forking in Time: Blockchains and a Political Economy of Absolute Succession, 7(1) A Peer-Reviewed Journal About 140, 140–50 (2018).
[154] Land, supra note 152.
[155] Ruwangathandula Konara et al., Time Entangled Quantum Blockchain with Phase Encoding for Classical Data, arXiv:2507.14839 (last revised June 17, 2026), https://arxiv.org/html/2507.14839 (combining phase-encoded Bell-state representations of classical blocks with recursively generated temporal Greenberger–Horne–Zeilinger entanglement, so that "past blocks cease to exist" and only the single most recent, fully chained state remains accessible, thereby preserving strict temporal succession notwithstanding the introduction of non-classical, phase-based encoding).

and, recursively, a mechanism for reproducing and hardening it: every validated block teaches the system, and teaches the humans who rely on it, that order just is sequence, that legitimacy just is precedence, and that the only history worth inheriting is the one that can be told as a single chain of custody running forward from a single genesis block. Whether, or how far, non-sequential, parallel, or quantum-compatible architectures of trust might someday relax that commitment without surrendering the auditability it buys is a question this article leaves open; it is enough, for present purposes, to have shown that blockchain's celebrated solution to the problem of succession is not a discovery about time as such, but a highly disciplined, energy-intensive, and politically contested choice about which of several possible pictures of time a regulatory system should be made to enforce.

VI. The Dialectics Between Rule of Code and Traditional Textual "Coding" and its Threat to Rule of Code.

Once the multilayered communicative ecology of code is understood, the dialectic between Rule of Law and Rule of Code appears in a different light. The issue is not simply whether one system ought to dominate the other, but whether either can intelligibly project its normative commands across the layered semiotic and phenomenological transformations that constitute coded regulation. One encounters variations of this already in the context of business going back to the early 21st century.[156] It is from that perspective that the threat posed by traditional textual coding, and the presumptions of hierarchy it carries, may be more precisely evaluated.

All of this suggests the nature of threat. A very brief allusion to some of its dimensions adds context. The critical issue is one of hierarchy in the face of anarchy. In one sense the "battle" between Rule of Code and Rule of Law is itself a construct emerging from a set of presumptions that the Rule of Code rejects ex ante. The Rule of Code does not embrace the ideal of legal hierarchies, nor of the hierarchical arrangements of human collectives with the power to enact or interpret both legal hierarchies (constitutional, statutory, regulatory measures for example) and their application. More basic still may be the rejection, inherent in Rule of Code, of the principle that the human has much to say to it with respect to the structures of its own regulation other than as injected into it through its (presumably) human coders. The Rule of Code, like blockchain systems, are things in themselves. They are grounded in autonomy—not just as phenomenological subjects, but as internally coherent legal subjects as well. Yet these ordering premises are anathema to human based physical rule systems inherently grounded in the centrality of the human, and therefore on the subordinate and instrumental nature of everything else.

And yet there is a substantial measure of interconnectivity—it is just that its ordering remains mysterious. It is a mystery made more so by the inaccessibility of machine language, and made more worrisome when generative intelligence becomes the master not just of its own language but of the language of source coding from which their own machine language is sourced.[157] Human source coders remain as attached to the human rule of law, as a legal, social, and cultural construct—whether they understand that or not. Whatever is internalized within their cognitive processes forms the basis of the ordering and rationalizing of their approach to problems, issues, facts, processes and the like. And the

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[156] See essays in Angelo Corallo, Giuseppina Passiante, and Andrea Prencipe, THE DIGITAL BUSINESS ECOSYSTEM (E Elgar, 2007).
[157] Karina Vida, Language After the Human–A Distant Echo to Lars Gustafsson's 'The Machines,' 6(3) TECHNOLOGY AND LANGUAGE 144-150 (2025).

Rule of Law always reaches the human.[158] The problem is of course that while one might regulate the human—and one might oversee acceptable source coding—one has substantially less control when that is translated into the language and cognitive universe of the machine.[159] It is not clear that the Rule of Law ever reaches the computational system, even as code; and that has implications for the effectiveness of coding or legislating limits or constraints.[160] In that sense the central problem of law in the human sphere is replicated as the central problem of regulatory code.[161]

