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# Managing Systemic Risk in Legal Systems

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## Managing Systemic Risk in Legal Systems

J.B. RUHL\*

*The American legal system has proven remarkably robust even in the face of vast and often tumultuous political, social, economic, and technological change. Yet our system of law is not unlike other complex social, biological, and physical systems in exhibiting local fragility in the midst of its global robustness. Understanding how this “robust yet fragile” (RYF) dilemma operates in legal systems is important to the extent law is expected to assist in managing systemic risk—the risk of large local or even system-wide failures—in other social systems. Indeed, legal system failures have been blamed as partly responsible for disasters such as the recent financial system crisis and the Deepwater Horizon oil spill. If we cannot effectively manage systemic risk within the legal system, how can we expect the legal system to manage systemic risk elsewhere?*

*This Article employs a complexity science model of the RYF dilemma to explore why systemic risk persists in legal systems and how to manage it. Part I defines complexity in the context of the institutions and instruments that make up the legal system. Part II defines the five dimensions of robustness that support functionality of the legal system: (1) reliability, (2) efficiency, (3) scalability, (4) modularity, and (5) evolvability. Part III then defines system fragility by examining the internal and external constraints that impede legal system robustness and the fail-safe system control strategies for managing their effects. With those basic elements of the RYF dilemma model in place, Part IV defines systemic risk and explores the paradoxical role of increasingly organized complexity brought about by fail-safe strategies as a source of legal system failure.*

*There is no way around the RYF dilemma—some degree of systemic risk is inherent in any complex adaptive system—but the balance between robustness and fragility is something we can hope to influence. To explore how, Part V applies the RYF dilemma model to a concrete systemic risk management context—oil drilling in the deep Gulf of Mexico. The legal regime governing offshore oil exploration and extraction has been blamed as contributing to the set of failures that led to the catastrophic Deepwater Horizon spill and is at the center of reform initiatives. Using this case study, I argue that the RYF dilemma model provides valuable insights into how legal systems fail and how to manage legal systemic risk.*

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Modern institutions and technologies facilitate robustness and accelerate evolution but enable catastrophes on a scale unimaginable without them . . . .<sup>1</sup>

#### INTRODUCTION

How would you design a legal system to be *robust*? The American legal system has proven remarkably enduring even in the face of vast and often tumultuous political, social, economic, and technological change, so it must be robust. Yet our history is riddled with crises exposing a pernicious fragility in law revealing itself at inopportune and unanticipated times and places. Notwithstanding what is believed to be a secure legal infrastructure for abating and responding to significant social and economic catastrophes, these crises keep happening and law often not only fails to come to the rescue, it is frequently deemed to be part of the problem and in need of reform. I need only mention the financial system crisis and the *Deepwater Horizon* oil spill as recent examples.<sup>2</sup> Why is that? How can it be that our legal system is robust and fragile at the same time?

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1. David L. Alderson & John C. Doyle, *Contrasting Views of Complexity and Their Implications For Network-Centric Infrastructures*, 40 IEEE TRANSACTIONS ON SYSTEMS, MAN, & CYBERNETICS 839, 843 (2010).

2. See FIN. CRISIS INQUIRY COMM'N, THE FINANCIAL CRISIS INQUIRY REPORT (2011) [hereinafter FINANCIAL CRISIS] (assessing causes of the financial crisis including failures in regulation); NAT'L COMM'N ON THE BP DEEPWATER HORIZON OIL SPILL & OFFSHORE DRILLING, DEEP WATER: THE GULF OIL DISASTER AND THE FUTURE OF OFFSHORE DRILLING (2011) [hereinafter DEEP WATER] (assessing causes of the oil spill including failures in regulation). See generally *infra* Part IV.B (financial crisis); Part V (oil spill). For a broad and

Legal scholars have described our and other legal systems as robust<sup>3</sup> or fragile,<sup>4</sup> but not usually both. Not surprisingly, as the terms imply, the clear preference is for being robust.<sup>5</sup> Seldom, however, is any content provided to elaborate what it means for a legal system to be robust or fragile, much less how a legal system can be both robust *and* fragile. It helps little to interchange robust with synonyms such as “strong,” or “healthy,” or “stout” and to define “fragile” as the opposite. What do

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thoughtful examination of regulatory failure, including whether it is in fact as responsible for the financial crisis, the oil spill, and other social and economic calamities as is often claimed retrospectively, see generally REGULATORY BREAKDOWN: THE CRISIS OF CONFIDENCE IN U.S. REGULATION (Cary Coglianese ed., 2012).

3. See, e.g., Cai Congyan, *China–US BIT Negotiations and the Future of Investment Treaty Regime: A Grand Bilateral Bargain with Multilateral Implications*, 12 J. INT’L ECON. L. 457, 490 (2009) (“[G]enerally speaking, Chinese investment can be fairly treated and protected in the United States where the legal system is robust . . .”); Carl N. Edwards, *In Search of Legal Scholarship: Strategies for the Integration of Science Into the Practice of Law*, 8 S. CAL. INTERDISC. L.J. 1, 33 (1998) (claiming that “[t]he American legal system is astonishingly responsive yet robust,” but not explaining the difference); James D. Fry, *International Human Rights Law in Investment Arbitration: Evidence of International Law’s Unity*, 18 DUKE J. COMP. & INT’L L. 77, 146 (2007) (“[T]he international legal system seems to have been sufficiently robust and flexible to have weathered both hot and cold wars of the past few centuries.”); John Fabian Witt, *Contingency, Immanence, and Inevitability in the Law of Accidents*, 1 J. TORT L., June 2007, at 1, 27 (2007) (“[I]t is the common law system (in its American variation, at any rate) that has the most robust system of tort law.”).

4. See, e.g., Michael J. Bazylar, *Nuremberg in America: Litigating the Holocaust in United States Courts*, 34 U. RICH. L. REV. 1, 147 (2000) (referring to “the new and fragile legal systems of the post-Communist nations of Eastern Europe”); Henry J. Bourguignon, *The Federal Key to the Judiciary Act of 1789*, 46 S.C. L. REV. 647, 700 (1995) (“An effective Supreme Court, however, was needed to hold a fragile Union’s legal system together . . .”); Sherri Burr, *The U.S. Supreme Court and the Alvarez-Machain Cases: Recasting International Law*, 13 U.S.-MEX. L.J. 105, 105 (2005) (referring to “the fragile international legal system that formulates customary law”); Tom Parker, *Prosecuting Saddam: The Coalition Provisional Authority and the Evolution of the Iraqi Special Tribunal*, 38 CORNELL INT’L L.J. 899, 905 (2005) (describing “Iraq’s still-fragile legal system”); William P. Quigley, *Thirteen Ways of Looking at Katrina: Human and Civil Rights Left Behind Again*, 81 TUL. L. REV. 955, 968 (2007) (“[T]he New Orleans criminal legal system, which was fragile before, essentially collapsed after Katrina.”).

5. See, e.g., Elizabeth Rindskopf Parker, *National Security Advice for a New Administration: Initial Thoughts*, 3 J. NAT’L SECURITY L. & POL’Y 227, 238 (2009) (“[A] central plank [for national security policy] must be a robust international legal system . . .”); Benjamin J. Richardson, *Is East Asia Industrializing Too Quickly? Environmental Regulation in Its Special Economic Zones*, 22 UCLA PAC. BASIN. L.J. 150, 182 (2004) (“Singapore was virtually alone in emerging relatively unscathed from the East Asian financial turmoil because it had a reliable, robust legal system . . .”); Zhao Xiuwen & Lisa A. Kloppenberg, *Reforming Chinese Arbitration Law and Practices in the Global Economy*, 31 U. DAYTON L. REV. 421, 422 (2006) (pointing to “development of a more robust legal system” as a positive trend in Chinese legal and economic conditions); Yesha Yadav, *The Specter of Sisyphus: Re-Making International Financial Regulation After the Global Financial Crisis*, 24 EMORY INT’L L. REV. 83, 100 (2010) (“[A] sharper focus on the creation of a robust regulatory architecture at the international level may better support the work of regulators . . .”).

those terms mean when applied to legal systems? More to the point, is there a way to manage the robustness and fragility of law?

Questions like these are within the domain of complexity science—the study of complex adaptive systems, systems “in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution.”<sup>6</sup> Although forged in the physical sciences, social scientists have begun to incorporate complexity science to better understand and manage complex social systems, with law being no exception.<sup>7</sup> Central to complexity science is the problem of *local* fragility that results from the tradeoffs inherent in system design decisions aimed at enhancing *global* system robustness.<sup>8</sup> In their recent technical article on this problem, systems engineers David L. Alderson and John C. Doyle develop a sophisticated model for describing and probing what they call the “robust yet fragile” (RYF) dilemma, showing that it is an inherent quality of any complex adaptive system and explaining how it poses difficult system design issues.<sup>9</sup> They sum up the dilemma succinctly:

Historically, we have done a poor job in managing the fragilities created by our complex networks, from global warming to ecosystem destruction, global financial crises, etc. In many cases, past failures are due to fragilities that were direct side effects of mechanisms that promised to provide great benefits, including robustness. . . . [For example,] [w]e are much better at designing, mass-producing, and deploying network-enabled devices than we are at being able to predict or control their collective behavior once deployed in the real world. The result is that, when things fail, they often do so cryptically and catastrophically.<sup>10</sup>

Understanding how the RYF dilemma plagues legal systems is important to the extent law is expected to assist in managing systemic risk—the risk of very large local or even system-wide failures—in other social systems.<sup>11</sup> Not all risk is

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6. MELANIE MITCHELL, *COMPLEXITY: A GUIDED TOUR* 13 (2009) (emphasis omitted). The term “complex adaptive system” is often used to distinguish between complex systems that are highly adaptive (such as an ecosystem) versus nonadaptive (such as a hurricane). *Id.*

7. For an overview of complexity science and how the social sciences, including law, have integrated it, see generally J.B. Ruhl, *Law's Complexity: A Primer*, 24 GA. ST. U. L. REV. 885 (2008). Further details on complexity in the legal system are provided *infra* Part I.

8. See JOHN H. MILLER & SCOTT E. PAGE, *COMPLEX ADAPTIVE SYSTEMS: AN INTRODUCTION TO COMPUTATIONAL MODELS OF SOCIAL LIFE* 9–10, 27–31, 139–40 (2007).

9. See Alderson & Doyle, *supra* note 1, *passim*. Reference to “design” in complex adaptive systems models “in no way implies a designer but merely some process, such as Darwinian evolution.” *Id.* at 841. Of course, humans are (or try to be) the conscious designers of social systems.

10. *Id.* at 839.

11. The concept of systemic risk has gained prominence in legal scholarship primarily in connection with regulation of financial systems, for which it is widely asserted that “regulation has an important role to play in managing systemic risk.” Iman Anabtawi &

systemic, and not all system failures are the result of systemic risk. Rather, “systemic risk is the risk of having not just statistically independent failures, but interdependent, so-called ‘cascading’ failures in a network of  $N$  interconnected system components. That is, systemic risks result from connections between risks (‘networked risks’).”<sup>12</sup> It is the potential for cascading that is so problematic where systemic risk is high, as even “a localized initial failure . . . could have disastrous effects and cause, in principle, unbounded damage as  $N$  goes to infinity.”<sup>13</sup> The legal system, as a complex adaptive system, is susceptible to its own systemic risks, yet too often this is overlooked when exploring how law can manage systemic risks elsewhere. If we cannot effectively manage systemic risk within the legal system, how can we depend on the legal system to manage other systemic risks?

This Article builds on the Alderson-Doyle RYF dilemma model to help inform how system design can contribute to managing systemic risk in legal systems.<sup>14</sup> But before explaining what I hope to accomplish with their model, a few words are necessary about what I do not set out to establish. First, although I use two recent catastrophes—the financial crisis and the *Deepwater Horizon* oil spill—to motivate examination of systemic risk in the legal system, I am not suggesting that social and economic catastrophes are always indicia of legal system failure, or that legal system failure necessarily leads to social and economic catastrophes. It may be, for example, that the offshore drilling regulatory system was actually quite robust and prevented numerous other potential catastrophic spills we don’t know about because they didn’t happen.<sup>15</sup> And it may be that the legal system is failing

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Steven L. Schwarcz, *Regulating Systemic Risk: Towards an Analytical Framework*, 86 NOTRE DAME L. REV. 1349, 1352 (2011). See generally *infra* Part IV.B. This Article advances a theory of systemic risk that is broader in scope and intended to be applicable to social and economic systems besides the financial system, including the legal system.

12. Dirk Helbing, *Globally Networked Risks and How to Respond*, 497 NATURE 51, 51 box 1 (2013). Helbing’s article provides a sweeping, and positively scary, account of systemic risk in social systems.

13. *Id.*

14. Although a number of legal scholars including myself have begun to incorporate complexity science into legal theory, see Ruhl, *supra* note 7, at 909–10 (collecting references), the RYF dilemma has not received formal theoretical development. Also, the concept of “robustness,” which is central to the RYF dilemma theory and used widely in complexity science, is similar to the concept of “resilience” used widely in social-ecological systems theory. Cf. William A. Brock, Karl-Göran Måle & Charles Perrings, *Resilience and Sustainability: The Economic Analysis of Nonlinear Dynamic Systems*, in PANARCHY, 270–75 (Lance H. Gunderson & C.S. Holling eds., 2002); C.S. Holling, Lance H. Gunderson & Donald Ludwig, in PANARCHY, *supra*, at 3, 15–18; Marten Scheffer, Frances Westley, William A. Brock & Milena Holmgren, *Dynamic Interaction of Societies and Ecosystems—Linking Theories from Ecology, Economy, and Sociology*, in PANARCHY, *supra*, at 195, 202–03. A number of legal scholars including myself have begun to incorporate resilience theory into legal theory, but again not in ways that capture the RYF dilemma model. See, e.g., J.B. Ruhl, *General Design Principles for Resilience and Adaptive Capacity in Legal Systems—With Applications to Climate Change Adaptation*, 89 N.C. L. REV. 1373 (2011). Because I find the RYF dilemma model particularly useful for thinking about how complexity science and resilience theory inform legal system design, especially in getting at the problem of managing systemic risk, I believe it merits separate and focused examination.

15. See Christopher Carrigan & Cary Coglianese, *Oversight in Hindsight: Assessing the U.S. Regulatory System in the Wake of Calamity*, in REGULATORY BREAKDOWN, *supra* note

miserably without any social or economic catastrophes as markers. Rather, catastrophes tend to focus people and policymakers on finding causes and solutions, with eyes often turning in both respects toward the legal system. I share the concern of others that this often politically motivated, after-the-fact rush to “never let that happen again” may overstate the case that legal system failure is a causal agent and thus lead to maladaptive legal reform responses.<sup>16</sup> On the other hand, catastrophes are at least *prima facie* evidence that laws intended to regulate a particular problem don’t always succeed, making legal system failure a candidate for causal analysis. Of course, many factors operating on and within the legal system can lead to its failure, including factors having little to do with system design, such as inadequate funding, political pressure, and the personal motivations of legal actors. My thesis, however, is that even with no other such causal force in play, the architecture of legal systems necessarily embeds some degree of systemic risk in the system’s behavior, and that the architectural design matters as to how much.

Of the many goals and criteria for legal system design, therefore, the only one I care about here is managing for the degree of systemic risk within the legal system. I acknowledge that society might decide that other goals and criteria take priority, and that tradeoffs likely exist between designing for them and designing for systemic risk. I also acknowledge that even when made the top priority, purposively managing for systemic risk in the legal system will not eliminate failures in the legal system or other social systems. But I hope to show that *not* purposively managing for systemic risk carries a potentially huge cost. Hence, recognizing that I am wearing blinders, my sole purpose in this Article is to bear down on the challenge of managing systemic risk in legal systems.

With that scope in mind, Part I defines complexity in the context of the institutions and instruments that make up the legal system. Part II defines the five dimensions of robustness that support functionality of the legal system: (1) reliability, (2) efficiency, (3) scalability, (4) modularity, and (5) evolvability. Part III then defines fragility, examining the design constraints that impede system robustness and the fail-safe system-control strategies for reducing their effects. Constraints exist at component, system, and protocol levels of a system, and those three forces also combine to produce emergent system-wide constraints as well. Regulating these effects is difficult. The predominant fail-safe strategies rely primarily on using ultraquality system components, redundancy in system operations, and sensors to detect undesirable conditions, with feedback mechanisms to alert system operation actuators to anticipated consequences.