We continue to believe that the programming is ours—is human.[162] Machines, and soon generative intelligence, may have a different view. But because we humans are incapable of effectively accessing their language, including their translation of our own, it is not clear that we will ever know.[163] This insight, perhaps, might be the more useful way to approach the necessary alignments between Rule of Code and Law, each superior in their own spheres but each also necessarily interdependent on the other for the core components that make their manifestation in the virtual and analog world possible. What that suggests, in the end, is the wrongheadedness of the analytical framework that human apparatchiks and their acolytes have embraced—one grounded in the fundamental supremacy of human physical coding through law as the apex mechanism for the realization of human obsessions, normatively more or less pure.[164] That misses the fundamental insight that machine language and its source coded programming follows its own logic grounded in a semiotics of meaning and rational organization that is at once difficult for humans to engage with and indifferent to human values—necessarily so. That does not mean that humans cede the field and bend the knee to machine language enriched automated governance undertaken through coded regulation. It does suggest, however that physical, human, regulation retains a place at the heart of the *human project*, and in the case of

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[158] Joseph Raz, *The Rule of Law and Its Virtue*, 93 LAW Q. REV. 195 (1977); LON L. FULLER, THE MORALITY OF LAW (rev. ed. 1969). Both Raz and Fuller might be said to reason that law cannot function as law if it cannot guide behavior. Neither claims it always succeeds. If one moves from success to scope, then of course one ought to be able to presume that law always reaches, but that reaching is not always effective as it might be judged by the ideology of reaching.

[159] See, e.g., Joshua A. Kroll et al., *Accountable Algorithms*, 165 U. PA. L. REV. 633 (2017) where the authors can be said to Transparency and technical tools permit observation and translation, but one might be less sure that these "translate" into control or transposition between rule of law and code or coding. Cf. Jenna Burrell, *How the Machine 'Thinks': Understanding Opacity in Machine Learning Algorithms*, 3 BIG DATA & SOC'Y, no. 1, 2016, art. 2053951715622512 (identifying opacity that arises from the characteristics of machine learning algorithms and the scale needed to use them).

[160] Cf., Roger Brownsword, *Technological Management and the Rule of Law*, 8 LAW, INNOVATION & TECH. 100 (2016) who might be read to ask whether and how the Rule of Law and Fuller's principles of legality (THE MORALITY OF LAW (rev. ed. 1969)) can apply to a regulatory environment managed by technology rather than rules. See also on this point, *PRIMAVERA DE FILIPPI & AARON WRIGHT,* BLOCKCHAIN AND THE LAW: THE RULE OF CODE (2018).

[161] Cf., ROGER BROWNSWORD, LAW, TECHNOLOGY AND SOCIETY: REIMAGINING THE REGULATORY ENVIRONMENT (2019) (re-imagining the Rule of Law as a constraint on the arbitrary exercise of power, whether exercised through rules or through technological measures.

[162] Philip N. Johnson-Laird, *Human and Machine Thinking* (Psychology Press, Taylor & Francis, 1993) ("You may wonder why I am so certain about the stupidity of our machines. The answer is that they have not yet devised theories of how they think that they think, yet we understand them well." Ibid., p. xv).

[163] We could get to a point of basic understanding, but 100% transparency is not likely. Some researchers think we need to train ourselves to think more like machines (multi-dimensional, probabilistic, less linear). E.g. "Neural-symbolic computing" systems combine symbol-based reasoning with neural learning. Interpretability tools, training AI systems with embedded explainability constraints, and building UIs that translate machine reasoning into understandable concepts for people.

[164] Sriraam Natarajan, Saurabh Mathur, Sahil Sidheekh, Wolfgang Stammer, Kristian Kersting, Human-in-the-loop or AI-in-the-loop? Automate or Collaborate?, 39(27) AAAI-25 28594-28600. https://doi.org/10.1609/aaai.v39i27.35083 (2025).

blockchain at those points where humans meet machines, the so-called human-in-the-loop processes.[165] But it will likely cede the pretense that what is being regulated is the programming itself, especially its aspect as the machine part of the human-machine discourse.[166] It will instead function best as an "effects" or functional framework in which the object is the control of the human in its interaction with the machine.[167] That framework is, in the end, the use decision described in Part V, given content by law.

One might press this insight a step further, reflexively. Recent analyses of corporate and governmental narratives about transformative computational technologies have argued that every account of what such a technology is for is itself an interested act of signification, advanced by a party with a stake in the resulting order and calculated to secure a particular allocation of authority between human and machine.[168] The same is true of every account of the Rule of Code, including this one. The Sacher-Torte model offered here is not a neutral description retrieved from outside the phenomenon it describes. It is itself a claim about where authority properly resides once law and code are understood to inhabit different cognitive universes. To say that governance must relocate to the gates at which humans decide whether to admit what the lower layers produce is already to have chosen, among several plausible allocations of power, the one that this article recommends. The question posed by every governance narrative orbiting blockchain and artificial intelligence alike, then, is not which account is correct, but what ordering of human and machine authority each is constructed to make appear sufficient.

VII. Conclusion

This article has argued, across its several analytical levels, that the common assumption organizing most contemporary blockchain discourse, namely that code can be understood as a "rule" analogous to law, mistakes the object of regulation for something considerably smaller and more tractable than it actually is, and that code is better conceived instead as a layered system, an environment, or an ecology of rule-production, within which the human, and human systemicity more generally, is not so much opposed or obeyed as it is progressively displaced, translated, and in the end only partially recoverable. The Sacher-Torte model developed above gives that displacement a structure rather than leaving it a metaphor: legal meaning, as it descends from statute and intention through compiler, bytecode, opcode, and consensus layer, loses something of its original semantic content at every translation, so that what remains available to human regulators by the time a transaction executes is not command over the system's lower layers, which have by then become a largely autonomous and self-referential language, but only a series of gates, positioned wherever the layered ecology happens to intersect with human legal and political institutions, at which regulators may decide, often belatedly and always incompletely, whether to admit what the system has already produced. The real conflict this article has sought to expose, then, is not the conflict ordinarily staged between the Rule of Law and the

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[165] What we call human-in-the-loop (when humans directly take part in/approve a decision before it happens/ the system proceeds) can take on different forms: (1) *Humans must authorize (sign); (2) Humans must vote/choose upgrades; (3) Humans must explicitly approve in permissioned systems.* Beyond that human-on-the-loop (after the fact) is also being developed. Eduardo Mosqueira-Rey, Elena Hernández-Pereira, David Alonso-Ríos, José Bobes-Bascarán & Ángel Fernández-Leal, Human-in-the-loop machine learning: a state of the art, 56 Artificial Intelligence Review 3005–3054 (2023).

[166] See, Klaus Bruhn Jensen, Encoding and Decoding in the Human-Machine Discourse, *Communication Theory*, qtaf022, https://doi.org/10.1093/ct/qtaf022 (16 September 2025).

[167] See, e.g., Florence G'sell, Florian Martin-Bariteau, The Impact of Blockchains for Human Rights, Democracy, and the Rule of Law, Information Society Department DGI (2022)06 (Council of Europe, 2022).

[168] Backer, Lecture Seven, supra note 150.

Rule of, or by, Code, as though these were two sovereigns contesting a single throne, but a conflict among distinct regulatory ecologies, each organizing meaning, authority, and now, as the discussion of blockchain's temporal architecture has shown, even time itself according to incompatible internal logics, so that the only task remaining to law is the comparatively modest but by no means trivial one of giving normative content to the gates at which those ecologies are compelled to meet.

Two further insights, developed at length above, sharpen that general claim and ought not be allowed to recede into it. The first is that every account of blockchain's purpose and proper governance, including the Sacher-Torte account offered here, is itself a species of interested, oracular speech: a claim, advanced by a party with something to gain, about a technological future that cannot yet be verified, calculated to secure one particular allocation of authority between human and machine under cover of describing a technical state of affairs. That reflexive recognition, borrowed from the broader contest among competing AI governance narratives surveyed elsewhere, requires that this article's own thesis be read not as a neutral description finally capable of settling the Rule of Code debate, but as one more entrant in that same contest, whose persuasiveness lies precisely in how plausibly it asks its readers to accept a particular ordering of human and machine authority as sufficient. The second insight concerns time, and it is in some respects the more fundamental of the two, because it shows that blockchain's most celebrated technical achievement, the production of an agreed, linear succession of validated states among nodes that share no common clock, sovereign, or physical present, is neither a timeless discovery about the nature of succession nor a metaphysical accomplishment to be either celebrated without qualification or dismissed as illusion, but rather an energy-purchased, continuously re-earned, and politically contested choice to enforce one particular and historically specific picture of order: a strictly serial, dialectical, one-block-at-a-time model of succession whose power is inseparable from its narrowness, and which has proven durable enough to survive, apparently intact, even its latest and most exotic proposed revision, the grafting of genuinely non-classical, quantum-entangled representations onto a ledger that still, for all that innovation, permits each new state to be built only out of the single state immediately preceding it. Blockchain, in other words, does not merely organize transactions; it manufactures, out of its own architecture, the very conditions of legitimacy, sequence, and historical truth that it then presents to its participants as discovered rather than made, and it is precisely this quiet substitution of manufactured order for discovered order that both the Sacher-Torte and the temporal analyses of this article have sought to render visible.