Using the RYF dilemma model developed in Parts I through III, Part IV defines systemic risk, showing how the drive to overcome robustness constraints through fail-safe strategies adds inexorably to system organization, complexity, and risk of failure. As system architecture depends more and more on the interdependent components and system protocols needed to support fail-safe strategies, any local failure could cascade through the system to reach catastrophic proportions. Over time, as each local failure is met with new fail-safe strategies, system architecture

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2, at 1, 13 (“We see the disasters that were not prevented; we seldom see evidence of the disasters that were successfully prevented . . .”).

16. *See id.* at 1–9.

grows more complex, and systemic risk becomes embedded in the system. Paradoxically, therefore, the very measures taken to respond to local failures can add to the risk of catastrophic failures.

There is no way around the RYF dilemma—some degree of systemic risk is inherent in any complex adaptive system—but the balance between robustness and fragility is something we can hope to influence. To explore how, Part V applies the RYF dilemma model to a concrete legal systemic risk management context—oil drilling in the deep Gulf of Mexico. The legal regime governing oil exploration and extraction in the deep Gulf regions has been blamed as contributing to the set of failures that led to the *Deepwater Horizon* spill and is at the center of reform initiatives. Using this case study, I argue that the RYF dilemma model provides valuable insights into how legal systems fail and how to manage legal systemic risk.

## I. COMPLEXITY

Complexity science studies complex adaptive systems in all their glory, and defining complexity is a broad and dense topic, the full scope of which is neither possible nor necessary to explain here.<sup>17</sup> What follows in this Part, therefore, is an abbreviated foray into complexity science meant to establish two core concepts essential to developing the RYF dilemma model and applying it to legal systems—interconnected structure and emergent behavior.<sup>18</sup>

### A. Interconnected Structure

First we must distinguish between complexity and complicatedness. My sense is that saying the American legal system is complicated requires no proof here, but is it complex? Complicatedness and complexity are not the same. The “very basic question we must consider is how complex, versus complicated, are social worlds.”<sup>19</sup> The distinction goes to the essence of complexity science:

In a complicated world, the various elements that make up the system maintain a degree of independence from one another. Thus, removing one such element (which reduces the level of complication) does not fundamentally alter the system’s behavior apart from that which directly resulted from the piece that was removed. Complexity arises when the dependencies among the elements become important. In such a system, removing one such element destroys system behavior to an

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17. For an extensive discussion of what complexity means, see MITCHELL, *supra* note 6, at 94–111.

18. Some of what appears in this section is an extremely condensed version of material found in Ruhl, *supra* note 7.

19. MILLER & PAGE, *supra* note 8, at 27.



extent that goes well beyond what is embodied by the particular element that is removed.<sup>20</sup>

No experienced lawyer could fail to appreciate the difference between complicated and complex, as so defined, in our legal system.<sup>21</sup> For example, a statute might specify that an agency *may* consider any or all factors from a long, intricate list when making a certain decision to protect public health. That might make for a complicated decision process. But we could pluck out one of the factors and make the process less complicated without making it less (or more) complex—the factor may be independent from the other factors and simply allow the agency to make another discrete analysis. But if the statute specifies that the agency *must* consider all the factors and *balance* them to *most effectively* protect public health, the factors no longer are independent, and plucking out one of them could significantly alter the analysis. And this is merely a simple example. Statutes that cross-reference provisions internally and from other statutes, or assign responsibilities to multiple agencies, ramp up the interconnectedness of the system,<sup>22</sup> and the judiciary's hierarchical structure and practice of *stare decisis* fundamentally link courts with courts and opinions with opinions in ways that produce complicated *and* complex (as defined herein) institutional and instrumental connections.<sup>23</sup>

Complexity science studies these structural interagent dependencies and the system-wide effects they produce.<sup>24</sup> While there is no universally agreed upon

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20. *Id.* at 9. Thus “work is needed on distinguishing the complex . . . from the just complicated in the presence of many possible explanatory models and imperfect data.” Nicholas W. Watkins & Mervyn P. Freeman, *Natural Complexity*, 320 *SCIENCE* 323, 324 (2008).

21. I stress here that I am using a specified definition of complexity not only to differentiate mere complicatedness but also to define complex adaptive systems. Complexity could also be defined in practical terms. For example, Peter Schuck “define[s] a legal system as complex to the extent that its rules, processes, institutions, and supporting culture possess four features: density, technicality, differentiation, and indeterminacy or uncertainty.” Peter H. Schuck, *Legal Complexity: Some Causes, Consequences, and Cures*, 42 *DUKE L.J.* 1, 3 (1992). Louis Kaplow defined complexity of legal rules as “the number and difficulty of distinctions the rules make.” Louis Kaplow, *A Model of the Optimal Complexity of Legal Rules*, 11 *J.L. ECON. & ORG.* 150, 150 (1995). I am not suggesting these or other definitions of legal complexity are wrong or incomplete, only that this is not how complexity science defines complexity.

22. See J.B. Ruhl & James Salzman, *Mozart and the Red Queen: The Problem of Regulatory Accretion in the Administrative State*, 91 *GEO. L.J.* 757, 796–806 (2003) (exploring the difference between complicated and complex sets of legal rules).

23. See Jonathan F. Mitchell, *Stare Decisis and Constitutional Text*, 110 *MICH. L. REV.* 1, 11–24 (2011).

24. In ecology, for example, “[t]he importance of ecosystem complexity and the vast array of interconnections that underlie ecosystem function is certainly one of the most important lessons of 10 decades of ecological research and natural resource management experience.” NORMAN L. CHRISTENSEN, ANN M. BARTUSKA, JAMES H. BROWN, STEPHEN CARPENTER, CARLA D’ANTONIO, ROBERT FRANCIS, JERRY F. FRANKLIN, JAMES A. MACMAHON, REED F. NOSS, DAVID J. PARSONS, CHARLES H. PETERSON, MONICA G. TURNER & ROBERT WOODMANSEE, *THE REPORT OF THE ECOLOGICAL SOCIETY OF AMERICA*

metric for measuring complexity in such a system,<sup>25</sup> the theoretical model has come to rest on a collection of agent and system properties that are at the core of complexity.<sup>26</sup> Alderson and Doyle contend that the key to such properties for purposes of the RYF dilemma model are “large and/or diverse number of components, the complexity of their interconnections and interactions, and the complexity of the behaviors that result.”<sup>27</sup> This framework is easy for anyone with any training in law to map onto the legal system, and I do so here only to set up the context for probing the RYF dilemma model.

At any given time, the components of the legal system consist of a broad diversity of institutions—the organizations of people who make, interpret, and enforce laws and instruments—and the laws, regulations, cases, and related legal content the institutions produce.<sup>28</sup> For my purposes, we can put aside the question of what institutions and instruments are in or out of the legal system; what is important for now is that there is a collection of such components we call the legal system. These components are interconnected and interactive. The institutions are interconnected through structures such as hierarchies of courts and legislative creation and oversight of agencies, and they interact in forums such as judicial trials, legislative hearings and debates, and agency rulemakings. The instruments also are interconnected through mechanisms such as code structures and interact through cross-references and other devices. When we turn the system on, it behaves—the network of institutions and the maze of instruments get to work. An agency adopts a rule, which prompts another agency to enforce a different rule, which leads to litigation before a judge, who issues an opinion that is overruled by a higher court, which prompts a legislature to enact a new statute, and so on. The institutional agents follow procedural rules (e.g., notice and comment), and the instrumental agents are embedded within rules for rules (e.g., canons of statutory construction), but there is no central controller. There are hierarchies for various institutions (e.g., courts) and instruments (e.g., federal law supremacy), but there is no master agent controlling *the system*.

### B. Emergent Behavior

The legal system’s *structure* thus appears to be complex, but how do we know if the system’s *behavior* is complex? The system property most important for my (and most) purposes in this sense is emergence. The core idea of the emergence

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COMMITTEE ON THE SCIENTIFIC BASIS FOR ECOSYSTEM MANAGEMENT, *reprinted in* 6 ECOLOGICAL APPLICATIONS 665, 669 (1996).

25. See MILLER & PAGE, *supra* note 8, app. at 233–36; Alderson & Doyle, *supra* note 1, at 840.

26. See MILLER & PAGE, *supra* note 8, at 19–20. For a review of these and other complex adaptive systems properties in the context of legal systems, see generally Ruhl, *supra* note 7, at 892–901.

27. Alderson & Doyle, *supra* note 1, at 840.

28. There are, of course, many different ways and terms used to describe the legal system, but for my purposes what matters are the components. It is quite common for legal scholars to speak of legal institutions and instruments in the way I use the terms to describe and discuss the legal system. Westlaw searches for the terms in the “Law Reviews & Journals” library turn up thousands of documents.

property is that the system exhibits macroscopic behavior that could not be predicted by examining the system components, interconnections, and interactions at microscopic scales.<sup>29</sup> In more technical terms, emergence has been defined as “complicated global patterns emerging from local or individual interaction rules between parts of a system.”<sup>30</sup> To put it in practical examples, “[t]hat a government is democratic or that a diamond is hard are properties defined at the level of the government or the diamond. They are not properties of the components of a government or a diamond.”<sup>31</sup> Because emergent system behaviors are the macroscale product of many such local interaction rules, it is not possible to predict emergent behavior simply by describing the interaction rules. Emergence thus is “a process that leads to the appearance of structure not directly described by the defining constraints and instantaneous forces that control a system.”<sup>32</sup>

Emergence permeates legal systems. For example, “many have observed[] [that] the common law is a complex adaptive system in which an array of agents, institutions, and social contexts together act to produce its substantive jurisprudence.”<sup>33</sup> That “substantive jurisprudence” emerges from the common law system through a process of gradual development and evolution of doctrine based on bedrock principles set down centuries ago. Although one must read the cases to know the common law of, say, property, the common law of property is something more than just the sum of the cases. The *Restatement of Property*, for example, is more than a case reporter—it is the product of tremendous effort by property law experts over time to synthesize case law into macroscale doctrinal themes and structures as well as specific principles. Indeed, the very process of legal research and argumentation, in common law or statutory fields, is at bottom a searching for emergent principles from the mass of relevant statutes, regulations, and cases. In short, the cliché that in law school one learns to “think like a lawyer” captures a very real feature of the legal system—that one cannot easily navigate it without an appreciation that it is, indeed, a *system*.

Emergent legal system behavior, while a product of the legal system’s structural interconnectedness, cannot be predicted from a reductionist study of the interconnected components. For example, legal concepts and principles—the

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29. MITCHELL, *supra* note 6, at 12–13.

30. P.-M. Binder, *Frustration in Complexity*, 320 SCIENCE 322, 322 (2008).

31. Russ Abbott, *Putting Complex Systems to Work*, COMPLEXITY, Nov.–Dec. 2007, at 30, 33.

32. James P. Crutchfield, *Is Anything Ever New? Considering Emergence*, in COMPLEXITY: METAPHORS, MODELS, AND REALITY 515, 516 (George A. Cowan, David Pines & David Meltzer eds., 1994). For a broad study of emergence in social and natural systems, see generally STEVEN JOHNSON, EMERGENCE: THE CONNECTED LIVES OF ANTS, BRAINS, CITIES, AND SOFTWARE (2001); Peter A. Corning, *The Re-emergence of “Emergence”: A Venerable Concept in Search of a Theory*, COMPLEXITY, July–Aug. 2002, at 18. For a history of the concept of emergence from its early development in general systems theory to its use in complexity science, see generally R. KEITH SAWYER, SOCIAL EMERGENCE: SOCIETIES AS COMPLEX SYSTEMS 10–45 (2005).

33. Daniel Martin Katz, Joshua R. Gubler, Jon Zelner, Michael J. Bommarito II, Eric Provins & Eitan Ingall, *Reproduction of Hierarchy? A Social Network Analysis of the American Law Professoriate*, 61 J. LEGAL EDUC. 76, 97 (2011) (footnote omitted).

instrumental agents in the legal system—can be broken down into finely grained components, as in the way legal research services such as Westlaw and Lexis have developed their KeyCite and Headnotes cataloguing systems. These cataloguing systems produce hierarchical concept frameworks by placing broad legal concepts such as constitutional law and environmental law at the top and then drill down from those broad concepts through successive levels of increasingly narrow subtopics. Bommarito’s study of opinion headnotes in over 23,000 Supreme Court cases illustrates the branching form of what this hierarchy looks like when laid out graphically.<sup>34</sup> As any lawyer knows, however, cases often are about more than one narrow sub-sub-subtopic. Rather, a particular judicial opinion could involve a combination of numerous broad and narrow concepts from various parts of this hierarchical framework. As Bommarito’s study vividly demonstrates, when mapped over masses of opinions and long time frames, these combinations exhibit patterns of concept relationships that are not inherently obvious from an examination of the multitude of discrete components of the concept hierarchy.<sup>35</sup> So, how do these patterns form? How does the multitude of discrete legal concepts get thrown together in thousands of cases over time in ways that exhibit strong *conceptual* interconnections? The answer lies in the work of the multitude of interconnected institutional agents in the legal system—the lawyers and judges—working within the system’s structure to litigate and decide cases. Factual contexts, litigation strategies, and judicial reasoning combine to bring together a web of legal concepts particular to each case, but as Bommarito’s study shows, over time we find the concept hierarchy as a whole to exhibit various strong and weak concept interconnections.<sup>36</sup> These revealed interconnection patterns are not explicitly built into or otherwise obvious from the concept hierarchy itself, the purpose of which, quite to the contrary, is about disaggregating legal concepts into finely grained discrete concepts. Rather, they are macroscale emergent behavior of the legal system.

The relationship between the organization of system component interconnectedness and the emergence of macroscale system behavior is critical to understanding the origins of the RYF dilemma. As a prelude to what follows in the next two parts of the Article covering robustness and fragility, which complete the model’s basic form, Alderson and Doyle drive this point home in succinct terms:

Emergence is . . . associated with unintended consequences for either good (an emergent benefit) or bad (an emergent fragility). Emergent benefits in organized systems are sufficiently rare as to be peripheral to this paper, much wishful thinking notwithstanding . . . . In contrast, emergent fragilities, whether unintended or the result of hard tradeoffs, are dominant problems in complex systems.<sup>37</sup>

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34. See Michael J. Bommarito II, Exploring Relationships Between Legal Concepts in the United States Supreme Court 3 fig. 1 (Nov. 5, 2009) (unpublished manuscript), available at <http://ssrn.com/abstract=1814169>.

35. See *id.* at 6–16.

36. See *id.* at 4–9.

37. Alderson & Doyle, *supra* note 1, at 841 (emphasis omitted).

## II. ROBUSTNESS

In the technical language of complexity science, a system or any of its properties is more robust the more invariant it is with respect to a set of shocks or perturbations.<sup>38</sup> Using this framework, a legal system could be described as robust if it remains relatively intact endogenously, notwithstanding disruptions from exogenous forces and endogenous failures. This is the meaning I will use, recognizing that it carries no particular normative baggage—what most Americans might consider a contemptible legal system could nonetheless be a robust one. In other words, one could define robustness of the legal system as its capacity to meet normative goals, but that is *not* the meaning I use.

That is not a trivial point. It is reasonable to assume that most citizens want their legal system to fulfill a particular normative orientation *and* be robust, as it wouldn't be much of a legal system if it were normatively desirable yet subject to collapse at any moment. To be sure, it may be the case that the measures necessary to maximize robustness in a legal system have consequences some of which may be normatively unsatisfactory.<sup>39</sup> It may also be the case that our normative desires for the other social systems limit our capacity to make the legal system robust.<sup>40</sup> I will return to these problems later; my aim in this Part is to explore what robustness of legal systems means independent of normative goals for law and other social systems.

In their deep examination of robustness in complex adaptive systems, Alderson and Doyle explain that several features of a system contribute to robustness: “*Reliability* involves robustness to component failures. *Efficiency* is robustness to resource scarcity. *Scalability* is robustness to changes to the size and complexity of the system as a whole. *Modularity* is robustness to structured component rearrangements. *Evolvability* is robustness of lineages to changes on long time scales.”<sup>41</sup>

Robustness thus captures more than stability, rigidity, or permanence, as it anticipates system-level change and evolution. Stability to fluctuations in external inputs may require changes in internal system parameters, which themselves are forces of perturbation. At its core, therefore, “robustness is a measure of feature persistence in systems where the perturbations . . . represent changes in system composition, system topology, or in the fundamental assumptions regarding the environment in which the system operates.”<sup>42</sup> The core of the robustness concept, therefore, is the “fitness of the ‘strategic options’ open to a system” for dealing with such perturbations.<sup>43</sup> While legal scholars do not use this precise terminology

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38. *See, e.g., id.* at 840.

39. For example, most Americans likely would oppose severe restrictions on due process even if shown to promote legal system robustness.

40. For example, Americans likely would oppose measures shown to promote legal system robustness if they were also shown to promote severe economic decline for children and the elderly.

41. Alderson & Doyle, *supra* note 1, at 840 (emphases in original).

42. Erica Jen, *Stable or Robust? What's the Difference?*, COMPLEXITY, Jan.–Feb. 2003, at 12, 13–14 (comparing stability and robustness).

43. *Id.* at 16.

and typology, each of these concepts finds a rich tradition of analysis and debate in legal scholarship.

#### A. Reliability

It makes intuitive sense that global reliability of the legal system—that it successfully works the way intended—would be a valued design goal, and that certain institutions and instruments are seen as pivotal in this respect. We might conclude, for example, that “[c]ertain forms of regulation have been found to work, while others have proved less reliable,”<sup>44</sup> or that “[r]espect for and deference to judicial precedent is what fortifies the integrity of our legal system; it is what makes the system reliable.”<sup>45</sup> In short, that the legal system should be reliable seems an uncontroversial aspiration.

System component failures erode global system reliability, however, meaning a robust system design must plan for component failure. The legal system is replete with such design features. Institutional component failures are corrected through mechanisms such as relief for ineffective counsel, judicial review of arbitrary agency action, and appellate review for clear error of judgment, and instrument failures are corrected through judicial review for statutes suffering from constitutional infirmities and agency rules inconsistent with clear legislative directives. By incorporating design features to detect and correct these and other institutional and instrument component failures, overall system reliability is enhanced.

#### B. Efficiency

Like most social systems, the legal system does not have the luxury of infinite resources—it must make do with what it has available in terms of institutional capacity. And the legal system can be quite expensive to operate,<sup>46</sup> making design for efficiency a practical necessity.

Designing for efficiency of the legal system is not the same question as how to design a legal system to promote efficiency in *other* social systems, such as land use or business transactions, a topic which has attracted considerable scholarly debate and is usually what is meant when efficiency and legal systems are discussed in the same breath.<sup>47</sup> The two design questions are potentially related, but

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44. Jeremy Waldron, “*The Experience and Good Thinking Foreign Sources May Convey*”: *Justice Ginsburg and the Use of Foreign Law*, 63 HASTINGS L.J. 1243, 1262 (2012).

45. Conor P. McEvily, *Vested Interests: The Federal Felon Body-Armor Ban and the Continuing Vitality of Scarborough v. United States*, 100 GEO. L.J. 1341, 1398 (2012).

46. See, e.g., Steven Shavell, *The Fundamental Divergence Between the Private and the Social Motive to Use the Legal System*, 26 J. LEGAL STUD. 575, 575 (1997) (exploring why “[t]he legal system is a very costly social institution”).

47. See, e.g., Giacomo A.M. Ponzetto & Patricio A. Fernandez, *Case Law Versus Statute Law: An Evolutionary Comparison*, 37 J. LEGAL STUD. 379, 380–411 (2008) (summarizing legal scholarship on efficiency-maximizing legal system designs and comparing common law and civil law systems). In that application, efficiency is a normative

quite distinct. For example, requiring decision makers to perform cost-benefit analysis of their proposed decisions might promote efficiency of resource allocations in other social systems if conducted thoroughly and reliably. Even when it achieves that normative goal, however, cost-benefit analysis might be a costly and potentially inefficient legal decision-making method, or it might promote efficient decision making—either way, that’s different from its efficiency effect on other social systems.

Efficiency of (as opposed to promoted by) the legal system is served by a broad variety of design mechanisms. For example, the legal scholars have observed that “standing requirements improve judicial decision-making, conserve judicial resources, and reduce conflict between the judiciary and the political branches”<sup>48</sup> and “[t]he main justification for plea bargaining is that it is necessary for the continued function and efficiency of the criminal justice system.”<sup>49</sup> As controversial as standing rules, plea bargaining practices, and similar measures may be, there is little doubt that by incorporating design features such as these, overall legal system resources can be more efficiently conserved.

### C. Scalability

Societies change in scale over time as the number of people, political units, and other components grow or contract in number, so it will be useful if social systems smoothly accommodate such scale changes and continue to deliver their functionality. This should be no less a design ideal for legal institutions and instruments than it is for, say, the economy. In other words, it would be odd for a society to design a legal system that depends for its functionality on a static social scale, tolerating little or no change in the number of people or size of jurisdiction.

Certainly the American legal system has been scalable in this respect, accommodating growth since its inception by hundreds of millions of people, hundreds of millions of acres, and thousands of political units on multiple jurisdictional scales. As Justice Breyer recently pointed out,

[T]he Federal government at the time of the founding consisted of about 2,000 employees and served a population of about 4 million. Today, however, the Federal Government employs about 4.4 million workers who serve a Nation of more than 310 million people living in a society characterized by rapid technological, economic, and social change.<sup>50</sup>

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goal for other social systems that the legal system is to support, whereas robustness of the legal system depends on efficient operation of legal institutions and instruments given the legal system’s resource limitations.

48. Joshua L. Sohn, *The Case for Prudential Standing*, 39 U. MEM. L. REV. 727, 728 (2009).

49. Tina Wan, Note, *The Unnecessary Evil of Plea Bargaining: An Unconstitutional Conditions Problem and a Not-So-Least Restrictive Alternative*, 17 S. CAL. REV. L. & SOC. JUST. 33, 39 (2007).

50. *Free Enter. Fund v. Pub. Co. Accounting Oversight Bd.*, 130 S. Ct. 3138, 3168 (2010) (Breyer, J., dissenting) (emphasis omitted) (citations omitted).

As people expanded into new territory, new states were formed that largely replicated judicial and legislative systems from other states, and doctrines such as Equal Footing allowed them to be absorbed into the existing federal legal system rather seamlessly.<sup>51</sup> Through this process, the legal system has steadily added more legislatures, courts, agencies, lawyers, and laws along the way,<sup>52</sup> and its scope of regulation has steadily expanded as its context expanded, now encompassing topics once unimaginable, such as nuclear power, airline safety, and the Internet.<sup>53</sup> Yet our legal system has retained its basic constitutive system and structure, albeit with some significant strains that could be attributed principally to growth in population or geography.<sup>54</sup>

#### D. Modularity

Many complex adaptive systems are modular, in that they are composed of small, densely connected, often overlapping groups of components.<sup>55</sup> Modularity promotes system robustness by allowing systems to work in parallel and to reconfigure, either in response to a component failure or as an adaptive move, without crashing the system. Indeed, although there is tremendous debate over which is the best configuration for given policy problems, it is widely agreed that the American legal system's federalism structure allows an institutional modularity, with approaches ranging from federal preemption to cooperative federalism, which can switch out and combine different scales and configurations of governance to respond to policy problems.<sup>56</sup> Legal

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51. See U.S. CONST. art. IV, § 3, cl. 1.

52. Some claim it has grown too much in proportion to growth of other social systems, more on which *infra* Part IV.A. See Shavell, *supra* note 46, at 575–76 (discussing views that growth of the legal system has been excessive).

53. See *Free Enter. Fund*, 130 S. Ct. at 3168 (Breyer, J., dissenting).

54. Consider, for example, the difficulty the nation and legal system experienced when adding new states to a union divided over the legal institution of slavery. See *Dred Scott v. Sandford*, 60 U.S. (19 How.) 393 (1857), *superseded by constitutional amendment*, U.S. CONST. amend. XIV.

55. See James P. Bagrow, Sune Lehmann & Yong-Yeol Ahn, *Robustness and Modular Structure in Networks* 1–2 (Feb. 24, 2011) (unpublished manuscript), available at <http://arxiv.org/pdf/1102.5085v1.pdf>.

56. See Jody Freeman & Daniel A. Farber, *Modular Environmental Regulation*, 54 DUKE L.J. 795, 805–37, 876–96 (2005) (discussing modular governance approaches). “Centralized federalism suggests that the federal government should address environmental problems on its own. Devolved federalism argues that environmental decisions are best made at the state and local level. Dual federalism posits that each level of government should have distinct and separate approaches to environmental regulation.” Benjamin K. Sovacool, *The Best of Both Worlds: Environmental Federalism and the Need for Federal Action on Renewable Energy and Climate Change*, 27 STAN. ENVTL. L.J. 397, 405 (2008). “[C]ooperative federalism is a system of shared authority between the federal and state governments” in which “state programs adopt environmental standards at least as stringent as the federal program. . . . [and] the federal government retains oversight authority.” David E. Adelman & Kirsten H. Engel, *Adaptive Federalism: The Case Against Reallocating Environmental Regulatory Authority*, 92 MINN. L. REV. 1796, 1811–12 (2008).



instruments also can be designed to provide modular flexibility, as in the famous metaphor of property as a bundle of sticks.<sup>57</sup>

### *E. Evolvability*

A robust complex adaptive system is not unchanging; rather, it incorporates change. For example, the “dynamic equilibrium” model now firmly in place in fields such as ecology is based on the assumption that change in natural systems is inherent even if it is bounded within predictable confines.<sup>58</sup> Thus, “any system that is expected to survive over the long term must have evolvability as a primary design consideration.”<sup>59</sup> Systems that cannot change tend to die.

Robust legal systems must evolve as well,<sup>60</sup> and legal scholars have for centuries devoted attention to assessing how and why they do.<sup>61</sup> The American legal system has unquestionably proven evolvable over time, capable of responding to changing context by changing itself. Indeed, the common law is practically designed to promote evolution. Consider, for example, that it is well accepted under the common law of nuisance that “changed circumstances or new knowledge may make what was previously permissible no longer so.”<sup>62</sup> Examples of such changes are numerous. At one time, the U.S. Supreme Court declared that “[i]f there is any fact which may be supposed to be known by everybody, and, therefore, by courts, it is that swamps and stagnant waters are the cause of malarial and malignant fevers, and that the police power is never more legitimately exercised than in removing such nuisances.”<sup>63</sup> Perhaps that made sense then. Today, by contrast, it would be unheard of for a court to condemn a wetland area as a nuisance; indeed, some courts now consider the draining or filling of a wetland to constitute a nuisance.<sup>64</sup>

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57. See Henry E. Smith, *Intellectual Property as Property: Delineating Entitlements in Information*, 116 YALE L.J. 1742, 1783 (2007) (“Property is the area of law concerned with those rights most based on exclusion. In our terms, this means that property law tends to define rights based on informational variables that bunch attributes and uses together and to treat them as a modular component of the legal system.”).

58. See Reed F. Noss, *Some Principles of Conservation Biology, as They Apply to Environmental Law*, 69 CHI.-KENT L. REV. 893, 893 (1994) (“Among the new paradigms in ecology, none is more revolutionary than the idea that nature is not delicately balanced in equilibrium, but rather is dynamic, often unpredictable, and perhaps even chaotic.”); see also Bryan Norton, *Change, Constancy, and Creativity: The New Ecology and Some Old Problems*, 7 DUKE ENVTL. L. & POL’Y F. 49 (1996); Jonathan Baert Wiener, *Law and the New Ecology: Evolution, Categories, and Consequences*, 22 ECOLOGY L.Q. 325, 325–29 (1995) (book review) (discussing the emergence of “new ecology” in science and law).

59. Abbott, *supra* note 31, at 42.

60. Robert Howse, *Moving the WTO Forward—One Case at a Time*, 42 CORNELL INT’L L.J. 223, 223 (2009) (“[A]ny legal system, if it is going to be effective, has to be able to evolve incrementally through practice.”).

61. For a survey of theories of legal evolution, see generally J.B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and Its Practical Meaning for Democracy*, 49 VAND. L. REV. 1407 (1996).

62. Lucas v. S.C. Coastal Council, 505 U.S. 1003, 1031 (1992).

63. Leovy v. United States, 177 U.S. 621, 636 (1900).

64. Palazzolo v. State, No. WM 88–0297, 2005 WL 1645974, at \*5 (R.I. Super. Ct. July

The common law of nuisance has responded to the modern science of wetland ecology and changed public perceptions to make a complete 180-degree turn on the status of wetlands,<sup>65</sup> but by no means would anyone consider the common law of nuisance to have been restructured as a system.<sup>66</sup>

### III. FRAGILITY

Envision a team of legal experts designing a legal system from the ground up with the aim of maximizing system robustness around the five attributes outlined above in Part II. It doesn't take much thought to anticipate that they would soon run into design tradeoffs if they worked to maximize all dimensions of system robustness at once. Investment to maximize efficiency, for example, may conflict with investment to maximize component reliability.<sup>67</sup>

Tradeoffs like these permeate the legal system. Consider what might happen if we were to increase the Constitution's evolvability by substantially lowering Article V barriers to amendments.<sup>68</sup> Without suggesting what the differences would be in the Constitution, it seems obvious there would be some, and that they would have an impact on other robustness features of the legal system.<sup>69</sup> One can easily

5, 2005) (finding a development that would fill a wetland a public nuisance based on "evidence as to various effects that the development will have including increasing nitrogen levels in the pond, both by reason of the nitrogen produced by the attendant residential septic systems, and the reduced marsh area which actually filters and cleans runoff").

65. For reviews of this doctrinal shift, see generally Michael C. Blumm & J.B. Ruhl, *Background Principles, Takings, and Libertarian Property: A Reply to Professor Huffman*, 37 *ECOLOGY L.Q.* 805, 819–30 (2010), and John Copeland Nagle, *From Swamp Drainage to Wetlands Regulation to Ecological Nuisances to Environmental Ethics*, 58 *CASE W. RES. L. REV.* 787, 789–96 (2008).

66. As environmental law scholar William Rodgers has suggested, "A striking aspect of nuisance law is its stasis (long term stability), recorded in familiar modes of judicial expression, common analytical techniques, and custom-bred indicators of decision. . . . The key to nuisance law, one might suppose, is found in the empirical lessons of its application recorded over time, less so in the articulated rules of decision." WILLIAM H. RODGERS, JR., *ENVIRONMENTAL LAW* § 2.1, at 113–14 (2d ed. 1994).

67. See Alderson & Doyle, *supra* note 1, at 840 (using the example of efficiency and reliability as possible system tradeoffs). Tradeoffs such as this are known more generally in complexity science as conflicting constraints. See Ruhl, *supra* note 7, at 902.

68. See U.S. CONST. art. V. For discussions of the Article V amending procedures as an obstacle to new amendments, see generally *RESPONDING TO IMPERFECTION: THE THEORY AND PRACTICE OF CONSTITUTIONAL AMENDMENT* (Sanford Levinson ed., 1995); JOHN R. VILE, *CONSTITUTIONAL CHANGE IN THE UNITED STATES* 1–13 (1994); Donald J. Boudreaux & A.C. Pritchard, *Rewriting the Constitution: An Economic Analysis of the Constitutional Amendment Process*, 62 *FORDHAM L. REV.* 111 (1993); Walter Dellinger, *The Legitimacy of Constitutional Change: Rethinking the Amendment Process*, 97 *HARV. L. REV.* 386 (1983); Kris W. Kobach, Note, *Rethinking Article V: Term Limits and the Seventeenth and Nineteenth Amendments*, 103 *YALE L.J.* 1971 (1994).