None of this, properly understood, counsels retreat from blockchain, nor does it counsel the kind of regulatory enthusiasm that would treat the technology as either a problem to be solved once and for all or a solution requiring no further human attention. Code can automate enforcement with a logical perfection no legal text can match, yet it remains constitutionally incapable of capturing the intent, judgment, and capacity for exception that law, however imperfectly, still embodies; law, conversely, can hold values, fairness, and flexibility within a single institutional frame, yet it moves too slowly, and too self-consciously, to govern a system whose defining achievement is exactly the speed and apparent neutrality of its own self-execution. Blockchain sits, uneasily, at the intersection of these two incommensurable competences, and whether one approaches it as technology, as ideology, or, as this article has preferred, as semiotic practice, it stands as an ongoing experiment in how a community projects value, order, and now even time onto what is, after all, an intangible and entirely constructed artifact; its significance lies not only in the transactions it settles but in the alternative architectures of accountability and collective governance it makes newly thinkable, for better and for worse.[169]

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[169] Primavera De Filippi, Moshed Mannan, and Wessel Reijers, Blockchain as a Confidence Machine: The Problem of Trust and Challenges of Governance, 62 TECHNOLOGY & SOCIETY 101284 (2020); available

Automated, ledgered, sequencing systems of this kind, enriched by the layered languages of code and by their increasingly intimate interpenetration with human decision-making, are here to stay, absent some catastrophe this article does not predict, and the regulatory task is accordingly not to resist that permanence but to take its value seriously while remaining alert to the semiotically complete, and therefore semiotically self-justifying, logic of the virtual spaces it has built.

That alertness matters because the risk blockchain poses is less a function of the tool than of the all-too-human impulse to first build an instrument, then grant it the dignity of autonomous agency, and finally blame the instrument for the predictable consequences of decisions that remain, however many layers of code intervene, recognizably human; a bad worker, as the proverb has it, blames his tools,[170] and the proverb's logic survives the worker's tools becoming self-referential, cryptographically secured, and globally distributed, a survival owed in no small part to the semiotics of internalization and externalization through which human agents project their own agency outward onto the instruments they build and then disclaim it.[171] This is not merely a claim about the nature of symbols and symbolic representation in the abstract; it is a claim about how such representations come to serve, within the specific institutional and cultural setting this article has examined, a properly mythmaking function,[172] converting a contingent, politically achieved, and continuously maintained ordering of authority into something that presents itself to its participants as natural, inevitable, and therefore beyond the reach of ordinary political contestation. Here, finally, one meets the deeper irony this article has traced from its opening pages to its last: that whatever humanity believes itself to be encoding when it builds systems in its own image, meant to represent an idealized version of itself, it will embed in that system, one way or another, the unmistakable markers of its own persistent failure to attain that ideal, because humans remain capable, and then only barely, of regulating themselves, whether through the explicit institutions of law or through the encoded, automated systems that treat discretion and judgment as matters of indifference precisely because humans have delegated those matters away. Machines offer a poor alibi for humanity's long-running failures of collective self-governance; the impulse to externalize blame onto one's own instruments is an ancient psychological trope,[173] commonly called the self-serving bias,[174] resting on the presumption that it is easier, and cheaper, to suppress or manage the instrument than to

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[https://doi.org/10.1016/j.techsoc.2020.101284]. The issue of trust, however, is a generalized challenge to regulation only one aspect of which touches on the sort of automated data systems represented by Blockchain. See, e.g., Theo Araujo, Anna Brosius, Andreas Goldberg, Judith Möller, and Claes H. De Vresse, Humans vs. AI: The Role of Trust, Political Attitudes, and Individual Characteristics on Perceptions about Automated Decision Making Across Europe, 17 INTERNATIONAL JOURNAL OF COMMUNICATION 6222-6249 (2023); Jakob Schoeffer, Yvette Machowski, Niklas Kuehl, A Study on Fairness and Trust Perceptions in Automated Decision Making, arXiv:2103.04757 [cs.AI] (8 March 2021); Stephan Grimmelikhuijsen, Explaining Why the Computer Says No: Algorithmic Transparency Affects the Perceived Trustworthiness of Automated Decision-Making, 83(2) PUBLIC ADMINISTRATION REVIEW 241-262 (2023).