69. There have been over ten thousand proposed amendments to the Constitution, very few of which have made it through the gantlet of Article V. See JOHN R. VILE, *ENCYCLOPEDIA OF CONSTITUTIONAL AMENDMENTS, PROPOSED AMENDMENTS, AND AMENDING ISSUES, 1789–1995*, at ix–xi, 363–80 (1996) (collating proposals by year). The amendment process thus obviously matters to the constitutional construct of a legal system. For a survey

imagine similar tradeoffs: having fewer judges could promote efficiency but reduce reliability, pervasive federal preemption of state law could promote reliability but reduce modularity, creating a new agency could increase modularity but decrease efficiency, and so on. Understanding these tradeoffs and the constraints on system functionality they produce lies at the heart of the design challenge for robustness of legal systems.<sup>70</sup>

Of course, a truly great legal mind might devise fail-safe strategies for working around this kind of conflict, but inevitably more constraints will arise as work continues on the system design. Designing a robust legal system thus is largely an exercise in identifying constraints on system functionality and then building fail-safe strategies into the system control architecture to minimize fragilities stemming from those constraints.<sup>71</sup>

#### A. Constraints on Robustness

Alderson and Doyle identify four kinds of constraints on system functionality: (1) component-level, (2) system-level, (3) protocols, and (4) emergent constraints. As with their dimensions of robustness, their constraints typology also maps remarkably well onto the legal system and legal scholars' concerns about the inherent limits of its performance.

##### 1. Component-Level Constraints

The first and most obvious constraint on robustness is that “[t]he components that comprise any system are typically constrained in terms of what they can do, even separately.”<sup>72</sup> For example, legal scholars have pointed to the cognitive capacities and biases of judges as constraining their decision-making reliability<sup>73</sup> and have analyzed various conditions that constrain the effectiveness of administrative agencies, such as so-called agency capture.<sup>74</sup> People have their

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of procedures for amending various state and national constitutions, see generally Elai Katz, *On Amending Constitutions: The Legality and Legitimacy of Constitutional Entrenchment*, 29 COLUM. J.L. & SOC. PROBS. 251 (1996).

70. See Samuel R. Gross, *The American Advantage: The Value of Inefficient Litigation*, 85 MICH. L. REV. 734, 742–47 (1987) (arguing that the American legal system may sacrifice efficiency in order to attain other goals such as superior accuracy).

71. See Alderson & Doyle, *supra* note 1, at 840 (stressing that these constraints arise “largely independent of the process by which this organization arises, whether by design or evolution”).

72. *Id.*

73. E.g., Chris Guthrie, Jeffrey J. Rachlinski & Andrew J. Wistrich, *Inside the Judicial Mind*, 86 CORNELL L. REV. 777, 784 (2001); Donald C. Nugent, *Judicial Bias*, 42 CLEV. ST. L. REV. 1, 1–20 (1994).

74. Mark C. Niles, *On the Hijacking of Agencies (and Airplanes): The Federal Aviation Administration, “Agency Capture,” and Airline Security*, 10 AM. U. J. GENDER SOC. POL’Y & L. 381, 390 (2002) (“This undue control and domination of federal administrative agencies, particularly by identifiable private parties that are subject to the regulatory authority of the agency, has been defined as agency or industry ‘capture,’ and has, of course, been all but universally seen as a negative consequence. Indeed, it is referred to as a ‘pathology’ in administrative governance, and consequently, a phenomenon to be either avoided or

limits, therefore legal institutions made up of people have their limits, and therefore the legal instruments the institutions produce have their limits.

## 2. System-Level Constraints

Just as there are constraints inherent in each component in a system, “there are complex constraints on the system as a whole that are not consequences of those on the components.”<sup>75</sup> These include functional requirements defining what the system needs to accomplish and environmental and operating requirements defining the conditions under which the system is working to achieve its functions.<sup>76</sup>

Here is where for the legal system we return to the question of norms. Legal systems are built to accomplish many functions, some of which are intended to fulfill certain internal norms, such as transparency or due process in legal decisions, and to promote certain norms in other social systems, such as financial system stability and environmental protection. Whatever these norms are is not important to my project—pick any set you choose. The point is that these norms act as functional requirement constraints on the system. If society demands that legal institutions be transparent in their decision making, striving to meet that norm could constrain their efficiency or reliability. If society demands that legal instruments promote public health protection, striving to meet that norm could place demands on legal institutions that limit their options.

Society might also place environmental constraints on the legal system, such as through limited budgets, political barriers to judicial appointments, and similar conditions that define what the system has to work with to fulfill its functions. Other social systems, such as education, health care, or defense, also can constrain the legal system by competing for resources or putting demands on legal institutions, such as increased litigation. Some of these constraints may reflect normative tradeoffs society has had to make, such as prioritizing scarce resources for different systems, or the simple reality that normative goals for one social system sometimes conflict with normative goals for another social system. When a nation is at war or in emergency times, for example, social priorities may change and demand that the legal system conform to new system-level constraints.<sup>77</sup>

## 3. Protocols

Protocols are “rules for the configuration and/or interaction of system components” and as such may, but will not necessarily, impose additional constraints on the overall system.<sup>78</sup> Some rules will limit the number of possible system solutions, but others may facilitate ways the system searches for robust solutions.

As any new law student quickly learns, the legal system has produced a dizzying plethora of rules for how it is supposed to operate, collectively known as legal

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remedied.” (footnote omitted).

75. Alderson & Doyle, *supra* note 1, at 841.

76. *See id.*

77. Mary L. Dudziak, *Law, War, and the History of Time*, 98 CALIF. L. REV. 1669, 1669–71 (2010).

78. Alderson & Doyle, *supra* note 1, at 841.

process or procedure. Indeed, it does not go too far to suggest that in the legal system, “procedure is power.”<sup>79</sup> Constitutional due process constrains the legal system,<sup>80</sup> cost-benefit analysis is a protocol imposed on many agencies,<sup>81</sup> and other vast rules of criminal, civil, and administrative procedure abound at all scales of governance. At the same time, these protocols facilitate the system’s functionality, however, they also can constrain—the rules must be followed, and following them limits options.<sup>82</sup>

#### 4. Emergent Constraints

Component-level, system-level, and protocol-based constraints can interact to produce emergent constraints that would not exist or be identified absent those interactions.<sup>83</sup> Indeed, “emergent fragilities, whether unintended or the result of hard tradeoffs, are dominant problems in complex systems.”<sup>84</sup>

Hard policy tradeoffs are ubiquitous in the legal system and can constrain legal institutions,<sup>85</sup> but more subtle and yet more pernicious are the unintended and largely unseen emergent constraints. For example, Jim Salzman and I have explored what we call “system burdens” resulting from the accretion of many legal instruments, all of which could be perfectly reasonable and efficient taken individually, but which collectively could produce perverse effects including inability of regulated entities to fully comply with the entire set of rules.<sup>86</sup> Component-level, system-level, and protocol-based constraints on the legal system could also generate similar emergent constraints operating on the legal system itself rather than on other social systems. For example, legal scholars have pointed to the unintended consequence of agency “ossification” as the product of agencies having to navigate a maze of complex administrative procedure, statutory mandates, and judicial review.<sup>87</sup> All of those system protocols serve salutary purposes—they are

79. Stephen B. Burbank, *The Class Action Fairness Act of 2005 in Historical Context: A Preliminary View*, 156 U. PA. L. REV. 1439, 1442 (2008).

80. See, e.g., Richard H. Fallon, Jr., *Constitutional Constraints*, 97 CALIF. L. REV. 975, 975–86 (2009).

81. See, e.g., Edward L. Rubin, *Passing Through the Door: Social Movement Literature and Legal Scholarship*, 150 U. PA. L. REV. 1, 61 (2001) (“[L]egislative and administrative decisions are supposed to represent good social policy because they follow some pragmatic decision-making protocol, like cost-benefit analysis . . .”).

82. See Burbank, *supra* note 79, *passim* (evaluating the impact of changes to federal class action procedure and jurisdiction).

83. See Alderson & Doyle, *supra* note 1, at 841.

84. *Id.*

85. Andrei Mamolea, *The Future of Corporate Aiding and Abetting Liability Under the Alien Tort Statute: A Roadmap*, 51 SANTA CLARA L. REV. 79, 145 n.269 (2011) (“[P]olicy tradeoffs are inherent in all judicial decisions.”).

86. See Ruhl & Salzman, *supra* note 22.

87. See, e.g., William S. Jordan, III, *Ossification Revisited: Does Arbitrary and Capricious Review Significantly Interfere with Agency Ability to Achieve Regulatory Goals Through Informal Rulemaking?*, 94 NW. U. L. REV. 393 (2000); Thomas O. McGarity, *Some Thoughts on “Deossifying” the Rulemaking Process*, 41 DUKE L.J. 1385 (1992); Mark Seidenfeld, *Demystifying Deossification: Rethinking Recent Proposals to Modify Judicial*

intended to promote legal system robustness—but their combined unintended emergent effect can be to stultify agency decision making.

### *B. Fail-Safe Strategies*

The set of constraints described in the previous section does not aggregate to produce some sort of composite metaconstraint with uniform effect throughout the system. Rather, their effects are such that a “system can have a property that is robust to one set of perturbations and yet fragile for a different property and/or perturbation,”<sup>88</sup> and hence “understanding RYF tradeoffs lies at the heart of the design challenges for network-centric infrastructures.”<sup>89</sup> So what do we do? Alderson and Doyle suggest a number of “design strategies for robustness”<sup>90</sup>—what I call fail-safe strategies—for plugging the holes opened by system RYF tradeoffs.

#### 1. Ultraquality Components

One obvious approach for managing component-level constraints on system robustness is to improve the quality of the system components so they rarely fail. Design for such ultraquality components would strive to improve repeat performance over time with acceptable costs of component production and operation.<sup>91</sup>

Ultraquality design in legal systems, for example, could focus on people through measures intended (at least ostensibly) to ensure quality, such as educational requirements, bar exams, continuing legal education, and qualifications for judges and administrators.<sup>92</sup> Institutional decision quality can also be managed through protocols such as cost-benefit analysis, data quality requirements, and peer review.<sup>93</sup> To be sure, some of these measures don’t produce enhanced quality, and some could be pretexts for other motives, but the point is clear enough—quality control is a viable fail-safe strategy within the legal system.

#### 2. Redundancy

Achieving ultraquality widely throughout the components of a system has its own set of constraints, such as cost and technology, and may simply not be possible to achieve at levels that significantly enhance system robustness if other forms of system constraints are substantial in effect. Provision for backups and other forms

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*Review of Notice and Comment Rulemaking*, 75 TEX. L. REV. 483 (1997).

88. Alderson & Doyle, *supra* note 1, at 840 (emphasis omitted) (internal brackets omitted).

89. *Id.*

90. *Id.* at 841–42.

91. *See id.* at 841.

92. *See* RICHARD L. ABEL, AMERICAN LAWYERS 151–56 (1989).

93. *See* Alexander Nathan Hecht, *Administrative Process in an Information Age: The Transformation of Agency Action Under the Data Quality Act*, 31 J. LEGIS. 233, 233–35 (2005); J.B. Ruhl & James Salzman, *In Defense of Regulatory Peer Review*, 84 WASH U. L. REV. 1, 1–35 (2006).

of redundancy in components and system subparts, although not always contributing to efficiency, thus is a well-studied and common strategy in systems application.<sup>94</sup>

Redundancy of components at a variety of scales is common in legal systems. Provisions for citizen suits, for example, allow citizens to step in as private attorney-general functionaries where public enforcement is inadequate.<sup>95</sup> Throughout the legal system mechanisms are provided for seeking second opinions, such as judicial review, bicameralism, and separation of powers.<sup>96</sup> Federalism in general is seen by many legal scholars, particularly those advocating dynamic federalism theory, as accommodating institutional redundancy to promote national policy goals.<sup>97</sup> While it may appear inefficient and cumbersome to have several agencies at different scales working away on some mutual policy problem,<sup>98</sup> the built-in redundancy can provide significant benefits including broadened policy space<sup>99</sup> and promoting synergy between the scales and the formation of informal networks among institutions.<sup>100</sup>

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94. See Alderson & Doyle, *supra* note 1, at 841.

95. See Robert D. Snook, *Environmental Citizen Suits and Judicial Interpretation: First Time Tragedy, Second Time Farce*, 20 W. NEW ENG. L. REV. 311, 316–18 (1998); Barton H. Thompson, Jr., *The Continuing Innovation of Citizen Enforcement*, 2000 U. ILL. L. REV. 185, 185–86 (2000); Miles A. Yanick, Note, *Loss of Protection as Injury in Fact: An Approach to Establishing Standing to Challenge Environmental Planning Decisions*, 29 U. MICH. J.L. REFORM 857, 874 (1996) (“Since the early days of the administrative state, citizen suits have been valued for allowing private persons to help monitor the activities of government agencies.”).

96. See Adrian Vermeule, *Second Opinions* 3–6 (Harvard Law Sch. Pub. Law & Legal Theory Working Paper Series, Paper No. 10–38, 2010), available at <http://ssrn.com/abstract=1646414>.

97. See Adelman & Engel, *supra* note 56, at 1796–1802; Robert B. Ahdieh, *From Federalism to Intersystemic Governance: The Changing Nature of Modern Jurisdiction*, 57 EMORY L.J. 1, 1–6 (2007); Robert A. Schapiro, *From Dualist Federalism to Interactive Federalism*, 56 EMORY L.J. 1, 1–10 (2006); Robert A. Schapiro, *Toward a Theory of Interactive Federalism*, 91 IOWA L. REV. 243, 246–54 (2005). Jody Freeman and Jim Rossi perceptively observe that the term “‘redundancy’ . . . compresses too much complexity” in this multiagency delegation context and suggest instead the term “shared regulatory space.” Jody Freeman & Jim Rossi, *Agency Coordination in Shared Regulatory Space*, 125 HARV. L. REV. 1131, 1145 (2012). Although not employing a complexity science model, their assessment of shared regulatory space examines many of the potential problems it poses for effective regulatory action. See *id.* at 1134–54.

98. For a thoughtful survey of “the ongoing tension between the oft-voiced judicial and scholarly preference for distinctly delineated federal and state roles and the reality of overlapping federal and state roles that one finds [in] federalism’s central debates,” see William W. Buzbee, *Asymmetrical Regulation: Risk, Preemption, and the Floor/Ceiling Distinction*, 82 N.Y.U. L. REV. 1547, 1549–57 (2007).

99. See Adelman & Engel, *supra* note 56, at 1808–11.

100. See *id.* at 1809–10 (summarizing literature suggesting that overlapping authority can promote initiative at one governance scale and spark other scales to follow promising policy innovations).

### 3. Sensors

Ultraquality and redundancy techniques “can be effective at providing robustness in the face of component uncertainty, but they do not help to achieve robustness to the external environment.”<sup>101</sup> Another broad strategy for managing constraints, therefore, is to design protocols that direct system components and subsystems how to respond to changes in endogenous or exogenous conditions. The first type of protocol necessary for implementing such a strategy consists of rules for sensing changed conditions of potential concern. These “[s]ystem sensors can monitor system performance; detect individual component wear, damage, or failure; and/or identify external threats and perturbations to the system.”<sup>102</sup> Indeed, if not all components can achieve ultraquality reliability, priority might be given to achieving ultraquality of sensor components, given their role in monitoring threats to the system.<sup>103</sup> Research on power grid networks has shown, for example, that disabling even a small number of network failure sensors can render the grid subject to new types of disturbances even when they remain robust to conventional disturbances.<sup>104</sup>

Legal system sensors include mechanisms such as predecisional impact assessments and monitoring, reporting, and disclosure requirements, all of which fall under the theoretical domain of what is known as “reflexive law.”<sup>105</sup> The National Environmental Policy Act (NEPA) is an example of a legal system sensor protocol for predecisional impact assessment. NEPA requires all federal agencies to

include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on—(i) the environmental impact of the proposed action, [and] (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented.<sup>106</sup>

The Council on Environmental Quality (CEQ), responsible for issuing regulations implementing NEPA’s mandated environmental impact statement (EIS) procedure for federal agencies, requires agencies to consider the direct effects, indirect effects,

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101. Alderson & Doyle, *supra* note 1, at 841.

102. *Id.*

103. *See id.* at 842.

104. *See* Yang Yang, Jianhui Wang & Adilson E. Motter, *Network Observability Transitions*, PHYSICAL REV. LETTERS, Dec. 21, 2012, at 258701-1, 258701-4.

105. *See* David Hess, *Social Reporting: A Reflexive Law Approach to Corporate Social Responsiveness*, 25 J. CORP. L. 41, 48–51 (1999) (explaining theory and development of reflexive law); Eric W. Orts, *Reflexive Environmental Law*, 89 NW. U. L. REV. 1227 (1995) (developing and applying theory of reflexive law in environmental field); Richard B. Stewart, *A New Generation of Environmental Regulation?*, 29 CAP. U. L. REV. 21, 127–51 (2001) (defining reflexive law and reviewing its instruments).

106. 42 U.S.C. § 4332(2)(C)(i)–(ii) (2006). This provision also requires statements on alternative actions, short- and long-term implications, and “any irreversible and irretrievable commitments of resources.” *Id.* § 4332(2)(C)(iii)–(v).



and cumulative impacts of actions they carry out, fund, or authorize.<sup>107</sup> The EIS thus serves as a sensor mechanism requiring agencies to investigate and evaluate impacts of their decisions. Similar predecision assessment measures apply in agency rulemaking as well. For example, the Regulatory Flexibility Act requires agencies to prepare a regulatory flexibility analysis for any rule that may have important economic impact on a significant number of small businesses, and similar predecision review measures abound in administrative law.<sup>108</sup> Of course, whether these kinds of sensors work, and whether they are efficient even if they do work, are important design questions, more on which below; the point made here is that our legal system has implanted many system sensors to evaluate itself internally, to detect changes in its environment, and to measure its interactions with other social systems.

#### 4. Feedback to Actuators

The point of building sensor protocols into a system is to provide relevant information about system failure potentials to system actuators—the components and subsystems that would use information to initiate system responses. As Alderson and Doyle summarize the function of these feedback protocols:

While the ability to maintain an appropriate level of situational awareness of both components and environment is critical for complex systems of all types, such visibility is of limited value if the system cannot act upon that information, and taking appropriate action typically drives complexity far more than does sensing. Using feedback interconnection of sensors and actuators, it is possible to combine

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107. The CEQ has defined *direct effects* as effects “which are caused by the action and occur at the same time and place,” 40 C.F.R. § 1508.8(a) (2012), *indirect effects* as effects “which are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable,” *id.* § 1508.8(b), and *cumulative impacts* as

the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

*Id.* § 1508.7.

108. Regulatory Flexibility Act, 5 U.S.C. §§ 601–12 (2012). The law was amended by the Small Business Regulatory Enforcement Fairness Act of 1996, Pub. L. No. 104-121, 110 Stat. 857, 864–68. For thorough descriptions of this and related prepromulgation review requirements, see generally Fred Anderson, Mary Ann Chirba-Martin, E. Donald Elliott, Cynthia Farina, Ernest Gellhorn, John D. Graham, C. Boyden Gray, Jeffrey Holmstead, Ronald M. Levin, Lars Noah, Katherine Rhyne & Jonathan Baert Wiener, *Regulatory Improvement Legislation: Risk Assessment, Cost-Benefit Analysis, and Judicial Review*, 11 DUKE ENVTL. L. & POL’Y F. 89 (2000); Daniel Cohen, *S.981, The Regulatory Improvement Act of 1998: The Most Recent Attempt to Develop a Solution in Search of a Problem*, 50 ADMIN. L. REV. 699 (1998). For a discussion of how one agency in particular implements these requirements, see generally Melissa Romine, *Politics, the Environment, and Regulatory Reform at the Environmental Protection Agency*, 6 ENVTL. LAW. 1 (1999).

components with very different properties to create systems with robustness that far exceeds that of components separately.<sup>109</sup>

Mechanisms for feedback to actuators run throughout the legal system<sup>110</sup> and between the legal system and other social systems.<sup>111</sup> NEPA, for example, does not merely require the preparation of an EIS by the decision agency, but also requires the decision agency to include the public and other federal, state, and local agencies in the design and evaluation of the EIS and to respond to their input in the final EIS.<sup>112</sup> Indeed, perhaps more than any social system, the legal system shows how “[f]eedback control can blend powerful but sloppy actuators with ultraquality sensors to create systems that approach the power of the actuators and the ultraquality of the sensors.”<sup>113</sup>

#### IV. SYSTEMIC RISK

With the basic components of complexity, robustness, and fragility defined, it is time to put them together into a theory of system failure. How is it that a robust complex adaptive system such as law, with all its fail-safe mechanisms guarding against failure, nonetheless fails, usually locally but sometimes catastrophically? Alderson and Doyle argue that, paradoxically, the causal source is the “complexity in highly organized systems [that] arises primarily from design strategies intended to create robustness.”<sup>114</sup> Alderson and Doyle devote their work to supporting this claim in their general model; in this Part, I do so in the focused context of legal systems.

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109. Alderson & Doyle, *supra* note 1, at 841–42.

110. See Jack M. Balkin, *Respect-Worthy: Frank Michelman and the Legitimate Constitution*, 39 TULSA L. REV. 485, 494 (2004) (“[T]he legitimacy of the system requires that there be some method of feedback—whether formal or informal—through which members of the political community can critique and change the dominant understandings of the constitutional/legal system. In terms of the American constitutional system, with its practice of judicial review, there must be formal or informal methods through which protestant constitutional interpreters can shape, influence, and affect judicial interpretations of the Constitution.”); Wulf A. Kaal, *Evolution of Law: Dynamic Regulation in a New Institutional Economics Framework* 4 (Univ. of St. Thomas Sch. of Law, Legal Studies Research Paper No. 13-17, 2013), available at <http://ssrn.com/abstract=2267560> (“Feedback effects may occur both between outcomes and institutions and between different rulemakers. Rules and rulemaking processes interact and evolve over time.”).

111. Susan Bandes, *We Lost It at the Movies: The Rule of Law Goes from Washington to Hollywood and Back Again*, 40 LOY. L.A. L. REV. 621, 623 (2007) (“[A] feedback loop exists between law and popular culture . . . that . . . has consequences for the shape of the legal system.”).

112. See 40 C.F.R. § 1503.1 (2012).

113. Alderson & Doyle, *supra* note 1, at 842.

114. *Id.* at 840.

*A. Organization Breeds Complexity*

One way of thinking of the legal system is as an enormous collection of fail-safe strategies for managing system constraints. Law's relations with other social systems—and law's internal set of rules—are designed to deliver higher quality components, redundancy, sensors, and feedback to actuators. As a system among the multitude of social systems, law's aim is to regulate constraints and failures the other social systems face: people killing people (criminal law), people dumping waste in rivers (environmental law), people not living up to agreements (contract law), people arguing over what constitutes income (tax law), and so on. Law, in this sense, is a fail-safe strategy for other social systems. Yet the legal system has layers of fail-safe strategies for its own internal constraints: appellate judges review lower court decisions, rules of civil procedure direct lawyers how to act, several agencies may have overlapping jurisdiction, and so on. Every feature in our modern legal system is, at bottom, part of a fail-safe strategy for managing constraints on the functionality of other social systems or of the legal system itself.

This collection of fail-safe strategies enhances legal system robustness, but it also increases its complexity. The proliferation of components, sensors, redundancies, feedback mechanisms, and actuator protocols between the legal system and other systems, and within the legal system, connect components across and within systems. As these design strategies are incorporated into the system architecture, the system components become “arranged in a very specialized structure that enables their functionality and/or robustness features.”<sup>115</sup> The organization of the system “is essentially the specialized structure that allows a system to satisfy the aforementioned constraints.”<sup>116</sup> But as more fail-safe strategies are added, interconnectedness, and thus complexity, also increases.

This tradeoff between fail-safe-produced robustness and organized complexity is evident in legal systems. For example, Jody Freeman and Jim Rossi offer a probing analysis of the pros and cons of delegated agency redundancy in regulatory systems.<sup>117</sup> While lauded by some as a source of regulatory system robustness,<sup>118</sup> Freeman and Rossi point out the barriers redundancy can present to effective governance, many of which stem from coordination problems.<sup>119</sup> Their solution, however, is to employ yet another fail-safe strategy—feedback to actuators—as they describe various ways to enhance interagency coordination within the multiagency “shared regulatory space.”<sup>120</sup> While their coordination facilitation proposals may reduce the adverse effects of redundancy, the stepped-up feedback structure of their vision of interagency coordination necessarily builds yet more organized complexity in the relevant system of agencies. This is not to say their proposals are not salutary, only that we must recognize that they carry with them the baggage of added system organization and complexity.

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115. *Id.*

116. *Id.* at 841.

117. *See generally* Freeman & Rossi, *supra* note 97.

118. *See* Adelman & Engel, *supra* note 56.

119. *See* Freeman & Rossi, *supra* note 97, at 1135–55.

120. *See id.* at 1181–91.

Indeed, Alderson and Doyle argue that “most of the complexity in highly engineered or evolved systems is in control processes that regulate the internal state and respond to external changes.”<sup>121</sup> In other words, “complexity in highly organized systems arises primarily from design strategies intended to create robustness.”<sup>122</sup> In short, system organization breeds system complexity.

After centuries of incorporating fail-safe strategies growing ever more diverse and targeted, the American legal system is perhaps one of the most stunning examples of organized complexity among all social systems. The full scope of its organizational architecture—codes of statutes and regulations, court systems, agency structures, common law doctrine—exceeds the grasp of any person, even highly experienced lawyers. Political scientist and law professor Daniel Katz and his colleagues have produced truly astounding case studies of law’s vast and nearly impenetrable networks of organization.<sup>123</sup> As one example of their body of work, consider the abstract for *A Mathematical Approach to the Study of the United States Code*:

The *United States Code* (Code) is a document containing over 22 million words that represents a large and important source of Federal statutory law. Scholars and policy advocates often discuss the direction and magnitude of changes in various aspects of the Code. However, few have mathematically formalized the notions behind these discussions or directly measured the resulting representations. This paper addresses the current state of the literature in two ways. First, we formalize a representation of the *United States Code* as the union of a hierarchical network and a citation network over vertices containing the language of the Code. This representation reflects the fact that the Code is a hierarchically organized document containing language and explicit citations between provisions. Second, we use this formalization to measure aspects of the Code as codified in October 2008, November 2009, and March 2010. These measurements allow for a characterization of the actual changes in the Code over time. Our findings indicate that in the recent past, the Code has grown in its amount of structure, interdependence, and language.<sup>124</sup>

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121. Alderson & Doyle, *supra* note 1, at 842.

122. *Id.* at 840.

123. See Michael J. Bommarito II & Daniel M. Katz, *A Mathematical Approach to the Study of the United States Code*, 389 PHYSICA A 4195 (2010); Michael J. Bommarito II, Daniel Martin Katz, Jonathan L. Zelner & James H. Fowler, *Distance Measures for Dynamic Citation Networks*, 389 PHYSICA A 4201 (2010); Michael J. Bommarito II, Daniel M. Katz & Jonathan L. Zelner, *On the Stability of Community Detection Algorithms on Longitudinal Citation Data*, 4 PROCEDIA SOCIAL & BEHAV. SCI. 26 (2010); Daniel M. Katz & Derek K. Stafford, *Hustle and Flow: A Social Network Analysis of the American Federal Judiciary*, 71 OHIO ST. L.J. 457 (2010); Michael J. Bommarito II, Daniel Katz & Jon Zelner, *Law as a Seamless Web? Comparison of Various Network Representations of the United States Supreme Court Corpus (1791–2005)* (June 3, 2010), available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1419525](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1419525).

124. Bommarito & Katz, *supra* note 123, at 4195.

Playing off of this description of their and other network theorists' work, any lawyer could follow along in this thought experiment: Arrange each title of the U.S. Code as nodes in a network. In layers starting below each node, add nodes for each title's major divisions, then again for the next subdivision, and so on down to the final sub-sub-sub-etc.-sections, connecting nodes in each branch with red connectors, so that you have constructed what looks like a hierarchy chart for each Code title. Now put connectors between any node within a single branch that cross-references a node in a different branch in that same Code title's hierarchy, and color all those connectors blue. Next put connectors between cross-referenced nodes from different Code titles and color those green.<sup>125</sup> Now repeat that same representation of interconnectedness for the Code of Federal Regulations, and then place connectors between the two networks to represent cross-references between the statutes and regulations. Do this for the legislation and regulations of all fifty states as well, and then add all the cross-jurisdictional references. Finally, turn the system "on" so all nodes and connectors are followed in real time, flashing or disappearing as they are activated through additional cross-references, new enactments, amendments, repeals, and so on.

With enough terabytes, computer power, and data collection this coarse network representation of law's organization could be constructed, refined, and studied to give us an eye into law's complexity.<sup>126</sup> My sense is that confident explanations for what is going on in the system would be elusive. Of particular interest for my purposes would be events such as rapid growth or decay in sectors of network structure, long periods of illumination or darkness in sectors of the system, bursts of illumination, and correlations between areas of activity or inertia in the system, as well as between activity or inertia in other social systems. While all that would be fascinating, however, the core question for my purposes is whether there is any way of knowing whether particular network structures, growth and decay, darkness and illumination, bursts of brightness, and other events tell us anything about the system's functionality and risk of failure. Katz's work suggests the structure, interdependence, and language of the legal system—its organized complexity—has grown<sup>127</sup> to what some have suggested are incomprehensible proportions.<sup>128</sup> But why if it is so impressively organized does it so frequently fail? Complexity science provides insights.<sup>129</sup>

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125. For a graphic representation of what this might look like, see *id.* at 4197 fig.1, and Romain Boulet, Pierre Mazzega & Danièle Bourcier, *Network Analysis of the French Environmental Code*, in *AI APPROACHES TO THE COMPLEXITY OF LEGAL SYSTEMS* 39, 43 fig.1 (Pompeu Casanovas et al. eds., 2010).

126. The tools of modern complex network science would allow for even more diverse and granular metrics and analytic tools than I have described here. See generally MILLER & PAGE, *supra* note 8.

127. See Ruhl & Salzman, *supra* note 22, at 770–75 (offering some metrics and statistics on growth of rules in the legal system); Shavell, *supra* note 46, at 575–76 (discussing growth in expenditures and number of lawyers).

128. See RICHARD A. EPSTEIN, *SIMPLE RULES FOR A COMPLEX WORLD* (1995); Bayless Manning, *Hyperlexis: Our National Disease*, 71 *NW. U. L. REV.* 767 (1977).

129. The study of failure has become a popular topic. Several noteworthy treatments of the subject, drawing in varying degrees from complexity science themes, include MARK

*B. Complexity Breeds Systemic Risk*

When the legal system has not succeeded in avoiding a failure in another social system or in the legal system itself, the call for new or reformed legal institutions and instruments can be deafening. In other words, we design more fail-safe strategies to patch up the problems the previous set did not adequately manage. As remedial as this may be at the microscopic scale of the particular problem under scrutiny, the macroscopic effects of applying this approach repeatedly should not be ignored. When more fail-safe strategies are added to the system, interconnectedness increases, which increases organization, which increases complexity. Robustness to the problem may be enhanced; however, exposure to failure also increases. In short, “[a]s systems become more complex, the number of points of failure inevitably also increases, and even the most experienced and intelligent individual cannot comprehend all possible failure scenarios with proactive risk analysis.”<sup>130</sup>

There are several causal sources for this paradoxical effect. The first is what I will call the *novel perturbation problem*. System robustness generally is designed for known sources of perturbation. The particular system control organization that develops over time to enhance robustness to the known problems, however successful in that respect, may unwittingly be highly susceptible to failure from a different, previously unknown (or at least unexpected) type of perturbation that just happens to expose a fragility in the system architecture that was not relevant to the previous set of perturbations.<sup>131</sup> A levee system, for example, might be designed to be highly effective against flooding, but if the area was not prone to earthquakes the design might not take that risk into account. A freak earthquake thus could expose the system to devastating failure.<sup>132</sup>

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BUCHANAN, UBIQUITY: WHY CATASTROPHES HAPPEN (2000); DIETRICH DÖRNER, THE LOGIC OF FAILURE (Rita Kimber & Robert Kimber trans., 1996) (1989); PAUL ORMEROD, WHY MOST THINGS FAIL (2005); CHARLES PERROW, NORMAL ACCIDENTS (1984).