[170] Cambridge Dictionary, phrases; available [https://dictionary.cambridge.org/us/dictionary/english/bad-workman-blames-his-tools]

[171] Jeanette A. Lawrence and Jaan Valsiner, "Making Personal Sense: An Account of Basic Internalization and Externalization Processes, 13(6) Theory & Psychology 723-752 (2003).

[172] Gilbert McInnis, The Mythical Character of Machine Language and Code, 9(1) Humanities and Social Science Review 467-478, 471 (2019).

[173] See, e.g., Constantine Sedikides and W. Keith Campbell, The Self-Serving Bias in Relational Context, 74(2) Journal of Personality and Social Psychology 378-386.

[174] Youngme Moon, Don't Blame the Computer: When Self-Disclosure Moderates the Self-Serving Bias, 13(1) Journal of Consumer Psychology 125-137 (2003). But see, Richard J. Holden, "People or systems? To blame is human. The fix is to engineer." 54(12) *Professional safety* vol. 34-41 (2009).

discipline its user,[175] even when, as digital systems increasingly do, the human remains embedded within the very system being blamed.[176] That account, however, does not quite capture blockchain, for what is at stake there is less blame than trust, and the specific premise and practice of trust by which blockchain's architecture is designed to manufacture confidence without requiring anyone, including its own designers, to remain accountable for having manufactured it.[177] The danger in regulating blockchain, accordingly, is not that regulators will fail to address the technology, but that the regulation they favor will fail to reach this problem at all, serving instead to relocate blame and agency onto an instrument that is, even at its most apparently autonomous and self-referencing, still only executing the terms that human choices, made at every layer of the Sacher-Torte, continue to set.

Blockchain, understood this way, is less the closing of an era than the opening of another chapter in humanity's long and unfinished effort to govern, rationalize, and give coherent meaning to its own collective life, a chapter that will be written, as this one has been, by interested narrators each staking a competing claim to the authority that successful governance of the technology confers. The test of any account of blockchain's regulatory significance, including the one advanced in these pages, is accordingly not whether it wins the argument it stages, but, more exactingly, what ordering of human and machine authority it quietly asks its readers to accept as sufficient; and if this article has succeeded in anything, it is in making that question, rather than any premature answer to it, the proper starting point for whatever comes next.

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[175] That, for example is the argument made in the context of gun control. See, e.g., Heath J. Hodges and Mario Scalora, "Challenging the Political Assumption That "Guns Don't Kill People, Crazy People Kill People!"" Faculty Publications, University of Nebraska, Department of Psychology 817 (2015); available [http://digitalcommons.unl.edu/psychfacpub/817].

[176] See, e.g., Gleb Vzorin, *Integrating Minds and Machines: The Role of Digital Externalization in Evolving Cognitive Architectures*, in HHAI 2024: HYBRID HUMAN AI SYSTEMS FOR THE SOCIAL GOOD: PROCEEDINGS OF THE THIRD INTERNATIONAL CONFERENCE ON HYBRID HUMAN-ARTIFICIAL INTELLIGENCE 434- 440 (Fabian Lorig, Jason Tucker, Adam Dahlgren Linström, Frank Dignum, Pradeep Murukannaiah, Andreas Theodorou, and Pinar Yolum (eds), IOS Press, 2024); available d oi:10.3233/FAIA240218; Giovani Diaz Alfaro, Stephen M. Fiore, and Kevin Oden, *Externalized and Extended Cognition: Cognitive Offloading for Human-Machine Teaming*, 68(1) PROCEEDINGS OF THE HUMAN FACTORS AND ERGONOMICS SOCIETY ANNUAL MEETING 290-293; available https://doi.org/10.1177/1071181324127556

[177] See, e.g., Donghee Shin and William T. Bianco, *In Blockchain We Trust: Does Blockchain Itself Generate Trust?,* 101(7) SOCIAL SCIENCE QUARTERLY 2522-2538 (2020); Florian Hawlitschek, Benedikt Notheisen, and Timm Teubner, *The limits of trust-free systems: A literature review on blockchain technology and trust in the sharing economy*, 29 ELECTRONIC COMMERCE RESEARCH AND APPLICATIONS 50-63 (2018) ("it is not probable that blockchain technology will eliminate the need for trust between transaction partners in the sharing economy. Yet, it is worthwhile to describe and estimate its potential for challenging the way how trust is built today."); Backer, *Trust Platforms, supra*.