130. Eric Fielding, Andrew W. Lo & Jian Helen Yang, The National Transportation Safety Board: A Model for Systemic Risk Management 34 (Nov. 14, 2010), *available at* <http://ssrn.com/abstract=1695781>.

131. Alderson & Doyle, *supra* note 1, at 842.

132. For an expansive treatment of the “novel perturbation” problem ranging from abstractions and musings to deep philosophical insights and formal mathematical ideas, see generally NASSIM NICHOLAS TALEB, THE BLACK SWAN: THE IMPACT OF THE HIGHLY IMPROBABLE (2d ed. 2010). Although Taleb seems at times to claim discovery of the novel perturbation problem, the idea has been at the core of complexity science since its inception, see MURRAY GELL-MANN, THE QUARK AND THE JAGUAR: ADVENTURES IN THE SIMPLE AND THE COMPLEX 123–34 (1994), though Taleb’s work has certainly popularized and refined it. Taleb’s second edition of the book added a postscript on robustness and fragility which, while mostly rambling personal musings, contains kernels of the RYF dilemma model. See TALEB, *supra*, at 305–29. His latest book, on his concept of “antifragility,” is in the same vein. See NASSIM NICHOLAS TALEB, ANTIFRAGILE: THINGS THAT GAIN FROM DISORDER (2012). *But see* N.N. Taleb & R Douady, Mathematical Definition, Mapping, and Detection of (Anti)Fragility (Aug. 2012), *available at* <http://ssrn.com/abstract=2124595> (developing a dense, formal model of antifragility, the property of increasing robustness to volatility). Although I enjoy and recommend reading Taleb’s work, and it is chock full of wonderful examples and insights, I find it difficult to extract a coherent theory, likely because Taleb

The second reason is what I will call the *shifted risks problem*. Investment in one type of fail-safe strategy might enhance its contribution to robustness but shift more risk to other fail-safe mechanisms not yet ready for the challenge because their fragilities had been masked by the previous failures of the now-improved component.<sup>133</sup> In the levee example, this could happen if the levee walls are raised in one area to stop frequent spillovers, but then downstream areas are revealed to be unprepared to receive higher flood levels that result as the high water is funneled downstream.<sup>134</sup> Their fragility was masked by the fragility of the upstream levee.

The third reason is what I will call the *failure cascade problem*. As system organization becomes more complex, even slight perturbations could have cascading and ultimately catastrophic consequences through the tightly interconnected system.<sup>135</sup> A sensor malfunction, for example, could send the wrong feedback signal to a system actuator that then sets off a chain of miscued signals down multiple connected feedback chains. In the levee example, if based on erroneous information an upstream floodgate operator takes the wrong action—say, by releasing too much floodwater—the effects can literally flow downstream to trigger actions and consequences of vast proportions.

Finally, there is what I will call the *spillover effect problem*. Adding a fail-safe strategy into the system could prove highly effective at addressing the target problem, but doing so also necessarily alters the system architecture. This reconfiguration could possibly have unintended effects at seemingly distant or unrelated places in the system, effects that expose a previously unknown fragility.<sup>136</sup> For example, building a levee system to withstand earthquakes, to manage river levels along the entire river, and with improved information sources very well might reduce flood damages, but it also may induce people and businesses to move into the floodplain so that when a failure does occur it actually imposes vastly higher damages.

The result of novel perturbations, shifted risks, failure cascades, and spillovers is the paradox that the “control systems are the primary source of RYF in complex systems, since the same systems that provide robustness under normal operating conditions can yield extreme fragilities if they fail or are hijacked.”<sup>137</sup> Fragility is, in this sense, an emergent property: Taken alone, every fail-safe strategy might

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openly purports to disdain theory. To be sure, overtheorization is of little practical value, but undertheorization has its downside as well—observations without theory are just observations.

133. Alderson & Doyle, *supra* note 1, at 842. Alderson and Doyle observe, for example, that enhancements in ultraquality computer hardware have shifted fragilities from hardware failures to software issues, such as exposure to viruses.

134. This kind of upstream-downstream tension is rampant in flood control and frequently leads to litigation, a current example involving federal government decisions regarding management of the 2011 Mississippi River flooding. *See, e.g.,* Quebedeaux v. United States, No. 11-389L, 2013 WL 4479834 (Fed. Cl. Aug. 20, 2013); Big Oak Farms, Inc. v. United States, 105 Fed. Cl. 48 (2012).

135. Alderson & Doyle, *supra* note 1, at 843. The cascade effect is a major study focus in ecology and ecosystem management sciences. *See* CHRISTENSEN ET AL., *supra* note 24, at 672 box 4 (“Trophic cascades are striking illustrations of the links between population dynamics and ecosystem processes.”).

136. Alderson & Doyle, *supra* note 1, at 843.

137. *Id.* at 842.

seem beautifully designed to handle its discrete target problem, but fragility nonetheless emerges from the system of fail-safe strategies. Adding yet more fail-safe mechanisms when the control system fails thus only adds to the emergent effect. As Alderson and Doyle explain:

[T]he emergence of complexity can often be seen as a spiral of new challenges and opportunities that organisms and/or technologies exploit, but which also lead to new fragilities, often from novel perturbations. When successful, fragilities are met with increasing complexity and robustness, which, in turn, creates not only new opportunities but also new fragilities, and so on. Managing or, ideally, preventing this “RYF complexity spiral” remains a central challenge in engineering, medicine, and human society.<sup>138</sup>

This RYF complexity spiral effect goes far in explaining what has in other contexts, particularly that of the financial sector, been referred to as “systemic risk.” Although there is no universal definition of financial systemic risk, two leading scholars on the topic, Iman Anabtawi and Steven Schwarcz, adopt one that captures the core problem:

[T]he risk that (i) an economic shock such as market or institutional failure triggers (through a panic or otherwise) either (X) the failure of a chain of markets or institutions or (Y) a chain of significant losses to financial institutions, (ii) resulting in increases in the cost of capital or

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138. *Id.* (footnote omitted). Cast at a much larger social scale, archaeologist Joseph Tainter’s work on societal collapse in which he postulates, based on extensive research on past societal-scale collapses, that social systems become more complex as they solve successive problems, and that eventually bearing the load of this increasing complexity itself becomes a problem requiring problem solving, which yields yet more complexity, and so on. Eventually the net benefit of more problem solving (i.e., of more complexity) becomes negative, and the society spirals into collapse. See JOSEPH A. TAINTER, *THE COLLAPSE OF COMPLEX SOCIETIES* (1988); Joseph Tainter, *Social Complexity and Sustainability*, 3 *ECOLOGICAL COMPLEXITY* 91 (2006). Tainter’s work has been profoundly influential, particularly in its challenge to the idea that so-called sustainable development is a possibility. See Karl W. Butzer, *Collapse, Environment, and Society*, 109 *PROC. NAT’L ACAD. SCI.* 3632 (2012) (without mentioning Tainter, arguing that past societal collapses are most attributable to incompetent governance, war, and pestilence, and that modern states are more equipped to handle these forces and thus less subject to collapse); Samuel Alexander, *Resilience Through Simplification: Revisiting Tainter’s Theory of Collapse* (Simplicity Inst. Report 12h, 2012), available at <http://ssrn.com/abstract=2095648> (challenging Tainter’s gloomy conclusion that sustainable development is not sustainable, arguing that “voluntary simplification” can reduce the complexity burden). In any case, Tainter’s work is not focused on the local shock-system failure problem of systemic risk taken up next in the text and which is my primary concern, so I do not weigh in on the explanatory value of his theory. On the other hand, if there is anything to Tainter’s theory, high systemic risk—that is, small shocks frequently leading to cascading failures in law and other social systems—is likely one indicia of a society passing the collapse tipping point he describes.



decreases in its availability, often evidenced by substantial financial-market price volatility.<sup>139</sup>

In less formal terms, they describe systemic risk as the propensity of the system “to transmit a localized adverse economic shock throughout the financial system, amplifying it in the process.”<sup>140</sup> Importantly, systemic risk theory emphasizes that it is not the size of the shock that matters most in triggering such a failure, as “even small random fluctuations may lead to full cascades if critical conditions are met.”<sup>141</sup> Rather, “systemic risk depends much more on ingredients such as the network structure, the safety margin and threshold distribution.”<sup>142</sup> The shock matters, but system organization matters more. Indeed, “[t]he threat is complexity itself.”<sup>143</sup>

Legal scholars dating back to the 1980s have written about systemic risk in financial systems,<sup>144</sup> but the recent global financial crisis has spawned a plethora of work on the topic focused on understanding system-wide effects. In their most recent work, for example, Anabtawi and Schwarcz develop a theory of the mechanisms of systemic risk. Although they do not adopt a complexity science model to explain these mechanisms, they do identify what they call the complexity of the financial system as being a result of, among other things, its structure as “a complex ‘network’ comprised of institutions, or ‘nodes,’ that are both interconnected and interactive.”<sup>145</sup> They dig deeper into financial system complexity, discussing the many ways in which the institutions are connected and the feedback effects that can lead to a “domino model of contagion.”<sup>146</sup> Another legal scholar working on systemic risk in the financial system, Lawrence Baxter, more rigorously employs complexity science to explain the system’s increasing complexity and the resulting exposure to fragility and cascading failures.<sup>147</sup>

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139. Anabtawi & Schwarcz, *supra* note 11, at 1353 (alteration in original) (quoting Steven L. Schwarcz, *Systemic Risk*, 97 GEO. L.J. 193, 204 (2008)).

140. *Id.* at 1355–56.

141. Claudio J. Tessone, Antonios Garas, Beniamino Guerra & Frank Schweitzer, *How Big Is Too Big? Critical Shocks for Systemic Failure Cascades*, 151 J. STAT. PHYSICS 765, 765 (2013).

142. *Id.* at 782; *see also* MITCHELL, *supra* note 6, at 255–57 (explaining system form as the channel for cascading failures).

143. MITCHELL, *supra* note 6, at 257 (internal quotation marks omitted).

144. *See, e.g.*, Helen A. Garten, *Regulatory Growing Pains: A Perspective on Bank Regulation in a Deregulatory Age*, 57 FORDHAM L. REV. 501, 560–61 (1989) (“[T]he goal of bank regulation, to prevent losses to the banking system as a result of bank failure, makes the regulatory system overinvested in particular banks whose failure poses systemic risks.”); Michael Gruson, *The Global Securities Market: Introductory Remarks*, 1987 COLUM. BUS. L. REV. 303, 308 (“What we should be concerned about is systemic risk—the risk arising from the systems of the international market as such—not the risk which relates to the individual investor or even an individual institution. Given the size of today’s predominant financial players, the failure of one could affect the whole market.”).

145. Anabtawi & Schwarcz, *supra* note 11, at 1371.

146. *Id.* at 1371–72.

147. Lawrence G. Baxter, *Betting Big: Value, Caution and Accountability in an Era of Large Banks and Complex Finance*, 31 REV. BANKING & FIN. L. 765, 852–68 (2012); *see*

Although not framed in the lexicon of the RYF dilemma model, much of what these legal scholars have to say resonates in Alderson's and Doyle's lament that "almost nothing appears sustainable in the long run, and catastrophic cascading fragilities seem increasingly commonplace."<sup>148</sup>

What is largely missing from the legal scholarship on systemic risk in the financial system, however, is an appreciation of the RYF complexity spiral and law's role in it. Anabtawi and Schwarcz, for example, position their work as identifying the financial system failures that led to the crisis and aim to "show that government can disrupt the transmission of systemic risk by addressing these failures."<sup>149</sup> Much of their work is devoted to proposing "policy tools for correcting such failures."<sup>150</sup> This is all well and good—it has to be thought about—but as the RYF dilemma model shows, it must be thought about with the RYF complexity spiral in mind, and not only for the financial system, but also for the legal system. In other words, as we invent and implement regulatory fail-safe measures are we unwittingly feeding the RYF complexity spiral not just in the financial system, but in the legal system as well?

With the exception of Baxter—who may be the exception because he uses a complexity science perspective—legal scholars of systemic risk do not anticipate this paradox. Baxter, however, recognizes that the many problems he and others identify in the structure of the financial system are just the tip of the iceberg:

[T]he problem is even deeper and more paradoxical because an additional dimension of complexity has also begun to manifest itself in the form of "regulatory complexity." Regulatory complexity stems not only from the huge volume of new regulations and regulators being hurled at the financial industry in an attempt to reduce the risk of financial instability, but also from the inherent contradictions in our public policy objectives, overlaps in agency missions, and the ebb and flow of political accountability that applies to regulators.<sup>151</sup>

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also Manuel A. Utset, *Complex Financial Institutions and Systemic Risk*, 45 GA. L. REV. 779 (2011) (emphasizing interconnectedness); Dimitrios Bisiias, Mark Flood, Andrew W. Lo & Stavros Valavanis, *A Survey of Systemic Risk Analytics* (U.S. Dep't of Treasury Office of Fin. Research, Working Paper No. 0001, 2012), available at [http://www.treasury.gov/initiatives/wsr/ofr/Documents/OFRwp0001\\_BisiiasFloodLoValavanis\\_ASurveyOfSystemicRiskAnalytics.pdf](http://www.treasury.gov/initiatives/wsr/ofr/Documents/OFRwp0001_BisiiasFloodLoValavanis_ASurveyOfSystemicRiskAnalytics.pdf) (although not explicitly adopting a complexity science analysis, detailing the numerous interconnected components of the financial system leading to systemic risk).

148. Alderson & Doyle, *supra* note 1, at 843.

149. Anabtawi & Schwarcz, *supra* note 11, at 1352.

150. *Id.* at 1381.

151. See Baxter, *supra* note 147, at 863–64 (footnotes omitted). Lynn Stout has more directly blamed legal failure—specifically, an obscure 2000 federal statute changing the rules for derivatives trading—for the financial system crisis, concluding that "the credit crisis was not due primarily to changes in the markets, it was due to changes in the law." Lynn A. Stout, *The Legal Origin of the 2008 Credit Crisis*, (UCLA Sch. of Law, Law-Econ Research Paper No. 11-05, 2011), available at <http://ssrn.com/abstract=1770082>. Although I do not have sufficient expertise in financial system regulation to evaluate claims like this, it is perfectly consistent with the RYF model that relatively minor tinkering within the complex financial regulatory system could lead to a cascade of failures.

Although Baxter does not develop the idea further, he clearly is on to something if one puts any stock in the RYF dilemma model. As I have suggested above, the legal system is in essence a social system for producing fail-safe mechanisms to manage systemic risk in other social systems (and within law).<sup>152</sup> As Baxter suggests, the paradoxical effect of “hurling” these fail-safes without attention to their complexity effects can be to add to rather than decrease systemic risk.<sup>153</sup> But even his focus is on how these regulatory fail-safes affect systemic risk of the *other* systems, whereas my focus is on their effects on systemic risk in the *legal* system.<sup>154</sup> Given the root cause of systemic risk, there is no reason to believe that the financial system is alone among social and economic systems in being susceptible to systemic risk, or that the legal system is immune to it. Some level of systemic risk is present in all complex adaptive systems, and the legal system arguably is as tightly interconnected and interdependent as any other. So when we invent regulatory fail-safes and “hurl” them at other social systems, we must also be mindful of managing their effects on the legal system that produced them.<sup>155</sup>

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152. See *supra* Part IV.A.

153. See Baxter, *supra* note 147, at 863–64. In their study of railway disasters, Lloyd Burton and M. Jude Egan describe the “hurling” response that often follows railway accidents as “reactive legislation, which will once again lead to reactive regulation.” Lloyd Burton & M. Jude Egan, *Courting Disaster: Systemic Failures and Reactive Responses in Railway Safety Regulation*, 20 CORNELL J.L. & PUB. POL’Y 533, 550 (2011) (emphasis omitted).

154. Similarly, Aviv Pichhadze has developed a theory of “regulatory systemic risk” that “arises from long-term imbalances that result from regulatory initiatives that are premised on a distorted understanding of market realities.” Aviv Pichhadze, *Regulatory Systemic Risk in US Securities Regulation*, LAW & FIN. MARKETS REV., May 2011, at 176, 176. While potentially an important observation for understanding financial market failure, the problem he identifies is not about systemic risk in the regulatory system itself, but how poorly designed regulatory systems—that is, ones not aligned with “market realities”—can contribute to systemic risk in the financial system. Good alignment with “market realities,” however, will not necessarily eliminate systemic risk in the regulatory system; indeed, it could increase or decrease legal systemic risk depending on how the regulatory system is designed to align with the market systems.

155. My brother and I suggested a dynamic something like the RYF complexity spiral at work in the legal system in an article we published many years ago. See J.B. Ruhl & Harold J. Ruhl, Jr., *The Arrow of the Law in Modern Administrative States: Using Complexity Theory to Reveal the Diminishing Returns and Increasing Risks the Burgeoning of Law Poses to Society*, 30 U.C. DAVIS L. REV. 405, 461–67 (1997). We argued that a new law might respond adequately to its target policy problem, but that spillover effects could generate other social problems, thus triggering new law initiatives, and so on into a “cycle of law” that builds “structural complexity” which, if the cycle runs unabated, “reaches levels of interconnectedness and intensity that pose the problem of increasing vulnerability to collapse.” *Id.* at 456, 467. Complexity science was nascent at the time, and our model leaned heavily on anthropological theory—for example, TAINTER, *supra* note 138. Having the benefit of over a decade of advancements in complexity science, I find the RYF model a more complete theoretical home for examining the spiral toward increasing complexity in legal systems.

## V. MANAGEMENT

Given that the legal system's organized complexity necessary for robustness is also what gives rise to the system's fragility, the two properties are stuck in the perpetual paradox of the RYF dilemma: any effort to reduce fragility by reducing organization would also reduce robustness, but increasing organization to increase robustness also increases fragility. The trick is to not fall into the RYF complexity spiral. As Alderson and Doyle suggest, without attention to this dilemma and the potential to enter its spiral, "[i]n the worst case, we might build increasingly complex and incomprehensible systems that will eventually fail completely yet cryptically."<sup>156</sup> Clearly, then, for law as for other social systems, "we need to better manage the tradeoff between functional robustness and emergent fragility."<sup>157</sup> While no management strategy will completely overcome the intrinsic RYF dilemma, Alderson and Doyle believe "we should be able to minimize the potential risk of catastrophic failure."<sup>158</sup> They recognize, however, that "there is little consensus on even the most basic strategies to avoid this in real-world networks."<sup>159</sup> The legal system offers a prime example, with legal scholarship mired in countless debates over what to do to improve its performance.

Leaning heavily on Alderson and Doyle's theory thus far, I argue here that their RYF dilemma model provides tremendous insight for building more consensus on systemic risk management strategies for the legal system. Note that I use the term *management* and not *control*. I do so to capture the necessary orientation for even beginning to think about influencing risk levels within legal systems. Direct, proactive control is for all practical purposes beyond our grasp. To be sure, we do have the power to intervene, but that's not the same as control—indeed, our power of intervention is part of the problem, isn't it? The difficulty of achieving *control* of a complex adaptive system

is rooted in the fact that two independent factors contribute to controllability, each with its own layer of unknown: (1) the system's architecture, represented by the network encapsulating which components interact with each other; and (2) the dynamical rules that capture the time-dependent interactions between the components. Thus, progress has been possible only in systems where both layers are well mapped . . . .<sup>160</sup>

My premise is that we have not yet "well mapped" both of these layers for our legal system. Research like that by Katz and others is advancing our knowledge for the architecture layer, but it is still quite nascent. Our knowledge of the dynamical rules layer is even more primitive. We may like to think we know how the legal system works and have it under our control, but then what explains legal-system

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156. Alderson & Doyle, *supra* note 1, at 851.

157. *Id.*

158. *Id.*

159. *Id.*

160. Yang-Yu Liu, Jean-Jacques Slotine & Albert-László Barabási, *Controllability of Complex Networks*, 473 NATURE 167, 167 (2011).

meltdowns? Rather, at most we can hope to design, monitor, learn, and respond with more design, optimistically thinking we know enough to adaptively manage legal systemic risk problems over time.

As a starting point for doing so, consider the original question: How would you design a legal system to be robust? What does a robust system look like—how does one assemble all the elements into a system architecture that makes it robust and minimizes systemic risk? Alderson and Doyle summarize the prototype of such a system:

1) They are highly modular (versus integrated); 2) they use diverse components that are imperfect (versus perfect); 3) they have late (versus early) binding of functionality. This allows for 4) a diversity of evolvable (versus frozen) capabilities and behavior; and 5) these systems have fast (versus slow) pace of change, and adaptive (versus preplanned) behavior via distributed (versus centralized) control, with extensive use of feedback.<sup>161</sup>

This set of attributes emphasizes two overarching themes. First, of the qualities of robustness, the prototype stresses modularity, scalability, and evolvability over reliability and efficiency. Second, of the fail-safe techniques, the prototype stresses redundancy, sensors, and feedback over ultraquality components. The core idea is to avoid constructing a rigid, highly integrated network of ultraquality, homogenous components with few sensors and centralized system actuators. Such a system might be robust for certain purposes, but it also is more likely to be susceptible to catastrophic failure cascades if a component fails—it is a short, direct, and unchallenging route up the few feedback loops to the centralized system actuator. Investing in component perfection and cutting out redundancy and other system “fat” in the quest for efficiency thus may seem prudent when everything is going smoothly, but may come back to haunt when a storm approaches. Instead, decentralized but extensive feedback networks hooked up to a modular and diverse array of system actuators are more likely to cut off a cascading failure chain, because more system actuators are available for receiving alerts, feedback can be rerouted, and system components can be switched out. The key is to be mindful of the potential for buildup of organized complexity in such a system by building in a sensor subsystem that looks *internally* for evidence of systemic risk.

Paradoxically, therefore, the success strategy for managing systemic risk in complex social systems is about investing in some inefficiency and sloppiness as well as self-monitoring. To be sure, it is not as if such a system has zero systemic risk—that is not possible. Rather, this kind of system is built around the assumption of inherent systemic risk and is designed to be on the watch for it and spring into action when signs of danger surface. Obviously, reliability, efficiency, and quality matter, and some hierarchy of system actuators may be necessary, but if the costs of system failure are potentially catastrophic, design for systemic risk management should be a priority. Through a case study and exploration of risk management techniques, this Part explores how to implement such a design priority.

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161. Alderson & Doyle, *supra* note 1, at 841.

*A. Legal Failure Case Study—The Deepwater Horizon Oil Spill*

The *Deepwater Horizon* disaster provides a rich context for translating this theory into practice. Although it may seem unusual to use an oil well blowout as an example of legal systemic risk when most of the legal scholarship on systemic risk focuses on financial systems, there are several good reasons for doing so. One is to provide a more generalizable theory of legal systemic risk by demonstrating that it applies outside the context of financial system regulation. Another reason is that, to be candid, it is easier in the *Deepwater Horizon* context to isolate and explain the legal systemic risk than it is in the financial crisis context. As legal systems go, the financial regulation system is dauntingly complex, and a full grasp is far outside the scope of coverage here. *Deepwater Horizon* represents a smaller-scale failure, to be sure, but nonetheless the story illustrates how discrete modules of the legal system (here, offshore oil drilling regulation) can crash catastrophically.

Also, and perhaps most saliently, the *Deepwater Horizon* event more clearly defines a critically important point for my purposes—that often times the contribution of legal systemic risk to social or economic catastrophe is masked by more visible and discrete causal forces, such as technological failures, human errors, and corporate malfeasance, stemming from systemic risk in the systems law regulates. As Alderson and Doyle put it, “‘human error,’ particularly when persistent, is often actually a symptom of system design problems.”<sup>162</sup> We must, therefore, “look[] past the proximal cause of any one observable failure to see whether it has merely triggered a fragility inherent to the system, one that should really be addressed with a system solution.”<sup>163</sup> Disaster policy experts Lloyd Burton and M. Jude Egan put this in practical terms in their discussion of the regulatory system failure lessons learned from a commuter rail disaster caused proximately by human error:

Human operator error is typically the first—and most agencies and firms hope—the last organizational refuge after an accident. The logic is that if the human operator failed in his duties—to err, after all, is human—then the system itself must not be broken. Blaming the human operator, and, if not the human operator, then malfunctioning equipment, tends to shield both industries and regulatory agencies from the costly and time-consuming process of governmental and public accident investigations that might reveal deliberate indifference and therefore necessitate systemic reforms—perhaps even some resignations.<sup>164</sup>

With those premises in mind, for my purposes all one needs to know about the *Deepwater Horizon* spill event itself is that it happened and was a spill of epic proportions, which everyone knows.<sup>165</sup> It was, in other words, the kind of event the legal system was supposed to help avoid. As extensive and damaging as the spill

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162. Alderson & Doyle, *supra* note 1, at 850.

163. *Id.*

164. Burton & Egan, *supra* note 153, at 536.

165. But if not, see DEEP WATER, *supra* note 2, at 173.

was, though, my concern here is what happened before the spill. In that respect, moreover, it is not necessary for me to describe and evaluate in detail the individual, corporate, and technological failures that contributed to causing the event; rather, my focus is on how the legal system regulating deep-water drilling failed in managing the risk of those events by failing to manage its own systemic risk. In other words, was the legal system designed robustly to manage *legal* systemic risk, and if not, how can it be reformed to improve performance in that respect?

### 1. Prelude

The 33,000-ton, \$350 million *Deepwater Horizon* drilling platform was considered the flagship of Transocean's fleet of offshore drilling rigs.<sup>166</sup> On April 20, 2010, under contract with BP America, it sat 4992 feet above BP's Macondo well, which at the time was six weeks behind schedule and \$58 million over budget.<sup>167</sup> Early that morning, and several times throughout the day, Halliburton Company engineers contracted by BP reported that they had successfully cemented the well to control pressure.<sup>168</sup> They were wrong.

The story of what went wrong on the rig takes up many pages, but according to the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling ("Commission") the immediate causes were "the product of several individual missteps and oversights by BP, Halliburton, and Transocean," all centering on the failure of the cement at the bottom of the well, the mud in the well and the riser piping, and the blowout preventer to contain hydrocarbon pressures in the well.<sup>169</sup> But there was more to it than that. Moving past blaming human errors for proximate causes, the Commission dug into the root causes and found among them the legal system:

The blowout was not the product of a series of aberrational decisions made by rogue industry or government officials that could not have been anticipated or expected to occur again. Rather, the root causes are systemic and, absent significant reform in both industry practices and government policies, might well recur. The missteps were rooted in systemic failures by industry management (extending beyond BP to contractors that serve many in the industry), and also by failures of government to provide effective regulatory oversight of offshore drilling.<sup>170</sup>

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166. *Id.* at 1–2.

167. *See id.* at 1–3.

168. *See id.* at 1–5.

169. *See id.* at 115.

170. *Id.* at 122. Groups of legal scholars from the Center for Progressive Reform have also published two studies of the blowout reaching similar conclusions. *See* ALYSON FLOURNOY, SIDNEY SHAPIRO, WILLIAM ANDREEN, THOMAS MCGARITY & JAMES GOODWIN, CTR. FOR PROGRESSIVE REFORM, *THE BP CATASTROPHE: WHEN HOBBOLED LAW AND HOLLOW REGULATION LEAVE AMERICANS UNPROTECTED* (2011) [hereinafter *BP CATASTROPHE*]; ALYSON FLOURNOY, WILLIAM ANDREEN, REBECCA BRATSPIES, HOLLY DOREMUS, VICTOR

To be sure, any failure by government to provide effective regulatory oversight can itself have many root causes, including inadequate resources, lack of political support, industry resistance, and human incompetence, all of which were in play in offshore drilling regulation.<sup>171</sup> It is beyond the scope of my coverage to detail each of these causal forces. But the Commission also zeroed in on a root cause of interest to me: the design architecture of the regulatory regime. Three features of that structure figured prominently in the Commission's analysis, and each maps easily onto the RYF dilemma model's lesson for how *not* to manage systemic risk.

First, the evolution of the nation's offshore drilling policy starting in the 1980s consolidated two conflicting system functions—getting energy and revenue out of the Gulf versus ensuring worker and environmental protection—into one system actuator—the Department of the Interior's Minerals Management Service (MMS).<sup>172</sup> From the time it was conceived in the early 1980s through the time of the *Deepwater Horizon* blowout, this single agency “would increasingly struggle to keep up with the pace of industry expansion, while juggling four distinct responsibilities—offshore leasing, revenue collection and auditing, permitting and operational safety, and environmental protection—requiring different skill sets and cultures.”<sup>173</sup> While perhaps promoting efficiency, this integrated, centralized regulatory structure sacrificed the modularity and diversity of components and actuators needed for management of systemic risk.<sup>174</sup>

Second, the MMS failed over time to manage its own RYF complexity spiral. Soon into its tenure, the MMS embarked, as it was supposed to, on regulation of the industry—to generate fail-safe measures. For example, MMS subjected oil and gas activities to “an array of prescriptive safety regulations” with “hundreds of pages of technical requirements.”<sup>175</sup> But the MMS “came progressively to suffer from serious deficiencies of organization and management.”<sup>176</sup> It lacked “a formal, bureau-wide compilation of rules, regulations, policies, or practices” and had “no formal process to promote standardization, consistency, and operational efficiency” across its many district offices.<sup>177</sup> In short, the MMS lost control of its increasingly organized complexity, which made it less effective at managing the industry's complexity.

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FLATT, ROBERT GLICKSMAN, JOEL MINTZ, DANIEL ROHLF, AMY SINDEN, RENA STEINZOR, JOSEPH TOMAIN, SANDRA ZELLMER & JAMES GOODWIN, CTR. FOR PROGRESSIVE REFORM, *REGULATORY BLOWOUT: HOW REGULATORY FAILURES MADE THE BP DISASTER POSSIBLE, AND HOW THE SYSTEM CAN BE FIXED TO AVOID A RECURRENCE* (2010) [hereinafter *REGULATORY BLOWOUT*]. The national commission investigating the financial crisis similarly concluded that “widespread failures in financial regulation and supervision proved devastating to the stability of the nation's financial markets.” *FINANCIAL CRISIS*, *supra* note 2, at xviii (emphasis omitted).

171. *DEEP WATER*, *supra* note 2, *passim*.

172. *See id.* at 63–67.

173. *Id.* at 67.

174. *See* Hari M. Osofsky, *Multidimensional Governance and the BP Deepwater Horizon Oil Spill*, 63 FLA. L. REV. 1077, 1107–09, 1126–28 (2011) (discussing this efficiency-modularity tradeoff in MMS structure).

175. *DEEP WATER*, *supra* note 2, at 68.

176. *Id.* at 78.

177. *Id.* (internal quotation marks omitted).



Third, the MMS essentially shut down its system sensors and feedback networks. One deactivated system sensor was NEPA, which as previously described is designed to promote agency predecisional consideration of environmental impacts.<sup>178</sup> A combination of congressional and MMS actions, however, changed the NEPA default rule for drilling in the Gulf to one of “categorical exclusion” from MMS review of industry activities unless the agency identified “extraordinary circumstances.”<sup>179</sup> In the cross-purposes structure of the agency, however, leasing personnel pressured science personnel against finding extraordinary circumstances even as drilling pushed into deeper and deeper Gulf waters.<sup>180</sup> As a result, the “MMS performed no meaningful NEPA review of the potentially significant adverse environmental consequences associated with its permitting for drilling of BP’s exploratory Macondo well.”<sup>181</sup> Similarly, although the Oil Pollution Act of 1990 (OPA) required industry to prepare, and the MMS to review, oil spill response plans including procedures to be followed in case of worst case spills,<sup>182</sup> the process deteriorated into a farce. BP’s plan for the Macondo well, for example, postulated 250,000 barrels as the worst conceivable spill (the spill was well over 4.5 million barrels), identified sea lions, sea otters, and walrus as among the species in the Gulf (they are not), and copied extensively from government resource agency websites.<sup>183</sup> MMS practices over time neutered numerous other environmental impact review laws,<sup>184</sup> to the point that the Commission concluded that “[n]otwithstanding statutory promises of layers of required environmental scrutiny . . . none of these laws resulted in site-specific review of the drilling operations of the Macondo well.”<sup>185</sup>

The combined effect of these three features of offshore drilling regulation was to erode the legal system’s capacity to manage its own systemic risk. The system was integrated (not modular), centralized (not decentralized), with one actuator (not many diverse actuators); it generated organized regulatory complexity to the point of falling into the RYF complexity spiral; and it snipped off all its environmental alert sensors. When drilling began to expand into deeper Gulf waters, the MMS might have at some threshold sensed that something was fundamentally different. It might have paused to examine *itself*, not only the industry, to explore whether its systems were operating robustly. But the entire system was free-falling in a failure cascade long before the *Deepwater Horizon* blowout—it was just a matter of when, not if. To be sure, other causal factors were in play, ranging from inadequate funding of the MMS to a myriad of failures with the industry,<sup>186</sup> but if law is expected to manage systemic risk in other systems, the regulatory structure that evolved over time for offshore drilling could not have helped. Indeed, it is as if it was designed to fail catastrophically.

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178. *See supra* text accompanying notes 105–07.

179. DEEP WATER, *supra* note 2, at 81–82.

180. *See id.* at 82.

181. *Id.*

182. *See id.* at 83–84.

183. *See id.* at 84.

184. *See id.* at 79–84.

185. *Id.* at 84 (emphasis in original).

186. *See id. passim.*

## 2. Postmortem

It is all too easy to look back on *Deepwater Horizon* and cast stones at the MMS, but the root problem wasn't just with the MMS or people within the agency—it was the system design that contributed to preventing the MMS from extracting itself from the slow burn to catastrophe, or even to see that it was in the failure cascade at all. Encouragingly, regulatory reform proposals following the blowout point in the right direction for reversing many of those design flaws.<sup>187</sup>

First, within weeks after the *Deepwater Horizon* blowout, Secretary of the Interior Ken Salazar put in motion an initiative to reorganize the MMS into three separate entities: the Bureau of Ocean Energy Management (BOEM), the Bureau of Safety and Environmental Enforcement (BSEE), and the Office of Natural Resources Revenue.<sup>188</sup> His instincts map well onto RYF systemic risk management theory. Disaggregating the MMS into the three agencies, each aligned with a different policy purpose, promotes a system modularity that better matches actuators with system functions and enables construction of more effective sensor and feedback networks.<sup>189</sup> Of course, funding, political oversight and pressure, and a host of other factors will determine how well the new design performs, but as a design matter the new structure is superior to the former.

There has been no shortage of proposals from the new agencies, Congress, legal scholars, and policy organizations for where to go from there. Not surprisingly, one major thrust has been to restore and strengthen the role of NEPA, OPA, and other environmental impact review laws in the offshore drilling regime.<sup>190</sup> This instinct also maps well onto RYF systemic risk management theory. Particularly with the reconstituted agency structure, activating a stronger sensor and feedback network linked to the environmental agency will better enable that system actuator to carry out its functions.

While there are many details to work out to implement the reconstituted actuator structure and the revival of a sensor and feedback network, these two reform thrusts are not so difficult to conceptualize and design. By contrast, other reform proposals focus on making the offshore drilling regulatory system more adaptive and more precautionary. These two themes, while consistent with RYF theory, impose difficult design problems.

The call for a more adaptive system focuses on regulatory designs that allow system actuators to respond adeptly to changes in the offshore drilling operating environment. This approach is in the bull's eye of RYF systemic risk management theory, but is also the most difficult to operationalize in our political system. The point of designing systems around modularity, scalability, evolvability, sensors, and

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187. I am for these purposes not focusing attention on tort and other remedial reform possibilities. See generally Robin Kundis Craig, *Legal Remedies for Deep Marine Oil Spills and Long-Term Ecological Resilience: A Match Made in Hell*, 2011 BYU L. REV. 1863.

188. DEEP WATER, *supra* note 2, at 55.

189. The Department has charted the division of functions at *An Overview of the Assignment of Regulations Between the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement*, BSEE.GOV, <http://www.bsee.gov/uploadedFiles/ChartBSEEOEMRegulatoryAuthorities.pdf>.

190. See, e.g., REGULATORY BLOWOUT, *supra* note 170.

feedback is to make them adaptive to shocks and local failures so the big failures can be averted. Clearly, as the Commission found, advances in drilling technology and industry expansion into the deep Gulf outstripped adaptive capacity in the MMS,<sup>191</sup> so it is natural to ask the BOEM and BSEE to be more adaptive. More generally, a rising theme in legal and policy scholarship on regulation is that agencies must be enabled to practice “adaptive management” to respond to change in the systems they regulate.<sup>192</sup> Few disagree with that in principle, but putting adaptive management into action has proven very difficult.<sup>193</sup> To put it bluntly, and without going into extensive detail here, with its intense focus on public participation in and judicial review of agency decisions, the conventional regulatory state is not designed for agencies to move quickly and adaptively.<sup>194</sup> I leave the design of administrative law for adaptive management to another day;<sup>195</sup> suffice it to say that it is a different legal systemic risk problem, one going well beyond offshore drilling regulation in its scope and potential for failure.

The call for a more precautionary system also is consistent with systemic risk management theory, which emphasizes design for a “safety margin” as essential,<sup>196</sup> particularly for dealing with the uncertainty of catastrophe.<sup>197</sup> But most of the legal scholars advocating this design feature can be read for the most part as demanding more and stronger regulation of the drilling industry.<sup>198</sup> Indeed, the BOEM and BSEE

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191. DEEP WATER, *supra* note 2, at 73 (“MMS was unable to maintain up-to-date technical drilling-safety requirements to keep up with industry’s rapidly evolving deepwater technology.”).

192. See J.B. Ruhl & Robert L. Fischman, *Adaptive Management in the Courts*, 95 MINN. L. REV. 424, 427–31 (2010).

193. See Craig R. Allen, Joseph J. Fontaine, Kevin L. Pope & Ahjond S. Garmestani, *Adaptive Management for a Turbulent Future*, 92 J. ENVTL. MGMT. 1339, 1341 (2011) (“[D]espite an illustrious theoretical history there has remained imperfect realization of adaptive management in [the] real world . . . .”); Craig R. Allen & Lance H. Gunderson, *Pathology and Failure in the Design and Implementation of Adaptive Management*, 92 J. ENVTL. MGMT. 1379, 1380 (2011) (“The implementation of adaptive management has proven to be difficult.”); Holly Doremus, *Adaptive Management, the Endangered Species Act, and the Institutional Challenges of “New Age” Environmental Protection*, 41 WASHBURN L.J. 50, 54 (2001) (“[S]kepticism about adaptive management comes from the lack of success stories to date.”); Carl J. Walters, *Is Adaptive Management Helping to Solve Fisheries Problems?*, 36 AMBIO 304, 304 (2007) (“[A]daptive management has been radically less successful than one would expect from its intuitive appeal.”).

194. See J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21, 34–53 (2005).

195. See, e.g., Robin Kundis Craig & J.B. Ruhl, *Designing Administrative Law for Adaptive Management*, 67 VAND. L. REV. 1 (2014).

196. See Tessone et al., *supra* note 141, *passim*.

197. See Daniel A. Farber, *Uncertainty*, 99 GEO. L.J. 901 (2011) (emphasizing precautionary principles to design for catastrophe uncertainty in regulatory systems).

198. One exception is Lori Bennear’s proposal to require offshore drilling operators to deposit an up-front bond to be refunded upon safe completion of the drilling activity. The bond would be priced at the estimated costs of a significant accident, but to promote better practices the price would be discounted for firms that earn high scores on independent third-party safety evaluations. See Lori S. Bennear, *Beyond Belts and Suspenders: Promoting Private Risk Management in Offshore Drilling*, in REGULATORY BREAKDOWN, *supra* note 2, at 49, 61–64.

have promulgated a comprehensive regulatory reform rule introducing many new regulatory requirements.<sup>199</sup> Surely, better management of systemic risk in offshore drilling was needed, and this new regulatory regime may deliver it. The question will be whether the new rules, as precautionary and powerful as they may be toward offshore drilling practices, initiate the kind of RYF complexity spiral in the legal system that MMS found itself in. Having a lot of regulations doesn't do much good if they are unmanageable. The instinct to hurl regulations at a problem is at its highest following a catastrophic failure cascade, but some lesson has to be taken from the fact that systemic risk in the legal system contributed to the catastrophe. MMS lost control of its own regulatory complexity; the BOEM and BSEE must avoid making the same mistake. There will be failures in offshore drilling, and the BOEM and BSEE must be careful not to react in knee-jerk fashion by inventing new fail-safes to paste on to the existing regulatory system without thinking about the systemic risk effects doing so generates within the regulatory system itself.

### *B. Moving Beyond Precaution and Adaptation*

Although adaptation and precaution are, with due care, appropriate design principles for managing legal systemic risk, they are not enough. As displayed in the post-blowout reform proposals, the focus in both cases is on the regulatory *problem*, not the regulatory *system*. Of course, one could turn adaptation and precaution inward on the regulatory system as well, focusing on managing legal systemic risk. Ultimately, however, regulatory design must pay attention to how the regulatory problem and the regulatory system coevolve by using what Burton and Egan, in their study of railway disasters, call Interdependent Systems Analysis (ISA).<sup>200</sup>

Resonating in complexity science research on “system of systems,”<sup>201</sup> ISA focuses inward on the regulatory system not failure by failure, but over the history of failures as components of the larger system. Under ISA, “disparate operational accidents are seen as taking place under a given set of rules, and the comparative analysis of individual accidents occurring within the same regulatory context may begin to reveal how the legal and regulatory context may be at fault.”<sup>202</sup> ISA uses timelines in which failures in the other social system—the one the legal system is designed to regulate—are mapped along with legislative, regulatory, judicial and other legal events in the relevant regulatory context and links between them explored, so as to constantly keep *legal* systemic risk in the scope of overall systemic risk management.<sup>203</sup> Every failure in financial systems, offshore drilling, and railway transportation has root causes, but assessing root causes one failure at a

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199. See 76 Fed. Reg. 64,431 (Oct. 18, 2011) (350-page rulemaking comprehensively overhauling regulation of offshore drilling).

200. Burton & Egan, *supra* note 153, at 558–61.

201. See, e.g., Mary Ann Allison, Ron Batdorf, Hao Chen, Hòa Generazio, Harcharanjit Singh & Steve Tucker, New England Complex Sys. Inst., *The Characteristics and Emerging Behaviors of System of Systems* (Jan. 7, 2004), available at <http://necsi.edu/education/one-week/winter05/NECSISoS.pdf> (discussing the study of interactions between complex systems).

202. Burton & Egan, *supra* note 153, at 558.

203. See *id.*

time obscures systemic risk, in particular systemic risk within the regulatory system designed to manage systemic risk in these other social systems. Incorporating ISA in legal systems thus is a much-needed design feature for managing legal systemic risk. Institutionalizing ISA thus should be a central goal of legal systemic risk management reform.

More holistically, managing legal systemic risk will require incorporating the kind of proactive, risk-based performance approach some policy analysts are suggesting for the financial system,<sup>204</sup> offshore drilling regulation,<sup>205</sup> and natural disaster planning.<sup>206</sup> Principal in this regard are stress-testing mechanisms, independent watchdog entities, and risk portfolio assessment. In their evaluation of financial regulation, for example, Dimitrio Bisias and colleagues at the Department of the Treasury recommend using a series of “forward looking risk measurement” analytics and stress tests to keep watch on financial systemic risk.<sup>207</sup> Similarly, Hari Osofsky explores safety drills and regional citizen advisory groups for offshore drilling regulatory reform,<sup>208</sup> and Jim Chen outlines ways of incorporating modern financial risk portfolio theory into disaster planning.<sup>209</sup> All of these proposals focus on the regulatory problem, but there is no reason to conclude they cannot be adapted to the legal system. Why should we design forward-looking risk measurement, stress testing, and risk portfolios for the social systems law regulates but not for the legal system itself? Rather, as Tony Arnold and Lance Gunderson have put it, “the legal system itself should develop and improve its own feedback loops to evaluate and adapt to the impacts of legal decisions and actions.”<sup>210</sup>

To be sure, we are much further along in designing proactive, risk-based tools for regulatory problems, because we have devised metrics and analytics for many of the relevant social systems. We have not made similar advancements in the study of legal systemic risk, largely because legal failure is usually treated as a one-off problem cured by one-off, targeted legal fail-safe reform. Researchers like Katz and others who are beginning to explore legal complexity *empirically*, rather than just theoretically, thus represent a critical movement toward the goal of getting a handle on legal systemic risk. For now, however, the RYF dilemma model compellingly establishes that legal systemic risk is best managed by designing legal institutions and instruments to incorporate modularity, scalability, evolvability, sensors, and feedback.

#### CONCLUSION

It is easy to hurl regulation at a policy problem and, if the problem persists, hurl some more. It is the legal system’s job to manage risk in other social systems, and

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204. See, e.g., Bisias et al., *supra* note 147.

205. See Osofsky, *supra* note 174, at 1122–30.

206. See Jim Chen, *Postmodern Disaster Theory* (Mich. State Univ. Legal Studies Research Paper No. 11-17, 2013), available at <http://ssrn.com/abstract=2141591>.

207. See Bisias et al., *supra* note 147, at 74–103.

208. See Osofsky, *supra* note 174, at 1122–37.

209. See Chen, *supra* note 206, at 64–97.

210. Craig Anthony (Tony) Arnold & Lance H. Gunderson, *Adaptive Law & Resilience*, 43 ENVTL. L. REP. 10426, 10441 (2013).

hurling regulation is one way to do it. As we know from the financial crisis, *Deepwater Horizon*, and countless catastrophes before them, however, regulation doesn't just not always work, many times it is part of what causes a failure cascade within and beyond the legal system. Even when regulation is not hurled, but rather is carefully thought out to manage systemic risk in other social systems, attention thus must also be paid to managing systemic risk within the legal system.

The RYF dilemma model provides several useful instructions in this regard. First, although building organization into the legal system makes intuitive and practical sense and at some level is necessary for functionality, left unchecked it leads inevitably to complexity and, consequently, fragility. Second, responding to local failures by adding more organization through new fail-safe measures keeps adding complexity, and thus new conditions of fragility, to the system, leading potentially to a spiral toward incomprehensibly complex system organization. Systemic risk—the potential for catastrophic failure cascades—rises in hand with the complexity spiral. Finally, while systemic risk cannot be brought to zero, system structures designed around modularity, scalability, evolvability, sensors, and feedback are best suited to managing systemic risk.

The *Deepwater Horizon* case study shows how robust the RYF dilemma model is for legal system design. Of course, no regulatory system could guarantee that *Deepwater Horizon* would not have happened or could never happen again; on the other hand, the regulatory system that was in place practically guaranteed that it would happen. The structure of offshore drilling regulation prior to the blowout illustrates many of the RYF dilemma model's parts in motion, and the reform proposals since the blowout map well onto the model's prototype for managing systemic risk.

The RYF dilemma model also shows how high the stakes are for regulatory design in three important respects. First, calls for more adaptive regulatory structures, which will be essential for law to manage systemic risk in other social systems, necessarily challenge deeply entrenched features of administrative law. Second, calls for heightened precaution that abound in environmental and other policy realms, while resonating in systemic risk management theory, must be implemented without fueling an RYF complexity spiral in the regulatory system. Without strong precautionary and adaptive capacities, it is difficult to imagine how the legal system can effectively manage systemic risk in *other* social systems; however, building precautionary and adaptive capacities into the legal system raises a host of challenges for managing systemic risk *within* the legal system. Interdependent Systems Analysis should be embedded in regulatory systems, therefore, to monitor legal systemic risk and its effects on risk in other social systems, and a broad agenda of proactive, risk-based performance tools should be built for the regulatory system, not just regulatory problems.

It would be sheer hubris to suggest that my or any set of prescriptions can weed out all systemic risk from legal systems. Trying to do so would likely be more dangerous than helpful. But once we recognize that there is such a thing as legal systemic risk—which if anything has been my goal for this Article—efforts to manage it are inevitable. Let us do so wisely, with care not to fuel the RYF spiral.